ASPECTS OF THE ECOLOGY AND EXPLOITATION OF THE FISHES OF THE KOSI BAY SYSTEM, KWAZULU, SOUTH AFRICA.

by

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Submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy, in the Department of Zoology, University of Natal, Pietermaritzburg). [1986]

These studies represent original work by the author and have not been submitted in any form to another University. Where use was made of the work of others it has been duly acknowledged in the text.

1986

What would the world be, once bereft
Of wet and of wilderness ? Let them be left,
O let them be left, wildness and wet;
Long live the weeds and the wilderness yet.

from "Inversnaid"

Gerard Manley Hopkins
(1824 - 1889)

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ABSTRACT

In this study the exploitation of the fish fauna of the Kosi estuarine system by man and natural predators is described and estimates made of the off-take and its species composition. The most important human exploitation, that by the traditional Zulu fish traps, was monitored over a four year period and the data collected were used to give an insight into the marine fish populations of the system.

All the physical parameters, which it was thought could influence the migrations of fish, were monitored and correlations between these and the daily and monthly fish trap catches were used to interpret fish movements into and out of the system. Reasons for the annual migrations and day to day movements of fish were investigated.

In order to establish relative off-takes by local fishermen and sport anglers fish were tagged inside the system and the recovery rates by the various fishing methods were used to calculate estimates of the percentage off-takes of these principal human exploitation methods. These data were also used to obtain estimates of the population sizes of the major marine fish species inside the system. Catch data were used to indicate the levels of estuarine dependence of these species. Where possible comparable data from other areas were used to indicate whether or not similar trends in catch abundance were obvious.

The ecological and economic importance of the Kosi system is discussed and its value to the local inhabitants stressed. Competition between the various fishing techniques is described and recommendations are made concerning future fish exploitation. Natural predation rates are also discussed and levels compared with those of other systems.

The fish food resources of the systems are considered in the light of recently declining salinities, destruction of swamp forests and increasing numbers of hippopotami. The implications of these changing factors are discussed as is their impact on the Kosi Bay fisheries.

INTRODUCTION

Kosi Bay is the only major estuarine system for a distance of 180 kilometres along the south-eastern coast of Africa between Delagoa Bay and the St. Lucia estuary. Of all systems along the Natal coast it has been described as the least spoilt (Begg, 1978) and it is the only one in the region not yet seriously affected by degradation caused by damage to the catchment area through the activities of man. It supports a traditional trap fishery which has been operative for hundreds of years, and has more recently attracted anglers from all over South Africa, albeit in small numbers.

The importance of estuaries as nursery areas to many fish species important to marine fisheries has been stressed (Wallace & van der Elst, 1975) and it has been shown that in general the primary productivity in estuaries is greater than that of the oceans (Whittaker & Likens, 1975). The ocean adjacent to Kosi is typical of the "coral sea" ecosystem which Parsons (1979) characterized as having particularly low primary production. The Kosi system is therefore likely to play an important ecological role in the area acting as a protected source of recruitment for several marine species while other Natal estuaries have become progressively less able to fulfill this function.

The Kosi Bay estuarine system, until the time of the current study, was only approachable over untarred road. There was no industrial development and the tourist access was extremely limited. The region surrounding the system was part of KwaZulu and at that time public access was limited by a strict permit system. The KwaZulu Government came under increasing pressure from the South African public to open up the area and allow greater tourist access. Increased access to tourists has, in recent years, led to an apparent conflict situation concerning the exploitation of the fish resources of the system. Many sport anglers considered that the fish traps were catching too many fish and the trap owners, in turn, saw increasing sport angling as a threat to the fish stocks and their livelihood (Tembe & Zwane, pers. comm.). Few data on fish exploitation in the Kosi system were available.

The conservation policy of the KwaZulu Government was defined as "wise utilisation of natural resources" (Tinley & Van Riet, 1981), and it was therefore decided to initiate a study to investigate the current exploitation of the fish resources of the Kosi system in depth. In 1981 I was appointed to carry out this study. It was the intention of the KwaZulu Government to develop the region along the lines which would maximise benefit to the local people and produce revenue for the administration while at the same time not destroying the character of the area, the fish populations and the traditional way of life. This study had to provide data to assist in attaining these goals.

There was an urgent need to investigate and resolve the apparent conflict situation. This could only be done once estimates of the total current off-takes by all parties as well as by natural predators had been established. The results of these investigations could then possibly be used to produce management guidelines on resource utilisation which would not only protect the system and fisheries but also allow a traditional fishery and sport angling exploitation on a sustainable yield basis without undue competition between locals and sport anglers.

At the time of commencement of the study, a tar road was completed to within eighteen kilometres of the system and the area was undergoing a marked transformation as the local people changed from a subsistence level of agriculture to a cash crop basis. Swamp forest destruction had occurred for a considerable period (Campbell, 1948) but in recent years had gained new impetus due to the increasing importance of cash crops. The importance of the various fisheries in the system both in terms of food production and the local economy therefore needed to be assessed. This could then be compared with other cash flows in the area in order to establish the level of dependency of the local people on fish from the system.

Since the turn of the century, when plans were drawn up to make the Kosi Bay system a harbour (Bruton, <u>et</u>. <u>al</u>., 1980), many development schemes for the system have been considered. In order to be able to assess the impact of such schemes on the fisheries, it was necessary to obtain data on many aspects of the ecology of the fishes of the Kosi system. Monitoring of fish trap and other fishing techniques and the assessment of the size of the fish stocks, although of paramount importance to such understanding, could only furnish part of the answer. Other aspects of the ecology of the fishes which have an influence on their movement into and out of the system and their exploitation of its resources, needed to be investigated if management objectives were to be realised. Recommendations to management and advice on development proposals required an understanding of the basic functioning of the Kosi Bay ecosystem.

The problems concerning the management of the Kosi Bay ecosystem and the conservation of its natural resources through exploitation on a sustainable yield basis, resolved into two sets of questions which this study set out to answer.

Firstly, in the short term, current exploitation of resources by the local inhabitants, and by people outside the area, needed to be evaluated in the context of the local economy. This involved estimating levels of exploitation in relation to stock sizes and assessing the probable impact, and would indicate whether immediate constraints needed to be imposed to ensure future sustainable yields.

Secondly, more refined management practices and research programmes which could assess the probable impact of proposed or likely developments required a longer term view. These needed a clearer understanding of the functioning of the ecosystem as a whole, particularly where it affects fish stocks and catches. It was obviously necessary therefore to establish why fish enter and leave the system, when they do so and in response to which proximate and intrinsic factors. Once this information is available the possible effects of change in response to development in the catchment (eg. swamp destruction or agricultural developments) and to natural changes (eg. salinity, silting etc.) can be assessed. Comparisons with other estuarine system are also only possible once it is understood how this one functions. Such comparisons may also prove useful in management.

1 DETAILS OF STUDY AREA

1.1 Position and size

The Kosi lake system is situated adjacent to the south-east shore of the African continent, between latitudes 26° 53' S and 27° 03' S and longitudes 32° 48' E and 32° 52' E (Figure 1). It is orientated roughly on an ENE - SSW axis (Begg, 1978).

The system drains into the Indian Ocean at its extreme northern point, 2,9 kilometres south of the Mocambique International Border (Figure 2). It comprises a series of saline, semi-saline and freshwater lakes connected by narrow, shallow channels. Apart from the mouth, it is separated from the Indian Ocean by high, vegetated dunes, the width of which vary from 400 metres at Bhanga Neck to 1 300 metres at Turtle Point. The summit of the dunes is located 3 kilometres north of Bhanga Neck and rises 94,2 metres above mean sea level (Government Survey, 1962).

The distance from the northern-most point in the system, at Kosi mouth, to the southern-most, Lake Amanzimnyama, is 14,2 kilometres. The lakes and surrounding depression run west of the dunes, parallel to the coast and attain a maximum width of 6,2 kilometres, with a mean width of approximately 4,0 kilometres.

Figure 2 shows the position of the lakes in the system and gives the names used in this survey. The names are those used by the local people and, with minor spelling adjustments, are those used by Tinley (1976) and most subsequent authors. Begg (1978) summarises the history of the names and comments on the confusion caused by the Government Printer misnaming some of the lakes in the 1 : 50 000 map of 1963.

1.2 Geology and origins of the Kosi lake system

The geology of the area has been studied and described by Orme (1973), Tinley (1976) and Maud (1980). The

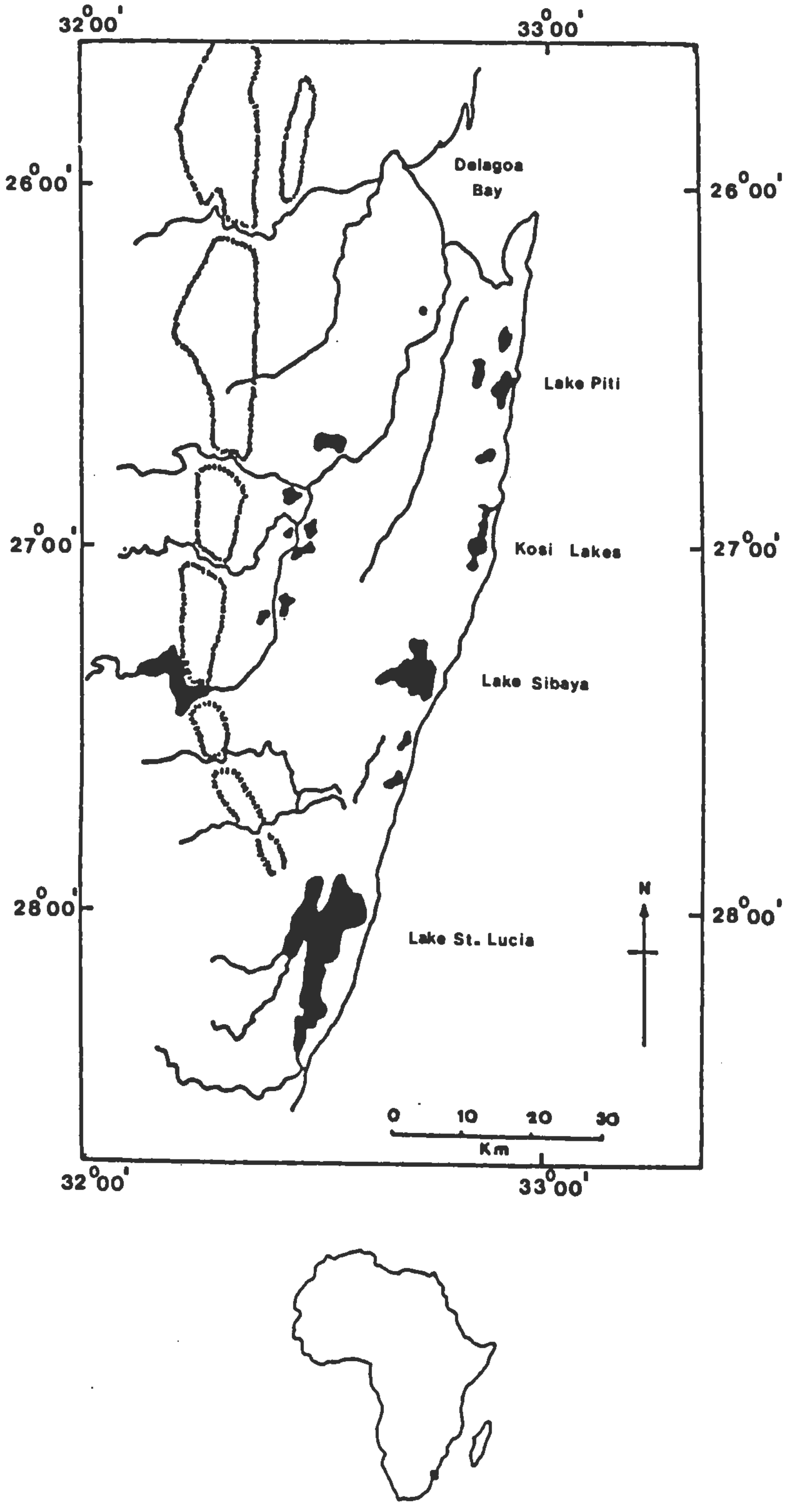


Figure 1. Map showing the location and size of the Kosi system in relation to other systems in the area.

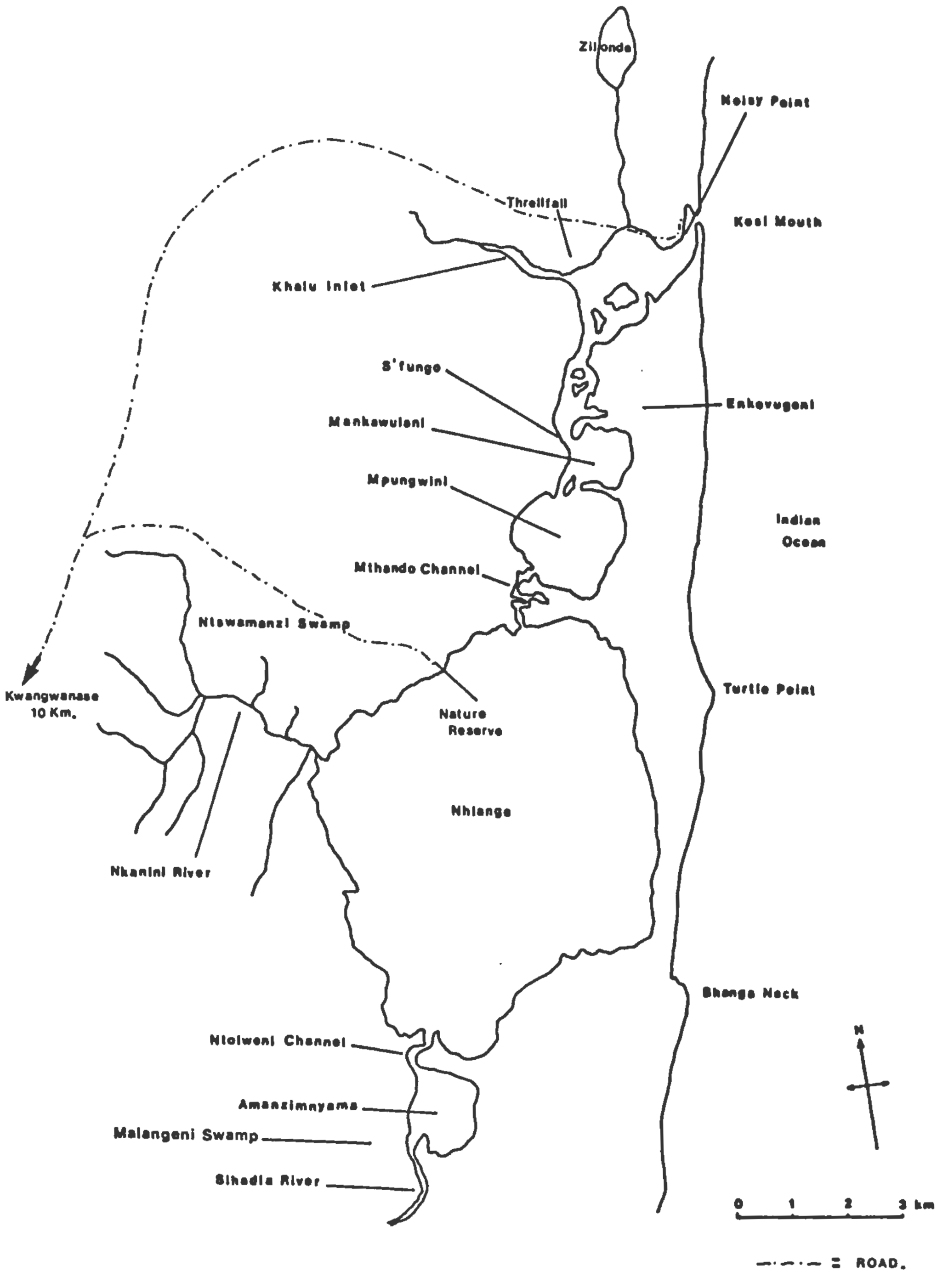


Figure 2. Map of the Kosi system showing major features and nomenclature used in this study.

following description summarises these accounts.

The series of coastal lakes were probably formed by the sea level rising since the last Ice Age to fill a river valley formed when sea level was at least 45 metres and probably up to 100 metres lower than it is at present (Du Toit, 1954 ; Hill, 1969 ; van Heerden, pers. comm.). The submergence of the valley could also have been caused by the subsidence of the shore east of a N - S axis inside the coast (King & King, 1959) although the former theory is more widely accepted (Maud, 1968). Whatever the cause, it does appear that the Kosi lake system, in common with Lake Sibaya and Lake St. Lucia, is the result of the innundation of river valleys. Silting has caused Lake St. Lucia to become very shallow. Due to the sandy nature of the soils and consequent lack of silt, some areas in the Kosi system are deep compared with Lake St. Lucia. Submerged river valleys can clearly be followed in Lake Sibaya and Nhlange, representing old courses of present day streams (Hill, 1969).

The substratum of the lakes is, with the exception of some soft sandstone along the NE shore of Nhlange, a mixture of Holocene and Pleistocene sand deposits (Orme, 1973). The only other rocky outcrop is a small exposed limestone reef just inside Kosi mouth, on the east shore of the south bank. Inside this is a limestone pebble beach (Broekhuysen & Taylor, 1959) which currently extends for 200 - 300 metres upstream.

The sandy substratum and surroundings of the system overlie the Port Durnford Beds (Maud, 1968 ; Hobday & Orme, 1974). This layer, which apparently does not exceed 50 metres in thickness (Maud, 1980), itself overlies a thinner layer, less than 30 metres thick, of Tertiary sediments. These Tertiary sediments in turn cover a much thicker layer of Cretaceous sediments.

As the shoreline was submerged, the mouth of the system was continually infilled by sands deposited by longshore drift, though probably not to the extent of being closed (Orme, 1973). This drift created a series of high dunes which run parallel to the coast, separating the lake system from the sea. The lowest point lies in the region of Bhanga Neck and it is at this point that people, since President Paul Kruger at the beginning of this century, have considered breaching the dunes to create a harbour (Bruton et. al., 1980).

Since the system was originally formed by the submergence of a river valley system, the wind and currents have had a considerable time in which to affect the topography. Orme (1973) suggests that the surface area of the water in the system has been reduced from 104 km^2 to the present 34 km^2, that is by 67,7%, since the submergence of the valley system. The presence of sand spits and lagoon sediments suggest that there has been much deposition of material around the margins of the lakes, particularly at stream mouths, and wave action has caused sand bar development.

The action of the wind and water over time has led to the tendency of the submerged valleys to become a series of roughly circular lakes with tombolas between them (Hill, 1969). This can clearly be seen in Kosi (Figure 2) and also in Lake St. Lucia. Kosi is regarded by Orme (1973) as having the best developed examples of segmentation, as this process is called.

Sediment deposition from the ocean is considered important by some authors (Hill, 1969 ; Orme, 1973). Sand is washed in through Kosi mouth particularly at spring tides. It has been assumed that there is a net inflow of sand into the system from the ocean (Broekhuysen & Taylor, 1959) and that the area inside the mouth is filling with sediment. Recent evidence, however, suggests that this may not be the case (van Heerden, pers. comm.).

There are suggestions that the fish traps or old fish trap stakes reduce water flow and thus aid sedimentation and that, as a result, the water depth, particularly in shallow areas, is becoming reduced (Campbell, 1948 ; Breen & Hill, 1969). In 1980, 10 gauge plates were driven into the sand in areas where sediment deposition would be most obvious. Results so far show that over the time monitored there has been no significant overall decrease in water depth. It may be that conditions have stabilised or that noticeable changes occur over a longer term. Campbell (1948) described his journey in a small boat from the lakes to the mouth. When his description is compared with present conditions, it appears that the depth of water has not decreased markedly since that date. Reports that the Kosi system will, through sedimenting soon be cut off from the sea, appear, therefore, incorrect in the short term.

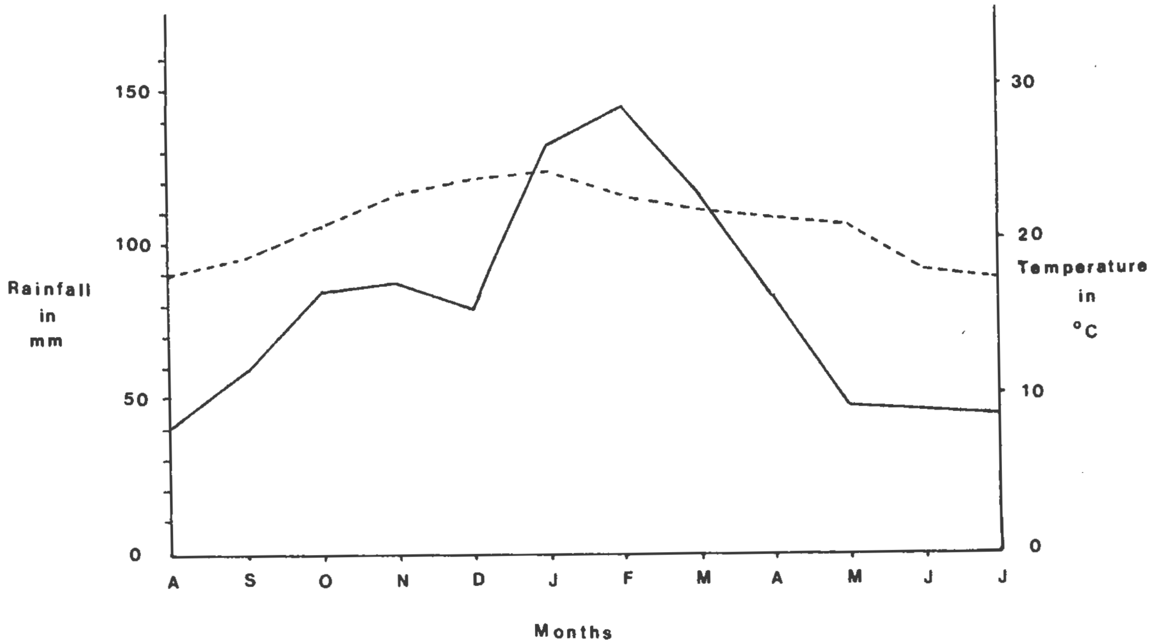
1.3 Climate

The climate of this part of Natal has been described by various authors (Schultze, 1965 ; Phillips, 1973 ; Tinley & Van Riet, 1981). The catchment area of the Kosi system may be regarded as Equatorial with a winter dry, the whole system lying between the 1 000 mm and 900 mm isohyets. Figure 3 shows the mean monthly rainfall and ambient temperatures of the Kosi area over a twenty year period.

Accurate rainfall figures and maximum and minimum air and water temperatures for the study period were recorded from a station on the NW shore of Nhlange. These are summarised in Appendix 1. Information on insolation and relative humidity is not available for Kosi; the most comparable station is Maputo, for which data are given in Table 1.

Various authors have summarised the wind data for the area (Begg, 1978 ; Tinley & Van Riet, 1981 ; Cyrus, 1984). The prevailing winds are north-east and south-east and thrice daily wind readings on the Beaufort scale, taken during this study on the north-west shore of Nhlange, indicate that winds are generally stronger in early summer with calmer weather in late summer and early winter.

Climate may be defined as regular weather (Hawkins, 1979), but although the regular weather prevails most of the time, irregular cyclones have a profound effect on the study area.



-------- : Ambient temperature °C

———— : Rainfall in millimetres

Figure 3. Mean monthly ambient temperatures and rainfall in the Kosi area based on the 20 year period 1960 - 1980 (after Tinley and Van Riet, 1981).

<u>Table 1</u>. Mean monthly percentage of daylight with sunshine (insolation) and relative humidity for Maputa (after Tinley & Van Riet, 1981)

	<u>Jan</u>	<u>Feb</u>	<u>Mar</u>	<u>Apr</u>	<u>May</u>	<u>Jun</u>
% insolation	53,0	57,1	56,8	66,4	73,8	77,2
% relative humidity	75,8	76,0	74,6	72,2	73,2	73,0
	<u>Jul</u>	<u>Aug</u>	<u>Sep</u>	<u>Oct</u>	<u>Nov</u>	<u>Dec</u>
% insolation	76,3	73,9	65,0	55,1	50,7	51,9
% relative humidity	73,2	73,0	72,9	73,9	74,9	74,9

During the period 1 - 3 February 1984 Cyclone Demoina brought 263 mm of rain and in the period 8 - 10 February 1985, although it was not reported as a cyclone, 583 mm of rain fell. These cyclones, though erratic, tend to dominate the weather regime by their presence or absence, since they are responsible for major concentrated rainfalls.

In the 1984/5 rainfall year, slightly more than 50% of the year's rain fell in three days. This amount of rain over such a short period had a dramatic influence on the whole area and on the Kosi system in particular. The water table rose quickly and most of the swamps and vleis surrounding Kosi were filled with water. Due to lack of rivers and steep slopes, large amounts of water seeped and flowed into the system continuously over a period of weeks. This had the immediate effect of reducing salinities. Turbidity throughout the entire system also increased as humus, tannins and silt were washed into it from the swamps which were partially scoured by the volume of water passing through.

1.4 Hydrology

Little work has been published on the hydrology of the Kosi system. Orme (1973) and Pitman (1980) both discussed the area as part of broader studies and their work is commented upon here. Orme (1973) suggests that only 5% of the annual precipitation in the Kosi area is carried in streams. Pitman (1980), when discussing Lake Sibaya, a similarly situated large water body 40 kilometres south of Kosi, regarded seepage from the catchment as the most important source of fresh water. This means that, unlike many other estuarine systems, Kosi is not one that is regularly scoured out by floods following heavy rains. It is a system of lakes fed principally by groundwater seepage.

1.5 Some aspects of the water chemistry of the Kosi system

The solute composition and properties of the water of the Kosi system have received some attention in the past, although this has largely been concentrated on Nhlange (Allanson & van Wyk, 1969 ; Hemens et. al., 1971 ; Boltt & Allanson, 1975).

Details of the dissolved solids in the water and the salinities recorded in recent years have been summarised by Begg (1978). Aspects of importance to this study are discussed later. Salinities in Nhlange have been generally falling since the first regular recordings were taken (Blaber & Cyrus, 1981). Figure 4 shows the course of this trend.

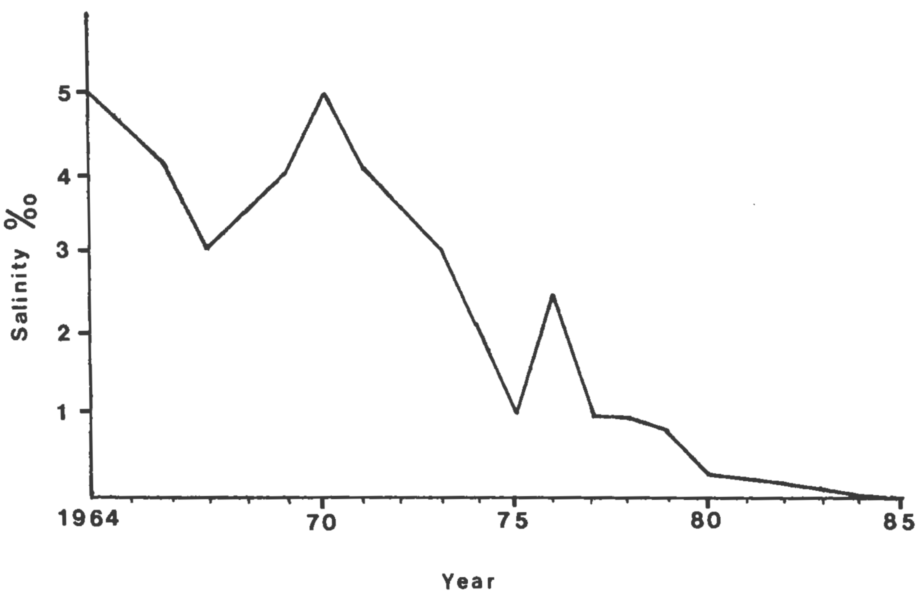


Figure 4. Mean salinities in Nhlange. (After Blaber & Cyrus, 1981 and this study).

The reasons are not clear, as salinities have continued to decline through both severe drought and cyclone conditions (Blaber & Cyrus, 1981). It could be related to more rapid run off from the catchment area due to destruction of the swamp forest for cultivation. Following Cyclone Demoina, in 1984, and the extremely high rainfall in February 1985 salinities in Nhlange have fallen to the point where it may now be regarded as a freshwater lake.

Primary production in the system is nowhere extremely high. Hemens et. al. (1971) reported levels of 62,4 $mgC/m^3/day$

in Nhlange and considered this lake moderately eutrophic. Since Nhlange is a large and fairly shallow lake (see page 18), this results in a considerable build-up of organic materials in the water of the system (Hemens et. al., 1971). According to Hemens et. al. (1971) the water has a fairly high nitrogen content, principally in the form of ammonia, which is incorporated into biological material and retained in the system. They suggest that the primary production rate is not particularly high in view of the amount of nitrogen present.

Hemens et. al. (1971) considered that, although the relative amounts of nitrogen and phosphorus required for cell division varies, for mixed algal communities in lakes it is about 16 : 1. This ratio in the water of Nhlange was found to be 50 : 1 by Hemens et. al. (1971) and they suggested that the amount of phosphorus present might be inadequate to allow the full utilisation of the nitrogen present in primary production.

1.6 Substrata and bathymetry

Begg (1978) has summarised available data on the substrata of the Kosi system and regards its general silt-free nature as its most outstanding characteristic. The substrata, particularly near the mouth, tend to be clean, white sands of a relatively large particle size, there being very little silt in the northern reaches (Hemens et. al., 1971). Further into the system the particle size tends to become smaller. Silt is found in the deeper areas of Mpungwini and Nhlange (Boltt & Allanson, 1975) where there is a thin layer over the shallows of these lakes.

The lakes exhibit well developed terracing (Hemens et. al., 1971 ; Boltt & Allanson, 1975), with steep inclines between these terraces. The terraces can be clearly seen from aerial photographs or in the bottom profiles of the transects by Boltt and Allanson (1975).

There is a tendency for organic materials, originating in the surrounding marshes or streams, to gravitate towards the deeper parts of the lakes. Here the materials are thought to be broken down by bacterial action, products diffusing into the system (Boltt & Allanson, 1975). In Mpungwini this organic material is trapped below a halocline. Hemens et. al. (1971) suggest that disturbance of this detritus, or the water above it, could lead to the whole lake becoming temporarily anoxic with resulting mass mortality of many organisms. This has, however, never been observed.

Amanzimnyama appears to have acted as a sedimentation basin (Hemens et. al., 1971) and this has resulted in a 1 - 2 metre deep, shallow lake overlying a thick layer of organic detritus.

1.7 Vegetation

Moll (1980) gives the most recent description of the vegetation of the study area. Aspects of importance to this study are briefly outlined here.

Extensive mangal communities occur in the shallows in the northern areas (Breen & Hill, 1969). These are of importance as they afford shelter to juvenile fish (Blaber, 1982) and are occasionally used in fish trap construction (Tinley, 1964).

The extensive swamp forests, principally around the western margins, have been described and mapped (Tinley & Van Riet, 1981). The two main streams entering the system, the Nkanini and Sihadla, pass through extensive areas of swamp and these serve to decrease flow rates and reduce sediment and detritus deposition in the lakes (Tinley & Van Riet, 1981).

Much of the area immediately surrounding the system is covered with dune forest (Moll, 1980). This is important in that it supplies much of the material necessary to maintain the fish traps (see Appendix 2).

1.8 Detailed description of the study area

In order to describe the characteristics of the system, it is best split into distinct, easily defined zones. Broekhuysen and Taylor (1959) described six zones in the northern areas in their study. In this study of the whole system, eight zones are recognised and described. The morphometry of these zones is shown in Figure 5 and is a synthesis of work by various authors including Hill (1969 ; 1975) and Allanson and van Wyk (1969).

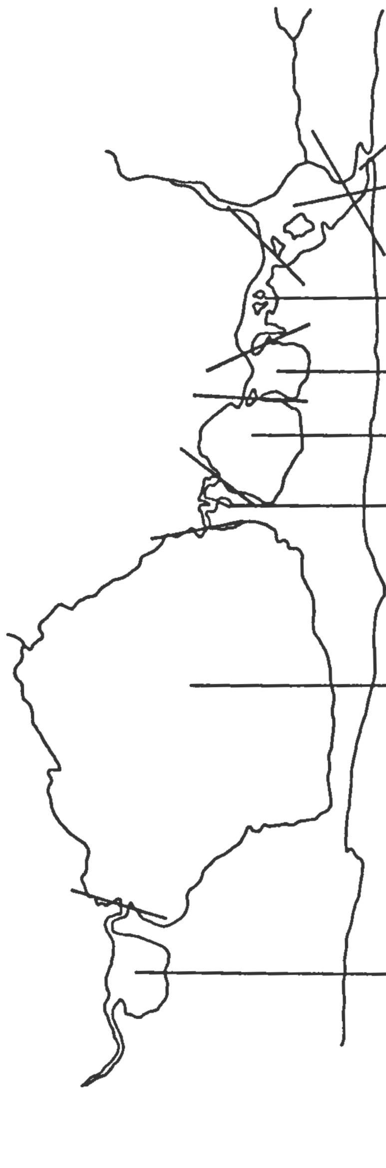
Zone 1. Kosi mouth

This zone stretches from the Indian Ocean into the system for a distance of about one kilometre, to the area called Noisy Point. It is characterised by severe tidal scouring which is particularly pronounced at spring tides. It is an extremely harsh environment and salinities and temperatures can vary greatly over a short period of time.

An outcrop of limestone with a rich and varied fish fauna (Blaber, 1978) is located inside the mouth on the south bank. Beyond this outcrop is a flat, shallow, sandy area supporting mangroves, mainly Avicennia marina (Breen & Hill, 1969). The northern shore has no rock outcrops and is fringed by dune forest vegetation. Small numbers of the mangrove Avicennia marina are found on the upstream side of Noisy Point.

Apart from the period August 1965 to January 1966, the mouth has not closed in living memory (Zwane, pers. comm.). This closure possibly resulted from low rainfall or high seas (Pike, 1967); it was mechanically reopened by man (Begg, 1978).

Broekhuysen and Taylor (1959) describe the channel to the ocean as being short and straight and about 15 to 20 metres wide. Begg (1978) describes it as being generally 20 to 50 metres wide, but that it could vary between 5 and 100 metres. During this study it was always in the range 20 to 50 metres,



Zone	Axial Length (Km.)	Surface Area (Km.^{2})	Max. Depth (m.)	Tidal Range	Current Speed (Km/h.)	Salinity ($^0/_{00}$)
1	1	0,5	3	FULL	1-5,5	0-35
2	2,5	2,5	2		0-3	0-35
3	2,5	1	2		0-3	0-32
4	1,25	0,9	8		0	0-32
5	2	2,8	18		0	0-18
6	1,25	0,01	3		0-3,5	0-18
7	8	35	31	NIL	0	0-1
8	2	1,5	3		0-1	0

Figure 5. Morphometry of the Kosi system and summaries of the physical characteristics of the zones during the study period (after Begg, 1978 and this study).

although the location of the mouth moved erratically north and south over a distance of about 100 metres.

The tidal flux usually has a pronounced lag, water continuing to enter the system after high tide and to exit well after low tide. This can result in salinities varying between 35 p.p.t. and 10 p.p.t. within a period of less than one hour. This is, however, dependent upon the time of the year, rainfall, wind and other physical factors, which greatly influence inflow and outflow on a daily basis.

During the period of heavy rainfall in February 1985 the salinity of the outflow dropped to that of freshwater, but the inflow, during strong south-east winds, was still approximately 35 p.p.t. The conditions described above mean that the organisms living in this zone must be euryhaline, eurythermal and either well attached to the substratum or powerful swimmers.

There were no fish traps in this zone during the study period.

Zone 2. Noisy Point upstream to the mouth of Khalu Inlet, including the large, shallow, roughly circular tidal basin

This zone is much more extensive than the previous one and is in the form of a large, shallow basin, most of which is exposed at low tides (Blaber, 1978). There is a deeper, permanent channel which flows from near the mouth of Khalu Inlet and follows the northern shore of the basin adjoining Zone 1 at Noisy Point.

The northern shore of this channel is well defined and the areas exposed at low tides are small relative to the south shore. A narrow strip of *Juncus kraussii* borders the water along the shore. Several small streams, draining from the swamps south of Zilonde, enter the system along this shore. The southern shore is less distinct and consists mainly of a mosaic of low mangrove covered islands and islets (Breen & Hill, 1969). Between the channel and the shore there are large expanses of sand banks, up to 400 metres wide, which are exposed at most low tides.

Physical conditions in this zone are not as severe as in Zone 1, except that during low tides up to 85% of the area is exposed as dry sand banks. Daily tidal influences in this area are pronounced. Salinity changes are buffered by the reservoir of water in the basin inside Kosi mouth. This means that even though the salinity regime does vary as much as in Zone 1, the changes happen over a period of several hours, as there is usually a larger standing volume of water which must be displaced or diluted. Temperature changes can be extreme in the shallow areas, especially on calm days in summer, when temperatures of 38°C may be attained (Blaber, 1982).

Many fish traps are found in this zone, located on the shallow sand banks on either side of the channel. These include some of the largest in the system, one being 450 metres long with 14 baskets.

Zone 3. From Khalu Inlet to Mankawulani lake

This zone approximates the middle of the tidal area of the system and as such is still subject to considerable salinity changes over short periods.

A broad, shallow channel, with *Phragmites australis* beds on the western shore and *Juncus kraussii* beds on the east, is the main feature of this zone. The channel varies in width between 100 and 200 metres, although at several points there are larger expanses of shallow, sandy, tidal areas adjacent to it. During neap tide periods, particularly in winter months, this zone becomes very shallow with little water movement while at most spring tides there is considerable water flow. The salinity can change radically, as a large volume of water must pass through what is a constricted area of the system.

Many fish traps are found bordering the channel in this zone.

Zone 4. Mankawulani lake

Mankawulani lake is the most northerly true lake of the Kosi system. It is roughly square in shape, measuring approximately 800 m x 800m with a NS - EW orientation (see Figure 2). This zone can be regarded as tidal since it is affected daily by the tides except during some calm neap tide periods. Conditions here change much more slowly than in the zones further north. Salinity changes tend to be longer term, as the volume of water entering during any spring tide is small compared with the volume of water in the lake.

Most of the time little water which differs markedly from the water already in the lake, enters Mankawulani. This results in a salinity regime which can only change slowly. Between June 1982 and May 1983 daily salinity readings taken near the NW corner of the lake remained between 16 and 27 p.p.t. However, in February 1984, rainfall during Cyclone Demoina resulted in the surface salinity of the lake falling to 4 p.p.t. In February 1985 further heavy rains flushed the whole system reducing the salinity to below 1 p.p.t. As there is usually a net outflow from the system, salinities diminish faster than they can increase.

During winter Mankawulani often exhibits a halocline, the deeper water being of a higher salinity than the surface water (Hemens et. al., 1971). The salinity is as a direct result of infusion of sea salts and therefore it is regarded as ectogenic meromixis (Allanson & van Wyk, 1969). When present, the halocline tends to stabilise the salinity in the deeper water of the lake, but heavy rainfall associated with strong winds destroys the halocline resulting in considerable and sustained drops in salinity such as those in 1984 and 1985.

Fish traps are present, concentrated on the western shore around the channels entering and leaving the lake.

Zone 5. Mpungwini lake

Roughly circular in shape, Mpungwini is approximately 1,6 kilometres in diameter. It is deep relative to Mankawulani, reaching a depth of 18 metres slightly east of centre (Broekhuysen & Taylor, 1959 ; Begg, 1978). The margins of the lake comprise Phragmites beds on the east and west shores, and open sandy beaches in the north and south. The substratum is sandy in the shallows with a thick layer of anoxic decomposing organic matter, producing hydrogen sulphide in the deeper areas (Allanson & van Wyk, 1969).

Tidal effect is usually limited to a net gain of saline water at spring tide periods and a net loss of water at neap tide periods. Mpungwini displays thermal stratification and a permanent halocline at depths of 8 - 9 metres ; anoxic conditions occur below 9 metres (Allanson & van Wyk, 1969). Salinity changes are frequently observed in the top layers of this lake but not below the thermocline. Temperature in the upper layers also fluctuates while that of the deeper water is relatively stable. During winter the deeper layers are warmer than the upper layers (Allanson & van Wyk, 1969) but convective mixing is prevented by the halocline. The upper and lower layers are distinct throughout the year, the lower layers being inhospitable to most of the larger forms of marine life.

A few fish traps are scattered around the periphery and close to the mouths of the channels entering and leaving the lake.

Zone 6. Mthando channel

This is a narrow, 8 - 20 metre wide, winding channel connecting lakes Mpungwini and Nhlange. There is nearly always a strong flow of water. The margins of the channel comprise, in the main, dense Phragmites beds. Moll (1978) postulated that the remaining area of grassy banks is being quickly eroded by scouring and the wave action from passing boats. He suggested that urgent attention be paid to the problem in order to establish the rate of erosion. The increasing number of boats (Bourn pers. comm.), combined with recent heavy rains appear to have greatly accelerated the process of erosion (pers. obs.). There is some confusion as to whether the wave action of boats discourages (Moll, 1978) or encourages (Blaber, pers. comm.) the growth of Phragmites. Since all the larger marine fish in Nhlange migrate through the channel any geomorphological change may affect the ease with which they do this.

During the study period, April 1981 to March 1985, the flow was usually from Lake Nhlange into Lake Mpungwini. However, in summer, during periods of low rainfall and spring tides, the current can reverse its flow and bring in clear water of much higher salinities.

This zone contained no fish traps.

Zone 7. Nhlange lake

By far the largest of the lakes, Lake Nhlange is ovoid in shape with the longer axis being in an ENE - SSW (Hill, 1969) direction. The longer axis is nearly 8 kilometres and the shorter 6,5 kilometres. Approximately 90% of the shoreline of Nhlange consists of Phragmites beds and the remainder is open sandy beaches. The Zulu word "Nhlange" means reeds and this lake is aptly named.

Particularly in the north end of the lake there are large areas of sandy shallows with an E - W pattern of wave generated sand bars, as can be seen from aerial photographs. One stream, the Nkanini, filters through the extensive Ntswamanzi swamp before entering the lake on the western shore (see Figure 2). Much of the lake is less than 5 metres deep and the mean depth is 7,2 metres (Hill, 1969). There is no permanent thermocline or halocline and it is thought that there is sufficient dissolved oxygen throughout the lake to sustain fish and invertebrates (Allanson & van Wyk, 1969). A complicated system of temperature layering does exist, although the temperature ranges found by Allanson and van Wyk (1969) were never greater than 3° C throughout the water column. Due to the shallow nature of the lake and large surface area, there is thought to be regular "turnover" (Hemens et. al., 1971). A marked surface seiche effect can occasionally be seen in the charts from an Ott water level recorder on the NW corner of the lake (records are kept by the Department of Environment Affairs, Pretoria).

Salinities during the study period were always below 2 p.p.t. except in the region of the mouth of Mthando channel after it had been flowing into Nhlange. These have been used to update Blaber and Cyrus's (1981) summarised mean salinities in Figure 4 on page 9. Salinities during the study period were determined by means of a temperature corrected optical salinometer. Since this cannot be accurately read below 1 p.p.t., figures in this range are approximations.

Few fish traps are left around the margins of Nhlange. During the study period the number ranged from 0 - 3. According to aerial photographs and local knowledge, however, about 20 years ago there were approximately 15 working fish traps in Nhlange.

Zone 8. Ntolweni channel and Amanzimnyama lake

Ntolweni channel is 50 - 70 metres broad with a mean depth of approximately 3 metres. It is nearly one kilometre long with banks which are roughly 60% grassy and 40% *Phragmites* beds. The flow of water is almost always from Amanzimnyama to Nhlange; such flow is usually slow but in periods of high rainfall or strong SE winds it can become stronger.

There is no thermal stratification and the salinity is such that the channel and the lake may be regarded as fresh. There is no tidal effect, although the surface seiche described earlier does have a localised effect on flow. Lake Amanzimnyama is roughly square in shape with a length of 1,5 kilometres on a NS and EW alignment. It has a fairly uniform depth of 2 metres and there is much organic matter in the substratum.

Hemens *et. al.* (1971) consider this lake to act as a sedimentation basin for the Sihadla river which flows into it on its southern shore. The Sihadla river is the largest flowing into the system, but it passes through an extensive swampy area before entering the lake and thus flow rates are reduced. These, combined with the fact that the catchment area of the stream comprises podsolized sands (Tinley & Van Riet, 1981), result in very little silt entering the system at present.

The margins of most of Amanzimnyama lake are 2 - 20 metres wide beds of *Phragmites*. There are small, sandy stretches, but these are few in number and are only 5 - 10 metres long. The presence of considerable numbers of *Hippopotamus amphibius*, combined with the relatively shallow water, have resulted in this lake being largely ignored in most surveys of the area (Hemens *et. al.*, 1971 ; Blaber, 1978).

During the study period there were no working fish traps in this zone.

2 MAN AND THE KOSI SYSTEM

2.1 Introduction

Man has been resident around the Kosi system in fairly high densities for centuries. Some of the earliest and best records of Homo sapiens in Africa, from circa 100 000 years B.P., are from Border Cave which is situated in the mountains approximately 75 kilometres west of the Kosi system (Beaumont et. al., 1978 ; Beaumont, 1980). Items recovered from the cave such as fish, dolphin and whale remains, showed that at that time man was extensively exploiting marine resources (Cooke et. al., 1945 ; Beaumont et. al., 1978 ; Bruton et. al., 1980). At that time the coastline was close to the Lebombo mountains (Maud, 1980) and it is probable that Homo sapiens, who was then a successful terrestrial hunter and scavenger (Bruton et. al., 1980), followed the coastline as it progressed eastwards. Iron age shell middens have been found in coastal dunes at Enkwazini, on the eastern shores of St. Lucia (Hall & Vogel, 1978) and many shell middens are also present on the coastal dunes near Kosi (pers. obs.).

As the present Kosi system developed it is probable that man concentrated around this area because much of the adjoining land was relatively fertile and fish and crabs were readily available from the system. Felgate (1965) studied the habits and living conditions of the people on the eastern shore of Mankawulani and estimated the human density at 60 $/km^2$. This figure is much higher than that of the drier, central portion of Maputaland (Balfour-Cunningham, 1985). In spite of this relatively high population density, the low technology, subsistence level of agriculture and migrant labour draining a large proportion of the active adult males, have all resulted in the Kosi system being considered the least spoilt major estuary in Natal (Begg, 1978).

The area around the Kosi system is controlled by four Indunas, or headmen, of the Tembe Tribal Authority. Tribal influences were still very strong during the study period and these rigidly controlled the allocation of land, fish trap sites and the way of life. Towards the end of this period new factors, such as availability of supermarket foods, modern technology, inflation, unemployment and a fast growing population, began to markedly influence the socio-economy of the area. At the time of writing a balance was being sought which would guarantee the local people their rights while protecting this unique area from being spoilt.

2.2 Distribution and description of permanent human inhabitants

The area may be split into three distinct zones.

Zone 1. Eastern shores

In recent years this area had a high population density. Felgate (1965) gave a minimum figure of 84 homesteads in this zone, but by the end of this study period the figure had declined to 39. Emigration from the area was mainly due to there being no shop or vehicular access. The people of the area were becoming increasingly dependent upon a cash economy and only small-scale agriculture was possible on the dunes. Water was only available from wells dug at the base of the dunes resulting in it having to be carried to the homesteads, most of which were situated over the summit of the dunes in order to escape mosquitoes. Few cattle were kept in this area as the only grazing of any value was on the flat land between Nhlange and Mpungwini and north of Mankawulani.

Palm wine was produced in this zone, but the palm tapped was *Phoenix reclinata*. This only produces about one half of the amount of sap produced by *Hyphaene natalensis*, which was tapped commercially in other areas of Maputaland (Balfour-Cunningham, 1985).

The poor soils, presence of bush pigs, *Potamochoerus porcus*, and hippopotami, *Hippopotamus amphibius*, have combined to reduce the percentage of land under cultivation in this zone from in excess of 50% (Tinley, 1958) to less than 20% at the end of this study (pers. obs.). The area falls within the Coastal Forest Reserve which was proclaimed in 1950 and since that time little has been done to encourage the people to stay.

Felgate (1965) reported that only 38% of the homesteads in this zone had men who operated fish traps. He also found that only 12% owned cattle and 9% had goats. It was often the same families who owned all three resources. It appears that, even at the time of Felgate's work, most homesteads were not very productive and subsisted to a great extent on money sent by salary earning family members in the cities. This being the case, there was little reason to stay in an isolated area, but a great incentive to move nearer to a trading centre.

Zone 2. Western shores

Populations densities here were quite stable, but dynamic (Tembe, pers. comm.). People were continually moving west to be nearer the town of KwaNgwanase, while others were entering the area from the east. This zone is 1 - 2 kilometres wide adjacent to the western shores of the system and contained approximately 50 homesteads during the study period. Much of this area was also forest reserve. The Coastal Forest Reserve is north and east of Threllfall school, and the Malangeni Forest Reserve roughly follows the margin of dense bush from the Kosi Bay Nature Reserve around and including most of the Malangeni Swamp to the eastern shores of Amanzimnyama (see Figure 2 in Chapter 1).

In this zone the main occupation was operating fish traps. Nearly all homesteads had access to fish traps, palms which could be tapped or swamp gardens where sugar cane and bananas were the main crops.

Zone 3. West of Kosi system

Population densities were higher nearer KwaNgwanase and the densities near the town were increasing at a considerable rate. Much of the land was cultivated for grain crops in the grassy areas, sugar cane and bananas were grown in the swamps and vegetables in the vleis. The percentage of land under cultivation increased to about 90% of that available around KwaNgwanase and the remaining forest thickets were under extreme pressure from slash and burn agriculturalists (Steele, pers. comm.). Many cattle were owned and grazed in this area and many of the adults were employed in the cities or in KwaNgwanase at the hospital, shop or in Security Forces.

Few fish trap owners lived in this zone and most people were involved in cultivating in the swampy areas extending to the west of the Kosi system.

General

A general statement on the human presence in the area is that in the immediate environs of Kosi there was an overall decrease in the human population density.

There was no large-scale industry and agriculture was in the main at a subsistence level due to poor soils, unpredictable rains and bad agricultural practices. Several small commercial banana and sugar cane gardens had sprung up, but these were illegal and discouraged. Several proposals and plans have been drawn up for the area (Thorrington-Smith et. al., 1978 ; Tinley & Van Riet, 1981 ; Willems & Willems, 1983) and all place emphasis on the utilisation of the area's natural resources without destroying these resources and the tourist potential, which could substantially increase the cash flow. The current policy of the local conservation body is therefore to enable tourists to enter the area in ways and numbers which will bring revenue to the local people but not change the present character of the area.

2.3 Tourist presence

Sport anglers began using the system towards the end of the 1940's. In 1950 Natal Parks Board built a camping facility, which is still in use, on the north-western shores of Nhlange (Goodman, 1984). In 1955/56 the camp was enlarged and improved and a total of 15 campsites were made available for the use of tourists. During this study period these sites were available at a maximum of 7 people per site, giving a total of 105 tourists per night.

Various organisations such as the South African Police and Health Department occasionally used fishing camps near the tourist camp. A private company had a recruiting office and two Government Departments had buildings at Kosi mouth. All these buildings occasionally accommodated anglers, but access was limited, numbers small and influence on the area minimal.

2.4 Local economy

Although there is almost no industry or mining in the area, several natural resources are exploited for economic gain when production exceeds local consumption.

a) Fish traps

During spring tide periods the traditional fish traps often catch fish in excess of the needs of the local people. When there are surplus fish, women take these for sale at KwaNgwanase market, 17 kilometres away. The price at the market is approximately double that at Mankawulani. A survey of the economics of the fish traps was carried out as part of the fish trap monitoring programme described in Chapter 4 and the results are summarised in Table 2.

Table 2. Results of survey of fish sales from traps.

Year	No. of fish sold	Value of fish sold at traps	Value of fish sold at market
1982	15 872	R 4 553	R 7 056
1983	23 855	R 9 732	R 18 684
1984	23 977	R 11 719	R 21 563

As can be seen from Table 2, the fish traps bring in a large amount of money to the area as well as providing protein for the local people. The trap owners obtain the money from fish sales at the traps and the people who take the fish to market obtain the higher price. Several trap owners now send their families to market to sell the fish in order to obtain greater profits themselves. The women taking the fish for resale at the market do, however, serve to spread the financial benefits beyond the 56 families directly concerned with the traps (this study).

b) Sale of Phragmites reeds

The sale of *Phragmites* reeds is of major economic importance in Maputaland. Balfour-Cunningham (1985) gives a figure of R 38 000.00 for their value in the period of May 1982 until April 1983. Much of this trade was carried out in KwaNgwanase, but most reeds sold there were harvested further west.

Quantities of *Phragmites* reeds were cut around the Kosi system, particularly around the Mthando channel. Most, however, were cut for local building needs and not for sale. Although few *Phragmites* reeds from the Kosi area were sold in KwaNgwanase, quantities were sold at local homesteads. Harvesting of the reeds depended on reed availability and market forces. Discussions with local people and headmen produced a figure of about 4 women cutting reeds for sale each day. Each woman cut roughly one standard bundle, valued at R 2.00 daily.

Using the estimates available, the economic importance of *Phragmites* to the area is thus :

Number of women cutting daily x Price of bundle x Days in Year

= 4 x 2 x 365

= R 2 920.00 per annum.

c) Sale of Juncus kraussii

The Kosi system contains large stands of this plant (Begg, 1980). At peak harvesting time busloads of women came from as far away as Empangeni to cut and collect these plants (Zwane, pers. comm.). No accurate figures are available for the amount of money brought to the region by this resource as there were no real controls. At least four homesteads in the area generated income from the sale of these reeds and from the sale of traditional sleeping mats made from them.

There was also a craftwork organisation in KwaNgwanase which used J. kraussii as one of its raw materials. Balfour-Cunningham (1985) gives a figure of R 14 109.00 as the total annual value of all the craftwork during his study period. The actual sale of J. kraussii probably does not generate much more than R 1 000.00 per year at present. This estimate is based on discussions with local people (Tembe & Zwane, pers. comm.).

d) Sale of crabs

Almost every day during the study period about five women could be seen digging up and catching various species of crabs among the mangroves and marshlands surrounding the Kosi system. On occasion these crabs were strung onto freshly cut thin sticks and roasted over a fire, to be taken to market at KwaNgwanase and sold. Usually 20 - 30 crabs were put on each stick and each woman carried about 20 sticks. The sticks were sold at 20 cents each yielding about R 4.00 per trip. Most of the sale of crabs coincided with old age pensioners receiving their pensions from KwaNgwanase. This occurred every second month and there were usually 30 - 40 women selling crabs. The crabs were collected and sold throughout the year and an estimate of the amount of money generated from this could be obtained from the following :

Mean no. of women/day x Price of stick x No. of stick/woman x No. of pension payouts/year

= 35 x 20 cents x 20 x 6

= R 840.00

Over and above this figure, crabs were sold erratically at market throughout the year and at local dipping tanks. Only women dug sold or bought crabs as this was locally regarded as womens' business. The effects of the removal of large numbers of crabs from the system were not known and the situation urgently needs to be investigated.

e) Sale of crops

Various crops from the Kosi area are sold at KwaNgwanase market. The major types being bananas, sugar cane and various kinds of vegetables. No accurate estimate is possible of the economic importance of these crops, but during the study period the areas under cultivation for cash crops were so small as to be of little importance. Grain crops were not generally sold as there was rarely any surplus.

f) Palm wine

The sale of palm wine from *Hyphaene natalensis* brought R 157 732 annually into Maputaland according to Balfour-Cunningham (1985) during his study period. The immediate Kosi area, however, has very few palms of this species and the wine which is produced is generally not sold for export, though it is often bartered locally for fish.

General

Only the traditional fish traps occupied any sizeable daily work force in the Kosi area. Approximately 40 - 50 men were kept busy each day building and maintaining the fish traps. No people were fully occupied cutting either *Phragmites* or *Juncus*, although numbers of people did cut both for sale on a regular basis. It is clear that fish is the natural resource which dominates the local economy, but is itself of minor importance when compared with other cash flows in the area.

Table 3 summarises the cash flows in the Kosi area and serves to compare the amount produced from natural resources directly with that from other sources. As will be discussed later money is generated by illegally gill netted fish from the Kosi system, but no estimates were possible.

Table 3. Summary of estimated cash flow in Kosi area and revenue generated from the sale of natural resources during the period 1/4/84 - 31/3/85.

Source of revenue	
a) Payouts	Money generated
1. Pension payouts	R 269 231,00
2. Mining company salary payouts	R 470 000,00
3. Nature conservation salaries	R 43 000,00
4. Security Force salaries	R 5 000,00
5. Private enterprise salaries (shops)	R 7 774,00
TOTAL :	R 795 005,00
b) Natural resources	
1. Fish from traps	R 21 563,00
2. *Phragmites* reeds	R 2 920,00
3. *Juncus kraussii*	R 1 000,00
4. Crabs	R 840,00
TOTAL :	R 26 323,00

Data in Table 3 were obtained from :

a1. Figures obtained from the Magistrate's Office - KwaNgwanase
a2. Figures obtained from The Employment Bureau of Africa
a3. Figures obtained from KwaZulu Bureau of Natural Resources and Natal Parks Board

a4. Figures estimated from personal observation and enquiries

a5. Figures obtained from shop owners

2.5 The importance of the Kosi system.

For centuries the local inhabitants have subsisted on fish and crabs from the Kosi system, wild fruits and a few crops grown in the surrounding soil (Junod, 1927). In recent years, with the advent of migrant labour and more recently considerable retrenching, the system has provided a source of food and income for the elderly and unemployed. There are few kwashiorkor cases reported from the surrounding area (Fogel, pers. comm.) and although the average per capita income of the area is probably among the lowest in Natal, there is little hunger.

The fish trap system is well regulated and functions smoothly (Kyle, 1981a). Many trap sites are vacant and any local person prepared to work may build and operate a trap once he has completed some formalities. Rod and line fishing with the simplest of equipment and spear fishing using a very simple spear, also produce food. Fifty-six families were found to depend directly on the fish traps and virtually all the families in the area benefit from the fish and crabs (this study).

Begg (1978) rated Kosi as foremost amongst Natal's estuaries in terms of its conservation potential. It contains the largest variety of fish species of any Southern African estuary (Blaber & Cyrus, 1981) and several are considered rare or restricted (Skelton, 1977 ; Kyle, 1981b).

Estuaries are considered to act as nursery areas for marine fish species (Wallace & van der Elst, 1975) and Sykes (1963) has presented convincing evidence that a decline in marine fish populations can be associated with estuarine destruction and mismanagement. Blaber (1982) considered that, for at least one marine sport species, Kosi alone may be responsible for recruitment.

2.6 Threats to the Kosi Bay fishery.

Over fishing by the local people has been considered a threat to the fishery at Kosi by visitors (Campbell, 1948) while many local people accuse the sport anglers of over fishing (Zwane, pers. comm.). Gill netting is disliked by trap owners and sport anglers alike and its effects have been commented upon by researchers at Kosi (Cyrus, 1980 ; Blaber, pers. comm.).

In order to determine the scale of these fishing methods, plus that of natural predation and to assess their impact on the larger fish populations at Kosi, monitoring schemes and a tag and recovery programme were carried out.

Fishing by man, other than by fish traps, plus natural predation are discussed in Chapter 3. The catches of the fish traps are discussed in detail in Chapter 4 while tagging studies relating human off-takes to fish population sizes are covered in Chapter 6.

In this way the suggested threats to the Kosi Bay fishery were investigated in order to produce guidelines for the management of the fishery.

3 EXPLOITATION OF THE FISH RESOURCE

3.1 Fishing methods

3.1.1 Introduction

It is obvious from the statistics given in Chapter 2 that although the direct economic importance of natural resources in the area is small relative to other sources of revenue, the fish resource is the most important. As well as generating income for the fishermen, fish are an important source of animal proteins to the people of the area. The traditional fishery at Kosi may be described as artisanal (Welcomme, 1978) in that most of the fish are used by the fishermen and any excess is sold or bartered.

The Kosi system is reported as sustaining an intensive fishery (Bruton, 1980) and its function as a source of recruitment to marine fish populations has been stressed (Blaber, 1982). These factors combine to make the conservation of the fish resources of the Kosi system of paramount importance. Conservation, which has been described as the wise management of renewable natural resources (Tinley & Van Riet, 1981), cannot be carried out unless current levels and effects of off-takes are known. For this reason an in depth survey of all forms of exploitation of and predation on the fish of the Kosi system was urgently required.

In this section the various ways in which man takes fish from the system are examined. Each method is discussed and the current level of knowledge of catch composition and off-take is given. The effects of these on the system and the benefits derived are discussed. The current legal status, management attitudes and controls are also briefly discussed.

3.1.2 The Kosi Bay fish traps

The catches of these traps were monitored over the period 1/4/81 - 31/3/85. The traps are briefly described in Appendix

2 and the results are discussed in detail in Chapter 4.

3.1.3 Rod and line fishing by local people

Numbers of local people occasionally angle in the system and considerable numbers of fish are caught. Most fishing was carried out by boys aged between 8 and 18 years. No girls or women were seen fishing at Kosi, although in the nearby Pongolo system women play an increasing role in all fishing activities (Pooley, 1980).

The catches of rod and line fishermen were sampled throughout a one year period during the present study; the results are summarised in Table 4. The results of a survey of the catches of 20 children angling in Kosi by Cyrus and Blaber (1984a) are included in this table. It is the mass of food obtained by the method, however, which is a measure of its importance to the local population. An estimate of the mass of fish caught was calculated from the mean mass for each species caught, multiplied by its daily catch per unit effort (C.P.U.E.) and totalling for all species. Table 5 summarises the results of these computations. As with many of the extrapolations in this study, no absolute accuracy is claimed; they represent best estimates within the limitations dictated by logistical considerations.

It can be seen from Table 4 that, numerically, the most important components in the catches of this group were Rhabdosargus spp. (38,8%), Gerres acinaces (34,7%) and Terapon jarbua (17,1%). Other species, although seasonally significant, together formed only 9,4% of the total sample of 7 104 fish. The C.P.U.E. appeared to be somewhat lower in the winter months than in summer and the number of children found fishing were also smaller.

The fishing was influenced by many factors such as weather, school holidays and availability of species. It was impossible to accurately estimate the total off-take by these children, as the number fishing at any time varied between 0 and 50. Cyrus and Blaber (1984a) give a figure of not less

Table 4. Sample of rod and line catches of children - March 1983 - February 1984

Month	No. of boys	Total fish	C.P.U.E.	Gerres acinaces %	Rhabdosargus spp. %	Therapon jarbua %	Acanthopagrus berda %	Oreochromis mossambicus %	Gerres rappi %	Other %
Mar	20	252	12,6	32	34	31	1	-	-	2
Apr	56	725	12,9	14	54	18	8	-	-	6
May	106	1 126	10,6	3	71	10	13	-	-	3
Jun	38	316	8,3	6	83	5	4	-	-	2
Jul	3	30	10,0	40	40	20	-	-	-	-
Aug	5	23	4,6	-	65	-	-	-	-	35
Sep	22	165	7,5	48	37	11	-	-	-	4
Oct	56	641	11,4	65	17	15	-	-	-	3
Nov	91	1 175	12,9	59	19	12	-	7	-	3
Dec	174	1 987	11,4	43	30	18	-	-	5	4
Jan	57	420	7,4	37	32	27	-	-	-	4
Feb	16	244	15,3	9	25	60	2	-	-	4
TOTAL	644	7 104		2 468	2 753	1 216	226	82	99	260
MONTHLY MEAN			11,0	34,74	38,75	17,12	3,18	1,15	1,39	3,66
CUMULATIVE %				34,74	73,49	90,61	93,79	94,94	96,33	99,99
Cyrus & Blaber (1984)			12	55	15	8	All other species combined		-	22

than 15 children fishing on any day during their survey. For the purposes of analysis it was assumed that each catch measured was the result of one child fishing for one day since catches were measured in the late afternoon.

Table 5. Results of survey of 644 rod and line fishermen - estimate of mass of daily catch.

Species	C.P.U.E.	Estimated mean mass (n = 20)	C.P.U.E. x mean mass
Rhabdosargus spp.	4,27	24,5 gm	104,6 gm
Gerres acinaces	3,83	48,5 gm	185,8 gm
Terapon jarbua	1,89	21,0 gm	39,7 gm
Acanthopagrus berda	0,35	200,0 gm	70,0 gm
Oreochromis mossambicus	0,13	320,0 gm	41,6 gm
Gerres rappi	0,15	25,0 gm	3,8 gm
Other species	0,40	51,0 gm	20,4 gm
Estimate of daily mass of fish caught per fisherman = 465,9 gm.			

Discussion on species caught

i) *Rhabdosargus* spp. (*Rhabdosargus sarba*; *Rhabdosargus holubi* and *Rhabdosargus auriventris*).

It was found that people monitoring catches in the field could not distinguish sufficiently well between the three species of this genus found in the system for them to be separated with confidence. Consequently, for this study, the genus is treated as one. Figure 6 shows the length frequencies of catches and it can be seen that for the year there is a mean of 130 millimetres (T.L.).

R. auriventris is a small fish, the angling record for which is 0,8 kg (van der Elst, 1981). It is not accurately known at which length this fish reaches maturity but it is probably at a smaller size than for the other two species of the genus at Kosi.

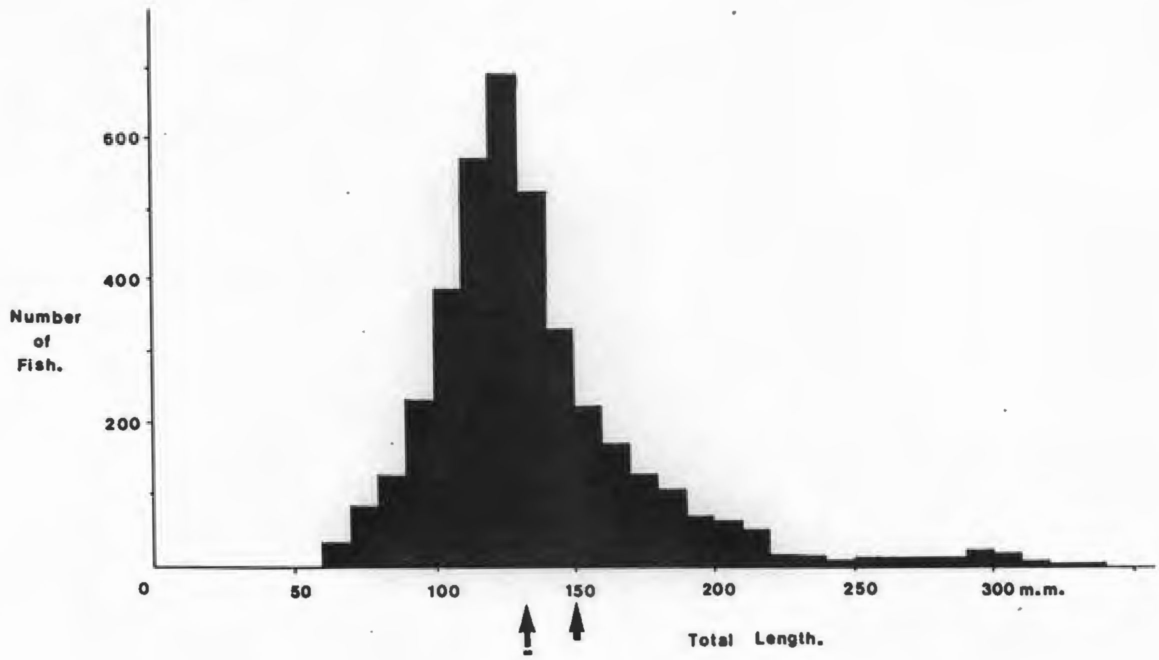


Figure 6. Length frequency analysis of 3 939 Rhabdosargus spp. caught by children on rod and line between March 1983 and February 1984 where ↑ indicates the legal minimum total length for R. auriventris and ↑ the mean catch length.

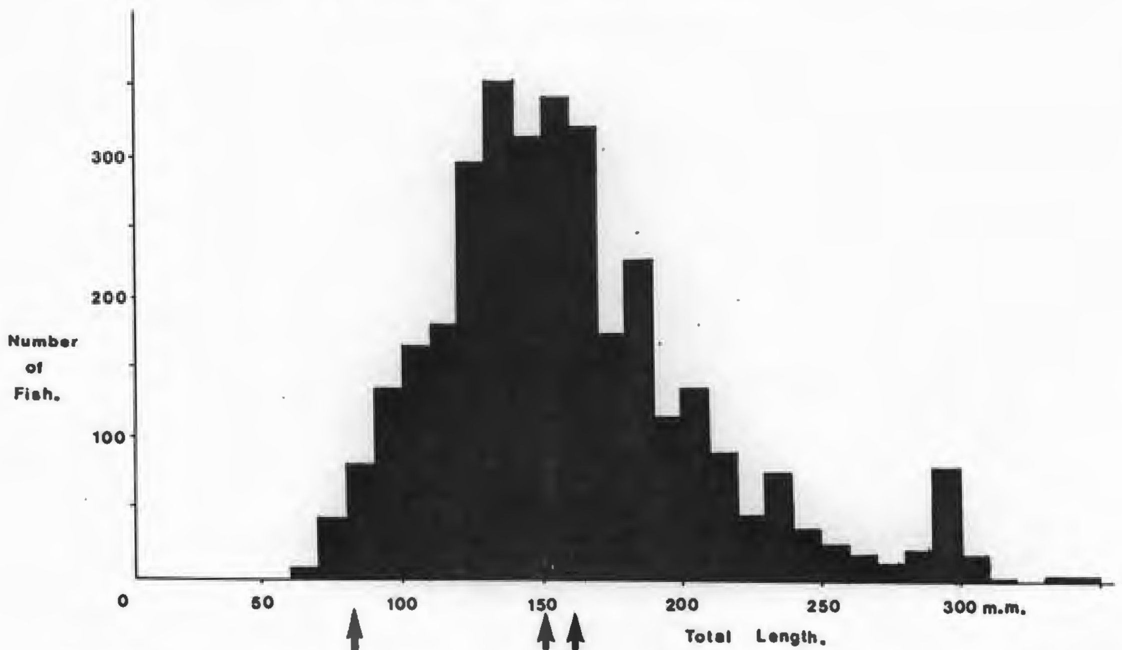


Figure 7. length frequency analysis of 3 325 G. acinaces caught by children on rod and line between March 1983 and February 1984 where ↑ indicates the legal minimum total length, ↑ the mean and ↑ the total length at maturity.

R. holubi is larger than the previous species, with an angling record of 2,3 kg (van der Elst, 1981). It probably reaches maturity as a length of between 150 millimetres and 180 millimetres (T.L.) (Day & Morgans, 1956 ; wallace, 1975b).

R. sarba grows to a much larger size than the other two species, attaining a mass in excess of 11 kg (Smith, 1977). Sexual maturity is attained at about 250 millimetres (T.L.) (van der Elst, 1981).

Identification of a sample of 257 fish caught by angling showed 81% to be *R. auriventris*. Figure 6 shows the length frequencies of catches of *Rhabdosargus* spp. and the legal minimum length for *R. auriventris* is indicated. Since *R. auriventris* probably matures at less than 150 millimetres (T.L.) and the indications are that most *Rhabdosargus* caught are of this species, the capture of these fish represents to a large extent utilisation of mature or near mature individuals of a species not appearing in the catches by other fishing methods monitored in this study.

ii) *Gerres acinaces*

The smallscale pursemouth, *G. acinaces*, was the species caught in largest numbers by the anglers. Since the mean length (see Figure 7) was considerably greater than that of the *Rhabdosargus* spp., this species was probably the most important to the children as a food source. Over the period covered, *G. acinaces* constituted 34,7% of the total number of fish sampled. Most fish fell between 100 and 200 millimetres (T.L.) (see Figure 7). van der Elst (1981) states that individuals exceeding 80 - 90 millimetres (T.L.) are mature and thus over 90% of individuals caught were of mature length. *G. acinaces* does not form a large part of any other human fish utilisation at Kosi.

iii) *Terapon jarbua*

Thornfish, *T. jarbua*, accounted for 17,1% of the sample.

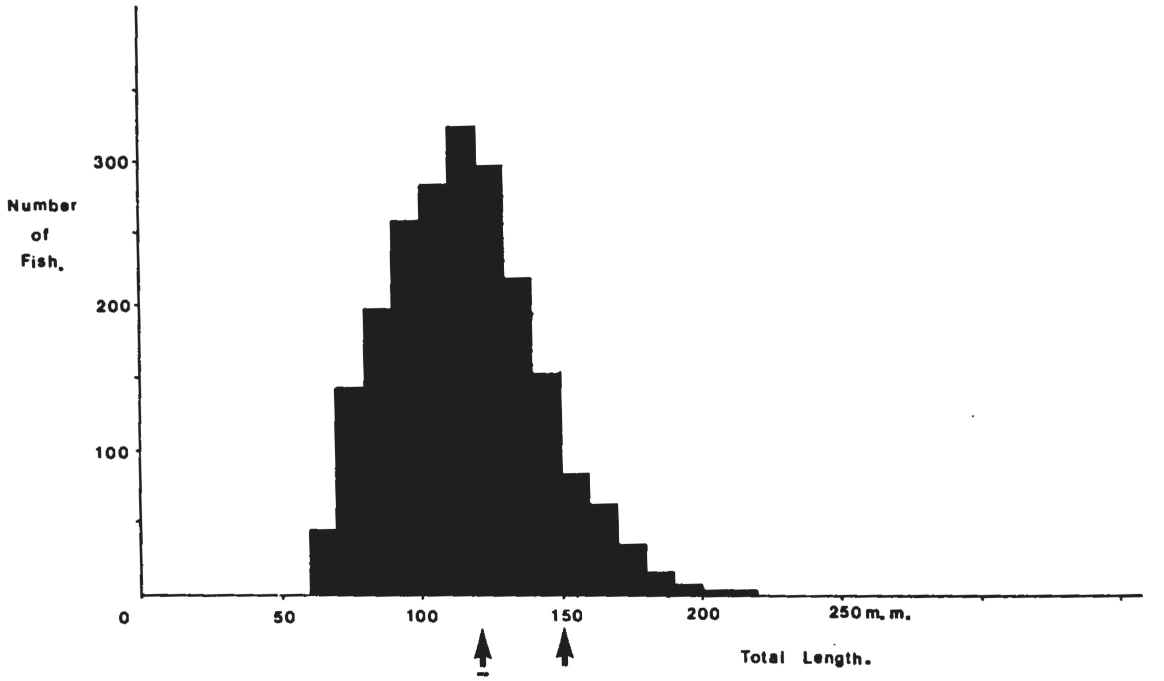


Figure 8. Length frequency analysis of 2 124 T. jarbua caught by children on rod and line between March 1983 and February 1984 where ↑ indicates the legal minimum total length and ↑ the mean total length.

The mean size of the fish throughout the year was 120 millimetres (T.L.) and the length frequency statistics are shown in Figure 8.

From evidence in this chapter and in Chapter 4 T. jarbua does not form an important proportion of any other fish off-take by man at Kosi. Whitfield and Blaber (1978) described its scale eating habits and the abundance of scales from fish caught in the traps and cleaned at the edge of the water, will provide extra food for this species. Of 73 T. jarbua stomachs examined during this study 64% contained fish scales which accounted for approximately 75,9% of the total stomach contents by bulk (see Chapter 4 for method). The capture of large numbers of this species represents not only the utilisation of a species otherwise little used by man at Kosi, but also a reduction in numbers of a species reportedly detracting from the quality of sport angling (van der Elst, 1981).

iv) Remaining species

Small numbers of the following species were also caught - Acanthopagrus berda, Oreochromis mossambicus, Gerres rappi, Lutjanus argentimaculatus, Lutjanus fulviflamma, Ambassis spp. and Monodactylus spp. Catch length frequency analysis of results show that with all of these species most of the fish caught were mature and the capture of Ambassis spp. and Monodactylus spp. again represents the exploitation of species otherwise unimportant to man.

Conclusions

It is clear from results that large numbers of small fish were caught by children. Analysis shows that many of the fish caught were mature fish of small species or of a species not otherwise heavily utilised by man inside Kosi. Furthermore, in one case a nuisance species to tourist fishermen forms an important part of the catches of the children. Superficially it appears that these young anglers were illegally taking large numbers of immature fish from the system. Closer examination suggests that current size limits and bag limits should be changed. Any change in the law, however, would be difficult to enforce as some of the species concerned are very similar to each other.

As can be seen from Tables 4 and 5 much food was made available by this method and some fish species otherwise little used by man at Kosi were caught in a controllable fashion. This method of catching fish is regarded by local people as an important supplement to trap catches. When these are poor, some fish could always be caught in this manner (Zwane, pers. comm.).

3.1.4 Spear fishing by local people

Introduction

Traditionally the people surrounding the Kosi system have used spears to catch free swimming fish (Tinley, 1964 ; Felgate, 1965 ; Cyrus & Blaber, 1984a). Spearing was carried out in the shallows of the system and could be done by individuals or in small groups. Felgate (1965) wrote of groups of up to 200 people involved in large drives, but during this study period the largest group seen was 10. There were four main techniques used to catch fish by spear at Kosi.

a) Groups of children chasing fish into the shallows

Using this technique, species of the Muglidae, particularly *Liza macrolepis*, were usually caught. It was mainly practised by children, usually at weekends or during school holidays and most commonly in summer when the water was warm.

b) Individuals spearing fish in channels

During this type of spearing, the target fish was usually of a species of Gerreidae or one of the Muglidae. Adults usually practised this technique which required much more stealth than that previously described.

c) Stalking fish in Phragmites beds

In spring, *Oreochromis mossambicus* males excavate depressions in the sand which they will defend which makes them particularly vulnerable. Other species regularly caught were *Acanthopagrus berda* and some species of Muglidae. This method was particularly successful in Mthando channel in early summer when, during spring tides, the flow of water reversed and visibility improved because of the clear saline water which flowed through. Catches of up to 30 kilograms of *O. mossambicus* by a single person were recorded.

d) Spearing with goggles

Spearing fish while swimming under water is extremely difficult as sight is badly impaired. The use of shop bought goggles has recently changed this (Cyrus, 1980). Using this method individuals or small groups of spear fishermen floated or swam through the clear water, usually in the channels in the northern end of the system or just downstream of Lake Mankawulani. This was occasionally a very successful method (Begg, 1978) as individual fish were targetted and could be approached very closely.

Catches of over 100 fish have been recorded (Potter, pers. comm.). Spearing with goggles was discouraged by the authorities as it was not traditional and may well have been responsible for a reduction in species diversity at Kosi mouth (Blaber, pers. comm.)

Monitoring of the spear fishing catches

Spot checks were made on spear fishing catches throughout the period March 1983 to February 1984 and the results are summarised in Table 6. Results do not include data from spearing using goggles.

Discussion on spear fishing

As can be seen from Table 6, the mean daily spear fishing

Table 6. Results of spear fish catch monitoring of 127 spear fishermen during the period March 1983 - February 1984

Species	Total	% of catch	Cumulative % of catch	C.P.U.E.	Mean mass of fish (n=20)	C.P.U.E. x mean mass
Gerres rappi	232	32,31	32,31	1,83	0,30 kg	0,55 kg
Oreochromis mossambicus	211	29,39	61,70	1,66	0,45 kg	0,74 kg
Liza macrolepis *	182	25,35	87,05	1,43	0,29 kg	0,41 kg
Mugil cephalus	29	4,04	91,09	0,23	0,45 kg	0,10 kg
Pomadasys commersonni	20	2,79	93,88	0,16	0,95 kg	0,15 kg
Acanthopagrus berda	16	2,23	96,11	0,13	0,32 kg	0,04 kg
Rhabdosargus sarba	13	1,81	97,92	0,10	0,33 kg	0,03 kg
Gerres acinaces	7	0,97	98,89	0,06	0,29 kg	0,02 kg
Valamugil buchanani	6	0,84	99,73	0,05	0,44 kg	0,02 kg
Lutjanus argentimaculatus	1	0,14	99,87	0,01	0,46 kg	0,01 kg
Anguilla marmorata	1	0,14	100,01	0,01	1,50 kg	0,02 kg
TOTAL	718	100,01		5,67		2,10

* - Figures for *L. macrolepis* will include small numbers of *Valamugil robustus* as well, as these were combined with *L. macrolepis*.

catch is estimated at over 2 kg. Up to 25 people were counted spear fishing in the system at one time, but usually the number was considerably less. As will be shown in Chapter 4 fish traps primarily produced fish around spring tides and most of the trap operators were middle to old aged men, whereas spear fishermen tended to be young and fit and most successful at neap tides or low water during the spring tide period. The climate, hydrology and fish of the area made the Kosi system very suitable for spear fishing.

Spear fishing without goggles requires skill, is time consuming and, considering the number of people resident in the area, few people fished in this manner. Fishing with spear guns was not practised by local people and tourists were not allowed to spear fish inside the Kosi system. The philosophy of the conservation authority in the area was to protect the "reef" fish inside the mouth. Local people could spear without goggles and tourists could use goggles but not spear guns. In this way the local people could obtain food, the tourists could see a tropical reef fish fauna and both the food resource and reef fauna were maintained.

Conclusions

As can be seen in Table 6 spear fishing produced a fairly large quantity of food. According to local knowledge, the level of traditional spear fishing has not changed noticeably in recent years (Zwane. pers. comm.). The use of goggles with traditional spears has, however, caused concern in some quarters (Cyrus, 1980 ; Blaber, pers. comm.) and this needs to be investigated.

3.1.5 Angling by tourists

Introduction

Most tourists were based at the camp on the north-west corner of Nhlange. Their principal activity was fishing from boats on the three main lakes of the system. Fishing was by rod and line only.

Monitoring catches

In order to obtain estimates of the tourist catches voluntary questionnaires were issued to all tourists entering the camping area during 1983.

Questionnaires were issued regardless of interest in fishing and tourists were asked to submit a nil return if they did not fish. In this way a good reflection of the tourist catches should be possible although as with all such surveys the seriousness with which the tourists regard the questions is critical.

During the period 1/1/85 - 31/3/85 checks were carried out to establish whether the catches recorded by the tourists were accurate when compared with the same catches monitored independently on the shore. It was found that most of the catch returns completed by the tourists were correct in species and number, but some estimates of mass, particularly of the larger fish, were not accurate. Examples of tourist estimates and actual means are given in Table 7.

Table 7. Comparison of tourist questionnaires - masses and actual masses.

Species	Mean tourist guess	Mean actual mass
P. commersonni	1,64 kg (n = 217)	0,91 kg (n = 100)
R. sarba	0,51 kg (n = 155)	0,46 kg (n = 100)

Results from the forms voluntarily completed, summarized in Table 8, indicate the proportion of different species caught.

Of the 221 groups of tourists who visited the camp site during the year of this survey, 42 completed the questionnaire satisfactorily, thus the above results are for approximately 19% of the tourist catch for that year. If the questionnaires completed are assumed to be a random sample of 19% of the catch, and the mean fish mass is known, then an estimate can be made of the total number and mass of fish taken out of the system by the tourists in that year.

Table 8. Species composition of tourist fish catches from questionnaires

Species	Number	% of catch	Cumulative % of catch
P. commersonni	648	50,86	50,86
R. sarba	379	29,75	80,61
A. berda	85	6,67	87,28
Caranx spp.	36	2,83	90,11
Sphyraena spp.	25	1,96	92,07
Other	101	7,93	100,00
TOTAL -	1 274		

Table 9 gives extrapolated total numbers of each species caught and gives the corrected mean masses of each species.

Table 9. Estimation of total tourist catch at Kosi from voluntary questionnaires during 1983. Mass estimates are corrected according to Table 7 and the same data for the other species

Species	Number	Extrapolated total no.	Mean mass	Estimated total mass
P. commersonni	648	3 410	0,91	3 103 kg
R. sarba	379	1 994	0,46	917 kg
A. berda	85	447	0,43	192 kg
Caranx spp.	36	189	0,79	149 kg
Sphyraena spp.	25	131	1,07	140 kg
Other	101	531	1,16	616 kg
TOTALS	1 274	6 702		5 117 kg

The mean mass is the mean of a sample of at least 50 fish of each species except for *Sphyraena* species, for which the sample was 31.

Almost 50% of the tourist returns were discarded as they lacked sufficient information, were badly completed or were clearly not taken seriously. Once the poorly completed returns were eliminated, valuable data could be obtained from the remaining returns. The fishing pressure of the tourists was fairly constant from year to year during the study period. This was because the number of camp sites remained the same and they were nearly fully booked over holiday periods and almost empty at other times.

Species of fish caught in significant numbers and combined in "other" in Tables 7 and 8, include Lutjanus argentimaculatus, Oreochromis mossambicus, Elops machnata, Gerres acinaces and Clarias gariepinus.

3.1.6 Gill netting

Gill netting was introduced to Maputaland in the Pongolo system in the 1940's (Tinley, 1964) but it only came to prominence in the Kosi system in more recent years (Kyle, 1981a). The local Assistant Magistrate in 1952 (Gregory, pers. comm.) reported that gill netting was allowed in Amanzimnyama for a short time, although there was a limit on mesh size. Netting was allowed in that lake because there were no fish traps due to the presence of crocodiles and the local people had no safe way of catching fish in numbers. Gill netting was soon discouraged as it was found impossible to control within the decided limits.

At the beginning of this study gill netting in the channels in the north of the Kosi system was widespread and common. It was illegal and for the following reasons strong measures were taken against it by the Nature Conservation Authority early in 1981.

1. Netting across the demarcated 30 metre clear channel between the fish traps served to interfere with the free migration of fish into and out of the system.

2. Uncontrolled netting catches all species and all sizes

of fish and in 1981 control was impossible.

3. In the shallow channels and clear water of the Kosi system, fish enter the nets only at night and the gill netters were often tempted to steal fish from the fish traps under cover of darkness.

4. Most gill netting was controlled by people from outside the Kosi environs and vehicles were often organised to transport the catch hundreds of miles away, where better prices could be obtained (Kyle, 1981a).

5. Competition and friction between gill netters and fish trap owners was rapidly leading to the collapse of the traditional fish trap system which is regarded as an important cultural heritage by the Zulu people (Tembe, pers. comm.).

Table 10 summarises the species composition of the catches of some gill nets seized by the KwaZulu Bureau of Natural Resources during 1981. No quantitative data are available on the level of gill netting at Kosi. Levels fluctuated, depending on anti-gill netting patrols and the availability of fish and markets. An indication of the intensity of gill netting carried out over the study period may be obtained from the quantity of net seized during that period. Table 11 summarises these data.

Mesh size ranged from 70 millimetres to 125 millimetres stretch with a mode of 85 millimetres. Pike (1967 ; 1971) recommended meshes of 80 - 105 millimetres as these were the most productive and least harmful sizes and this corresponded to that which was used most frequently by the local netters.

Although the results show that 40,33% of the fish confiscated were G. rappi, this figure is not a good reflection of the situation throughout the entire system. Further analysis of the results show that G. rappi was the species most often caught in Nhlange but gill nets were most easily seized in this lake. Figures for nets seized in the northern channels of the system showed fewer G. rappi, with members of the

Table 10. Species composition of catches of a sample of seized gill nets at Kosi and comparable data from St. Lucia.

Species	Number	Percentage	Cumulative percentage	Whitfield (1977) (St. Lucia)
Gerres rappi	198	40,33	40,33	-
Pomadasys commersonni	64	13,03	53,36	6,51
Mugil cephalus	62	12,63	65,99	46,39
Oreochromis mossambicus	35	7,13	73,12	22,79
Rhabdosargus sarba	28	5,70	78,82	3,20
Chanos chanos	22	4,48	83,30	0,42
Liza macrolepis	18	3,67	86,97	-
Acanthopagrus berda	14	2,85	89,82	1,81
Caranx spp.	10	2,04	91,86	0,03
Clarias gariepinus	8	1,63	93,49	0,87
Monodactylus spp.	8	1,63	95,12	-
Valamugil buchanani	7	1,43	96,55	-
Lutjanus argentimaculatus	4	0,81	97,36	-
Liza alata	3	0,61	97,97	-
Therapon jarbua	2	0,41	98,38	-
Ambassis spp.	2	0,41	98,79	-
Gerres acinaces	2	0,41	99,20	-
Sphyraena spp.	2	0,41	99,61	-
Tylosurus leiurus	1	0,20	99,81	-
Scomberoides lysan	1	0,20	100,01	-
TOTALS -	491	100,01	100,01	

Table 11. Details of gill nets and netting seized by the KwaZulu Bureau of Natural Resources in the Kosi system.

Year	Total number of nets	Total length
1981	301	2 602 metres
1982	112	1 852 metres
1983	88	2 325 metres
1984	56	1 246 metres

Muglidae being the most common fishes in nets confiscated there (see Table 37 in Chapter 7). During January 1980 at least two vehicles were taking loads of fish away for sale almost daily (Kyle, 1981a). Vehicles carrying gill netted fish were seldom seen with a load of under 150 kilograms, thus giving an indication of the netting success at that time.

Although Blaber (pers. comm.) did not regard gill netting at Kosi as inherently bad, he did consider it as virtually impossible for the system to sustain both a successful fish trap and gill netting fishery.

3.1.7 Other methods

Jigging, baited fish trap baskets and clubbing of fish in flooded areas were all observed at Kosi during the study. Jigging, the use of large, unbaited hooks to foul-hook fish, was illegal although it occurred regularly and could produce considerable quantities of fish. One individual apprehended while jigging in 1982 had 42 fish with a total mass of 25 kilograms in his possession.

It is not possible to estimate the total fish off-take by these minor methods, but compared with the methods discussed earlier they are not considered to be important. No poisoning or other methods of fish capture were observed in the area during this study.

3.2 Natural predation on fish

3.2.1 Introduction

The transparent water of the Kosi system does not favour bird predation on fishes (Cyrus & Blaber, 1984a) and this has led to the presence of a low species diversity and smaller numbers of avian piscivores when compared with other systems, such as St. Lucia (Whitfield, 1977). Cyrus and Blaber (1984a) regarded the white-breasted cormorant (*Phalocrocorax carbo*) and the reed cormorant (*Phalocrocorax africanus*) as the only avian fish predators of possible importance to the larger fish of Kosi. Several avian fish predators which occur at Kosi feed mainly in the southern freshwater areas of the system or in nearby pans but roost at Kosi during the night. Reptilian piscivores, the crocodiles (*Crocodylus niloticus*) and water monitors (*Varanus niloticus*), are also more common in the southern reaches and surrounding swamps.

Blaber (1973) reported that in an eastern Cape estuary density dependent avian predation on juvenile *Rhabdosargus sarba* reduced the population by 80%. Since it has been shown that avian fish predation in estuaries can have such an effect attempts were made to assess its impact on the fishes of the Kosi system.

3.2.2 Methods

Regular counts of *P. carbo* and *P. africanus* were made throughout the study period. The counts were made from a boat with two observers, usually the same two, travelling the length of the channels and lakes north of Nhlange. Each survey was carried out between 08h00 and 10h00 and as far as possible were completed during calm, dry weather in order to make results comparable. Both species of *Phalocrocorax* concerned are large, dark birds and were usually seen resting on fish trap poles or swimming in the clear water. The results should thus be fairly accurate.

P. carbo did not feed regularly south of the area covered by regular counts but small numbers of *P. africanus* were seen around the margins of the southern areas. Accurate counts in the southern regions were not possible because of the size of the area. Estimates could be misleading as many *P. africanus* roosting nightly around Nhlange were seen to leave early in the morning returning at dusk having apparently fed outside the Kosi system. *P. africanus* numbers are thus best estimates but probably represent "under counts" for the whole system.

Boat patrols were also regularly made in the southern areas of the system in order to estimate crocodile numbers, although dense vegetation made accurate counts impossible.

3.2.3 Avian piscivores

a) White-breasted cormorants (*Phalocrocorax carbo*)

P. carbo was the most obvious avian piscivore at Kosi during the study period. Roosting was communal and usually occurred on the fish trap stakes, where large numbers of birds congregated. Whitfield (1977) described the fishing method of the birds at St. Lucia which appeared similar to those observed at Kosi.

Jackson (1984) reported that at Kosi most prey items fell into the 20 - 130 millimetres (standard length) range. Larger prey items were, however, also taken and during this study a *Mugil cephalus* of 450 mm (T.L.) and a *Crenimugil crenilabis* of 380 mm (T.L.) were regurgitated when birds were approached. These fish are considerably larger than the maximum prey species size reported elsewhere for the species (Whitfield, 1977 ; Alletson, 1985) or previously from Kosi (Jackson, 1984).

Table 12 gives the number of *P. carbo* counted during this study. If those counted are assumed to feed at Kosi then the mean number of *P. carbo* feeding in the Kosi system daily was $\frac{564,4}{12} = 47,0$. Du Plessis (1957) found the daily food intake of caged *P. carbo* to be a maximum of 608,5 grams. Whitfield (1977) estimated that at St. Lucia they took in a mean of 454 grams of fish per day, but Junor (1972) reported that the diving piscivorous birds on which he worked, including *P. carbo*, ate 16% of their body mass daily and stated that the higher estimates were too generous. If Junor's (1972) figure is used with the mean daily number of birds from this survey and the mean bird mass from Maclean (1984) the following approximation of the annual off-take of fish by *P. carbo* at Kosi may be derived :

47,0 x 309 grams x 365 days
= 5 300,9 kg

Although the above figure can in no way be regarded as accurate, it is valuable in that it gives an idea of the importance of these birds in the overall off-take of fish from the Kosi system. An apparent correlation between the total biomass of avian piscivores and abundance of prey has been commented upon (Blaber, 1973 ; Whitfield, 1977). The numbers of P. carbo during the study followed an annual pattern (Kendall's Coefficient of Concordance = 0,818) which appeared closely related to the abundance of prey species in the shallows.

Table 12. Mean monthly counts of *P. carbo* from boat patrols

Month	1981	1982	1983	1984	Mean
Jan	-	70	46	67	61,0
Feb	-	13	-	66	39,5
Mar	26	29	51	19	31,3
Apr	25	16	22	-	21,0
May	10	8	40	20	19,5
Jun	25	14	-	14	17,7
Jul	42	-	49	31	40,7
Aug	58	50	-	37	48,3
Sep	83	62	74	64	70,8
Oct	86	48	-	-	67,0
Nov	94	51	75	-	73,3
Dec	84	65	74	-	74,3
TOTAL			-		564,4
Estimated daily mean			-		47

where - represents no data available

b) Reed cormorants (*Phalocrocorax africanus*)

Individuals and small groups of this species were often found in the northern reaches of the Kosi system. Table 13 summarises the numbers counted during the study. At Kosi P. carbo fed mainly in the northern clear, saline parts of the system, whereas P. africanus was more often found in the southern reaches (Cyrus & Blaber, 1984a).

Table 13. Mean monthly counts of P. africanus from boat patrols

Month	1981	1982	1983	1984	Mean
Jan	-	10	3	9	7,3
Feb	-	1	-	7	4,0
Mar	3	9	8	0	4,0
Apr	6	14	11	-	10,3
May	6,4	11	9	0	6,6
Jun	9	-	-	5	7,0
Jul	20	11	18	1	12,5
Aug	24	19	-	3	15,3
Sep	19	10	7	4	10,0
Oct	11	4	-	-	7,5
Nov	7	3,5	7	-	5,8
Dec	6	2	7	-	5,3
TOTAL			-		95,6
Estmated daily mean			-		7,97

where - represents no data available

Using Junor's (1972) figures for daily food consumption an estimate for the off-take of this species in this area is :-

7,97 x 87 grams x 365 days
= 253,09 kg

c) Fish eagle (Haliaeetus vocifer)

Observation throughout the study period indicated that there were 3 - 4 breeding pairs of fish eagles resident around the

Kosi system. In addition there were usually 2 - 3 juveniles at any given time. This gives a maximum total of 11 fish eagles and agrees with the estimate of about 6 resident pairs by Cyrus and Blaber (1984a).

Various workers throughout Africa have attempted to assess the daily food requirements of fish eagles. Brown (1980) estimated it as 145 grams and reported Sumba (unpublished data) as giving an estimate of 225 grams. Whitfield (1977) used a value of 200 grams. Since Whitfield's figure appears to approximate the mean of the other estimates and was established at St. Lucia, a similar system nearby, it is used in this study. If it is assumed that all resident fish eagles fed in the system all the time and that there was an average of three juveniles, then the annual quantity of food consumed could be estimated as :-

$$11 \times 200 \text{ grams} \times 365 \text{ days}$$
$$= 803 \text{ kg}$$

Whitfield (1977) found that over 60% of the diet of fish eagles at St. Lucia was made up of members of the Muglidae. Clarias gariepinus, Acanthopagrus berda, Tylosurus leirus, Oreochromis mossambicus, Pomadasys commersonni and Elops machnata all formed between 5 - 10% of their prey items. All these species were common at Kosi and observations here supported Whitfield's findings. Predation on fish by H. vocifer at Kosi observed by Cyrus and Blaber (1984a) was exclusively on mullet species. One H. vocifer was seen to take a live, injured Gerres rappi. During the winter months considerable numbers of Rhabdosargus sarba were seen dead or dying in Nhlange with various fins and parts of their bodies covered in a white fungal infection. Fish eagles were seen on several occasions picking up these fish.

d) Other avian predators

Throughout the study period notes were taken of the numbers of avian piscivores seen in the Kosi system. These, combined with the data on the previously reported avian piscivores are used to give estimates of the total avian piscivore numbers and off-takes at Kosi in Table 14. Daily food requirements for most species are taken from Whitfield (1977) while the remainder are estimated according to Junor (1972).

Information on prey species of other avian predators at Kosi is limited. Large groups of small terns (Sternidae) were regularly seen throughout the summer over Nhlange and Mpungwini, where they fed on shoals of the clupeid Gilchristella aestuarius congregated near the surface. Most other species fed mainly in the shallows and reedy margins and the food items were small fish, although herons and the giant kingfishers were seen taking crabs and amphibians as well. All the egrets also eat amphibians and insects (Maclean, 1984). The figures given here, however, assume that only fish were eaten. The figure of biomass of fish consumed is thus probably less than the estimate given in Table 14.

Although pelicans (Pelicanus spp.) were recorded as present in the system by Campbell (1969) and reported as common by Cooper (1974) they are no longer regularly seen in the area. Whitfield (1977) recorded pelicans travelling daily from breeding grounds at St. Lucia to feed in the Pongolo pans. Since the Kosi system is roughly equidistant with the Pongolo pans from St. Lucia, there must be a reason why the pelicans have stopped using Kosi. If pelicans were common at Kosi, their departure will have greatly reduced off-take by avian predators. Whitfield (1977) estimated that 87% of the daily avian fish off-take at St. Lucia was taken by white and pink-backed pelicans.

3.2.4 Reptile predation on fish

a) Varanus niloticus, the Nile monitor, was common at Kosi and fish are a part of its diet. The major part of the diet is, however, Insecta, Amphibia, Crustacea, Aves and Mollusca (Bruton & Haacke, 1980). Varanus predation on fish at Kosi is extremely difficult to estimate, but it is not on a scale

Table 14. Summary of the numbers of avian piscivores at Kosi from regular boat counts, their daily food intake and an estimate of their annual fish off-take

Species	Common name	Approx. mean daily no.	Consumption/day grams	Consumption/year kilograms	% of total
Phalocrocorax carbo	White-breasted cormorant	47	309	5 300,90	45,8
Haliaeetus vocifer	Fish eagle	11	200	803,00	6,9
Mesophoyx intermedius	Yellow-billed egret	15	145	793,88	6,9
Egretta garzetta	Little egret	15	140	766,50	6,6
Other Sternidae spp.	Small terns	100	19	693,50	6,0
Ardea cinerea	Grey heron	8	232	677,44	5,9
Ardea goliath	Goliath heron	2	693	505,89	4,4
Ardea purpurea	Purple heron	8	147	429,24	3,7
Ardea melanocephala	Black-headed heron	6	182	398,58	3,4
Ceryle rudis	Pied kingfisher	40	18	262,80	2,3
Phalocrocorax africanus	Reed cormorant	8	87	253,09	2,2
Pohierax angulensis	Palm-nut vulture	2	257	187,61	1,6
Pandion haliaetus	Osprey	2	238	173,74	1,5
Casmerodius albus	Great white egret	3	154	168,63	1,5
Megaceryle maxima	Giant kingfisher	4	55	80,30	0,7
Hydroprogne caspia	Caspian tern	2	91	66,43	0,6
TOTAL		-		11 561,53	

important to this study.

b) Crocodylus niloticus, the Nile crocodile, was present in the Kosi system and numbers are thought to be slowly increasing (Kyle, 1985). The official estimate of numbers accepted by the Maputaland Scientific Advisory Committee in 1981 was 10 specimens of over 1 metre in length. Crocodile counts were extremely difficult at Kosi as most large individuals were found in the extensive swampy areas in the south of the system. No specimens over 1 metre in length were resident north of Mthando channel during the study period.

Cott (1954) found that in Uganda individuals up to the length of 1 metre ate mainly insects (67% of their diet) and amphibians (15% of their diet). At 1 metre large fish formed only 1,5% of this diet while by the size of 2 metres this had risen to 13,5%. It was only by the length of over 3 metres that fish formed more than 50% of their diet.

Crocodiles at Kosi were concentrated in the swamps in the south of the system where large numbers of Clarias gariepinus, the sharptooth catfish occur. Throughout Africa the genus Clarias forms a major part of the diet of the Nile crocodile (Guggisberg, 1972), although it is recorded as eating considerable numbers of Mugil cephalus and other marine species at St. Lucia (Whitfield, 1977). Guggisberg (1972) reports a 2,3 metre crocodile at London Zoo as consuming a mean of 323 grams of food per day. Whitfield (1977) contrasts this with the calculated mean daily intake of a 2,3 metre crocodile at St. Lucia Crocodile Farm of 1 090 grams.

Since it was impossible to count the number of crocodiles at Kosi and it is not known accurately how much food they must consume daily or what proportion is fish, any calculation of off-take would be too inaccurate to be of value. Crocodiles capable of eating large fish were limited to the freshwater, southern areas. The effect of crocodiles on the marine fish species must be regarded as small.

3.2.5 Mammalian predation

The only mammalian piscivores were the clawless otter, *Aonyx capensis*, which was uncommon and had only been recorded once from the Sihadla river in the south (Kyle, 1981c), and water mongoose, *Atilax paludinosus*, which was common around the system. For this study 32 *A. paludinosus* scats were collected and examined microscopically and only one was found to contain fish remains. Whitfield (1977) found that 16% contained fish remains at St. Lucia and Rowe-Rowe (1975) obtained a figure of 9% in the Natal Midlands. No estimate of the number of water mongooses could be made. It is considered that such mammalian predation as did occur at Kosi had a minimal effect on the fish populations and the biomass of fish taken from the system by them was very small compared with the standing stock.

3.2.6 Fish predation

Fish predation is important and will be discussed later in this study.

4 THE FISH TRAP CATCH MONITORING SCHEME

4.1 Introduction

In 1980 the Maputaland Scientific Advisory Committee identified the monitoring of the catches of the fish traps as a priority project in the area. The traditional fish traps were numerous, reputedly badly controlled and their effect on fish populations and sedimentation in the Kosi system, had been the subject of considerable discussion (Campbell, 1948 ; Begg, 1978 ; van Heerden, pers. comm.).

Estimations on fish trap catch successes were based on casual observations (Bruton, 1974 ; Cyrus, 1980) and reports from sport fishermen and workers in the area (Tinley, 1964). Sport fishermen tended to the opinion that the fish traps were preventing fish from entering the lakes, were blocking the channels and were causing a shallowing of the northern reaches of the Kosi system. Researchers would not commit themselves on the effect catches had on fish populations (Cyrus, 1980). In 1980 the KwaZulu Government appointed me to map and monitor the fish traps and to obtain statistics on their catches.

4.2 Method

The locations of the fish traps were mapped and described, and it was found to be possible to record, on a daily basis, the catches of virtually all the fish traps in the area north of Mpungwini lake. A description of the traps is included in Appendix 2. Once locations of the traps had been mapped, the area was divided into five clearly demarcated areas. These were planned such that one man at a point near the centre could see all the fish traps in that sector. To each of these a local person, who could read, write and identify fish was allocated as enumerator. This man was paid a salary to be on duty at a vantage point in his area during the period of the day when traps could be tended. This time was dependent upon the season, weather, tides and the whim of the owner.

When a trap owner had emptied his trap, he was intercepted on his return to the shore by the enumerator. In practice it was possible to employ a well known trap owner as the enumerator in all the areas. Each enumerator was equipped with a metre-stick and a form on which to record details of the catch of each trap each day. Each fish was identified and measured to one millimetre of total fish length (T.L.) by the enumerator, but measurements were recorded to the nearest 10 millimetres for purposes of analysis. Each trap had been numbered and the enumerator had to account for every trap in his area each day. Nill returns were submitted when no catch was made.

Identification of fish was, at first, a problem. It was found that the local people had an exceptionally good knowledge of the fish, but that there were some differences of opinion as to the names of some of the species which were very alike. All identifications were made in Zulu, but a considerable effort had to be made to standardize Zulu names throughout the system. Certain species were known by a variety of names and many of the younger people tended to mis-identify some species and lump others together. Problems arose with the Muglidae, where six very similar species were caught in considerable numbers. By speaking to some of the older men of the area, names were found for all six species. These names and identifications were then handed on to all the people involved in measuring and identifying fish. In most cases satisfactory names and distinguishing features were found to enable each species to be correctly identified. A full list of Scientific, Zulu and English names is included in Appendix 3.

The only serious identification problem which could not be resolved was the genus Caranx. The local people believed that there was only one species, though there were males and females, old and young, accounting for the apparent difference. Several names were obtained but no consistent description could be found and no satisfactory identification made by all the enumerators. Under pressure they would identify to species level, but it was found on investigation that this was done arbitrarily and simply to satisfy the paymaster. After many frustrations it was decided that the only possibility was to treat the genus as a single entity. Fortunately the genus Caranx forms a minor part of the catch of the traps for most of the year. The major fish species caught in the traps were easily identified and the separation of all was found to be completely satisfactory before the actual catch monitoring began. Working as an enumerator became a sought after position as the work itself was not difficult and the remuneration, satisfactory. Enumerators were often able to work on the maintenance of their own fish traps while waiting for the other traps to be emptied.

Drinking and absenteeism were major problems in the initial phases of the project, but were overcome fairly rapidly. Drunkenness could immediately be detected when the daily returns were seen to be untidy, and attendance was checked on average every two to three days on an erratic basis by foot, boat or vehicle. After a few initial staff changes a good team was soon established. During spring tides and at other times when many fish were being caught, two enumerators were stationed in each area. Relief enumerators were always available and each man was given sufficient time off each month.

Before the monitoring scheme was instituted there had been a long series of meetings with local people and authorities. The first meetings had been with the local Chief and Tribal Council who had approved the plan in principle and supported it. The final meetings were a series held along the banks of the system with the relevant local Indunas and their people. As was found by Balfour-Cunningham (1985) the local people were extremely suspicious of any new idea and it took a great deal of time and effort to convince them that the monitoring scheme could not harm them or affect the fish catches.

Because the scheme had the approval of the Chief and Tribal Council, and because it would bring some employment to the area and was being conducted by people known locally, the fish trap owners co-operated remarkably well. At all the meetings the trap owners had complained about illegal gill netting. Initially the monitoring scheme was combined with an anti-gill netting effort. This was a major factor contributing to gaining the goodwill of the trap owners.

Occasionally personal problems, unrelated to work, would arise between the enumerators and the fish trap owners. When this happened the local Induna was called in to settle the dispute. On several occasions individual trap owners took exception to their fish being measured. In these cases the Induna would explain that the project had the approval of the Tribal Council and their co-operation was compulsory. As a last resort the fish trap owner could have been fined or have forfeited his fish traps to the Induna. However, for the duration of the project, this never occurred. In the latter stages of the study the Induna was permanently employed checking on the catch returns.

By the end of the study, the enumerators had a considerable local standing and having the fish measured had become part of the routine of emptying the traps.

The period of intensive catch monitoring was from the 1st April 1981 until the 31st March 1985. All fish data collected were entered on a Hewlett Packard 9825 B computer for basic analysis and organisation. All the physical parameters which could be monitored and might have had an effect on fish movements were also monitored during this period with a view to defining causes and effects on fish movements.

The fish trap catches mainly reflect the movement of fish from the lakes to the ocean and to a much lesser extent from the ocean to the lakes. Most of the fish species of the Kosi system are of marine origin (Blaber, 1978 ; Blaber & Cyrus, 1981) and all mature fish of the larger species must migrate to the ocean to spawn each year (Wallace, 1975b).

This being the case, the annual catch of the traps represents a sample of the mature marine fish populations of the Kosi system by catching a fairly constant proportion of each species each year. Appendix 4 gives details of the number of working fish traps on a monthly basis throughout the study period. As can be seen, the total number of traps working did not deviate by more than 14% from the mean. The actual variation in "total trap catch effort" was very small because the most productive traps were in permanent use throughout the study. The fluctuations in numbers mainly represented the less successful trap owners attempting to find better sites. By harnessing the daily catch effort it was possible to obtain data on the fish populations and migrations. The traps provided an ideal sampling method on a scale which would virtually be impossible to reproduce by experimental fishing. Most fisheries models are based on the catch statistics of a sample of commercial fishermen and some of these have proved to be remarkably accurate (Ricker, 1958). This method employs the entire catch of the fishermen using traps and should give a good insight into the status of the larger marine fish species at Kosi.

Since the traps have, on available evidence, been in operation for hundreds of years at roughly the same level of intensity, they must be in balance with fish populations occurring in the system today. If an additional intensive sampling programme were to be introduced, then the number of adult fish reaching the ocean would suffer a substantial reduction proportional to the new fishing intensity, and the trap catches would, presumably, also be affected. By exploiting an extant and continuing off-take, the advantages of large samples are obtained without the disadvantage of the population itself being distorted by the sampling.

The numbers, total length and species of fish caught were recorded by the enumerators. Masses were calculated from length frequency analyses, an example of which is shown in Appendix 5, combined with length/mass information from van der Elst (1981) and further data from this study.

Gonad condition was assessed by inspection of fish bought from trap owners, and gill netted and tourist caught fish. If only trap caught fish had been examined and fish movement was breeding related, then the sample would have been biased towards fish with developed gonads. Where possible, data were obtained from fish caught by various methods. Initially gonad condition was assessed by enumerators but this was found to be inaccurate. Nearly all examinations were therefore carried out by me and efforts were made to sample each species each month.

The estimated lengths of each species at maturity was obtained from the literature or by examination in the field (see Appendix 6). Only fish above these lengths were examined and initially the stages of gonad development used were those described by Wallace (1975b). A large amount of data were collected and since only a guide to the reproductive cycle was needed in this study, Wallace's (1975b) six categories were reduced to two : the conditions which Wallace (1975b) called "inactive and spent" were considered "inactive" and the rest as "active". Field examinations were separated into the six categories in order to record the presence of the developmental stages and of fish ready to spawn. The gonad condition data were reduced to two stages (see Appendix 6) for the statistical analysis in Chapter 5. Detailed examination of the trap caught fish was not normally possible, as the trap owners were extremely suspicious of anyone touching the fish, even when dead. A compromise was reached in many cases where a small slit was made in the abdomen of the fish and the gonads examined without being removed. In this way considerable numbers of fish could be investigated.

The feeding habits of the major species were assessed by stomach content analysis. Fish stomachs were collected principally from tourist caught fish as it was found that trap caught fish usually had empty stomachs. This was either through the fish not eating while migrating or due to their voiding the contents in the faeces in the period spent in the basket before final capture. All stomach content analyses were done by me using a binocular microscope. Data for important species are given in the form of pie charts.

The pie charts of percentage relative frequency were prepared to show the relative proportion of stomachs examined which contained one type of food in relation to the other food types. For the preparation of relative bulk pie charts, each stomach with food was given a rating of 10. The different food types were assessed as the relative amounts each food type comprised of the total amount and given a value between 1 and 10 with a total of 10 for each stomach. The values for all stomachs were then summed up to give a total relative bulk, and the proportions of each food type represented as pie charts. The ranking of this system was arbitrary, but the relative proportions should give a true indication of the importance of the various constituents in most cases. There will be a bias over emphasizing less important items since a minimum rating of 1 was given where a food type was present.

4.3 Results of fish trap catch monitoring programme

Table 15 shows the annual catch statistics as numbers and percentages of the fish caught in the fish traps. Table 16 gives the same data by mass for twenty of the most important species. Figure 9 shows the relative numerical importance of the major species for each year and compares this with the same data expressed as mass. The order in which the species are treated is that of the importance in terms of mass during the study, as this best reflects the importance of the species. Data on the remaining, unimportant species are included in Appendix 7.

4.3.1 Trap catch statistics of the major fish species of the Kosi system

In this section each species is treated individually, and trap catch data are discussed. A brief summary of the present knowledge of the species from published sources and from this study is also given. Fish nomenclature follows that of Smith (1975) and generic names not already given, but abbreviated in Tables 15 and 16, are stated in full when each species is discussed separately.

Table 15. Yearly catch statistics by numbers from the Kosi Bay fish trap monitoring programme. 1/4/81 - 31/3/85

Species	1981 - 2 No.	1981 - 2 %	1982 - 3 No.	1982 - 3 %	1983 - 4 No.	1983 - 4 %	1984 - 5 No.	1984 - 5 %	Total No.	Mean yearly %
1. *P. commersonni*	8 774	22,04	15 659	37,43	18 147	39,59	11 090	29,25	53 670	32,45
2. *M. cephalus*	12 602	31,65	6 972	16,67	11 653	25,42	10 244	27,02	41 471	25,07
3. *A. berda*	2 902	7,29	2 853	6,82	2 910	6,53	2 168	5,72	10 833	6,55
4. *V. buchanani*	517	1,30	687	1,64	769	1,68	1 656	4,37	3 629	2,19
5. *L. macrolepis*	6 409	16,10	5 453	13,03	3 286	7,17	2,386	6,25	17 534	10,60
6. *R. sarba*	1 347	3,38	3 696	8,83	2 058	4,49	605	1,60	7 706	4,66
7. *G. rappi*	3 329	8,36	3 565	8,52	3 445	7,51	4 687	12,36	15 026	9,08
8. *Caranx* spp.	651	1,64	648	1,55	898	1,96	1 030	2,72	3 227	1,95
9. *L. argentimaculatus*	677	1,70	459	1,10	203	0,44	194	0,51	1 533	0,94
10. *L. alata*	799	2,01	699	1,67	440	0,96	651	1,72	2 589	1,57
11. *C. chanos*	253	0,64	36	0,09	108	0,24	750	1,98	1 147	0,69
12. *Sphyraena* spp.	347	0,87	278	0,66	274	0,60	322	0,85	1 221	0,74
13. *E. machnata*	161	0,40	48	0,11	100	0,22	235	0,62	544	0,33
14. *O. mossambicus*	451	1,13	288	0,69	348	0,76	428	1,13	1 515	0,92
15. *P. indicus*	107	0,27	63	0,15	110	0,24	123	0,32	403	0,24
16. *S. lysan*	28	0,07	21	0,05	125	0,27	105	0,28	279	0,17
17. *G. acinaces*	135	0,34	174	0,42	158	0,34	108	0,28	575	0,35
18. *P. saltatrix*	191	0,48	23	0,05	80	0,17	24	0,06	318	0,19
19. *C. gariepinus*	16	0,04	-	-	18	0,04	11	0,03	45	0,03
20. *E. tauvina*	13	0,03	10	0,03	10	0,02	29	0,08	62	0,04
Other species	106	0,26	205	0,49	703	1,53	1 068	2,82	2 082	1,27
TOTAL	39 815		41 837		45 843		37 914		165 409	

MEAN ANNUAL CATCH = 41 352,3

Table 16. Yearly catch statistics by mass in kilograms from the Kosi Bay fish trap monitoring programme. 1/4/81 - 31/3/85

Species	1981 - 2		1982 - 3		1983 - 4		1984 - 5		Total	Mean yearly
	Mass	%	Mass	%	Mass	%	Mass	%	Mass	%
1. P. commersonni	9 987	25,02	19 095	48,01	19 373	43,70	11 377	30,75	59 832	37,16
2. M. cephalus	16 331	40,91	8 674	21,81	14 103	31,82	13 606	36,77	52 714	32,74
3. A. berda	2 293	5,74	1 999	5,03	1 998	4,51	1 477	3,99	7 767	4,82
4. V. buchanani	1 291	3,23	1 066	2,68	1 207	2,72	3 351	9,06	6 915	4,29
5. L. macrolepis	1 881	4,71	1 712	4,31	1 121	2,53	803	2,17	5 517	3,43
6. R. sarba	1 214	3,04	1 931	4,86	1 706	3,85	374	1,01	5 225	3,25
7. G. rappi	880	2,20	1 007	2,53	975	2,20	1 303	3,52	4 165	2,59
8. Caranx spp.	813	2,04	851	2,14	1 055	2,38	1 109	3,00	3 828	2,38
9. L. argentimaculatus	1 443	3,62	1 144	2,88	578	1,30	515	1,39	3 680	2,29
10. L. alata	724	1,81	1 067	2,68	690	1,56	719	1,94	3 200	1,99
11. C. chanos	1 555	3,90	220	0,55	182	0,41	899	2,43	2 856	1,77
12. Sphyraena spp.	729	1,83	642	1,62	552	1,25	611	1,65	2 534	1,57
13. E. machnata	265	0,66	82	0,21	278	0,63	343	0,93	968	0,60
14. O. mossambicus	223	0,56	132	0,33	173	0,39	228	0,62	756	0,47
15. P. indicus	31	0,32	76	0,19	125	0,28	135	0,37	464	0,29
16. S. lysan	26	0,07	14	0,04	99	0,22	71	0,19	210	0,13
17. G. acinaces	27	0,07	42	0,11	40	0,09	25	0,07	134	0,08
18. P. saltatrix	71	0,18	8	0,02	28	0,06	10	0,03	117	0,07
19. C. gariepinus	24	0,06	-	-	32	0,07	28	0,08	84	0,05
20. E. tauvina	12	0,03	7	0,02	12	0,03	17	0,05	48	0,03
TOTAL	39 917		39 769		44 327		37 001		161 014	
MEAN ANNUAL CATCH = 40 253,5										

161 014 kg caught in (7076 × [illegible]) i.e. 2843[illegible] trap days = 0,566 kg/trap/day.

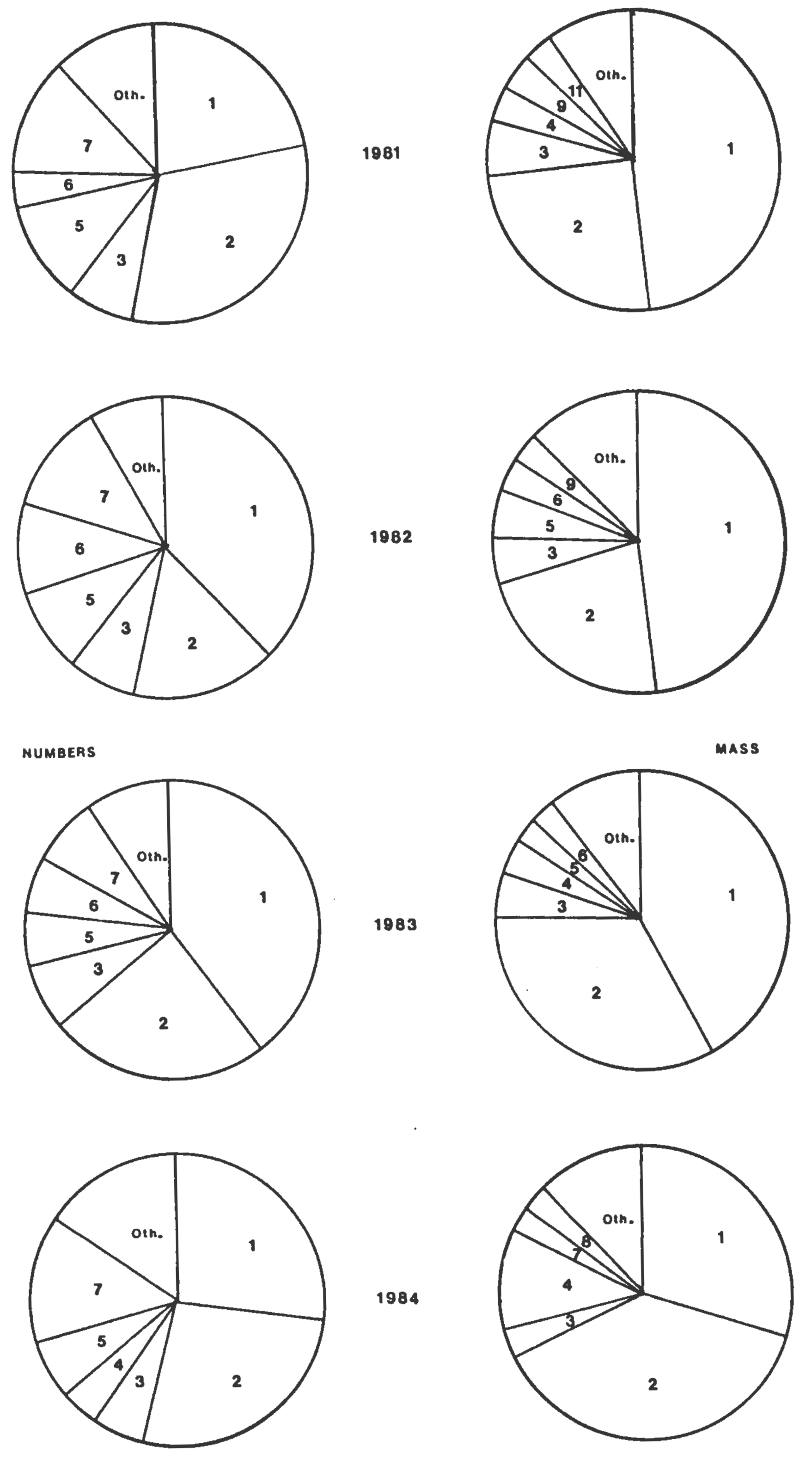


Figure 9. Relative importance of the major fish species caught in the Kosi fish traps assessed in terms of numbers and mass (Individual species are denoted by the numbers in Tables 15 & 16 ; oth - all other species).

1. Pomadasys commersonni (Lacépède 1802)

a) Trap catch statistics

	1981	1982	1983	1984	Total/mean
Number caught	8 774	15 659	18 147	11 090	53 670
Mean length (T.L.)	445mm	474mm	447mm	439mm	451mm
95% confidence limits (mm)	442 - 448	472 - 476	446 - 448	437 - 441	
Rank by numbers	2	1	1	1	1
Rank by mass	2	1	1	2	1

This is clearly the most important species in the trap catches. An example of a computer print-out on the basic analysis of one year's data is included in Appendix 5a and of the daily catch statistics in Appendix 5b. The annual pattern of catches and daily fluctuations will be discussed in Chapter 5.

Figure 10 shows the length frequency statistics for 1983, showing the size composition of the catches month by month. This figure suggests that if breeding takes place in late winter (Wallace, 1975b) there could be one age class at 420 mm (T.L.), one at 470 mm (T.L.), one at 530 mm (T.L.) and one at 580 mm (T.L.). These classes probably correspond with the ages 3, 4, 5 and 6 years old, which compares well to the age estimates given by van der Elst (1981). The percentages of each age class inside the system appear similar to those of the adult population in general (van der Elst, 1981).

As can be seen in Table 15, Appendix 9 and elsewhere trap catches fluctuated markedly from year to year. The pattern of fluctuation bears no obvious relation to the environmental parameters measured inside the Kosi system, and this will be discussed further in Chapter 5. A close relationship was found between the catch per unit effort (C.P.U.E.) of the fish traps and data from Natal shore fishing competitions. Data collected annually by the Oceanographic Research Institute (Adkin, pers. comm.) on shore fishing

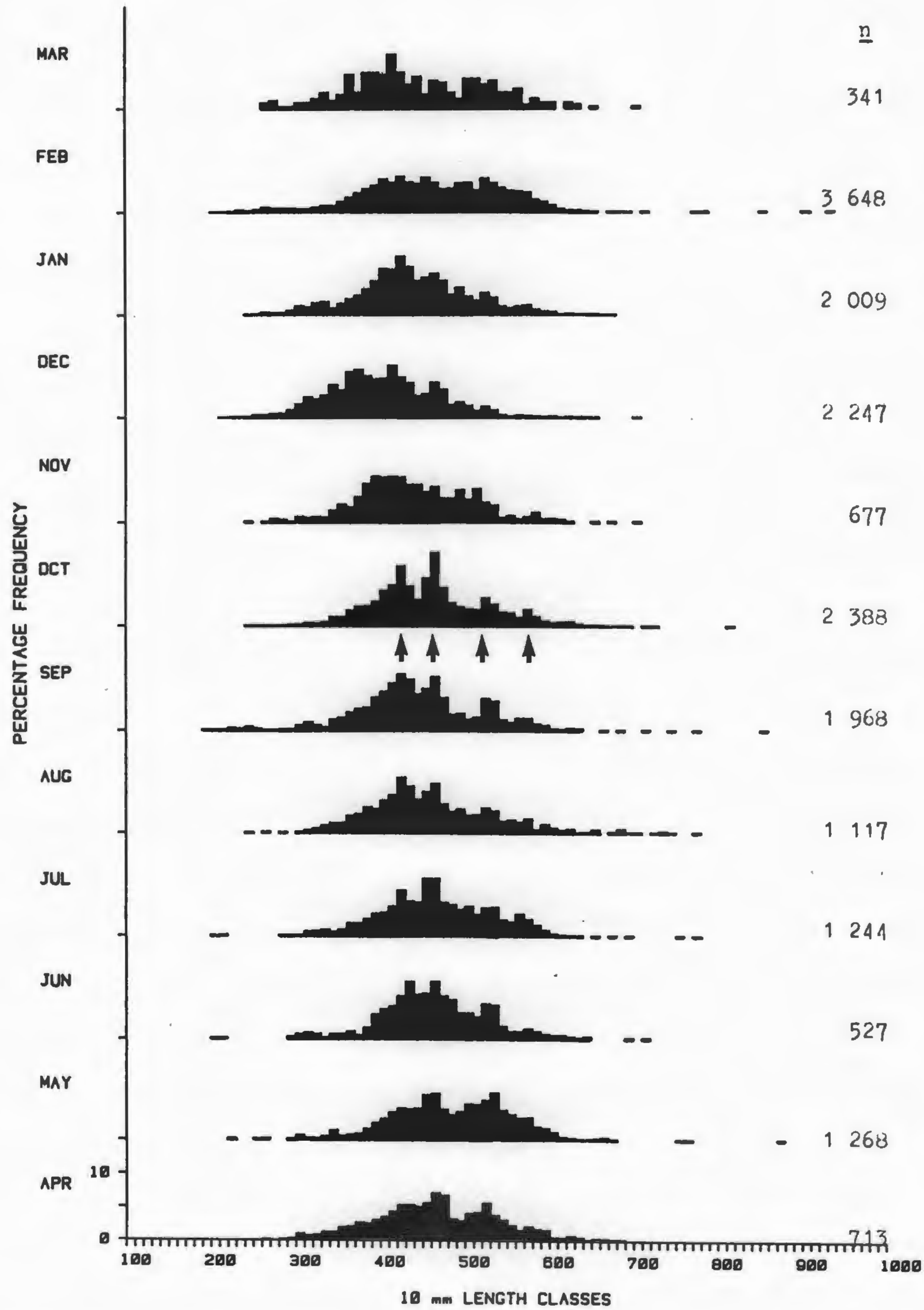


Figure 10. Length frequency analysis of P. commersonni trap catches month by month during the period April 1983 - March 1984 (▲ denotes probable age classes).

competitions should represent the abundance of P. commersonni in the inshore environment each year. Table 17 shows that if the total catches of the fish traps are regarded as a simple C.P.U.E., and these are compared with the shore fishing C.P.U.E., there is a highly significant correlation between the two sets of data.

Table 17. Comparison of C.P.U.E. from shore fishing competitions and fish traps

Year	Shore fishing	Fish traps
1981	0,14	8 774
1982	0,21	15 659
1983	0,23	18 147
1984	0,15	11 090

Correlation coefficient = 0,995 (Significant at $P < 0{,}01$ with 2 degrees of freedom)

This correlation indicates that the P. commersonni catches by the fish traps at Kosi vary yearly in the same way as those of that species along the Natal coast, implying that the same parameter controlled the abundance of both populations. These populations are spatially separated most of the time, but all breed in the inshore zone of the Natal coast (Wallace, 1975b). It is probable that the breeding success in the sea and recruitment into the catchable population year by year control abundance of this species similarly throughout the region.

The success of the fish traps in catching this species appears primarily dependent upon exogenic factors.

b) Gonad condition

As can be seen from Appendix 6, relatively few of the fish examined inside Kosi had gonads in an active condition. Wallace (1975b) considered that the absence of fish with well developed gonads inside Natal estuaries indicated these developmental stages to become manifest outside the estuarine environment. Data collected during this study indicate spawning to occur in late winter and agree with Wallace (1975b) that most of the mature P. commersonni inside the system are in their least active reproductive condition.

c) Feeding habits and diet

The food of P. commersonni is usually described as being Crustacea, Bivalvia and Polychaeta (Smith, 1977 ; van der Elst, 1981). The results of stomach content analysis of fish investigated for the study are given in Figure 11 which shows the selection of food items and the relative importance of each. It can be seen that P. commersonni in the saline areas of Kosi is largely dependent upon Callianassa kraussi and Hiatula lunulata, while in the fresh water it feeds mainly on the larvae of Chironomidae. Of note was the presence of fish in the diet of P. commersonni at Kosi. One 380 mm (T.L.) P. commersonni was found to have a 110 mm (T.L.) Ambassis natalensis in its stomach. Predation by this species on fish has not previously been reported.

d) General

P. commersonni is an estuarine common but not an estuarine dependent species (Wallace & van der Elst, 1975) and catch statistics can fluctuate markedly from year to year. It is well suited to the Kosi system where its food is plentiful. Decreasing salinity will not directly affect this species, as food is available in fresh water, but low salinity combined with low temperatures may occasionally approach levels lethal to this species (Blaber & Whitfield, 1976).

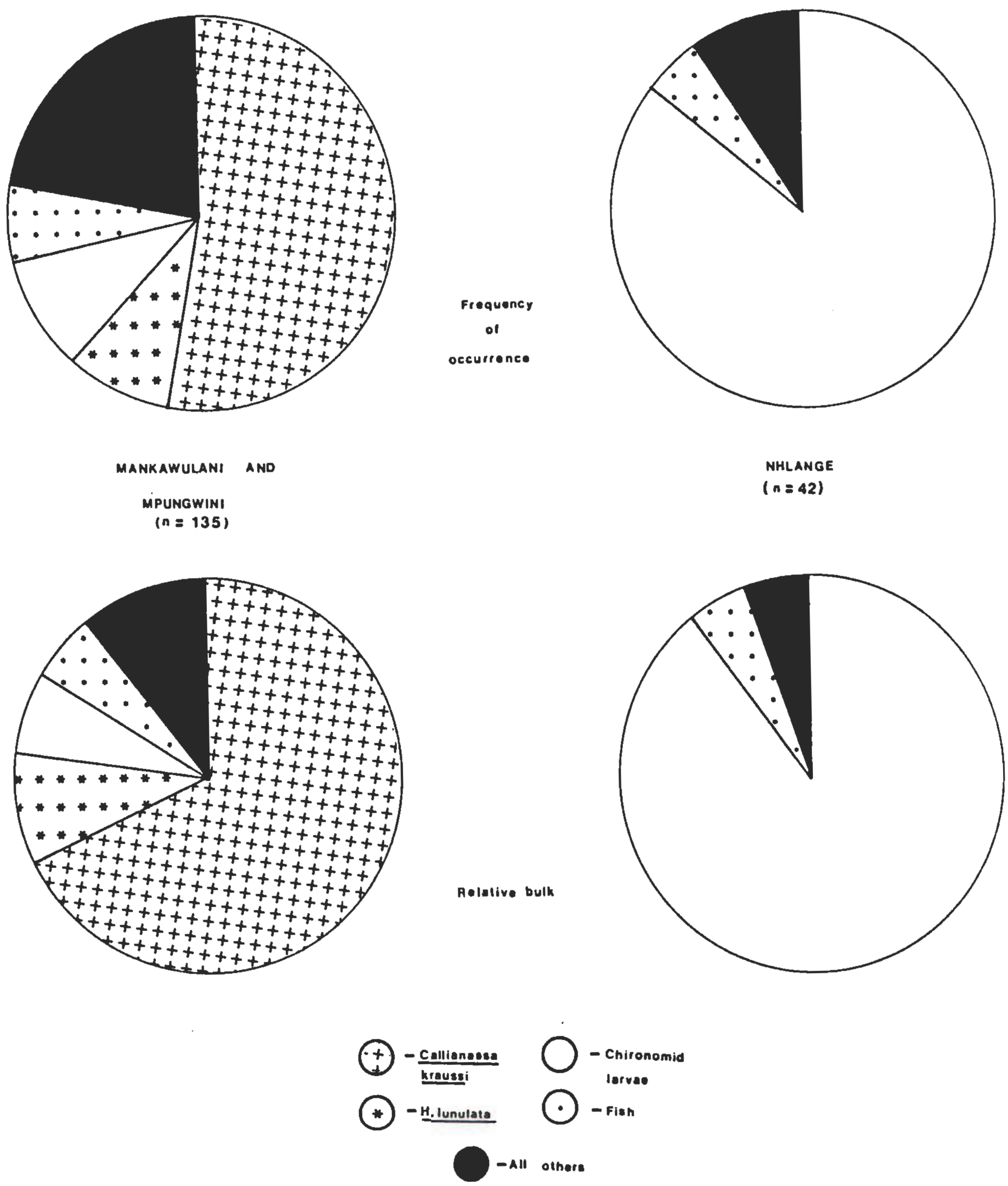


Figure 11. Results of stomach content analysis of P. commersonni from two areas in the Kosi system, showing frequency of occurrence and relative bulk of major food items.

2. Mugil cephalus (Linnaeus 1758)

a) Trap catch statistics

	1981	1982	1983	1984	Total/mean
Number caught	12 602	6 972	11 653	10 244	41 471
Mean length (T.L.)	451mm	456mm	455mm	467mm	457mm
95% confidence limits (mm)	449 - 453	453 - 459	453 - 457	465 - 469	
Rank by numbers	1	2	2	2	2
Rank by mass	1	2	2	1	2

During the study period M. cephalus was the second most important constituent of the trap catches, both numerically and in terms of mass. Figure 12 shows the monthly length frequency distributions and indicates possible age classes. The breeding season is thought to begin in May (Wallace & van der Elst, 1975) and in that month there are peaks in catch abundance at 420 mm (T.L.), 470 mm (T.L.), 520 mm (T.L.) and 570 mm (T.L.). Data from van der Elst (1981) suggest that these may correspond to 3, 4, 5 and 6 year old fish. All age classes appear to be represented in the trap catches in roughly the same proportion as that expected for the whole population (van der Elst, 1981).

This species is not completely estuarine dependent although it is said to be common in estuaries (Smith, 1977) and predominantly an estuarine species (van der Elst, 1981).

Trap catch numbers fluctuated by up to 45% from one year to the next and this did not appear related to parameters measured inside the system. This will be discussed further in Chapter 5. It is interesting to note that despite the considerable fluctuations in catches of P. commersonni and M. cephalus the total numerical proportion of the trap catches made up by these two species only varied between 54% and 65%. Evidence from this study is not conclusive, but results indicate that catches of the two species may sometimes be negatively correlated with each other. The correlation

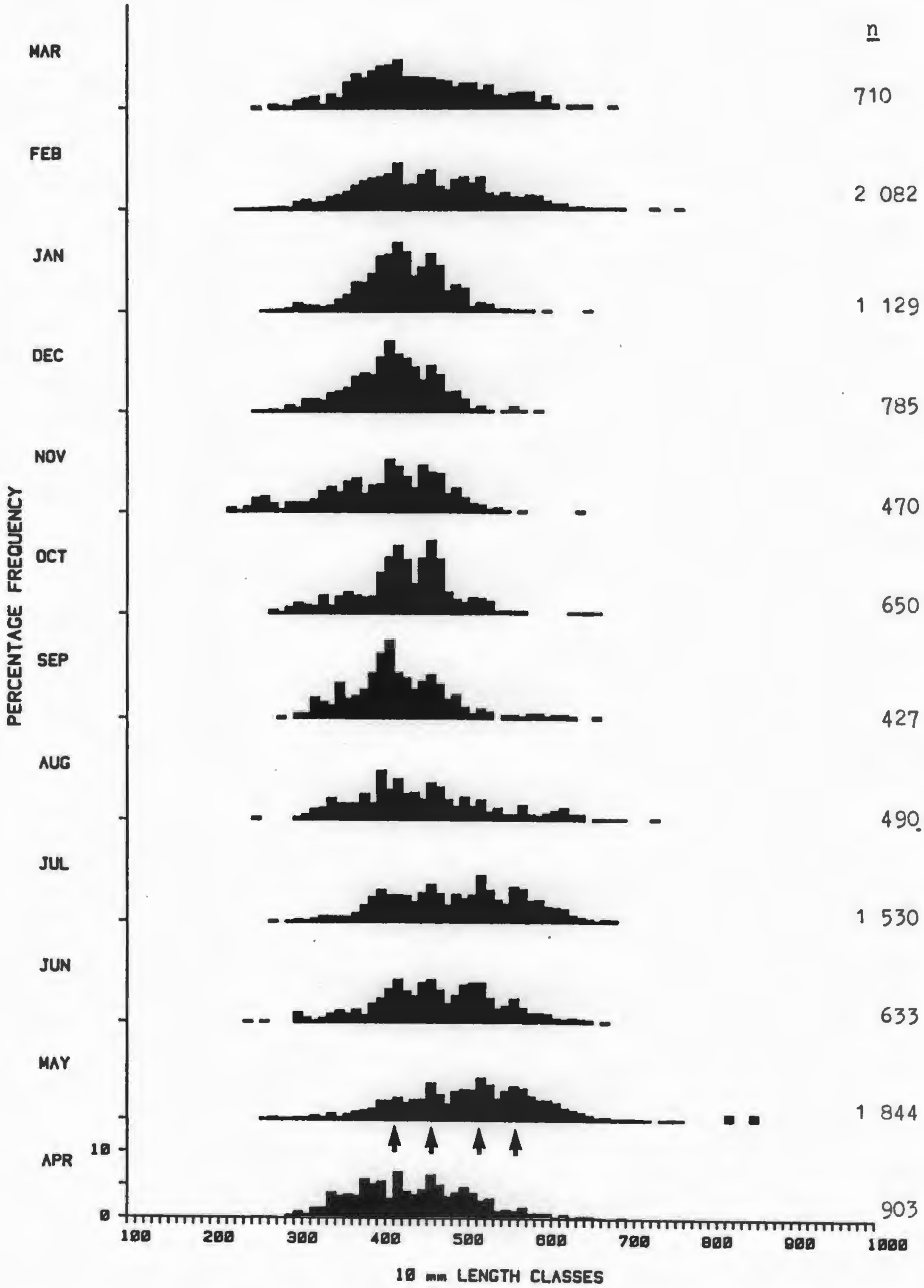


Figure 12. Length frequency analysis of M. cephalus trap catches month by month during the period April 1983 - March 1984 (▲ denotes probable age classes).

coefficient between the total annual catches of the two species over the four years is -0,36, which is not significant (at P = 0,1). Using the data for 1981, 1982 and 1984 only a significant correlation coefficient (at P = 0,1) of -0,99 is however obtained, but no valid reason for excluding the 1983 catches is immediately apparent from this study. A negative correlation, if proved true by further sampling, would have important implications for the stability of the fish trap fishery in as much as the amount of food produced annually would be similar regardless of species composition. The Kosi system offers an abundant food supply for M. cephalus (Blaber, 1978) and since the whole of the Kosi system falls within the recorded salinity tolerance of this species (Whitfield et. al., 1981) neither of these should be factors limiting the presence of M. cephalus at Kosi. The preference of this species for turbid water (Cyrus, 1984) does not appear to influence their presence at Kosi. The mean length of fish caught remained fairly constant, indicating a stability in population structure independent of population size.

The number of this species caught in the traps appears to be dependent on exogenic factors.

b) Gonad condition

As can be seen in Appendix 6, there is a clear annual spawning cycle with developing gonad conditions well represented inside the system. The only gonad conditions not found were ripe-running and partially spent. Fully developed, turgid gonads and freshly spent gonads were found in fish indicating that spawning takes place outside the system, but probably not far away. The data collected for this study closely parallel the findings of Wallace and van der Elst (1975) at St. Lucia.

c) Feeding habits and diet

M. cephalus is considered to be iliophagous throughout its range and during most of its life cycle (Blaber, 1976 ; 1978). All full stomachs examined at Kosi contained a mixture of sand and microscopic organisms. Fish were found with full stomachs throughout the system and at all times of the year. No evidence was found to indicate that food availability was a limiting factor in the system. Odum (1970) reported that M. cephalus could feed on either micro-algae or macro plant detritus, but favoured the former if both were available. At Kosi both are in abundant supply (Blaber, 1976 ; Begg, 1978) and as virtually no macrophyte detritus was found in stomachs, it appears that Odum's (1970) findings applied at Kosi.

d) General

The life cycle of M. cephalus is, in many ways, similar to P. commersonni. The main differences are that M. cephalus is probably more estuarine orientated and that recruitment to the estuarine environment is at an earlier stage. This species can tolerate conditions throughout the Kosi system.

3. Acanthopagrus berda (Forsskål 1775)

a) Trap catch statistics

	1981	1982	1983	1984	Total/mean
Number caught	2 902	2 853	2 910	2 168	10 833
Mean length (T.L.)	320mm	318mm	314mm	315mm	316mm
95% confidence limits (mm)	317 - 323	315 - 321	311 - 317	312 - 318	
Rank by numbers	5	6	5	5	5
Rank by mass	3	3	3	4	3

A. berda is the third most important component of the trap catches. Figure 13 shows the length frequencies of the catch month by month.

A. berda is regarded as an estuarine dependent species (Begg, 1978 ; van der Elst, 1981) and Begg (1978) stressed its decline in numbers which he ascribed to the degradation of many of Natal's estuaries. The most obvious features of the trap catches of this species at Kosi are the

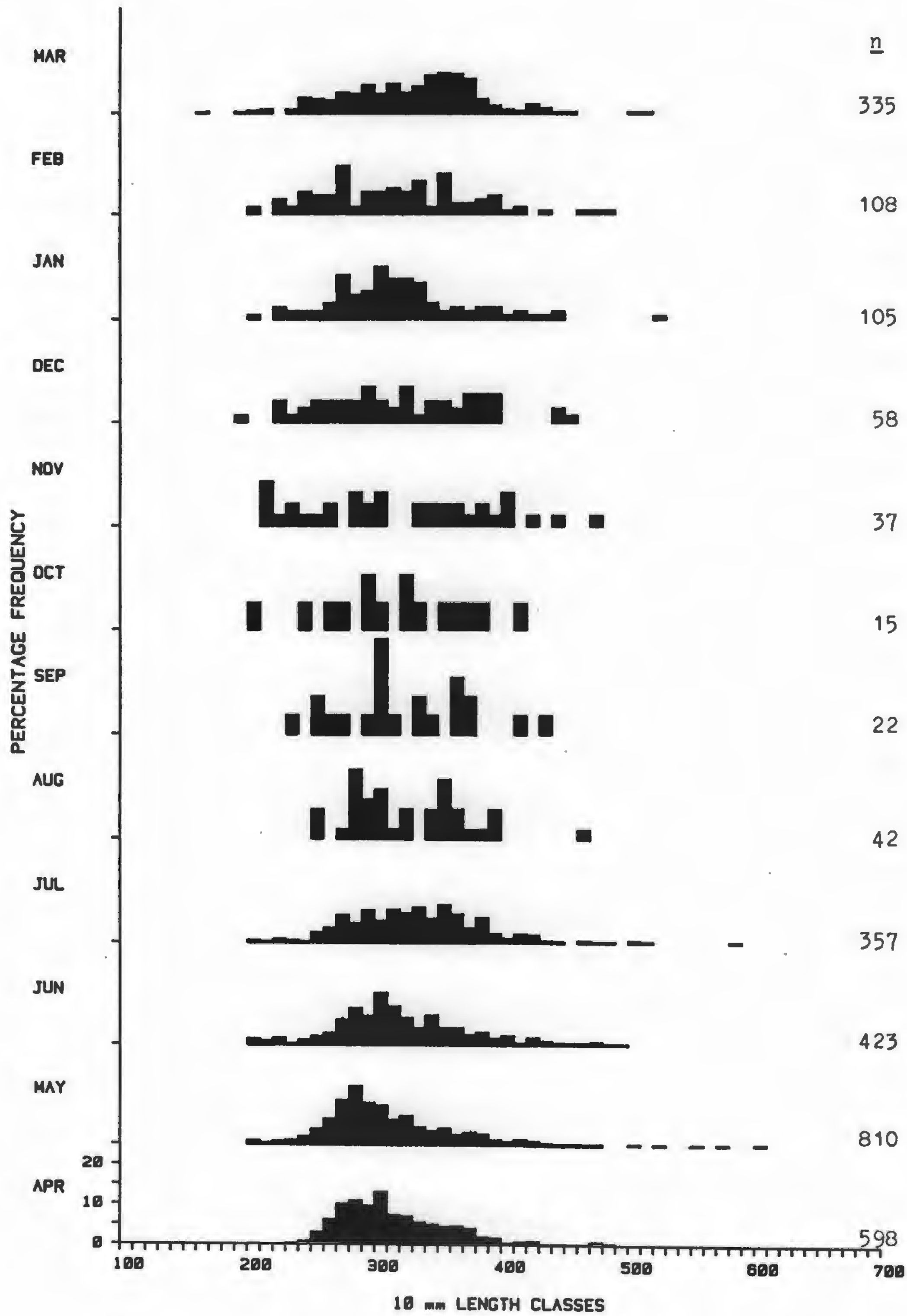


Figure 13. Length frequency analysis of A. berda trap catches month by month during the period April 1983 - March 1984.

degree of constancy in numbers from year to year and the similarity in yearly mean lengths. Either the parameters controlling this species were very stable during the study period or the species can maintain stable numbers through a wide range of conditions.

The reduction in trap catches in 1984 could have been due to more fish escaping from the traps. This was because of the exceptionally high water levels following rains shown in the recordings of the Ott apparatus at S'fungo (Station W7R04 of the Department of Environment Affairs). This occurred during the annual peak catch period for A. berda. According to records the water level was up to 500 mm higher than the usual high spring tide peak. Fish trap baskets are constructed to project between 1 000 mm and 1 500 mm above high spring tide level in order to contain fish which can leap out of the water (see Appendix 2). The binding above the usual high water level is not as carefully completed as that below, resulting in some of the gaps between sticks being larger than those lower down. Only "narrow" fish may escape and it is known locally (Zwane, pers. comm.) that A. berda is the only one of these species which tries to escape near the surface of the water. G. rappi and other species attempt to escape principally near the bottom. This was regularly seen in the traps when these species were being caught.

According to trap catches the numbers of A. berda leaving Kosi each year appear similar. Since breeding is thought to occur near estuaries (van der Elst, 1981) the numbers spawning annually near Kosi should also be similar. Recruitment to Kosi should therefore be principally dependent on breeding stock from Kosi, unlike species such as P. commersonni which appear dependent upon fish from a large portion of the coastline.

Constancy in numbers of adult A. berda leaving Kosi each year should result in continued constancy whereas for non estuarine species this need not be the case. Fish trappers (Tembe & Zwane, pers. comm.) reported that annual catches of A. berda have not changed noticeably in living memory.

Because nearly all of the life cycle of A. berda is completed within the estuary (Wallace, 1975b) the number of this species in the Kosi system is more dependent on endogenous factors than many of the other species.

b) Gonad condition

Contrary to the findings of Wallace (1975b) at St. Lucia, all stages of the reproductive cycle were found to be well represented inside the Kosi system. As can be seen in Appendix 6, gonad development could clearly be followed as the fish prepared for spawning in the ocean in late summer. Several ripe-running and partially spent fish were found and during late summer shoals of A. berda were present immediately inside Kosi mouth. From the evidence of this study it appears that nearly all of the life cycle of A. berda takes place inside the system. Spawning appears to occur very close to Kosi mouth and it seems that the fish return to the estuary mouth almost immediately after spawning.

c) Feeding habits and diet

The diet of A. berda is usually described as wide and including Crustacea, Polychaeta, Bivalvia and Pisces (Smith, 1977 ; van der Elst, 1981). Data from this study are shown in Figure 14 and confirm that the diet of this species is diverse. Most authors, including van der Elst (1981), regard the species as being principally a benthos feeder and scavenger. Data from this study, however, indicate that predation on small fish is very important to A. berda at Kosi. The presence of large numbers of A. berda along the margins of the channels of the system indicate an abundant food supply.

An interesting point illustrated by Figure 14 is the presence of fresh Phragmites tips in the stomach of this species. These tips must have been grazed as they projected out of

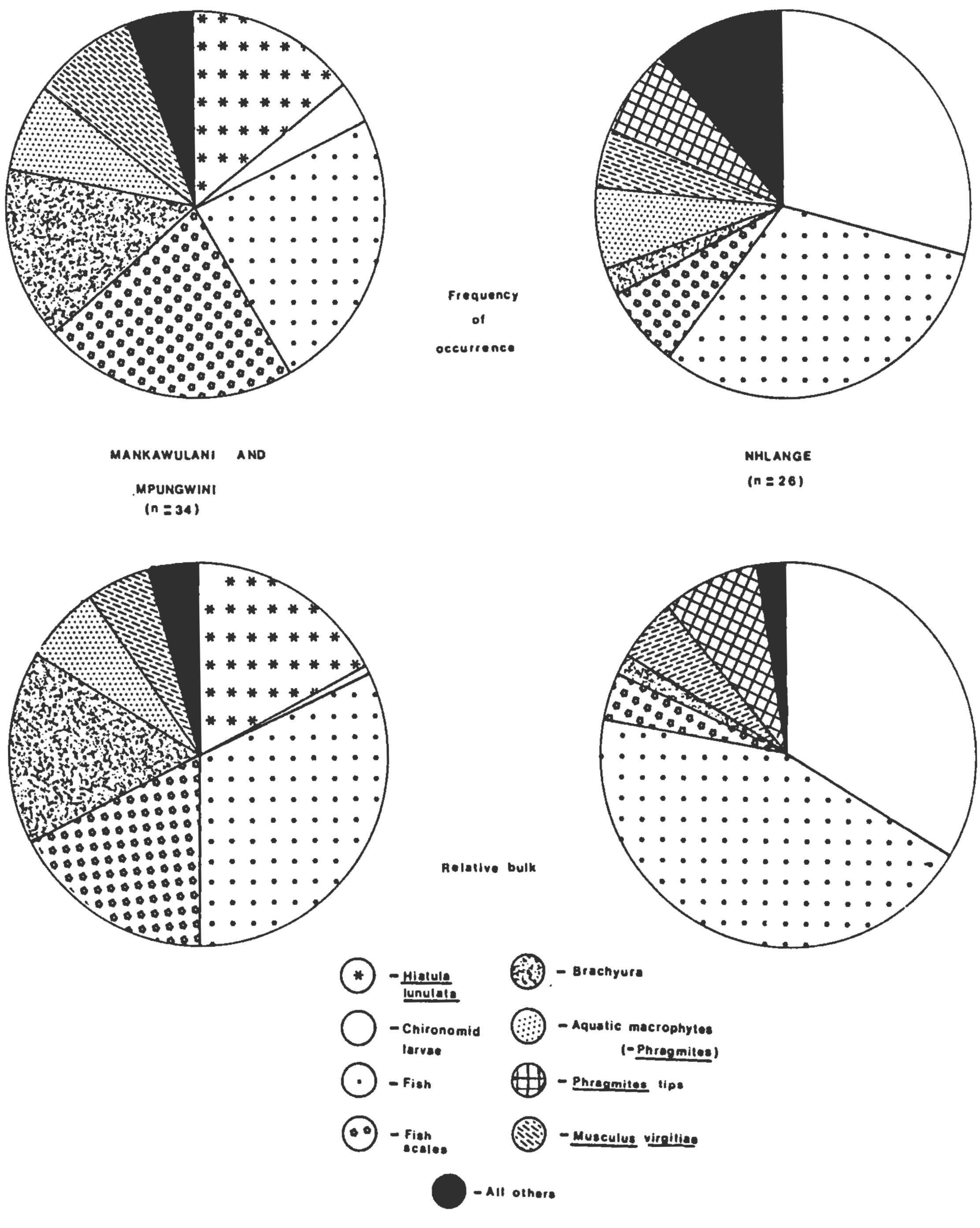


Figure 14. Result of stomach content analysis of A. berda from two areas at Kosi, showing relative frequency of occurrence and relative bulk of major food items.

the sand and were present in several of the stomachs examined.

d) General

Although nowhere common, this species is found throughout the Kosi system. One specimen was caught and tagged approximately one kilometre up the Nkanini River. It is estuarine dependent and stable in numbers. No evidence was found of regular interaction between the population at Kosi and those of other estuaries. The species is reportedly rarely found far from estuarues in the marine environment (van der Elst, 1981) and during this study, of the 672 A. berda tagged inside the Kosi system, none of the 37 recoveries were made outside Kosi.

e) Recruitment

It was not possible, considering the scope of the study, to obtain sufficient data on the recruitment on all or even the more important fish species at Kosi. Recruitment is, however, an important feature of estuarine fish ecology and so an attempt was made to obtain data on one species and this could then be compared to data from other systems. A. berda is the third most important fish to the trappers at Kosi, is estuary dependent (van der Elst, 1981) and has received special attention in this study (see Chapter 6). For these reasons sampling of juvenile fish was carried out through one annual cycle in the channels of the north of the system. The nets used were initially fine mesh (approximately 1 mm stretch) hand nets, then later 4 mm stretch hand nets and finally a 10 mm stretch mesh, 20 metre long seine net with a 1 metre drop and a 1 metre bag. The results are summarised in Figure 15.

The growth rate of the first year class of A. berda can be obtained from the power curve calculated from the data collected. It is clear that a major recruitment of this species takes place at a very early stage. van der Elst (1981) states that eggs are shed at sea but that shortly after hatching the juveniles enter estuaries. Wallace and van der Elst (1975) found that recruitment could take place

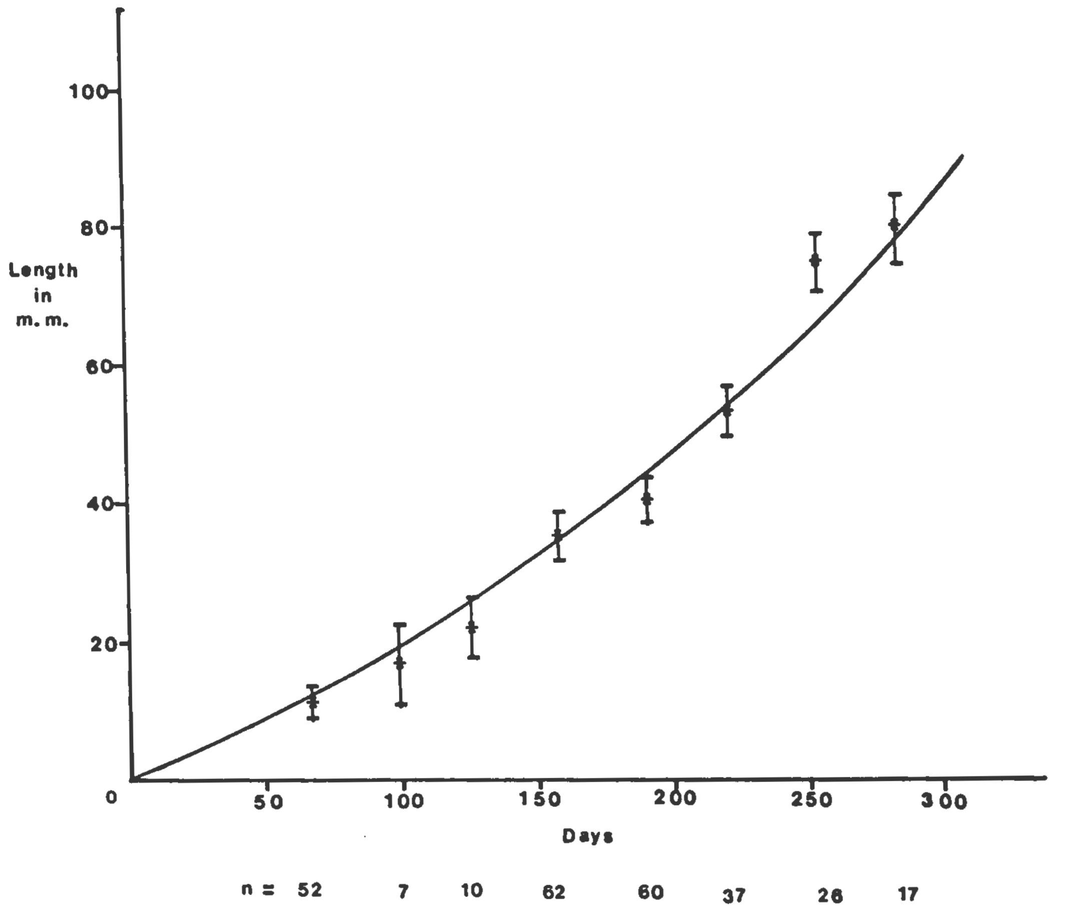


Figure 15. Regression of mean lengths of juvenile <u>A. berda</u> against time showing growth during their first ten months in the Kosi system in 1983/4. A power curve of $Y = 0{,}03X^{1{,}38}$ was calculated and has been included to indicate the growth rate. (T - bars denote 95% confidence limits of mean values and 31 st March was designated day 0).

with individuals as small as 10 mm (T.L.), but was more common in the size range 20 - 30 mm (T.L.) and most common at a length of 30 - 50 mm (T.L.) during early summer.

Many of the juveniles were caught in the reedy margins of channels and only specimens of 40 mm (T.L.) and over were found in Nhlange. This suggests that the reeds provide a suitable habitat for young fish in early stages of growth. Mixed shoals of the juveniles of A. berda and Rhabdosargus species were often found together. The data collected at Kosi indicate that for this species the pattern is similar to that recorded at St. Lucia by Wallace and van der Elst (1975).

4. Valamugil buchanani (Bleeker 1853)

a) Trap catch statistics

	1981	1982	1983	1984	Total/mean
Number caught	517	687	769	1 656	3 629
Mean length (T.L.)	486mm	489mm	499mm	538mm	503mm
95% confidence limits (mm)	473 - 499	479 - 499	490 - 508	531 - 545	
Rank by numbers	10	8	8	6	7
Rank by mass	6	8	5	3	4

This species showed a general increase in numbers caught in the traps during the course of the study. The reason for this was not clear as Wallace (1975a) reported this species as less tolerant of lowered salinity than L. macrolepis, whose trap catches decreased. On investigation it was found that V. buchanani was present in considerable numbers in Mpungwini in salinities approaching 0 p.p.t., and occasionally specimens were found in Nhlange. No long term trend was noted by the local people for this species (Tembe & Zwane, pers. comm.) but Table 18 shows the significant negative correlation between V. buchanani catch numbers and the mean salinity measured in the margins of Mankawulani during the study period.

Table 18. Correlation between catch statistics of *V. buchanani* and salinity in Mankawulani.

Year	Mean salinity (p.p.t.)	Catch by numbers
1981	17,0	517
1982	15,5	687
1983	13,4	769
1984	7,0	1 656

Correlation coefficient (r) = -0,988
significant at P < 0,02 (with 2 degrees freedom)

Although not necessarily cause and effect, the figures in Table 18 show that during the study the catches of *V. buchanani* increased proportionately to the decrease in salinity. Wallace (1975a) found that the lower salinity limit for *V. buchanani* in St. Lucia was 20 p.p.t. and that it appeared to be less euryhaline than *L. macrolepis*. Results here indicate the opposite condition where there is a correlation between *V. buchanani* and *L. macrolepis* numbers of -0,83, indicating that *L. macrolepis* numbers may decrease with falling salinity.

Blaber (1978) and Blaber and Cyrus (1981) showed *L. macrolepis* as present in Nhlange and *V. buchanani* as absent from this lake. Both species occurred in Nhlange during the study, although neither were common. *V. buchanani* was abundant in Mpungwini and *L. macrolepis* was only common north of Mankawulani. It appears that both species are tolerant of low salinities but that *V. buchanani* is more tolerant while *L. macrolepis* prefers the more saline areas of Kosi. Blaber (1976) reported both species present in the more saline area of St. Lucia but found that their stomachs contained different food and sand particle sizes. He suggested that interspecific competition for food is reduced by substrate particle size selection and possibly differences in feeding periodicity.

Catches of this species were too small to give meaningful monthly length frequency distributions.

Abundance of this species in trap catches appears dependent principally upon endogenous factors.

b) Gonad condition

As can be seen in Appendix 6 few data were collected during this study. Wallace (1975b) found only the least active gonad stages to be represented inside the St. Lucia system. A similar situation was found at Kosi, although in general the fish leaving the system had developing gonads and there was a fairly clear run of these fish to the ocean in middle to late summer.

c) Feeding habits and diet

All stomachs examined contained a mixture of sand and micro-organisms. Blaber (1976) found V. buchanani to be iliophagous although as it selected for smaller particle size it probably did not compete directly with M. cephalus and other members of the Muglidae. Both V. buchanani and M. cephalus are reported as feeding principally on diatoms (Blaber, 1976).

d) General

The peak of abundance in the trap catches of the species is in late summer and as this coincides with several other species its importance in trap catches is not as great as that indicated by the rank by mass. The numbers have also increased steadily during the study from 1,3% of the catch in 1981 to 4,49% in 1984. This, combined with the increase in mean length over the same period, has led to V. buchanani forming an important though small proportion of the trap catch.

5. Liza macrolepis (Smith 1846)

a) Trap catch statistics

	1981	1982	1983	1984	Total/mean
Number caught	6 409	5 453	3 286	2 386	17 534
Mean length (T.L.)	282mm	293mm	309mm	307mm	297mm
95% confidence limits (mm)	280 - 284	291 - 295	307 - 311	304 - 310	
Rank by numbers	3	3	4	4	3
Rank by mass	8	5	6	8	6

The catches of this species showed a clear and steady decline during the study. Wallace (1975a) gave a lower salinity tolerance of roughly 10 p.p.t. and although a few specimens were caught in Nhlange during the study, a significant correlation coefficient of 0,91 showed that the falling salinities were probably causing a fall in the number of this species caught in the system. L. macrolepis was found principally in the shallows around the entrance to Khalu and large dense shoals were regularly seen there throughout the study. Few specimens were found in any of the lakes. Figure 16 shows the 1983/4 monthly length frequency distributions.

b) Gonad condition

Data on gonad condition are summarised in Appendix 6. All developmental stages of the reproductive cycle were well represented inside the system, with a prolonged exodus of gravid fish during winter.

c) Feeding habits and diet

L. macrolepis is iliophagous. Whitfield (1980) found the mean particle size from stomach contents of the species at Mhlanga to be considerably larger than those from M. cephalus and significantly smaller than those from L. alata. Blaber (1976) found filamentous algae to be the most common food item in stomach contents of these fish.

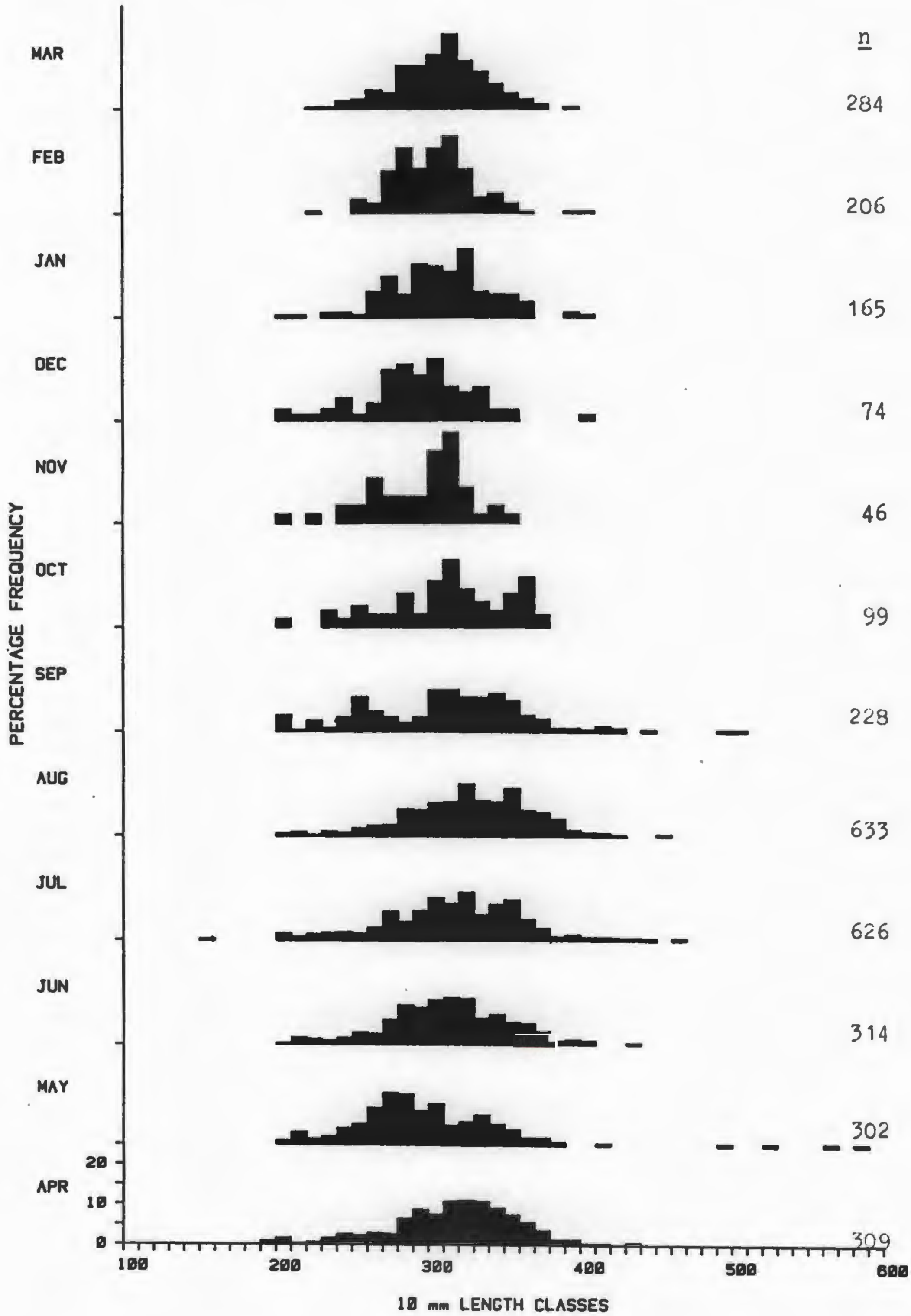


Figure 16. Length frequency analysis of L. macrolepis trap catches month by month during the period April 1983 - March 1984.

6. Rhabdosargus sarba (Forsskål 1775)

a) Trap catch statistics

	1981	1982	1983	1984	Total/mean
Number caught	1 347	3 696	2 058	605	7 706
Mean length (T.L.)	353mm	315mm	361mm	316mm	336mm
95% confidence limits (mm)	346 - 360	312 - 318	356 - 366	311 - 320	
Rank by numbers	6	4	6	10	6
Rank by mass	7	4	4	12	5

Although this used to be one of the most important species of fish caught in the Kosi fish traps (Tembe & Zwane, pers. comm.), its numbers and importance have declined in recent years.

Blaber and Cyrus (1981) suggest that low salinity may be the factor limiting certain species during winter at Kosi. Throughout the period of Blaber and Cyrus's (1981) study numbers of adult R. sarba were still found in Nhlange, but no adults were caught there during this study. Salinities in general have been dropping in the Kosi system for at least twenty years (Blaber & Cyrus, 1981 ; this study) and it appears that numbers of R. sarba have also been declining. Local residents and tourist fishermen regularly reported catching adult R. sarba in Nhlange in the 1960's and Blaber and Cyrus (1981) record adults in Nhlange prior to 1981, but only in summer. The combination of low temperature and low salinity appears to have reached critical levels for adults of R. sarba, in a fashion similar to that reported for Rhabdosargus holubi in the Kleinmond estuary by Blaber (1973).

No correlation was found between the annual catches of the fish traps and C.P.U.E.'s by anglers elsewhere in Natal.

Figure 17 shows the monthly length frequency statistics for R. sarba. When these are compared with the data of van der

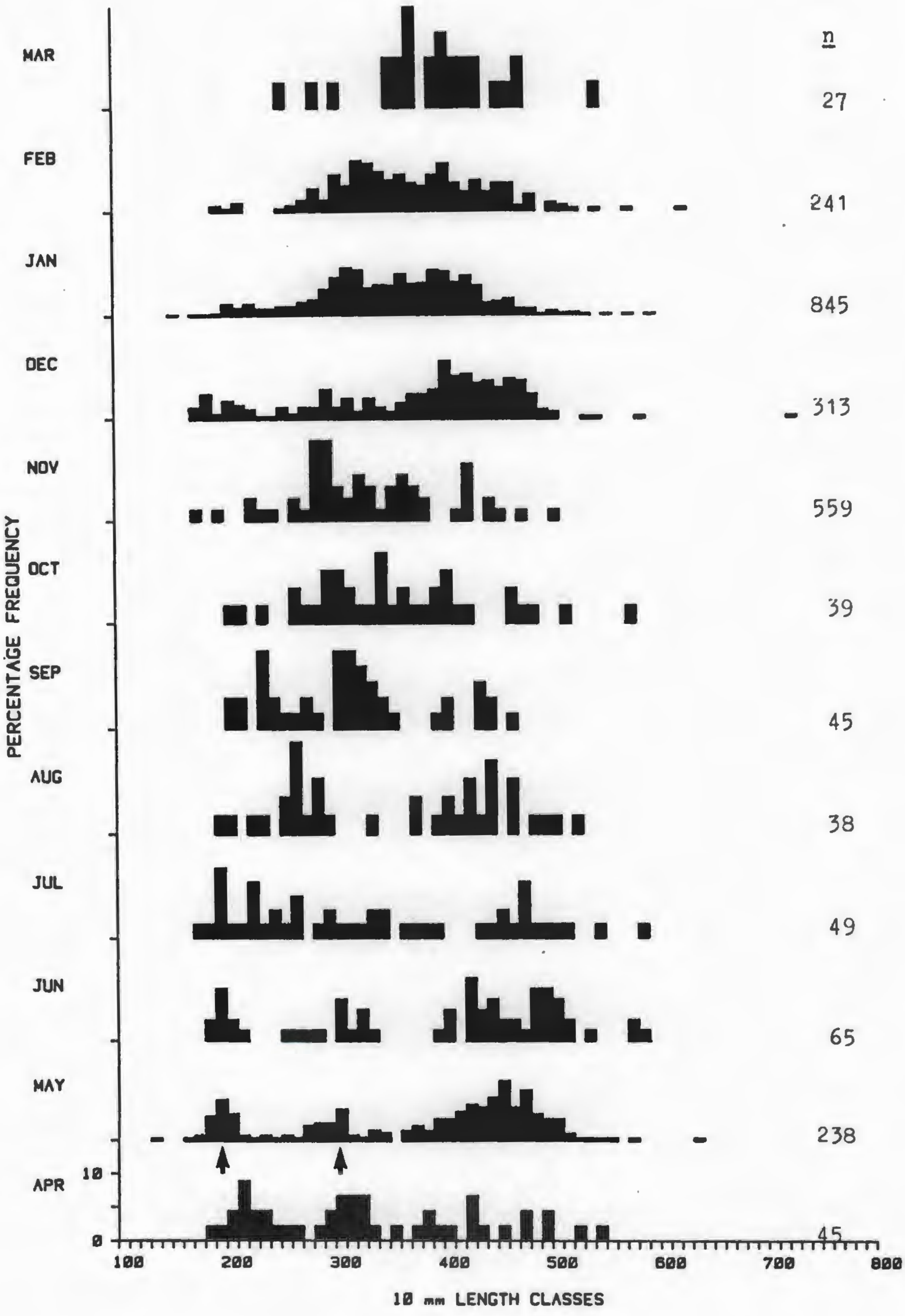


Figure 17. Length frequency analysis of R. sarba trap catches month by month during the period April 1983 - March 1984 (▲ denotes probable age classes).

Elst (1981) it appears that the larger size classes are not well represented inside Kosi. Breeding begins in May (Wallace, 1975b) and if this month's data are used, peaks in catch abundance can be distinguished at 180 mm (T.L.) and 300 mm (T.L.) probably corresponding to ages of 2 and 3 years. These data are, however, not conclusive and the age structure is not clear.

Annual trap catches fluctuated dramatically. This is not easily correlated with any quantifiable parameter, but it is possible that catches reflect fish moving out of the system to the sea due to conditions inside becoming unfavourable. High rainfall reduced salinity, and if salinity is critical to R. sarba, these catches should be higher in wetter months and on a daily basis with heavy rainfall, reflecting fish leaving the system. This is discussed in Chapter 5.

b) Gonad condition

Wallace's (1975b) statement that gonad development does not take place inside St. Lucia estuary appears true for Kosi as well. As can be seen in Appendix 6 few mature fish were found and most of those examined had gonads in the least active phases. It appears that spawning takes place long after R. sarba have left the system and that they do not return immediately thereafter.

c) Feeding habits and diet

Figure 18 shows the analysis of stomach contents of R. sarba caught by tourists in the lakes. All the fish were caught on C. kraussi bait, but clearly this is not normally an important food item. The diet of this species is described as consisting mainly of various Bivalvia, Echinodermata and Crustacea (van der Elst, 1981) and inside Kosi the most important dietary component is the bivalve mollusc Hiatula lunulata, with small fish, various crabs and plant material also featuring significantly in stomach contents. Occasionally the remains of fairly large fish were found in stomachs, as well as Gilchristella aestuarius and Croilia mossambica. It appears

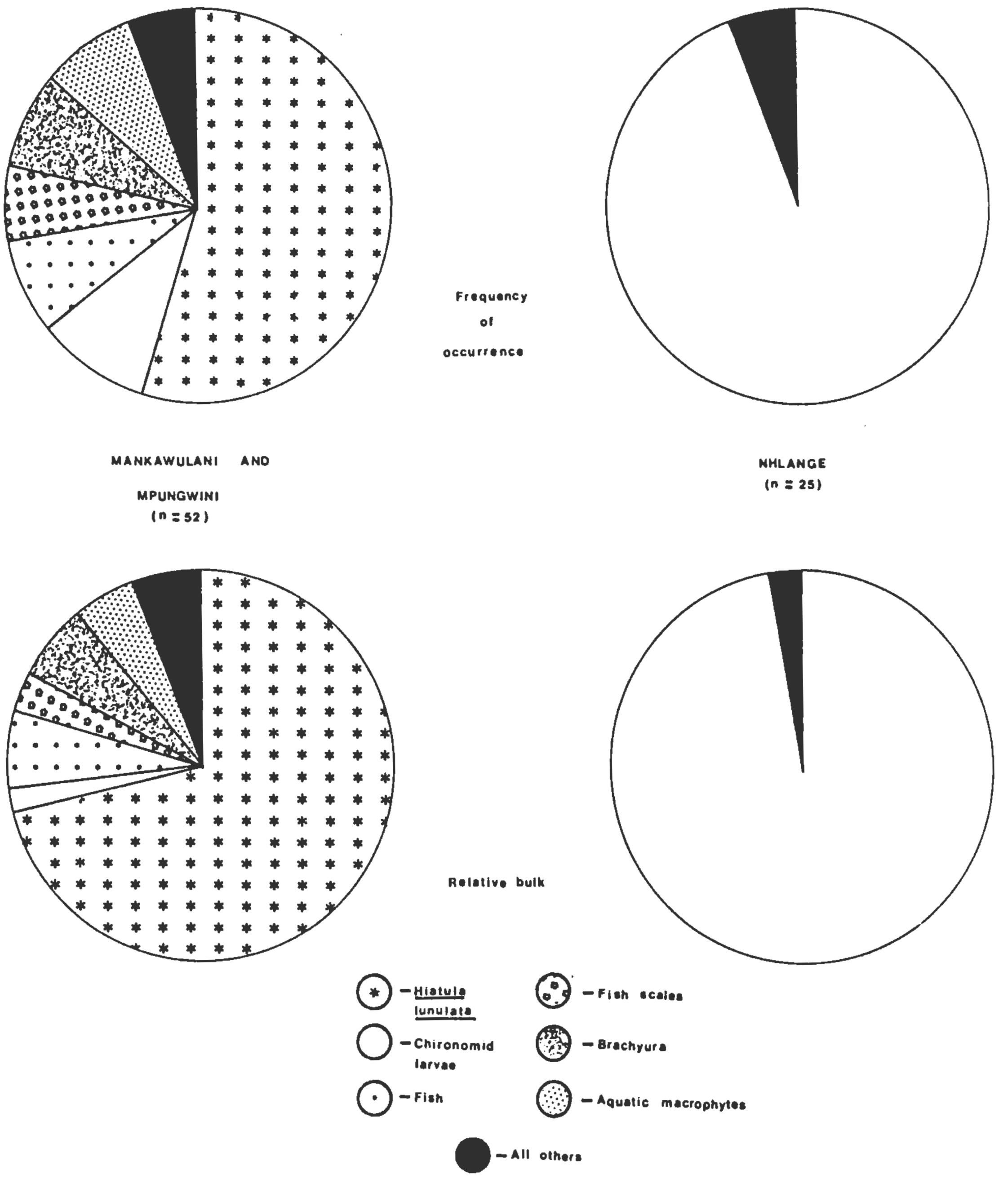


Figure 18. Results of stomach content analysis of R. sarba from two areas at Kosi, showing relative frequency of occurrence and relative bulk of major food items.

that at Kosi many species of fish not normally regarded as piscivorous catch and eat fish.

H. lunulata is not found in the area of Kosi from which adult R. sarba are absent. In the past, however, this was not the case, as there is no evidence that H. lunulata occurred in Nhlange in recent years when adult R. sarba were present. Juvenile R. sarba from Nhlange were found to have only chironomid larvae and pupae in the gut, and since adult R. sarba in Mankawulani also ate chironomid larvae, food does not appear to be the factor limiting R. sarba in Nhlange.

d) General

The erratic nature of the annual catches appear unrelated to measured conditions inside the system. Factors influencing catch abundance are discussed in Chapter 5.

7. Gerres rappi (Barnard 1927)

a) Trap catch statistics

	1981	1982	1983	1984	Total/mean
Number caught	3 329	3 565	3 445	4 687	15 026
Mean length (T.L.)	266mm	279mm	279mm	281mm	276mm
95% confidence limits (mm)	264 - 268	277 - 281	277 - 281	279 - 283	
Rank by numbers	4	5	3	3	4
Rank by mass	9	9	8	5	7

Trap catch numbers and mean lengths of G. rappi at Kosi over the study period showed a considerable degree of stability, similar to that of A. berda. The main discrepancies are in the 1984 catch statistics, where those for A. berda were lower than in the previous year while those of G. rappi increased. The explanation for this most probably lies in the ability of A. berda to escape from traps during high water and the fact that a greater proportion of G. rappi stray from the channels into the traps under the same circumstances

(Zwane, pers. comm.). If left in a trap for over 24 hours, A. berda will almost invariably escape while G. rappi generally dies (Tembe, pers. comm.). As a result of the greatly increased water levels following heavy rains in 1984, (see Appendix 1), trap catch statistics of these species were strongly influenced.

The 1983 catch data expressed as length frequencies are given in Figure 19. As can be seen few fish of over 350 mm (T.L.) are caught in the traps, but this corresponds to the maximum length attained by this species (Smith, 1977).

From the tagging programme described in Chapter 6, it appears that a smaller proportion of this species is caught in the fish traps than of most other important species. This is largely due to the small size of adult G. rappi. Only the best made traps can catch and hold G. rappi.

A review of the literature on this species produced no references to it previously having been regarded as estuary dependent, although Cyrus and Blaber (1982) reported on its preference for lower salinities in the Kosi system. The gonad conditions, stable trap catches and apparent absence of this species in the marine inshore environment along the Natal coast, all suggest that in the Kosi system at least, this species has developed a strongly estuarine associated life cycle.

Although the numbers of this species caught each year are considerable, the small size of the fish and marked seasonal fluctuations in catches reduce their overall importance to the trap owners. G. rappi is most important to the local people during peak catches in December when those of other species are often poor. By January and February other species such as P. commersonni are usually caught in considerable numbers. It is an abundant species in the lakes at Kosi, particularly Nhlange (Cyrus & Blaber, 1982 ; this study) and at present fish traps are the only legal way in which this species may be utilised to any great extent.

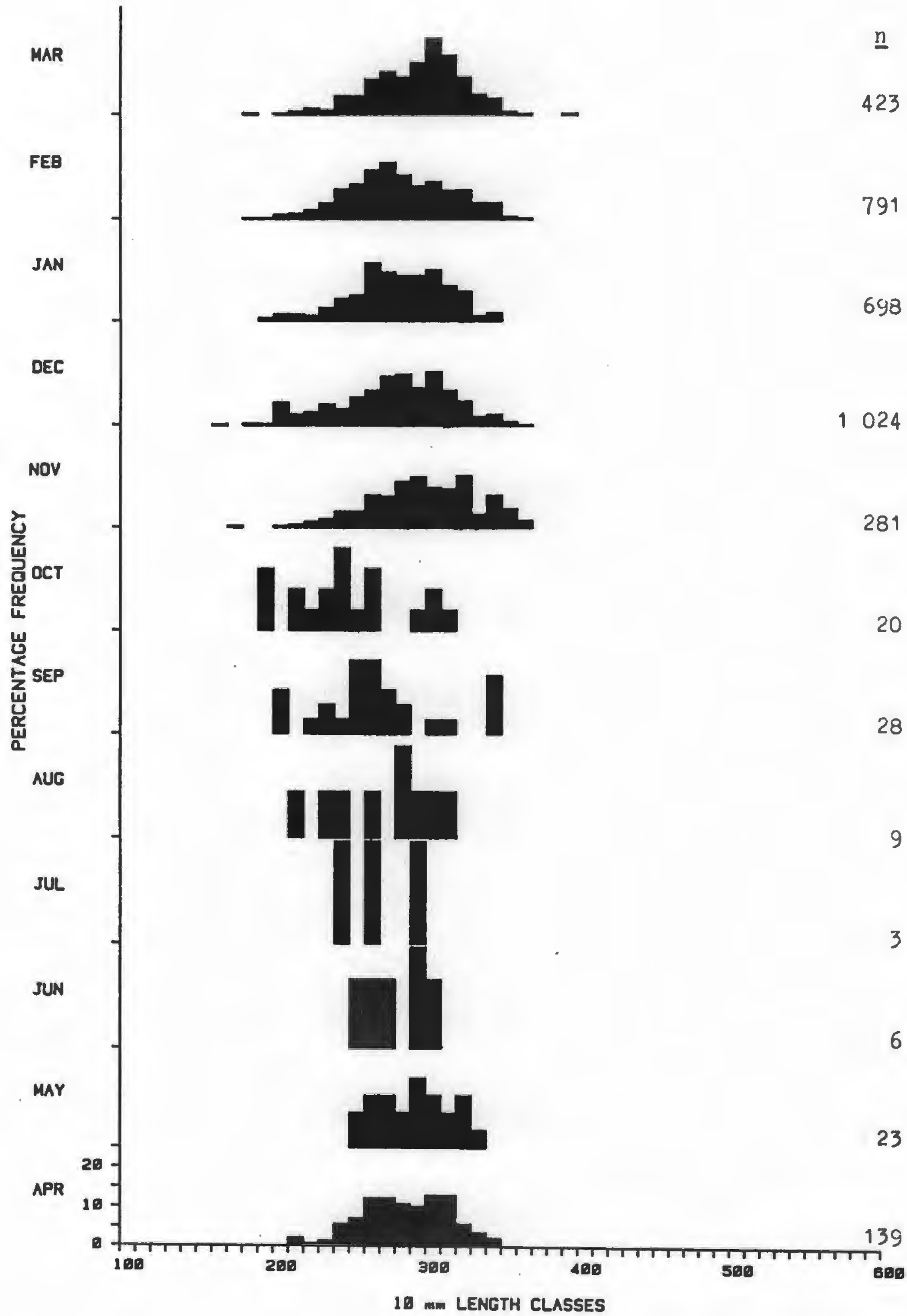


Figure 19. Length frequency analysis of G. rappi trap catches month by month during the period April 1983 - March 1984.

b) Gonad condition

Data collected for this study given in Appendix 6 show an obvious breeding cycle culminating in a clear spawning run to the ocean in mid-summer. Cyrus (1980) recorded the same cycle. During his work on *Gerres* at Kosi, Cyrus (1980) found no "spent" individuals inside the system. He further stated that the absence of large specimens supports the view that *G. rappi* does not return to Kosi after spawning. As can be seen in Figure 19 a large proportion of the trap catch in 1983 - 4 was over 280 mm (T.L.) while Cyrus (1980) considered *G. rappi* of 144 - 180 mm (standard length) as large. In 1984 of 34 *G. rappi* over 280 mm (T.L.) examined from gill nets in Nhlange, 25 were in a spent condition, suggesting that they do appear to return to the lakes after spawning. The presence of numbers of *G. rappi* with spent gonads in Nhlange in late summer and the virtual absence of this condition in trap caught fish confirm that, for this species at least, the trap catches do largely reflect the seaward movement of fish.

c) Feeding habits and diet

Cyrus and Blaber (1983a) carried out a detailed study of the genus *Gerres* at Kosi. Results showed that the diet was dependent upon the food available. In the northern area of the system the diet was varied, but consisted mainly of *Hiatula lunulata* siphon tips and chironomid larvae which made up 60% and 29% of the energy intake respectively. Cyrus and Blaber (1983a) state that chironomid larvae are the most important food item there, and these findings were confirmed in this study, where 121 fish stomachs were examined with only chironomid larvae and pupae being identifiable. Cyrus and Blaber (1983a) do not stress that this species is dependent for most of the year on one food type which is abundant in Nhlange (Boltt & Allanson, 1975). Other food items are only of importance to *Gerres rappi* over short periods during migrations.

d) General

Trap catches of this species from year to year are fairly stable. Tagging (see Chapter 6) indicates that these catches represent only a small percentage off-take from a population sustained by an abundant food supply (Cyrus & Blaber, 1983a) and limited principally by natural predation and their capture by man (Cyrus & Blaber, 1984a). Predation rates on Gerreidae at Kosi have been described by Cyrus (1980) and Cyrus and Blaber (1984a). Their studies reflect the current level of knowledge, except that the data on the effect of gill netting are incorrect. Both studies report that illegal gill netting catches consist mainly of juvenile *G. rappi* and *G. acinaces*. Data from gill nets confiscated over a 4 year period, described in Chapter 3, show that although *G. rappi* forms a large percentage of net catches, *G. acinaces* catches are very small. Nearly all the *G. rappi* caught were adult due to the average net mesh being 80 mm stretch as opposed to 6 mm bar size given in the above studies.

According to estimates of current human off-take (see Chapter 6) there appears to be potential for an increase in the exploitation of this species before off-take levels seriously influence the population or recruitment.

8. *Caranx* species

a) Trap catch statistics

	1981	1982	1983	1984	Total/mean
Number caught	651	648	898	1 030	3 227
Mean length (T.L.)	386mm	423mm	415mm	389mm	403mm
95% confidence limits (mm)	375 - 397	414 - 432	407 - 423	382 - 396	
Rank by numbers	9	9	7	7	8
Rank by mass	10	10	7	6	8

Several species of *Caranx* are caught, although most of the fish are *C. sexfasciatus* and *C. papuensis* juveniles. Significant numbers of *C. ignobilis* and *C. melampygus* juveniles are also caught, as well as adults of *C. sexfasciatus* and *C. ignobilis*. The exact proportions of each species caught are not known and the shoaling habits of juveniles of this genus make sampling an inaccurate measure of these.

The numbers of these species caught yearly during the study indicate a general increase in numbers. In the 1960's Kosi was well known to sport fishermen as a system where adult *C. ignobilis* of 35 - 40 kilograms were regularly caught (Gregory, Nsele, Potter, Ryman & Zwane, pers. comm.) in the traps and by tourists. By the late 1970's fish in this size range had virtually disappeared from all catches inside the system. This period coincided with the increase in gill netting in the channels in the north. Data from nets confiscated in these channels showed a considerable proportion of *Caranx* species amongst the catch. Constant all night patrolling of these channels during spring tides was started in 1981 which caused the channels to have fewer nets at these times. An increase in *Caranx* in the fish traps has been ascribed to this by many local people (Zwane, pers. comm.).

The total annual catches of *Caranx* had a negative correlation ($r = -0,87$) with salinity in Mankawulani during the study. During the period when larger *Caranx* were much more common the salinity was much higher (Blaber & Cyrus, 1981) and thus it appears that the situation is more complex than indicated above.

During the 1984 - 1985 season considerable numbers of mature *C. ignobilis* and *C. sexfasciatus* were again evident in the system judging from tourist and fish trap catches. Adults of these two species occurred throughout the system, which agrees with the findings of Blaber and Cyrus (1983), who found them to be the most euryhaline species of the genus. Blaber and Cyrus (1983) gave the minimum salinity tolerated by these species as 0,5 p.p.t. but since that study the salinity in Nhlange has dropped below this figure and both are still well represented. C. melampygus juveniles were present in Mankawulani when salinities fell to 1 p.p.t., which is well below the lower limit of salinity tolerance of 6 p.p.t. given by Blaber (1982) and approximately 8 p.p.t. given by Whitfield et. al. (1981). Juvenile C. papuensis were common in Nhlange during the last two summers of the study, although their salinity tolerance range is given as 4 - 35 p.p.t. in Blaber and Cyrus (1983).

b) Gonad condition

No reproductively active members of this genus were found inside the Kosi system during this study period (see Appendix 6). Blaber and Cyrus (1983) recorded the same result at Kosi and several other Natal estuary systems.

c) Feeding habits and diet

The major component of the diet of the adult Caranx species in Kosi is fish (Blaber & Cyrus, 1983). Although juveniles of certain species are reported as eating large numbers of Mysidacea (Blaber & Cyrus, 1983), the sub-adult and adult forms of all the species preyed mainly on small fish (Blaber & Cyrus, 1983). The main fish prey species were found by Blaber and Cyrus (1983) to be Ambassis natalensis, Ambassis productus, Gilchristella aestuarius, Glossogobius giuris and Croilia mossambica. Data from this study are given in Table 39 on page 194. The presence of considerable and increasing numbers of piscivorous fish in what is often regarded as a fish nursery area (Begg, 1978) is important. For visual predators, such as the Carangidae (van der Elst, 1979) the clear water of the Kosi system is very suitable and yet few P. commersonni or members of the Gerreidae or Muglidae have been found in Caranx stomachs at Kosi. Table 39 shows that much of the predation pressure of Caranx species at Kosi is on adults of small fish species whose life cycles are completed within the lakes of the system, and not on the juveniles of marine-spawning larger species of fish. Analysis of the stomach contents of larger Caranx species during this study confirms the importance of these small species in their diet. Blaber and Cyrus (1983) found the estuarine clupeid, Gilchristella aestuarius, to be the most important food source for C. papuensis at Kosi.

9. Lutjanus argentimaculatus (Forsskål 1775)

a) Trap catch statistics

	1981	1982	1983	1984	Total/mean
Number caught	677	459	203	194	1 533
Mean length (T.L.)	480mm	518mm	546mm	526mm	517mm
95% confidence limits (mm)	469 - 491	506 - 530	529 - 563	506 - 546	
Rank by numbers	8	10	12	14	10
Rank by mass	5	6	10	11	9

The trap catch statistics of this large piscivorous fish have steadily declined through the study period. The reason is unclear, although salinities have been steadily dropping. L. argentimaculatus is regularly recorded from fresh water (Khaled, 1985) and is commonly referred to as the river snapper (Bruton & Kok, 1980). Food availability at Kosi should not have been declining and no other causes for the apparent dwindling numbers were identified. Tourist catch returns do not show a similar pattern. No comparative data are available from other areas and it is therefore not possible to establish whether there is a general decline in numbers in the region.

b) Gonad condition

Active gonad conditions were rarely found inside the Kosi system (see Appendix 6). Spawning is reported to take place in the offshore region (van der Elst, 1981).

c) Feeding habits and diet

The prey of this species consists mainly of small fish (van der Elst, 1981) and analysis of stomachs during this study, shown in Table 39 Chapter 7, indicate that Gerreidae, Muglidae, Gobidae, *Ambassis* spp. and *Rhabdosargus* spp. constitute most of the food.

10. *Liza alata* (Steindachner 1892)

a) *Trap catch statistics*

	1981	1982	1983	1984	Total/mean
Number caught	799	699	440	651	2 589
Mean length (T.L.)	545mmm	573mmm	574mm	593mm	571mm
95% confidence limits (mm)	535 - 555	564 - 582	564 - 584	585 - 601	
Rank by numbers	7	7	9	9	9
Rank by mass	12	7	9	9	10

During the summer months *L. alata* formed a small but important proportion of the trap catches. No trend in numbers was obvious and no correlation with environmental parameters was found (see Chapter 5). Whitfield *et. al.* (1981) gave a lower salinity limit for this species of approximately 1 p.p.t. and Blaber and Cyrus (1981) recorded *L. alata* as present in Nhlange at 0,5 p.p.t.. Throughout the study there was no obvious increase or decrease in this species in Nhlange and it appears that *L. alata* can tolerate fresh water for considerable periods of time.

b) *Gonad condition*

As can be seen in Appendix 6, data on gonad conditions collected for this study show early stages of development inside the lakes of the system and catch statistics show a clearly defined exodus of mature fish with turgid, well developed gonads in late summer.

c) *Feeding habits and diet*

L. alata is another iliophagous species. Whitfield (1980) found that in Mhlanga estuary the mean sand particle size in the stomach was significantly larger than that of any other common member of the Muglidae at Kosi. Blaber (1976) found a similar situation at St. Lucia and further found that filamentous algae and terrestrial plant debris were the most important components of their diet.

Species 11 - 20

Together these species constituted approximately 5% by mass of the trap catch during this study. Catches varied considerably from year to year and at times certain species did attain a measure of importance. Table 19 summarises this. Each species is commented upon briefly and aspects of importance to this study are discussed in this section.

11. Chanos chanos (Forsskål 1775)

As can be seen from Tables 15 and 19, the trap catches varied greatly in numbers and mean length from year to year. In 1981 and 1982 the modal length was 1 000 mm (T.L.) and in 1983 and 1984, 520 mm (T.L.) and 640 mm (T.L.) respectively. Whitfield (pers. comm.) quoted in Blaber (1978) regarded C. chanos as a summer visitor to St. Lucia. Blaber (1978) recorded large shoals of the species irregularly entering the Kosi system to feed on detritus and then leaving again the same season. Evidence from the present study supports this and it is apparent that, in the last two years of the study, it was mainly shoals of smaller fish which entered the system. As can be seen in Appendix 6 no reproductively active fish were found inside the system. The large size, shoaling habits and seasonal abundance patterns of the species (Blaber, 1978) probably account for the erratic nature of trap catches. Although approximately 1 555 kilograms of this species was caught in 1981, 92 fish weighing nearly 650 kilograms were caught in one basket in one day.

Table 19. Ranking by mass and numbers and the mean length of species 11 - 20.

Species	1981				1982				1983				1984				Total		Total
	No	Mass	L	SE	No	Mass	L	SE	No	Mass	L	SE	No	Mass	L	SE	No	Mass	Mean L
11. C.c.	13	4	940	8	16	12	927	28	16	13	576	16	8	7	578	5	13	11	755,25
12. S.spp.	12	12	667	11	12	11	697	12	11	11	673	10	12	10	669	10	12	12	676,50
13. E.m.	16	13	678	12	15	14	696	25	17	12	699	17	13	13	615	13	15	13	672,00
14. O.m.	11	14	320	4	11	13	315	4	10	14	323	4	11	14	332	3	11	14	322,50
15. P.i.	17	16	452	6	14	15	457	13	15	15	444	10	15	15	440	10	15	15	448,25
16. S.l.	18	18	471	23	18	17	439	16	14	16	471	8	17	16	438	5	18	16	454,75
17. G.a.	16	17	254	5	13	16	242	4	13	17	252	5	16	18	253	3	14	17	250,25
18. P.s.	14	15	355	4	17	18	349	13	18	19	337	9	19	20	365	18	17	18	351,50
19. C.g.	19	19	531	44	20	20	-	-	19	18	592	28	20	17	665	5	20	19	596,00
20. E.spp.	20	20	409	33	19	19	369	33	20	20	503	59	18	18	333	16	19	20	403,50

where L = mean length in millimetres (T.L.)
SE = standard error of mean length

12. Sphyraena species

Members of this genus represented in the catches of the Kosi fish traps are Sphyraena barracuda, Sphyraena bleekeri, Sphyraena jello and Sphyraena qenie. Identifications are difficult below genus level (de Sylva, 1973 ; Blaber, 1982). Blaber (1982), in his work on S. barracuda in Kosi, stated that no specimens of this species longer than 500 mm (standard length) were caught inside the system. It is probable that the three other species made up most of the catch of this genus in the present study. The mean length of these fish caught yearly is fairly constant but greater than the length of S. barracuda said to be found here (Blaber, 1982). The proportions of each species are unknown.

As with Caranx species no reproductively active specimens were found during this study (see Appendix 6) or that of Blaber (1982), although mature length individuals of all the species except S. barracuda are not uncommon.

13. Elops machnata (Forsskål 1775)

Although few specimens of this species were caught, the mean mass of approximately 1,6 kilograms and a marked seasonal abundance pattern (see Chapter 6), suggest that it is occasionally important to the trap owners. Table 15 shows that numbers caught fluctuated markedly from year to year. No comparable data are available for other areas, but it is probable that this pattern reflects annual abundance in the ocean adjacent to Kosi.

Wallace (1975a) gives a lower salinity limit for E. machnata as 15 p.p.t. at St. Lucia but in the Kosi system they were present in Nhlange at less than 0,5 p.p.t.

The diet of this species is reported as small fish and shrimps (van der Elst, 1981) but at Kosi the species was regularly seen in shoals feeding on dense congregations of Gilchristella aestuarius in Mpungwini and Nhlange. Data from this study, summarised in Table 39 Chapter 7, indicate that this species is heavily dependent on G. aestuarius. E. machnata and occasionally Caranx species and Sphyraena species drive shoals of G. aestuarius to the surface, where flocks of terns (Sternidae) congregate and dive on the clupeids forced to the surface. This phenomenon was regularly observed during summer.

14. Oreochromis mossambicus (Peters 1852)

O. mossambicus is euryhaline, but as salinities drop it becomes more abundant (Blaber, 1978). Blaber (1978) records it as present only in the lakes and at the mouth of Khalu inlet but during this study it was found to be abundant, breeding throughout the system from the south to opposite Khalu inlet. It currently forms a small but seasonally important segment of the trap catches. The diet consists almost exclusively of diatoms (Bruton & Kok, 1980).

15. Platycephalus indicus (Linnaeus 1758)

This species is occasionally caught in the traps but is of little importance to the local people.

16. Scomberoides lysan (Forsskål 1775)

Although Blaber and Cyrus (1983) indicated that this was the most abundant Carangid in the Kosi system, they formed a very minor part of the trap catches. They are a very slender fish and the smaller specimens are not caught in traps ; they are easily caught in seine nets. Trap catches show no clear pattern over the study period. Blaber and Cyrus (1983) gave a salinity tolerance of 0,5 - 35 p.p.t. for sub-adults, and it appears that the salinity in Nhlange is now too low for the species, as only one specimen was reported from there during the study. Juveniles are less euryhaline (Blaber & Cyrus, 1983) and the area of the Kosi system suitable for this species is decreasing.

17. Gerres acinaces (Bleeker 1854)

This small species constitutes an unimportant proportion of the trap catches at Kosi, although it is common in the intermediate salinities of the main trap area (Cyrus & Blaber, 1982).

18. Pomatomus saltatrix (Linnaeus 1766)

van der Elst (1976) reported this species as probably migrating from Cape waters to Natal during winter. He reported the time of peak catches on the Natal south coast as July and the north coast as September. Trap catches peak in the period August to September. It is a marine species, near the northern limits of the Cape population's distribution (van der Elst, 1976). As an occasional winter visitor to the system it is regularly caught in small numbers in traps as far inside the system as Mankawulani.

19. Clarias gariepinus (Burchell 1822)

This freshwater fish is not important in trap catches. It is not normally found north of Mpungwini but occasionally small numbers enter the trap area of the system after heavy rainfall.

20. Epinephelus tauvina (Forsskål 1775)

These are marine visitors to the system, principally during the summer months. Due to the small numbers caught they are not important in trap catches.

4.3.2 Trap catch statistics of the minor fish species of the Kosi system

Together these twenty species constituted between 0,26% and 2,82% of the catch by numbers and a smaller proportion by mass. The yearly totals are generally too small to show significant trends (see Appendix 7). Three species, however, showed a strong tendency to be caught in increasing numbers during the study. These were tested for correlation with mean annual salinities in Mankawulani and coefficients of -0,86, -0,99 and -0,99 were obtained for Myxus capensis, Tylosurus leiurus and Valamugil robustus respectively. M. capensis is probably the most euryhaline of the Muglidae at Kosi. It has been recorded from most fresh waters of the Eastern Cape coastal region (Smith, 1977) and its salinity range includes 0 p.p.t. (Whitfield et. al., 1981). It was not common at Kosi and probably reaches its northern range limit here (Smith, 1977). T. leiurus has regularly been recorded from estuaries (van der Elst, 1981) and a salinity tolerance of 5 - 35 p.p.t. was reported by Whitfield et. al. (1981). V. robustus is reported as having the same lower salinity tolerance as Liza macrolepis but in the present study these two species' catches are negatively correlated (r = -0,984). Both species have similar size ranges and are commonest in the same areas of Kosi. Blaber (1976) found that each of these species selected for different food particle size, but had fairly similar food item dependencies. It appears that V. robustus may be replacing L. macrolepis in the Kosi system as salinities fall, although during this study the numbers of V. robustus were considerably smaller than those of L. macrolepis.

No other species showed consistent trends or trends easily related to measured parameters.

4.4 Significant trends in trap catches in the last thirty years.

The proportions of some of the species caught in the traps have remained fairly constant in living memory but others have recently changed significantly. Intensive discussions with trap owners, local Indunas and officials produced many suggestions as to the reasons for this. The most consistent ones, confirmed by written records and statements by visiting anglers, are as follows.

a) The decline in numbers and range of R. sarba (Nsele & Zwane, pers. comm.).

b) The virtual absence of very large specimens of Caranx ignobilis in the last decade. Very large specimens were regularly seen and caught by trap owners and tourist fishermen in the past. A confirmed record of one C. ignobilis of 43,1 kg caught in Nhlange in 1954 was found (Fr. Ryman, pers. comm.). The largest C. ignobilis recorded in this study was 19,5 kg.

c). The absence of very large Sphyraena spp. over the last decade. In the 1950's and 1960's the shoaling size of these fish was said to be 5 - 6 kg (Gregory, pers. comm.). Much larger fish were regularly caught by fish traps and tourists in Nhlange and one record of a specimen of 24,9 kg was found (Fr. Ryman, pers. comm.).

4.5 The influence of the fish traps on abundance of major fish species inside the Kosi system

The position and number of fish traps is very strictly controlled (Kyle, 1981a). The reasoning behind this was that channels had to be kept open to allow sufficient adult fish to reach the ocean to spawn in order to produce adequate recruitment to the system in order to maintain stocks. The only fish species abundance on which the fish traps or other catches may have a serious impact are those estuary-dependent species whose annual recruitment relies on adults from the Kosi system. In other words, the abundance of most larger fish species at Kosi is not greatly influenced by the trap catches.

Since the fish traps mainly catch adult fish leaving the system and it is recruitment to the system which determines population size, the catches of the fish traps could, in theory, be substantially increased without adversely affecting the Kosi fish populations. If the traps were to catch a larger proportion of the adult fish leaving the system, the indications are that the only species greatly affected would be A. berda and G. rappi which only constituted 7,45% of the catch by mass during the study.

This implies that the fish traps and their catches could be greatly increased, producing more food, on a sustainable yield basis. The wider implications, however, are much more important to the marine fishery along the entire Natal coast. The Kosi system is, at present, under least threat from pollution and other degradation of all the Natal estuaries (Begg, 1978). Not only does it serve as a nursery area for many important marine species (Blaber, 1982), but at the same time it produces, on a sustainable yield basis, significant quantities of food for the local people in a controlled manner. No other estuary system in Southern Africa does this.

4.6 The legal status of the fish trap catches

The legislation with jurisdiction over the catches of the Kosi Bay fish traps is the Natal Nature Conservation Ordinance (Number 15 of 1974). This contains regulations controlling the size and daily bag limits for marine fish caught in the region. Concern has been expressed about the capture of undersize fish in the traps (Brokensha, pers. comm.) and of the traps exceeding the daily bag limits and destroying stocks (Campbell, 1948).

In order to clarify the position the length frequency data during the study were analysed to determine the proportion of fish caught which were undersize. This information is given in Table 20. New legislation was introduced late in 1985 which significantly increased the minimum legal length of fish and although this did not apply during the study, the proportion of the trap catches which would have been illegal is also indicated in Table 20.

During the study period the month by month monitoring of the tourist catches indicated that the proportion of undersize fish caught and kept varied between 7 - 45%, with a mean of approximately 15%. A total of 4 500 fish were examined. The only way in which the trap owners can remove the fish from their traps is by spearing them and so no undersize fish caught in the traps can be released.

Table 20. The numbers and percentages of trap catches which were illegal or would have been illegal under new legislation

Species	1981		1982		1983		1984		Total	
	%	No.	%	No.	%	No.	%	No.	%	No.
P. commersonni	29,66	2 602	5,01	785	16,90	3 067	22,17	2 459	16,61	8 913
A. berda	0,55	16	0	0	0	0	0	0	0,15	16
R. sarba	20,69	279	17,79	657	10,83	225	29,15	176	17,35	1 337
G. rappi	2,53	84	0	0	0	0	0	0	0,56	84
L. argentimaculatus	26,30	178	10,90	50	6,40	13	14,40	28	17,55	269
P. saltatrix	3,90	7	0	0	5,00	4	3,70	3	4,39	14
Only small numbers of all other species were undersize.										
Total illegal	3 166		1 492		3 309		2 666		10 633	
Total catch	39 815		41 837		45 843		36 846		164 341	
% illegal	7,95		3,57		7,22		7,24		6,47	
% illegal under 1985 legislation	10,81		6,65		9,54		10,06		9,23	

Only the best made fish traps can catch small fish. If the proportion of undersize fish were considered too great then the few trap owners involved could be encouraged to make larger gaps between the sticks of the basket walls. The results of this study indicate that the number of undersize fish caught did not greatly influence fish stocks and the proportion was much lower than that caught and kept by the tourist fishermen.

During the study period, the daily bag limit for P. commersonni was 6 fish per fisherman. This bag limit was regularly exceeded by some fish trap owners. The vast majority of catches were, however, well below this and there is no way to stop fish entering a trap beyond an arbitrarily decided limit.

The law as it pertains to fisheries is designed to protect the stocks in order to allow continued exploitation. The total catch of the traps combined with the percentage off-take are the important statistics. This will be discussed later in Chapter 7. The only way to control trap catches is to manage the positioning and construction of the traps and current methods appear satisfactory.

5 STATISTICAL ANALYSIS OF TRAP CATCHES

5.1 Introduction

Trap catches of several species showed an obvious annual pattern, as, for example, shown by Gerres rappi (see figure 20). Others showed clear patterns of catch abundance not as readily explicable. As the aim of this study was to obtain an understanding of the ecology of the fishes of the Kosi system, apparent trends were investigated statistically. In this way quantitative data were obtained on the strength of relationships and levels of significance were derived.

Initially data were analysed in order to determine whether or not the trap catches simply reflected the random variation in the movement of fish on a monthly basis between the lakes and the ocean. If the movements of the fish were not in any pattern, then each fish would be as likely to enter or leave the Kosi system on any day or month of the year. This would result in similar daily and monthly trap catches. If this movement was not casual then the next step would be to test for a pattern in catches which was repeated on a yearly cycle. Casual movement would mean that the data could not be used to give any further insight into the species concerned whereas a regular pattern in trap catches would indicate that some parameters influenced or controlled them. Analysis of relationships between the annual trends of catches and those of measured parameters would show the strength of correlations between these patterns. The current level of knowledge could be used to indicate which relationships were causative and which coincidental.

5.2 Methods

Before any statistical analysis could be carried out it was necessary to establish whether or not the data were normally distributed. Several species' catch data were plotted and none of those investigated appeared to have normal distributions (one species is shown in Appendix 8). Study data for P. commersonni in 1981 were then compared with that

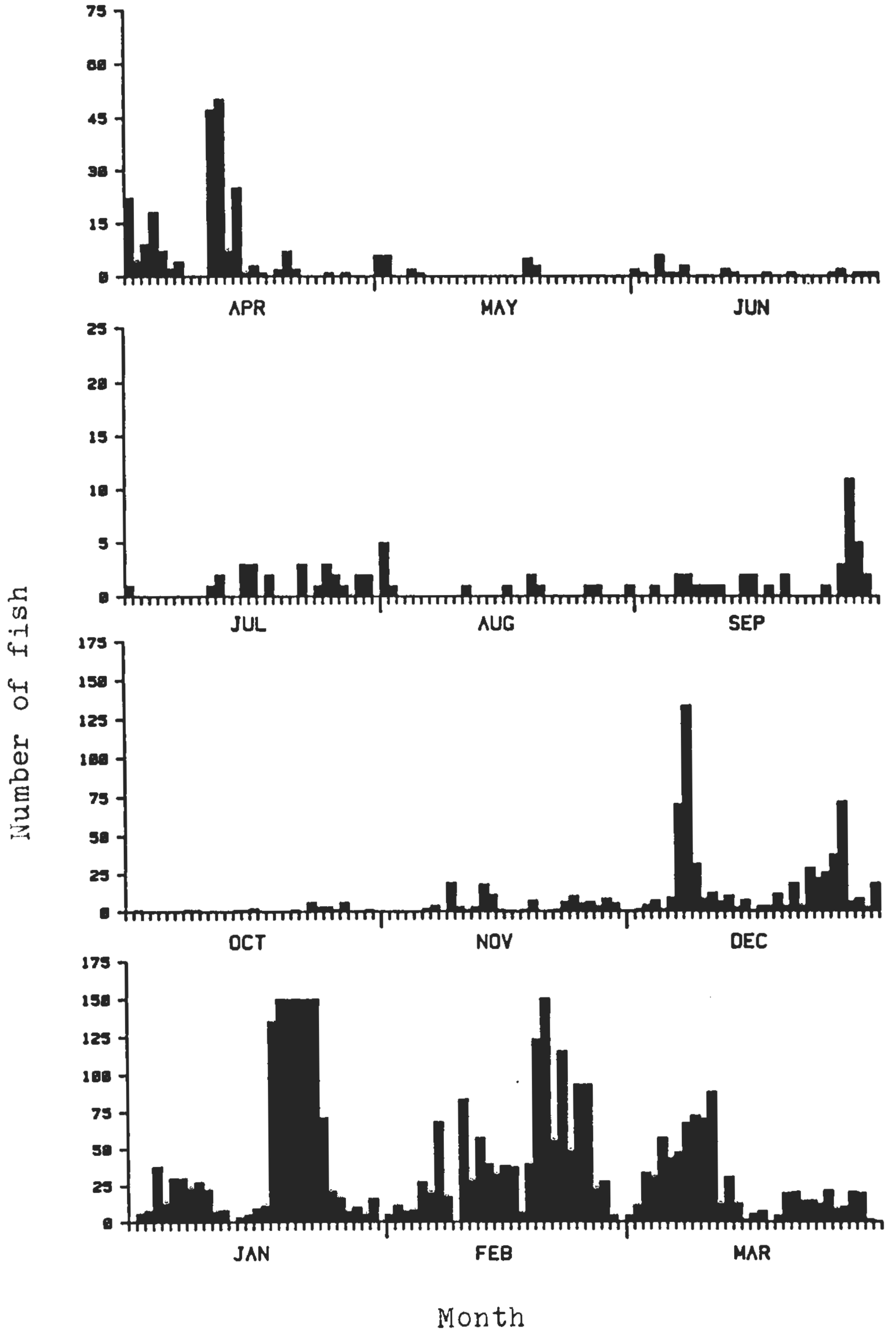


Figure 20. Daily total trap catches of G. rappi during the period 1/4/83 - 31/3/84 showing seasonal abundance patterns.

Figure 21 shows the obvious lack of correlation when gonad rank is plotted against catch rank.

Table 22. Correlations between monthly catch ranks and ranks of physical condition for species 1 - 3 on a yearly basis.

Parameters		Species	
	1	2	3
Gonad - 1981	-0,27	0,67 xx	0,90 xxx
1982	-0,17	0,55 x	0,95 xxx
1983	0,52 x	0,20	0,83 xxx
1984	-0,04	0,58 xx	0,75 xxx
TOTAL	0,00	0,66 xx	0,87 xxx
Temperature - 1981	0,63 xx	-0,27	-0,03
1982	0,76 xxx	0,10	-0,06
1983	0,27	0,36	-0,24
1984	0,85 xxx	-0,01	-0,45
TOTAL	0,76 xxx	0,02	-0,18

where x = P < 0,1
xx = P < 0,05
xxx = P < 0,01
(10 degrees of freedom)

Species 2. *Mugil cephalus*

The results indicate a significant correlation between numbers of *Mugil cephalus* caught and gonad condition. The largest catches in the system reflect a clear spawning run to the ocean towards the end of the summer months. Data on gonad condition are sufficient to give a good indication of the pattern of gonad activity and each year there is one clearly defined run of mature fish. The significant negative correlation between the ranking of *M. cephalus* catches and wind speed is due to the strong co-incidental correlation between gonad condition ranking and wind speed ranking.

Table 23. Correlations between monthly catch ranks and ranks of physical and gonad conditions for species 11 - 20 and levels of significance of these correlations during the whole study.

Parameter	Species									
	1 (Pc)	2 (Mc)	3 (Ab)	4 (Vb)	5 (Lm)	6 (Rs)	7 (Gr)	8 (C)	9 (Lar)	10(La)
Water temperature (Kosi)	0,76	0,02	-0,18	0,68	-0,79	0,69	0,96	0,89	0,98	0,30
Ocean temperature	0,61	0,22	0,02	0,65	-0,79	0,64	0,90	0,88	0,95	0,45
Wind	0,58	-0,65	-0,62	0,28	-0,01	0,11	0,56	0,42	0,38	-0,37
Rainfall	0,64	0,11	0,01	0,67	-0,66	0,67	0,68	0,78	0,67	0,32
Salinity (1983)	-0,25	0,01	0,65	-0,45	0,61	0,08	-0,73	-0,41	-0,36	-0,07
(1984)	0,31	-0,47	-0,44	-0,39	0,17	0,22	0,27	0,06	0,41	-0,34
Mean of salinity	0,03	-0,23	0,11	0,42	0,39	0,15	-0,23	-0,17	0,02	-0,20
Gonad total	0,00	0,66	0,87	-0,01	0,51		0,94			0,87
Water temperature (Kosi)	xxx			xx	-xxx	xx	xxx	xxx	xxx	
Ocean temperature	xx			xx	-xxx	xx	xxx	xxx	xxx	
Wind	xx	-xx	-xx				x			
Rainfall	xx			xx	-xx	xx	xx	xxx	xxx	
Salinity (1983)			xx		xx		-xxx			
(1984)										
Mean of salinity										
Gonad total		xx	xxx		x		xxx			xxx

Species numbers correspond to those used in Appendix 2 and throughout this study.

where x = P 0,1 ; xx = P 0,05 and xxx = P 0,01 (10 degrees of freedom)

Table 24. Correlations between monthly catch ranks and ranks of physical and gonad conditions for species 1 - 10 and levels of significance of these correlations during the whole study.

Parameter	Species									
	11(Cc)	12(S)	13(Em)	14(Om)	15(Pi)	16(Sl)	17(Ga)	18(Ps)	19(Cg)	20(Et)
Water temperature (Kosi)	0,88	0,90	0,85	0,70	0,73	0,62	0,24	-0,89	0,73	0,58
Ocean temperature	0,85	0,95	0,92	0,57	0,79	0,64	0,15	-0,92	0,66	0,58
Wind	0,33	0,16	0,02	0,78	-0,14	-0,23	0,00	-0,09	0,29	-0,08
Rainfall	0,80	0,77	0,72	0,49	0,72	0,40	-0,04	-0,73	0,76	0,51
Salinity (1983)	-0,30	0,60	-0,73	-0,68	-0,11	-0,64	0,01	0,26	-0,64	
(1984)	-0,05	0,02	0,15	0,52	-0,16	-0,32	0,12	0,13	0,03	
Mean of salinity	-0,18	0,31	-0,29	-0,08	-0,14	-0,48	0,06	0,20	-0,30	
Gonad total							0,32			
Water temperature (Kosi)	xxx	xxx	xxx	xxx	xxx	xx		xxx	xxx	xx
Ocean temperature	xxx	xxx	xxx	xx	xxx	xx		xxx	xx	xx
Wind				xxx						
Rainfall	xxx	xxx	xxx		xxx			xxx	xxx	x
Salinity (1983)		xx	xxx						xx	
(1984)				x						
Mean of salinity										
Gonad total										

Species numbers correspond to those used in Appendix 3 and throughout this study.

where x = P 0,1 ; xx = P 0,05 and xxx = P 0,01 (10 degrees of freedom)

Table 25. Correlation coefficients between ranking of physical parameters.

Physical parameters	1	2	3	4	5	6
1. Water temperature - Kosi		0,96	0,38	0,74	-0,66	0,30
2. Water temperature - ocean			0,29	0,73	-0,58	0,15
3. Monthly wind averages				0,25	-0,47	0,34
4. Rainfall					-0,50	-0,08
5. Salinity - 1983						-0,13
6. Salinity - 1984						

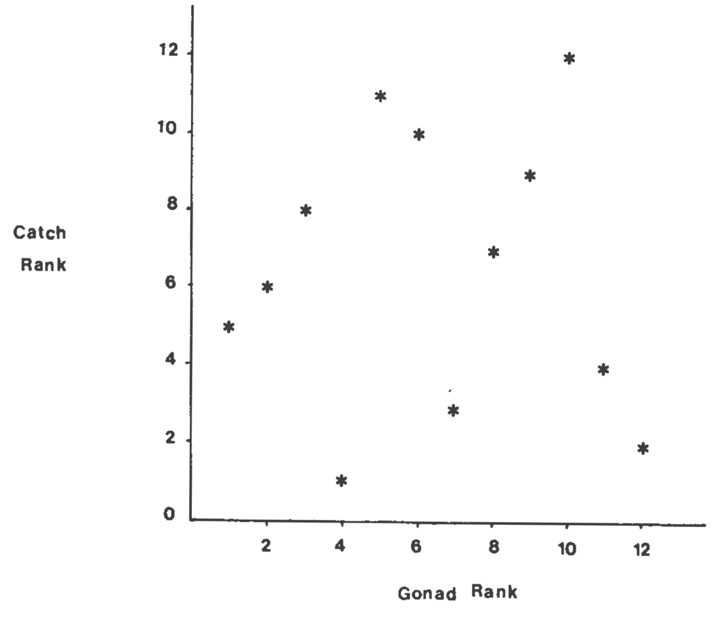


Figure 21. Mean monthly gonad rank plotted against catch rank for P. commersonni showing lack of correlation between these parameters.

Figures 22 and 23 clearly show the relationship between catch size and gonad condition. Data on the spawning season from Wallace and van der Elst (1975) are included and these confirm the spawning related nature of the M. cephalus catch statistics. These figures also serve to demonstrate the advantages and disadvantages of using the ranking of data as a method. The monthly total catches for September and October are 1 534 and 1 533 respectively. Using ranking the smallest difference between ranks is one unit. In this example a difference of one unit of rank represents changes in catch of between 1 and 2 376 fish. The result of this is that the graphic picture becomes distorted during the months of similar catches. The overall picture is, however, substantially the same.

The graph of catch rank against gonad rank in Figure 24 shows the degree of correlation between these parameters for M. cephalus.

Species 3. Acanthopagrus berda

There is a highly significant positive correlation between trap catches and gonad condition as is shown in Table 22. The correlations between numbers caught and wind speed and salinity in 1983 are likely to be due to co-incidence. The gonad condition ranking of A. berda has a -0,55 correlation with wind velocity and the salinity ranking of 1984 shows no correlation with trap catches.

Figure 25 shows the correlation between gonad rank and catch rank.

Figures 26 and 27 show the data from this study compared with the breeding season given by Wallace (1975b).

A. berda is an estuary dependent fish (van der Elst, 1981) thus at Kosi most of its life cycle is spent inside the system. The only time it is caught in large numbers in the traps is when it is migrating to the ocean to spawn towards the end of summer.

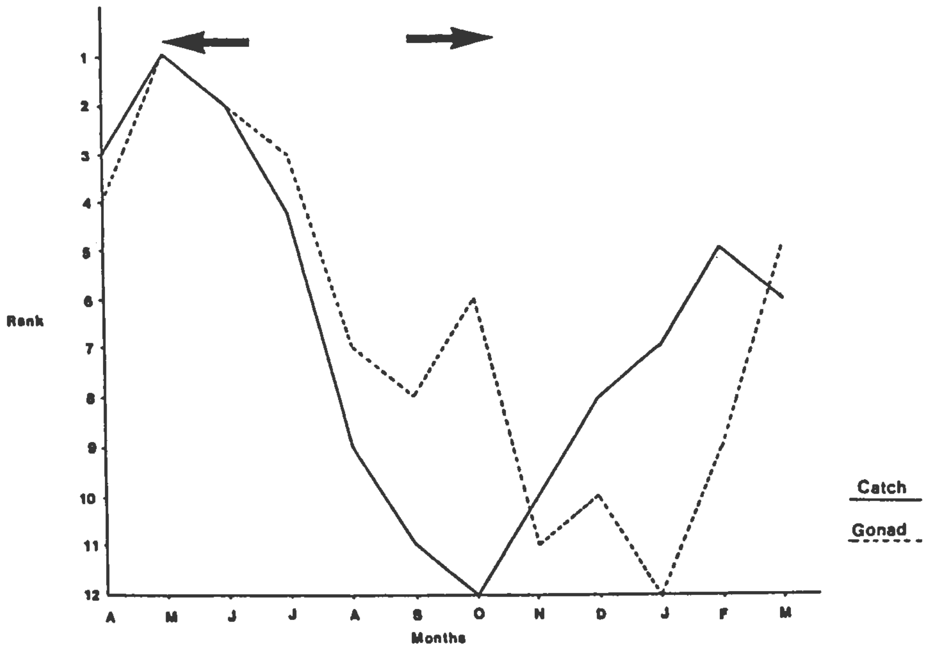


Figure 22 Graphical representation of monthly gonad condition ranking and total trap catch ranking of M. cephalus showing relationship between these parameters, with the spawning season indicated ⟷.

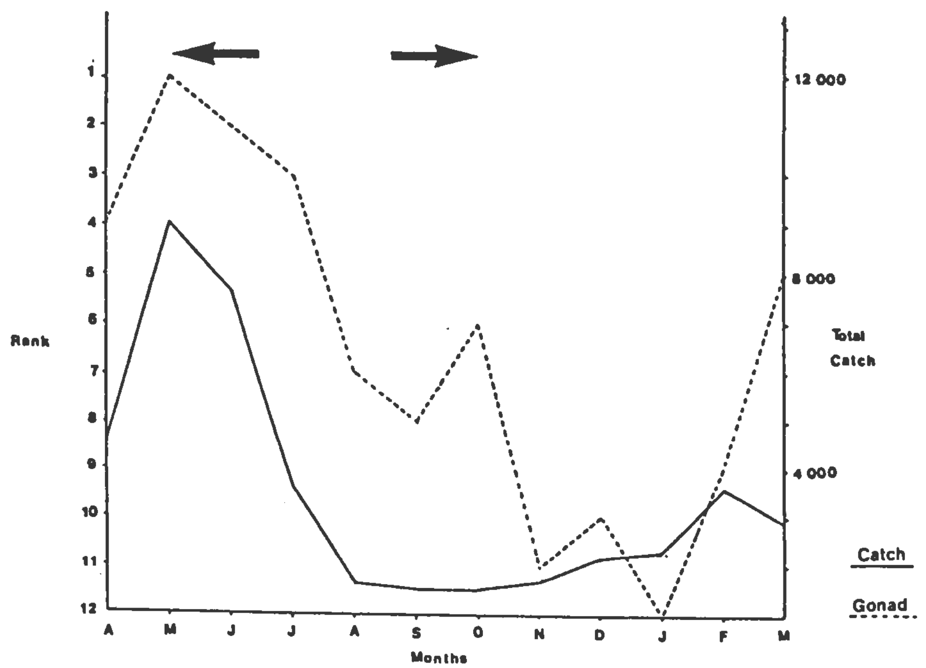


Figure 23 Graphical representation of monthly gonad condition ranking and total trap catches by numbers for M. cephalus showing relationship between these parameters using actual catch data instead of ranked catches, with the spawning season indicated ⟷

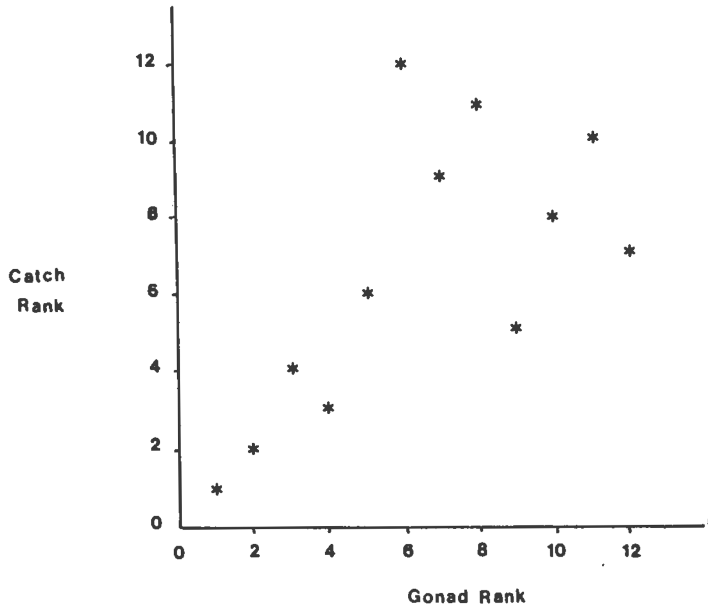


Figure 24. Mean monthly gonad rank plotted against catch rank for M. cephalus showing degree of correlation between these parameters.

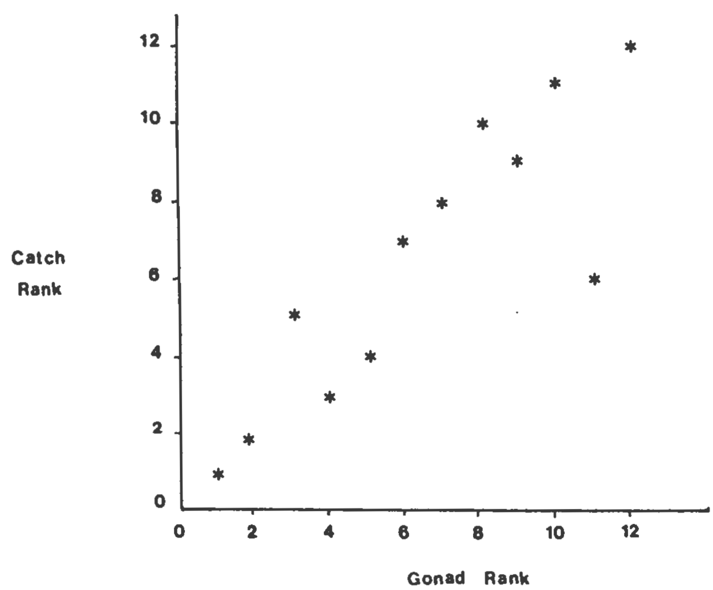


Figure 25. Mean monthly gonad rank plotted against catch rank for A. berda showing strong correlation between these parameters.

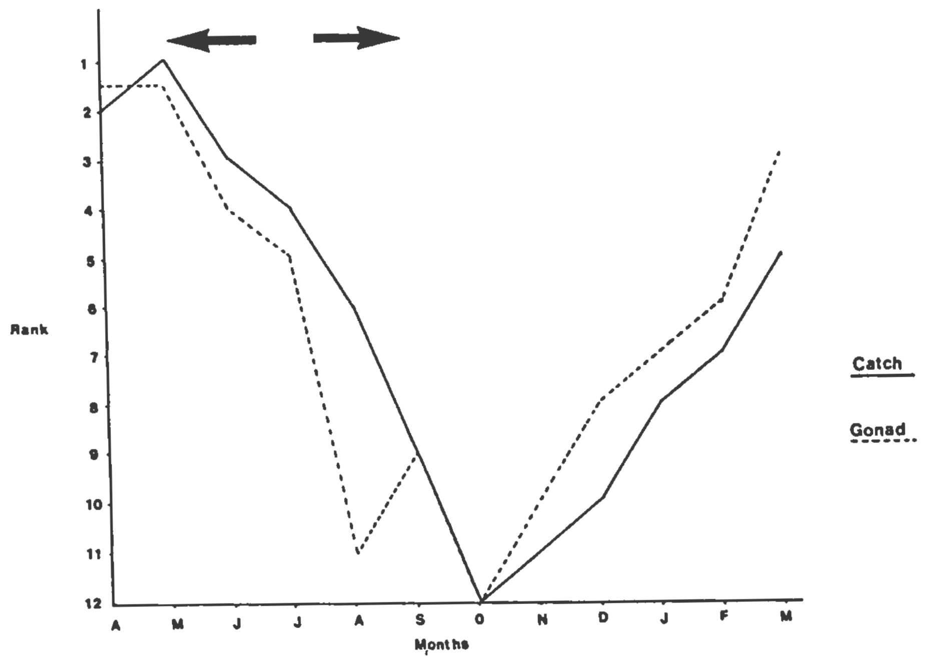


Figure 26. Graphical representation of monthly gonad condition ranking and total trap catch ranking of A. berda showing relationship between these parameters, with the spawning season indicated ⟷.

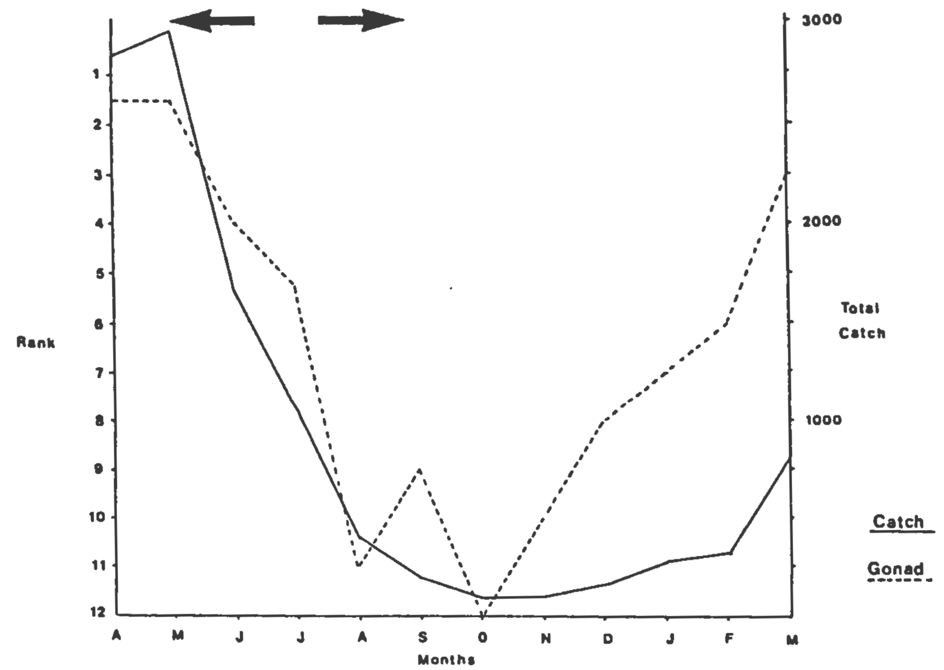


Figure 27. Graphical representation of monthly gonad condition ranking and total trap catches by numbers for A. berda showing relationship between these parameters using actual catch data instead of ranked catches, with the spawning season indicated ⟷.

Species 4. Valamugil buchanani

Few fish of this species with active gonads were caught inside the system as was found by Wallace (1975b) for St. Lucia. There is a significant degree of concordance in the rank of catches from year to year, but this does not appear to be closely related to the breeding cycle. The most significant correlation is between trap catches and the warm water months inside the system. This indicates that there is a general exodus of V. buchanani from the system during the summer months.

Species 5. Liza macrolepis

Data on gonad condition were insufficient to produce a clear ranking for this species. Spawning is thought to take place over a protracted period during winter and to occur near estuary mouths (Wallace, 1975b). The results given here show a significant positive correlation with the gonad data available and a negative correlation with the warmer months. From field observations it is clear that much of the catch of this species is of mature specimens migrating to the ocean to spawn. The long breeding season and spawning probably occurring close to estuary mouths, make the overall trend less obvious as catches of fish in active gonad condition extend over a long period of time.

Species 6. Rhabdosargus sarba

As was shown earlier, the degree of concordance in catches of this species from year to year is small. This means that there is little consistency in the annual catch abundance, and thus no clear correlation with any physical parameters could be expected. The erratic nature of the catches of R. sarba in estuaries has been commented upon (Wallace, 1975b) and this has resulted in the true nature of the movements of this species being difficult to ascertain. The total figures from this study over the four year period show a significant correlation with the warmer temperatures. As was stated in Chapter 4, considerable numbers of this species under a length of 20 mm (T.L.) are recruited to the system. These fish grow inside the system and migrate to the ocean before their gonads are fully developed. This movement to the ocean generally takes place during summer, but the parameters controlling it are not yet apparent. Factors influencing the movement of this species will be discussed further later in this chapter.

Species 7. *Gerres rappi*

This estuary dependent species shows a clear summer month migration to the ocean to spawn. The cycle is obvious each year and these results agree with the findings of Cyrus (1980). Figure 20 shows the daily catch statistics for *G. rappi* in 1983/4 and demonstrates this migration.

Species 8. *Caranx* species

The strongest correlations that these species show are those with the water temperature inside and outside the system. No useful data were obtained on the gonad condition for this genus. The correlation with rainfall is again explained by the inter-parameter correlation shown in Table 25.

van der Elst (1980) gives data on the catches of Carangidae from the shore and these show the same peak of abundance towards the end of summer. Little is known about the breeding of the Carangidae, but it is thought to occur offshore. The movement into estuaries is incidental and not a necessary part of the life cycle. The catches of the Carangidae in the traps reflect the seasonal abundance and the movements of these fish in the inshore environment during the warmer months.

Species 9. *Lutjanus argentimaculatus*

This species shows a catch pattern very similar to that of the *Caranx* species at Kosi. It is primarily a summer active species whose movements inside Kosi are probably related to food and feeding. Few reproductively active fish were found inside the system (see Appendix 6).

Species 10. Liza alata

The cycle of activity of this species is similar to that of M. cephalus. As can be seen in Table 23 the best trap catches are strongly related to active gonad condition. Good trap catches reflect the annual migration to the ocean to spawn in late summer.

Species 11. Chanos chanos

C. chanos is a marine species which occasionally enters the Kosi system in summer and appears to leave again the same year. No fish were found with active gonads and very few juvenile fish were caught. There is little evidence that many stay in the system throughout the year, as it is easily caught in gill nets and yet very few were found in nets in winter. Trap catches reflect the return of this species to the ocean, generally in summer.

Species 12. Sphyraena species

The catches of this genus inside Kosi reflect the same trends as the Carangidae. It is primarily a summer month visitor.

Species 13. Elops machnata

This is another summer visitor. No E. machnata were found with active gonads and in winter very few of this species were caught.

Species 14. Oreochromis mossambicus

Data on gonad condition of this species were not sufficient to allow a true ranking to be made. Catches show a strong annual cycle and from field observations the best catches are made during peak breeding activity. It is principally during the breeding season that this Kosi resident species enters the shallow margins of the lakes where the traps occur. Most breeding takes place in summer (Bruton & Kok, 1980) and this probably results in the significant correlations between high catches and warm temperatures in Table 24. The strongest winds also occur in summer.

Species 15. Platycephalus indicus

Although numbers caught were small, when the data for the four years are combined there is a pattern which shows a significant correlation with the warmer months. Few specimens were found to have active gonads. The breeding season is variously thought to be spring and summer (Wallace, 1975b) and winter to spring (van der Elst, 1981). Trap catches probably reflect the movement of these fish to the marine environment in order to spawn. Gonad condition data from this study indicate breeding as occurring at the beginning of summer.

Species 16. Scomberoides lysan

A significant correlation was found between the trap catches and the warmer months. No fish were found with active gonads and so this is thought to be another summer visitor.

Species 17. Gerres acinaces

As was stated earlier, there was no obvious annual pattern in the trap catches. This has resulted in no clear correlations with any of the parameters considered. It is thought (Cyrus, 1980) that the breeding cycle of G. acinaces is similar to that of G. rappi, but as can be seen from Table 24 no significant correlation was found. The small size of G. acinaces relative to G. rappi (Smith, 1977) resulted in small numbers being caught as most G. acinaces escape between the sticks of the fish trap basket.

Species 18. Pomatomus saltatrix

This species migrates up the coast of Natal in the cooler months (van der Elst, 1981) and the catch ranks of the Kosi fish traps show a significant correlation with those of the Natal Rock and Surf catches (van der Elst, 1981). It is an incidental winter visitor to Kosi and this is reflected in the strong negative correlation with the warmer months.

Species 19. Clarias gariepinus

A freshwater fish, this species is occasionally caught in fish traps, nearly always associated with heavy rain. Most rain occurs in the summer months and so although the strongest correlation is that with the wettest month there is also a significant correlation with temperature. It has been reported that following heavy rain C. gariepinus will enter flooded areas in search of food or to spawn (Bruton, 1979). At Kosi heavy rain will temporarily depress salinities in shallow water and enable C. gariepinus to enter the areas where the traps are found.

Species 20. Epinephelus tauvina

Numbers of this species caught were small, and there is no significant concordance in rank between the four years' data. When the monthly totals over the four years are summed there is a significant correlation with temperature. This species is another marine summer visitor.

Summary

The fish trap catches at Kosi represent different types of movement for the various species, but may be summarised as follows :-

a) Spawning runs by estuary dependent species.

3. Acanthopagrus berda
7. Gerres rappi
17. Gerres acinaces

b) Spawning runs by partially estuary dependent species.

2. Mugil cephalus
5. Liza macrolepis
10. Liza alata

c) The entry and the return to the ocean of summer visitors.

8. *Caranx* species
9. *Lutjanus argentimaculatus*
11. *Chanos chanos*
12. *Sphyraena* species
13. *Elops machnata*
16. *Scomberoides lysan*
20. *Epinephelus tauvina*

d) Movement, probably breeding related, by freshwater fish.

14. *Oreochromis mossambicus*

e) Temporary immigration to principal trap area by freshwater fish.

19. *Clarias gariepinus*

f) The entry and return to the ocean of winter visitors.

18. *Pomatomus saltatrix*

g) General warm month migrations to the ocean by partially estuary dependent species.

1. *Pomadasys commersonni*
4. *Valamugil buchanani*
6. *Rhabdosargus sarba*
15. *Platycephalus indicus*

5.3.4 When the fish run do catches conform to a recognisable pattern ?

As was shown earlier most fish species show seasonal trends in trap catches related to temperature or gonad condition. These factors work over a yearly cycle and the periods of relative abundance usually stretch over weeks or months. The question now asked is whether the catches slowly build up to a peak and tail off or fluctuate radically on a daily basis within the annual period of abundance.

If movement was only controlled on an annual cycle basis then at the peak period of catches the numbers caught daily should be similar. In order to test this the period three days before and three days after the highest catch of each species in the first year was examined. A null hypothesis was erected and then tested using the Chi-squared and Kolmogorov-Smirnov Goodness-of-fit tests.

Null hypothesis : Fish movement is arbitrary over the seven day period around the best catch in a yearly cycle.

Daily catch statistics such as those in Figure 28 show that in at least one species there is a very pronounced daily fluctuation in catches even at peak catching periods. This judgement, as well as two significance test results, are given in Table 26. This table shows that in all species for which more than 50 fish were caught in the test period, there were very clear significant differences from the levels of the test statistic expected under the null hypothesis. The Chi-squared test indicated that in 18 of the 20 species there was a significant difference at the $P = 0,05$ level and in the other cases the number of fish in the sample was very low.

It is clear for all the species caught in large numbers, and probably for all species, that there are significant fluctuations in trap catches around the peak period. These would not be expected unless some parameters influenced catches on a daily basis.

5.3.5 During periods of catch abundance are the catches related to any recognisable and quantifiable physical parameters ?

It has already been shown for most species that there is a clear annual cycle of catch abundance which is related to recognisable parameters. It has also been shown that on a day to day basis something is controlling or modifying the trap catches.

The simplest way in which to investigate the daily influences is to look for correlations between trap catches and measured physical parameters. The only ones which could be used in

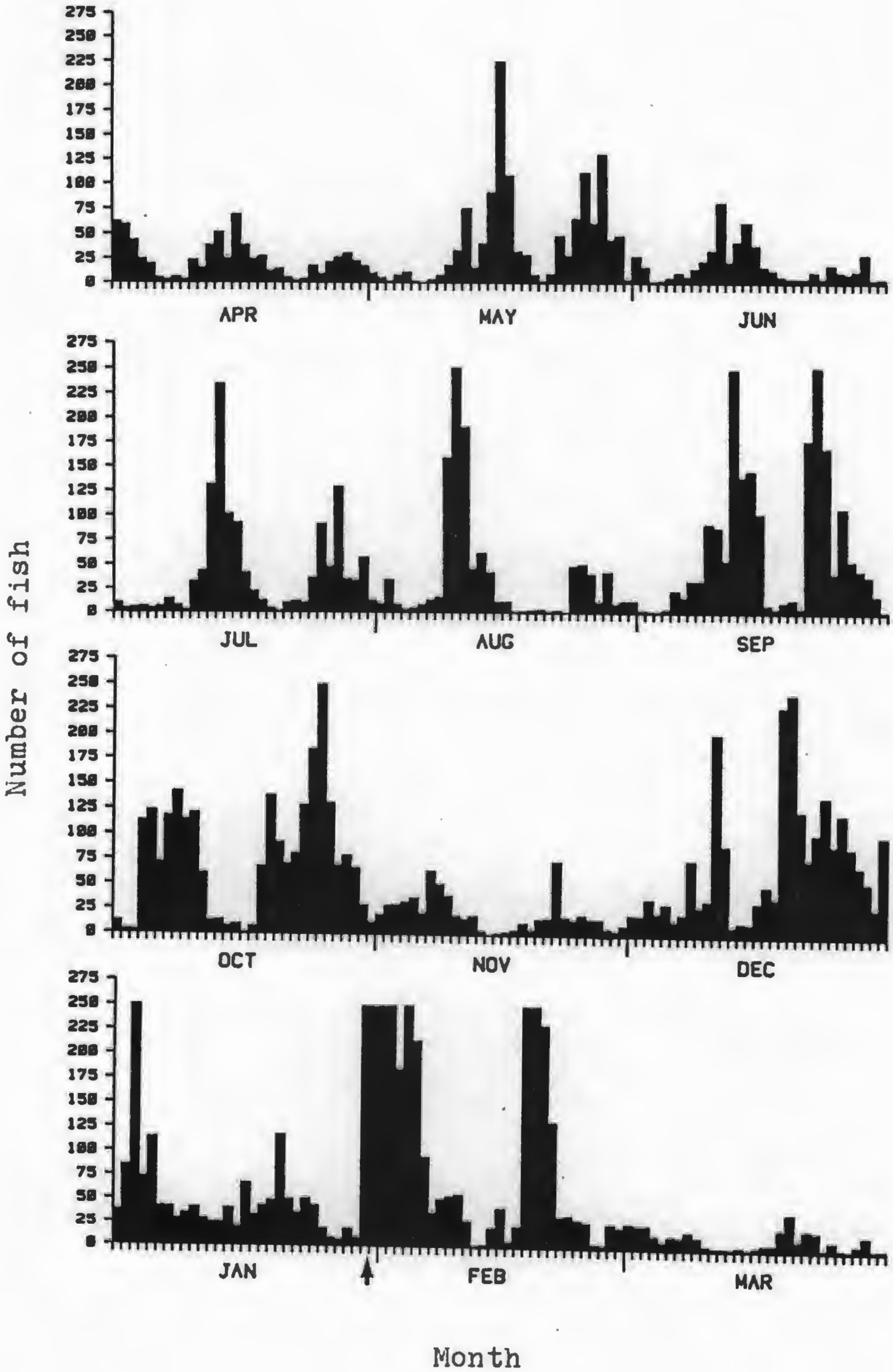


Figure 28. Daily total trap catches of P. commersonni during the period 1/4/83 - 31/3/84 showing marked 14 day cycles of abundance and good catches following heavy rain during Cyclone Demoina (▲).

Table 26. Test period and levels of difference from random fluctuations around peak catch.

Species	Peak catch	n	Obvious ?	x^2	K-S
1. *Pomadasys commersonni*	Dec 12 1981	499	Yes	xxx	xxx
2. *Mugil cephalus*	Jun 3 1981	1 267	Yes	xxx	xxx
3. *Acanthopagrus berda*	Apr 22 1981	325	Yes	xxx	xxx
4. *Valamugil buchanani*	Dec 14 1981	43	Yes	xxx	xxx
5. *Liza macrolepis*	Oct 14 1981	586	Yes	xxx	xxx
6. *Rhabdosargus sarba*	Feb 22 1982	249	Yes	xxx	xxx
7. *Gerres rappi*	Feb 8 1982	385	Yes	xxx	xxx
8. *Caranx* species	Apr 6 1981	68	Yes	xxx	xxx
9. *Lutjanus argentimaculatus*	Mar 28 1982	143	Yes	xxx	xxx
10. *Liza alata*	Apr 8 1981	112	Yes	xxx	xxx
11. *Chanos chanos*	Jan 12 1982	129	Yes	xxx	xxx
12. *Sphyraena* species	Apr 18 1981	43	No	xxx	-
13. *Elops machnata*	Mar 25 1982	11	No	xxx	xx
14. *Oreochromis mossambicus*	Feb 8 1982	46	Yes	xxx	-
15. *Platycephalus indicus*	Mar 26 1982	15	No	xxx	-
16. *Scomberoides lysan*	Apr 10 1981	6	No	xx	-
17. *Gerres acinaces*	Sep 5 1981	38	Yes	xxx	xxx
18. *Pomatomus saltatrix*	Jul 31 1981	30	No	xxx	xx
19. *Clarias gariepinus*	Sep 13 1981	2	No	-	-
20. *Epinephelus tauvina*	Dec 31 1981	3	No	-	-

where : n = number of fish caught during test period
x = P < 0,1
xx = P < 0,05
xxx = P < 0,01
x^2 = Chi-squared test
K-S = Kolmogorov- Smirnov test
Test period = 3 days before to 3 days after best trap catches

such an analysis were those for which numerical values could be obtained on a daily basis during the period tested. These parameters were as follows :-

a) Water height - maximum height attained during each twenty-four hour period from readings at the Ott apparatus at S'fungo.

b) Wind - readings of wind speed on the Beaufort scale were taken at 20h00 on the previous day and 08h00 on the day on which the catch was made. These were summed to give a total value for each period indicating the wind intensity during the night when the fish would enter the traps.

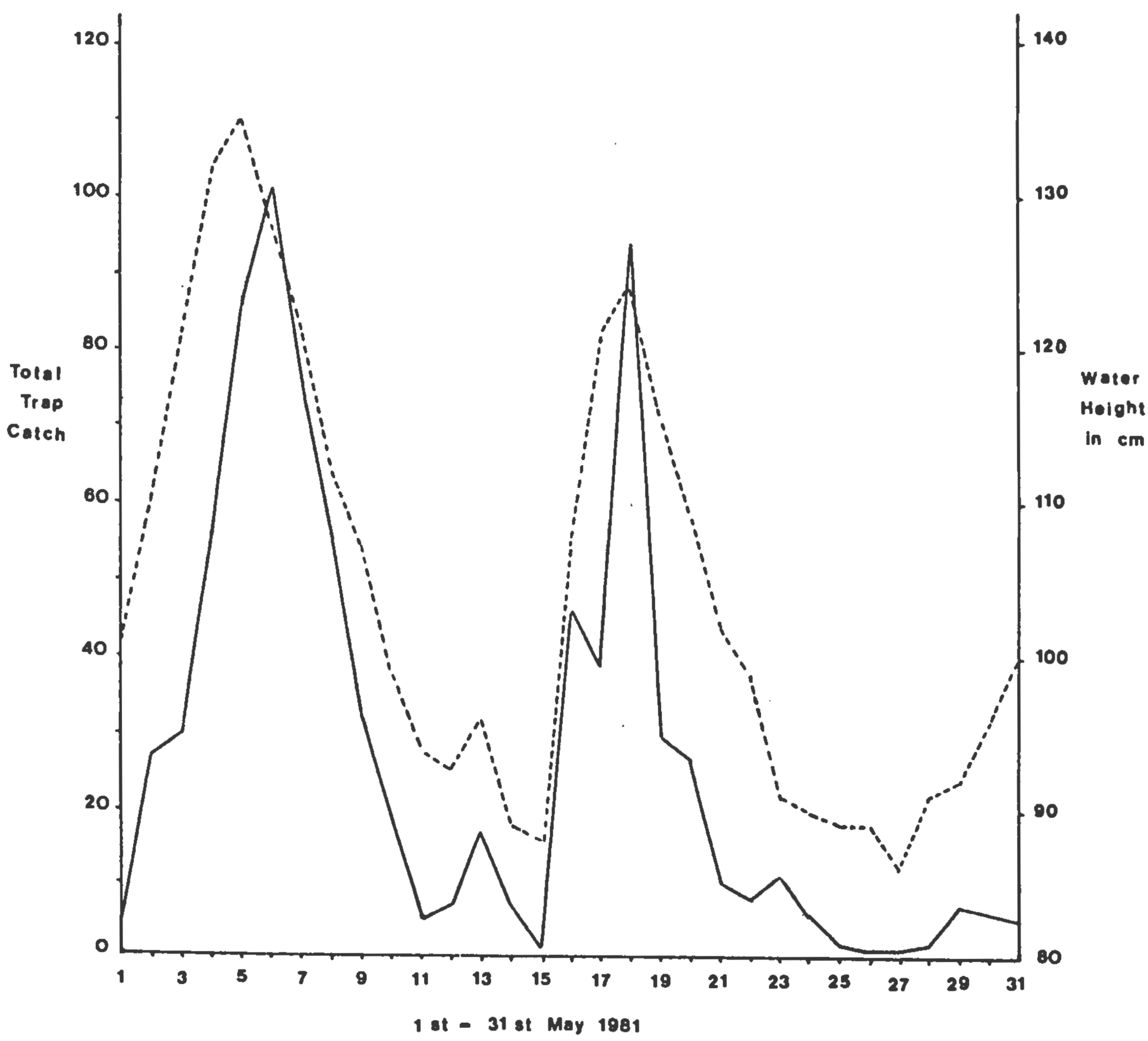
c) Rain - rainfall readings from the station on NE Nhlange were used.

d) Temperature - maximum daily temperature readings from the same station as the rainfall were used.

In order to obtain meaningful results large numbers of fish had to be caught during most or all of the test period. This was only possible for the ten most abundant species. Product-moment correlation coefficients were calculated between the daily catches and each of the parameters described. The period investigated was the month of highest catches during an annual cycle for which the physical parameter data were available. Results and levels of significance are given in Table 27.

The most obvious correlation is that between daily catches and water height. Figure 28 shows the daily catches of _P. commersonni_ and a fourteen day cycle of catch abundance, correlating with that of water height, is evident. Figure 29 shows the close relationship between the catch of _P. commersonni_ and water height during the first month of the study.

The parameters used in this investigation were examined to establish whether any showed significant correlations with



where ——— = trap catch and ------- = water height

Figure 29. Graph representing total trap catch of <u>P. commersonni</u> and water height at Ott apparatus during the period 1 - 31 May 1981 showing the close relationship between these two sets of figures.

each other. None were found at P = 0,05 level. Partial correlations were calculated to investigate the relationship between catches and wind, rain and temperature with the effect of the correlation with water height removed. This invariably resulted in low correlation coefficients between catches and the other parameter concerned.

Table 27. Product-moment correlation coefficients between trap catches and physical parameters and their levels of significance calculated on a daily basis over one month test periods.

Species	Water height		Wind	Rain		Temperature	
1. P.c.	0,81	xxx	-0,21	0,24		-0,16	
2. M.c.	0,56	xxx	0,07	0,03		-0,33	
3. A.b.	0,78	xxx	-0,16	0,46	xx	-0,19	
4. V.b.	0,81	xxx	0,22	0,02		-0,14	
5. L.m.	0,48	xx	0,32	0,05		-0,02	
6. R.s.	0,67	xxx	0,32	-0,05		0,03	
7. G.r.	0,64	xxx	0,25	0,14		-0,39	x
8. Car.	0,49	xx	0,21	-0,06		0,06	
9. L.ar.	0,36	x	0,04	0,05		-0,15	
10. L.al.	0,35		-0,31	0,004		-0,53	xx

where x = significant at $P < 0,001$
xx = significant at $P < 0,01$
xxx = significant st $P < 0,05$

Partial correlation between catch and rain for A. berda, with the effect of the correlation with water height removed, reduced the correlation coefficient to 0,40, which is significant at the P = 0,05 level. This indicates that there is a correlation between the trap catches of the species and rainfall which is not explained by the possibility of rainfall increasing the water height.

Gerres rappi and Liza alata show significant negative correlations with temperature. Figure 20 shows that in February 1984 in a similar fashion to that during the test period (February, 1982), the catches of G. rappi tended to increase throughout February, while Appendix 1 shows that mean maximum air temperatures fell during these periods. This result appears to be more a general trend in catches and temperatures than a cause and effect situation on a daily basis, as temperatures continue to decrease after this period as do catches. L. alata shows a similar pattern but there is another important factor, the phase of the moon, which will be discussed later in this section. The results in Table 27 indicate that there are no other significant correlations between the parameters tested for the species examined.

Some of the factors considered as possibly influencing fish movement on a daily basis could not be easily quantified. The phase of the moon is reported by local people (Zwane, pers. comm.) to be important for some species while certain species were thought to favour movement during rising water as the tides build up to peak spring tide. In order to investigate the effects of these parameters tests for ordinal data had to be employed.

Approximately equal periods of new and full moon occurred during the study period. Similarly approximately equal periods of rising and falling water height, related to spring and neap tides, were experienced. If twenty days were selected randomly throughout the year, it would be expected that approximately one half would be from during new moon phases and one half from full moon phases. A comparable situation would exist with respect to rising and falling water.

Comparing the twenty best catch days in each year for each species with the expected values for each parameter would give an indication of the validity of the above suggestions. Equal numbers of days of each condition would indicate no influence while any influence of the parameter considered would increase the number of days during which conditions for migration were favoured. Significance of deviations from expected values for the nul hypothesis were determined by Chi-squared tests. The results are summarised in Table 28.

Table 28. The number of days, out of 80 best catch days during this study, which fell during new moon and rising water phases and t e significance levels of these results using the Chi-squared test.

Species	New moon		Rising water	
1. P.c.	48		44	
2. M.c.	59	xxx	43	
3. A.b.	51	xx	44	
4. V.b.	47		36	
5. L.m.	42		51	xx
6. R.s.	45		56	xxx
7. G.r.	42		40	
8. Car.	41		40	
9. L.ar.	61	xxx	30	-x
10. L.al.	66	xxx	26	-xxx

where x = P < 0,05
xx = P < 0,02
xxx = P < 0,01

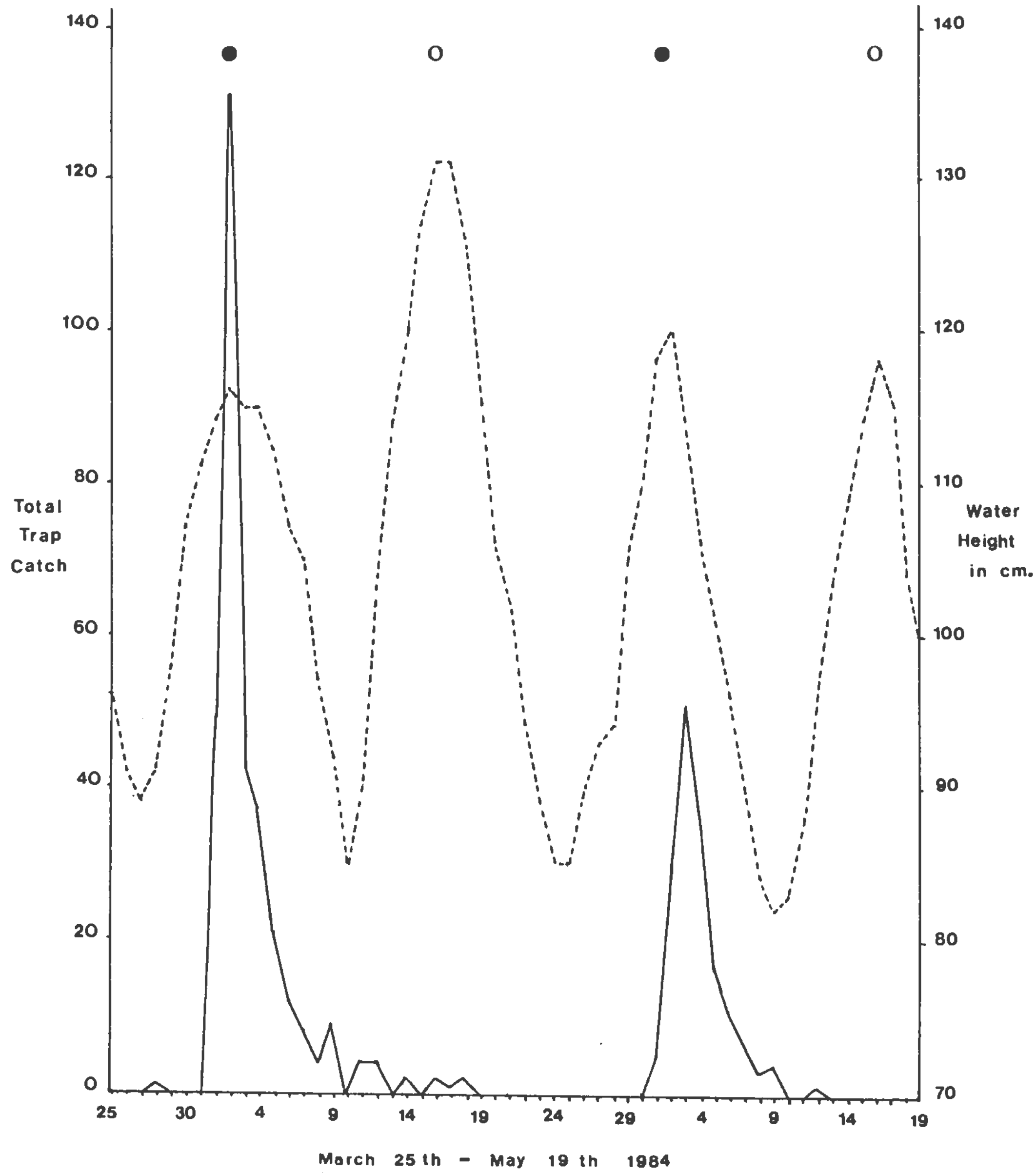
Discussion on results in Table 28.

Phase of moon

For this investigation each 28 day lunar cycle was split into two equal phases. The 14 days nearest full moon were considered full moon phase and the remainder new moon. Three species showed a strong tendency to migrate over the new moon phase rather than the full moon. The most important consistent difference between the moon phase periods is that the new moon period can only be dark while the full moon period is generally lighter at night although this is dependent on cloud cover. It appears that several species choose to move during the darker periods. *M. cephalus* and *L. alata* are both members of the Mugilidae, and each migrates to the ocean to spawn towards the end of summer. To do this entails movement through a long stretch of shallow, clear channel.

Figure 30 shows how *L. alata* selects for the new moon phase in which to undertake this movement. This explains the result in Table 27 as in the month tested the new moon was at the end of the month when the temperatures were cooler. *M. cephalus* shows a similar but less distinct pattern. These two species have probably evolved to select for the darker moon periods in order to reduce fish predator pressure. The margins of the channels between the lakes and the ocean at Kosi are lined with *Phragmites* beds and in these are considerable numbers of piscivorous fish such as *L. argentimaculatus* and *Sphyraena* species (Blaber, 1982). van der Elst (1981) describes how *L. argentimaculatus* ambushes prey by sight from cover and states that in estuaries the Mugliaae form a large part of their prey. To most piscivorous fish sight is important in the capture of prey and thus capture will be more difficult during dark nights. Data from St. Lucia (Whitfield, 1977) show that of 9 recorded dates of arrival of *M. cephalus* shoals at St. Lucia mouth, having come from the lakes, 7 were during the new moon phase. Although not conclusive ($0,10 < P < 0,05$) this does suggest that the same phenomenon may occur there, though not as pronounced, in spite of much higher turbidities in St. Lucia (Cyrus, 1984). In studying the turbidity preferences of estuarine fish in St. Lucia estuary, Cyrus (1984) classed *M. cephalus* as being predominantly found in waters of intermediate turbidity. *L. alata* was not discussed, although two other members of the genus were stated to prefer clear to partially turbid waters. The Kosi system is a clear water system (Blaber, 1982) and it could be that a preference for turbid water is reflected in the choice of dark periods in which to migrate through shallow, clear water.

L. argentimaculatus and *A. berda* also show a significant trend towards more often being caught during new moon periods. These two species are also similar in some respects. Both spend much time in dense cover (van der Elst, 1981) and in the vicinity of the fish traps (pers. obs.). The two species have good eyesight, resulting in them rarely being caught in gill nets although they may be common at gill net sites. It is possible that the higher catches of these



where o = full moon and ● = new moon

——— = trap catch ------- = water height

Figure 30. Graph representing daily total trap catches of <u>L. alata</u> and water height at Ott apparatus during the period 25th March - 19th May 1984 showing relationship between these two sets of figures during the new and full moon phases.

species during dark periods are more a reflection of fish entering the valves of the baskets when they cannot see that the area beyond in enclosed. In clear water the fish can see that the basket is fenced in and field experiences have shown that it is extremely difficult to drive either of these species into such areas. It is clear from observations in the field that when A. berda is left inside a fish trap for any period it will patrol the periphery of the basket, select the largest gap between sticks, and try to force its way out of the gap chosen. Good light or clear conditions are a pre-requisite for this type of escape.

Water height rising or falling

Several species react significantly to rising or falling water levels but are possibly reacting in this way for different reasons. R. sarba catches show a tendency to increase during rising water. This could result from fish of this species, which are "ready to migrate", being stimulated by an increase in water flow into Mankawulani where they gather.

L. macrolepis, which shows the strongest tendency to be caught during rising water, is found in considerable numbers in the region of the fish traps at all times. During neap tide periods water currents slow down and the fish there retreat to deeper water areas. When the water rises again the fish in the trap region increase their feeding activities and exploit newly inundated areas. The result in Table 28 is probably a reflection of an increase in feeding activity as the water rises and a reduction in catches results when the water level drops.

L. alata and L. argentimaculatus catches both tend to be increased during the period of falling water. The most obvious difference if the fish move while the water is falling is that they would tend to do so with the current rather than against it. The reason for this is not clear.

5,4 Discussion on the daily influences on trap catch abundance.

It is clear from the daily catch figures such as those in Figure 28 and the significant results in Table 28 that water height has the most important influence on daily fish catches. The term used here is water height, as it is a daily reading of the height that the water attains above an arbitrary datum. The parameter measured could also be described as water depth as this amounts to the same.

Before considering this phenomenon further, it is necessary to explain that the results are not simply a reflection of the efficiency of the traps at different water heights. As is explained in Appendix 2, nearly all the traps are capable of catching fish throughout the complete range of water heights attained during the lunar cycle. Fluctuations in trap catches thus reflect differing numbers of fish passing through the fish trap area.

Much work has been carried out in Africa on the effects of raised water levels and floods on the movement of fish, although this has principally been concerned with freshwater species in river systems (Lowe-McConnell, 1975 ; Welcomme, 1979). Coke (1973) recorded the dependency of spawning and migration of several fish species in the Pongolo floodplain while Welcomme (1979) found that flood water initiated immediate longitudinal migration in several African floodplains. In these cases, however, the species were freshwater and the fish movement was principally upstream (Lowe-McConnell, 1975) or lateral in a river system (Welcomme, 1979). The situation in the Kosi system is different in that the principal migrations are by marine species and the movement is towards the ocean during both incoming and outgoing tidal conditions. In many cases the movement is not as clearly or immediately related to spawning as is usually the case on floodplains.

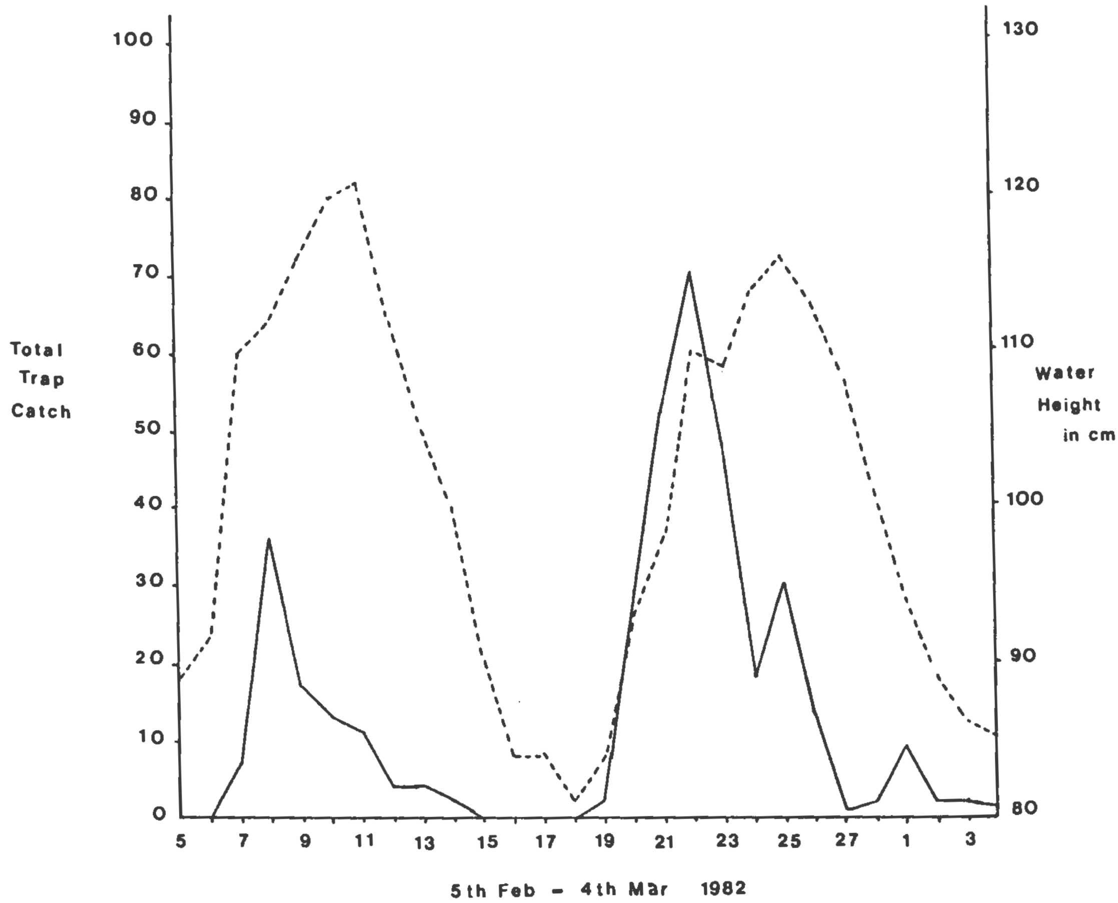
In order to investigate the relationship between catches and water height in the Kosi system more closely, these were examined over fourteen day water height cycles. There could be a close and direct relationship between catches and water height throughout the range of water heights or possibly a threshold which must be reached before movement takes place.

Data for P. commersonni were examined over the first fourteen day cycle for which sufficient data were available and adequate numbers of fish were caught. This period, 29 th April 1981 to 12 th May 1981, was used to indicate the relationship between catches of P. commersonni and water height. The results showed a clear direct correlation between catches and water height throughout the tidal cycle. The correlation coefficient of these sets of data is 0,87 and the rank correlation coefficient, 0,86.

The remainder of the ten most important species were tested in the same manner over the first fourteen day period of good catches and the results are given in Table 29. As can be seen from this table, all species tested show a significant correlation between water height and catch numbers over the fourteen day tidal cycle. If these results are compared with those of Table 28 some interesting comparisons may be made.

R. sarba shows the least significant result of the species tested. Table 28 indicates that this species favours rising over falling water and this can be seen clearly in Figure 31 where the peak of R. sarba catches occurs before the peak in water height. These results suggest that R. sarba awaits migration in the lakes and movement to the ocean is stimulated by the first inflow of water. The majority of the predisposed fish then migrate when the water is rising. After most of these fish have left the lakes there are few left ready to run even though the water may go on rising or remain high.

L. macrolepis also shows the same result in Table 28 and although more fish are caught on a rising water, the same trend in catches is still obvious during the falling phase. If the fourteen day period around the highest water is split in two and the first and second seven day periods are ranked in the same way as for Table 29, rank correlation



where ——— = trap catch and ------- = water height

Figure 31. Graph representing daily total trap catches of R. sarba and water height at Ott apparatus during the period 5th February - 4th March 1982 showing the trap catches peaking before the highest water level is reached.

coefficients of 0,71 and 0,88 are obtained for the two periods respectively. This indicates that there is a direct relationship between catch numbers of this species and water height throughout the cycle, although more fish tend to migrate during rising water.

L. alata shows a strong preference for falling water. This implies that they favour migrating to the ocean when swimming with the outgoing current. Once again if the period tested is split into the rising and falling phases and ranked, correlation between catches and water heights may be assessed. L. alata shows a rank correlation of 0,64 over the rising phase of water and one of 0,98 over the falling phase. Without doubt there is a relationship between this species and water height but this is expressed more strongly in the falling water phase. Figure 30 on page 143 shows this reaction of L. alata.

Table 29. Rank correlation coefficients (r) and levels of significance of catches for ten fish species and water heights during fourteen day water height cycles.

Species	Period tested	r	r^2 x 100	P
1. P. commersonni	29/4 - 12/5/81	0,86	74	0,001
2. M. cephalus	13/5 - 26/5/81	0,77	59	0,001
3. A. berda	4/4 - 17/4/82	0,85	72	0,001
4. V. buchanani	14/1 - 27/1/84	0,84	71	0,001
5. L. macrolepis	10/8 - 23/8/81	0,72	52	0,01
6. R. sarba	19/2 - 4/3/82	0,58	34	0,02
7. G. rappi	19/1 - 13/2/82	0,81	66	0,001
8. Caranx spp.	9/2 - 22/3/84	0,84	71	0,001
9. L. argentimaculatus	29/3 - 12/4/82	0,77	59	0,001
10. L. alata	27/3 - 9/4/83	0,66	44	0,01

where r = rank correlation coefficient
P = level of significance

It has been shown (Zar, 1974) that the value, r^2 x 100, gives an estimate for the percentage variation in one parameter accounted for by the relationship with the other. These values have been included in Table 29 and indicate that for all species examined this relationship accounts for a large amount of the variation during the period tested.

The strong correlation between P. commersonni catches and water heights make it possible to calculate regression coefficients for this species. The correlation is fairly constant from year to year, but the regression coefficients will vary, depending on the number of fish running that year. Correlation measures the intensity of the relationship while regression quantifies this (Simpson et. al., 1960). This means that there is always a close relationship between the catches and water height, but the quantitative relationship changes with the numbers of fish making the migration each annual cycle.

To some extent, for a period within one annual cycle, it is possible to predict overall catches of P. commersonni in the traps once that year's pattern and regression coefficients have been established. For the future this is an academic point, as it is not possible to establish this without monitoring many catches. Also, there are always a limited number of fish which will run and once they are out of the system the relationship and regression coefficients become meaningless. This happened in 1984 and 1985 when very heavy precipitation occurred before the end of the normal peak catches and it can be seen in Figure 28. The extremely high water levels resulted in very large numbers of fish leaving the system and after that period few fish were left to migrate, even if the water level had risen again. The level of water influences fish movement only if there are fish predisposed to migrate.

Over short periods there is a direct quantifiable relationship between catch numbers and water height. Figure 32 shows this relationship and a regression line has been included. This equation describes rough catch figures when water heights are

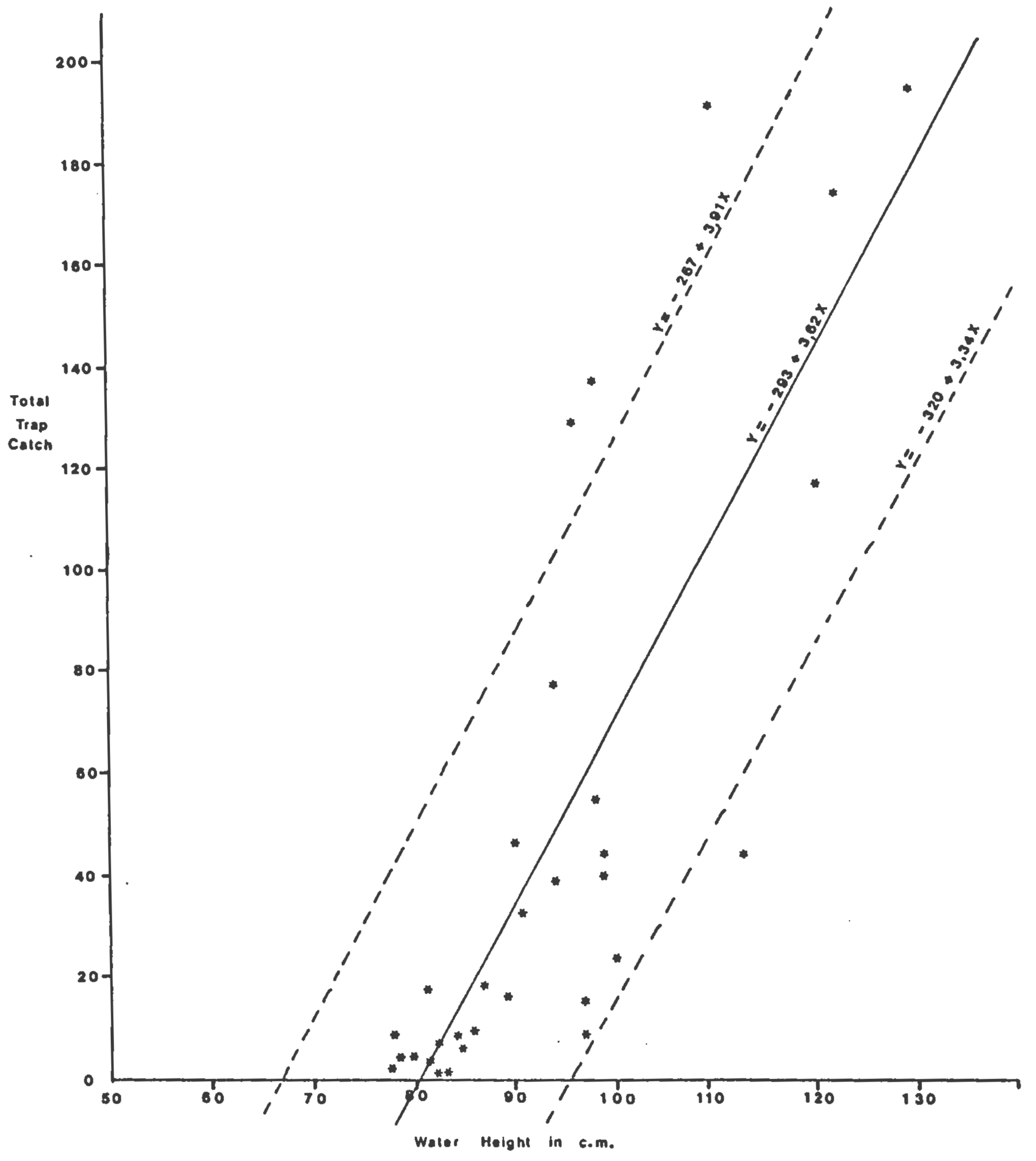


Figure 32. Total trap catch of P. commersonni plotted against water height at the Ott apparatus at S'fungo during the period 1 - 31 st March 1982. A regression line of Y = -293 + 3,62X was calculated and has been included as have the 95% confidence limits of this line. For these data an r^2 value of 0,66 was calculated and t = 7,49.

known. Unfortunately no two spring tides are comparable and numbers and proportions of P. commersonni ready to run vary with the season. Together this means that although there is a close relationship between catch numbers and water height, the quantitative nature of the relationship is constantly changing.

Muncy (in Welcomme, 1978) found a positive correlation between high water levels and fish catches two years later in a floodplain situation. This was due, however, to breeding success and not to immediate movement related to an increase in water height.

5.5 Discussions with local people about the influences of weather on catches.

The local people have been using similar fish traps for many years. Their knowledge of fish habits and movements is based on personal observation and the stories and folk lore of generations. In discussions with several trap owners about the trends in trap catches and influences of the weather several interesting points were made clear.

A relationship between water height and fish catches was well known. The seasonal trends in catches of each abundant species was also common knowledge and traps were often renovated shortly before expected runs of fish. The local people know that fewer L. alata will be caught in full moon spring tides than during new moon periods.

The predictive ability of the local people is highlighted by the fact that before good catches are made considerable numbers of women often come from KwaNgwanase, 18 kilometres distant, and congregate to buy fish following certain weather conditions. These women are rarely wrong. The various tests used in this chapter serve to confirm, further and in some cases quantify what the local people have suspected for generations.

5.6 General discussion and summary.

It is clear from the evidence in this chapter that the major movements of the most abundant fish species in the Kosi system follow annual patterns. These cycles, although related to parameters such as water temperature, are probably intrinsically or instinctively controlled. On an annual basis the cycles may be modified to some extent by slight changes in these parameters but certain features of the movements will be repeated each year. Fish will only migrate according to this cycle and so conditions which would initiate movement during this "normal" time for movement need not do so at other times. G. rappi, for example, which showed a highly significant correlation between catches and water height in Table 29 would not show such a result outside its period of trap catch abundance.

It is possible to predict at what times of the year certain species will be migrating in large numbers. It has also been shown that during these periods movement is related principally to water height, although this may be modified by other parameters. The daily influences are likely to be a simple stimulus-response relationship as the reactions to the changes in the physical surroundings are rapid and probably do not involve complicated physiological processes within the fish. The optimal physical conditions within the period of catch abundance will normally result in the best catches.

Catch abundance patterns are annually cyclic and the most important influence, water height, is also cyclic. These cycles together control fish movement, but they may be modified, depending on the species involved, by certain other parameters. The cycles control the proportions of fish moving, but the numbers, as was discussed in Chapter 4, are probably dependent on recruitment to the system.

6. THE FISH TAGGING PROGRAMME

6.1 Introduction

In order to establish the percentage off-take by the traps and to obtain an estimate of the size of the fish populations, an extensive fish tagging programme was undertaken (Ricker, 1958). Mature fish were tagged, since all the larger marine species spawn in the ocean (Wallace, 1975b) and had to pass through the areas of the traps before spawning each season. Tagged fish recovered and expressed as a proportion of the total trap catch would, if they had been randomly distributed in population, permit the estimation of the population size for any given species.

6.2 Materials and methods

At the beginning of the project fish were tagged whenever the opportunity arose. The fish were tagged immediately below the posterior dorsal fin in front of the peduncle. Three centimetre long Floy F.D. 67 spaghetti tags were used. The fish were caught by rod and line, seine nets and fish traps, then tagged and returned to the system (see Appendix 10). Numbers of fish tagged and recovery rates are given in Table 30. These served, initially, to evaluate the efficacy of the tagging programme.

Care was taken that the tag gun and the tags were clean. No antiseptic was used as this would quickly have been flushed out once the fish had been released. Many *Acanthopagrus berda* caught had scars which indicated that they had recovered from considerable open wounds.

Table 30. Recovery in first tagging programme.

Species	No. Tagged	Fish trap recoveries in one year No.	%
P. commersonni	88	4	4,5
A. berda	172	9	5,2
G. rappi	126	3	2,4
R. sarba	191	11	5,8
L. macrolepis	142	14	9,9
TOTAL -	719	MEAN -	5,6

It was later decided that an intensive focal fish tagging programme should be undertaken to give a better value for the percentage off-take of the fish traps. Logistical considerations dictated that a large enough sample of only one species could be tagged and thus the most suitable should be chosen. Such a species should conform to the following requirements :

a) it should be caught in sufficient numbers in the fish traps,
b) have a tough skin for tag retention,
c) be rugged enough to survive capture and tagging stress and injury,
d) be caught in sufficient numbers to provide meaningful tag recoveries, and
e) most of the life cycle should be undergone inside the Kosi system with a well defined annual spawning run to the ocean.

From catch statistics of the species in the system *Acanthopagrus berda* appeared the most suitable. Not only did it satisfy the above conditions, it also showed a remarkable consistency in the trap catch statistics and was known to have an estuarine dependent life cycle (van der Elst, 1981).

A. berda is an important estuarine angling species which has been little studied (Blaber, pers. comm.). A general decline in fishermens' catch statistics in Natal in recent years was reported by Begg (1978). Grindley and Heydorn (1979), in discussing mans' impact on the estuarine environment, commented on the decline in certain species, and singled out A. berda as having been particularly affected. Focussing on this species could, therefore, also yield further information of value to the management of stocks of this species per se. Apart from the tagging programme giving percentage off-takes by fishermen and an estimate of the fish populations, it could also indicate whether the A. berda population of the Kosi system was distinct from populations in other Natal estuaries.

The aim was to tag 500 mature A. berda in the southern reaches of the system before they moved through the fish trap area to the ocean to spawn. Wallace (1975b) found that all A. berda at St. Lucia in the size class 200 - 220 millimetres (T.L.) were mature, consequently only specimens over 200 mm (T.L.) were tagged.

The greatest disadvantage in using A. berda was the difficulty in capturing a sufficiently large number to tag. It is called the Sly Bream (Blaber, 1978) and described as a wary species (Smith, 1977) but apart from the difficulty in capture it is well suited to a tagging scheme such as this. Other species such as P. commersonni and G. rappi could have been obtained in large numbers, but these did not fulfil the conditions mentioned earlier. The larger the number of fish tagged the more accurate would be the estimates. The fish had, however, to be captured before an annual migration to the ocean. Every effort was made to capture as many A. berda as possible within the time available with a minimum target figure of 500. In spite of a sustained capture effort, this minimum was only achieved shortly before the annual peak in trap catches. The number of A. berda tagged equalled 23% of the total caught in the traps in that year.

Ricker (1958) gives details of the computations, limitations and problems involved in his "direct census" and these are followed here. He concludes that the method is accurate only if the following requirements are met :

1. the marked fish must suffer the same mortality as the unmarked fish,
2. the fish marked are as vulnerable to the fishing being carried on as are the unmarked ones,
3. the marked fish do not lose their mark,
4. the marked fish become randomly mixed with the unmarked,
5. all marks are recognised and reported on recovery, and
6. there is only negligible recruitment to the catchable population during the time the recoveries are being made.

1. Mortality

The first condition includes mortality from the capture and tagging, as well as possible extra predation pressure due to the tag making the fish more obvious to predators. One of the main reasons for choosing A. berda was because it is a remarkably rugged and hardy species. If any tagged fish appeared to be suffering from capture or tagging it was placed in a holding pen overnight for observation. If it was found to have recovered by morning it was released, if not it was killed and examined.

Increased mortality due to the tag was possibly important. Capture by rod and line and fish traps should not be influenced by tagging although that by spear could be. Only one tagged A. berda was caught in this way and this reflects approximately the proportion normally caught by this means.

Capture by natural predators could well be influenced by the presence of a brightly coloured plastic tag on an otherwise well camouflaged fish. It was found from recovered fish, however, that the tags themselves soon became coated by a filamentous green alga. Within two weeks the initial colour of the tags was virtually obscured by this alga, thus any increased predation resulting from tag presence would be limited to a short period after tagging.

Natural predators on mature A. berda were limited to fish eagles (Haliaeetus vocifer) and some of the larger piscivorous fish. Whitfield (1977) found that approximately five percent of the prey items of fish eagles were A. berda. It is, however, unlikely that the presence of a tag would attract a fish eagle, as the bird is probably attracted from distances of over 40 metres by the shape of the fish or ripples caused by its movement. Predation by other fish could be increased by the presence of a tag. Many piscivorous fish are visual predators (van der Elst, 1979) and the tag could serve to attract attention to the prey. The tagging, however, was done over a period and involved small numbers of fish at a time. This resulted in only very small numbers of tagged fish being seen by specific predators. Thus predator habituation would not have been likely. In individual cases, however, it is possible that an otherwise unseen A. berda could have been spotted by a predator because of the tag attracting attention. A. berda is usually found among submerged macrophytes or underwater objects, and at the slightest sign of danger it usually seeks good cover. The dorsal and anal fin spines are strong and sharp and these may also serve as a deterrent to predators.

Fish predation on mature A. berda is probably limited. Blaber (1982) found no evidence of A. berda in the stomach contents of 102 Sphyraena barracuda in the Kosi system, although there was some unidentified material. In further studies on the Carangidae in Kosi and other Natal estuaries, Blaber and Cyrus (1983) found no evidence of predation on A. berda. Of 245 prey species identified from stomachs of piscivorous fish for this study, only one A. berda was recovered from a Sphyraena spp..

In their study on the Gerreidae, Cyrus and Blaber (1984a) found evidence of very low predation rates by piscivorous fish on this genus and ascribed this to their forming " loose associations " rather than compact shoals. Major (1978) reported that fish predators have a higher success rate capturing fish from closely packed shoals. A. berda, like the Gerreidae, forms very loose associations and evidence from snorkelling and hand netting (pers. obs.) is that they scatter for cover in all directions when danger threatens. This behaviour would serve to confuse most predators and renders them extremely difficult to catch with small nets.

2. Fishing vulnerability

Tagged *A. berda* should behave in the same way as untagged *A. berda*. All recoveries of tagged fish were made closer to the ocean than to the site at which the fish were tagged and released. Towards the end of the tagging scheme *A. berda* caught north of Mankawulani were tagged and released in Mankawulani. This translocation was to ensure that all tagged fish were released upstream of the traps and so had to pass through the traps in order to reach the ocean to spawn. Several male fish, translocated and tagged, were already extruding milt, and all recoveries of these fish were made near the mouth of the system still extruding milt. It appears that *A. berda* has an extremely strong spawning drive and even the trauma of capture does not deflect this.

One *A. berda*, tagged after capture by rod and line from a jetty in Nhlange, was recaptured eighteen months later at the same site using the same method of capture. When examined the fish was in a spent condition and thus had spawned since being tagged. Since it appears that the tagging itself does not affect this migrating and spawning drive, the same proportion of tagged and untagged fish should enter the fish traps. There is also no evidence that tagging changes the feeding behaviour of the fish or their habits. One fish caught by rod and line and then tagged was recaught the following day by the same method. This then would mean that there should be no increase or decrease in the likelihood of a tagged fish being caught on rod and line, fish traps or spear. Condition 2 would appear to have been satisfied.

3. Tag loss

Tag loss is one of the most serious problems in most tagging programmes. There are two ways to minimise and quantify this condition, as some tag loss will almost certainly occur. Tag loss can be minimised by choosing the species and tag types carefully and can be quantified by running a control experiment. A. berda has a remarkably tough skin and in recaptured specimens it proved extremely difficult to pull the tag out. The tag occasionally broke before it was able to be pulled out. The tags used were small and offered little resistance to water and weeds.

Another tag site considered was the operculum, as used by van der Elst (in prep.). Tagging in the operculum was carried out in a few cases in the earlier tagging programme. In one recaptured Mugil cephalus, however, the tag was working its way out to the rear edge of the operculum and had it continued to do so it would soon have fallen out. This site could also interfere with breathing movements and possibly damage the opercular apparatus. Chilvers and Gee (1969), working on Tilapia spp. with F.D. 67 tags in various tag sites, found that the best tag site was the one used in this programme.

Blaber (1973) used the same type of tag on juvenile Rhabdosargus holubi and results from his control experiment showed that over a period of nine months tag loss was minimal. A control experiment to investigate tag loss rates was attempted but it was found to be very difficult to keep A. berda alive in an enclosure for any length of time. However, in the field, tagged fish from earlier programmes were still being recovered well after a year had passed. Three of the longest periods between tagging and recovery are recorded in Table 31. These recoveries indicate that tag loss during the period of this study should have been low.

High tag loss rates have been recorded in control experiments with F.D. 67 tags, but on other species using other tag sites (van der Elst, in prep.). Due to A. berda having a tough skin and the different tag site having been used, the loss rate should have been low over the recapture period, although it is impossible to accurately estimate. Tag sites on recovered fish were examined and none appeared to be enlarging or badly infected.

Table 31. The longest periods between tagging and recovery during this study.

Species	Date tagged	Recovery date	Period of freedom
A. berda	26/04/82	05/12/83	588 days
G. rappi	11/06/82	03/09/84	814 days
G. rappi	05/10/82	14/11/84	770 days

Since the fish were being tagged before the spawning run and recoveries were to be made during that run, the actual period of recapture was limited. The first few fish were tagged in November 1984 and the end of the possible recovery period was the end of August 1985. The longest period that a tag would have to stay in a fish was thus ten months. The median fish was tagged on the 25/01/85 giving a period of seven months and five days. Trap catches indicated that the major run of A. berda was over by the end of June, thus again considerably reducing the mean figure. The mean period between tagging and recovery in practice was 45,8 days.

4. Random distribution of marked fish

Mixing of marked and unmarked fish must have been nearly complete as most A. berda were tagged before they moved through the area of the traps. A. berda is not generally a shoaling species, although it does often move in loose groups of a few individuals. Members of the species caught in the traps are usually caught individually, except during well defined runs, when small numbers are caught together (Zwane, pers. comm.). Some tagged fish were caught with numbers of untagged fish, but no two tagged fish were recovered in the same catch.

During seine netting in December 1984, while attempting to catch A. berda for tagging, large numbers of Gerres rappi were caught. At that time it appeared doubtful whether sufficient <u>A. berda</u> could be caught and it was decided to tag <u>G. rappi</u> as well. In two hauls with a 125 metre seine net, 250 <u>G. rappi</u> were caught, tagged and released in the same way as the <u>A. berda</u>. By the end of the spawning period for <u>G. rappi</u> no recoveries had been made in the fish traps. The probable reason was that <u>G. rappi</u> forms large, dense shoals in the Kosi lakes in December prior to their spawning run. These shoals then migrate to the ocean as units. By tagging fish at this time, only one or two shoals were marked and not 250 individuals. There was thus no random mixing of marked and unmarked fish. The result of tagging from one or two shoals would be either an exceptionally high recovery rate if a marked shoal entered the traps or no recoveries if they avoided the traps.

Seine netting was later carried out in the same place where the <u>G. rappi</u> were caught for tagging. Considerable numbers of tagged <u>G. rappi</u> were recaptured up to five weeks after tagging, showing that the tagged fish did not all die or lose their tags and that the marked shoal remained in the same place for some time. It also appears that the shoals of <u>G. rappi</u> avoided the traps and this serves to emphasize the importance of the random mixing of marked and unmarked fish.

5. <u>Detection of marked fish</u>

Since virtually all the fish caught in the traps were examined by enumerators connected with the project, no tagged fish should have escaped detection. A small financial reward was given to the trap owner whose trap caught the fish as well as a bonus to the enumerator who reported the fish. At various demonstrations of tagging, at which the local Chief and sub-Chief were present, it was explained that it was as if a money voucher was being attached to the fish and that people were to catch the fish to recover the money. No evidence of tags not being returned was obtained.

6. <u>Recruitment to the population</u>

There should not have been recruitment into the catchable population. Since the catchable population comprised mature fish during the pre-spawning period of one season, and recruitment is annual, the catchable population should have had no recruitment during the period between tagging and recovery.

Towards the end of the programme A. berda in a spent condition would have re-entered the system and could have been caught in the traps. One tagged A. berda in a spent condition was recaptured in the traps towards the end of August but was not included in the calculations as only pre-spawning fish could validly be used in the estimates. All recovered fish were checked for gonad condition to avoid this problem.

6.3 Results

Table 32 summarises the results of the tagging of 500 A. berda. From these it is possible to obtain an estimate of the accuracy of the off-take figures and for the population of A. berda in the Kosi system.

Table 32. Results from the tagging of five hundred A. berda.

No. tagged	No. recovered in traps	No. recovered rod & line	No. recovered spear	Mean days free
500	23	4	1	45,8
Recovery rate (%)	4,6	0,8	0,2	

According to Ricker (1958) if the sample size is large, a measure of sampling variability may be obtained by the following equation :

$$VR = C \frac{R}{C} \left(1 - \frac{R}{C} \right)$$

where VR = variance of recaptures
C = catch (sample)
R = number of recaptures

Substituting the figures obtained the following result is produced :

$$VR = 2\ 168 \times \frac{23}{2\ 168} \left(1 - \frac{23}{2\ 168} \right)$$

$$= 22,76$$

The standard error is the square root of this and thus the standard error of the recoveries is 4,77.

This, in turn, allows confidence limits of the recoveries by the fish traps to be calculated using Student's t values with 22 degrees of freedom.

95% confidence limits for recoveries $= 23 \mp (2,07 \times 4,77)$
$= 13,10$ and $32,89$

99% confidence limits for recoveries $= 23 \mp (2,82 \times 4,77)$
$= 9,55$ and $36,45$

Conversion of these recovery figures into percentage off-takes gives the following results :

95% confidence limits = 2,62 and 6,58
99% confidence limits = 1,91 and 7,29

Estimate of the population of *A. berda*

The general formula for estimating population is :

$$\hat{N} = \frac{M\ C}{R}$$

where $\hat{N}$ = estimate of population
M = number marked
C = total catch
R = recoveries

Ricker (1958) suggests that the above formula tends to over-estimate the population and recommends using Bailey's (1951) formula :

$$\hat{N} = \frac{M (C + 1)}{R + 1}$$

This gives as an estimate of the population :

$$\hat{N} = \frac{500 (2\ 168 + 1)}{23 + 1}$$

$$= 45\ 187{,}5$$

Confidence limits of estimates of population may be obtained by substitution of the appropriate values of R in the above formula.

95% confidence limits of population of A. berda

$$\hat{N} = \frac{500 (2\ 168 + 1)}{32{,}89 + 1} \quad \text{and} \quad \frac{500 (2\ 168 + 1)}{13{,}10 + 1}$$

$$= 32\ 000 \qquad 76\ 915$$

99% confidence limits of population of A. berda

$$\hat{N} = \frac{500 (2\ 168 + 1)}{36{,}45 + 1} \quad \text{and} \quad \frac{500 (2\ 168 + 1)}{9{,}55 + 1}$$

$$= 28\ 959 \qquad 102\ 796$$

Sport angling catch statistics

Sport fishermen also catch considerable numbers of A. berda and it is possible to use tag recoveries from these catches to estimate off-takes and populations of A. berda. Estimates can be made (a and b) from both the earlier and the intensive A. berda tagging programmes and the results compared.

The only estimate of the total sport angling catch of A. berda is that obtained from the questionnaires completed by the anglers extrapolated to total catch. Sport angling pressure over the period, as reflected by campsite bookings, was fairly stable, and fish trap catches indicated that the population of A. berda was very stable during the study period. This being the case, the total sport angling catch of A. berda should similarly be stable. Table 33 summarises the results of sport angling recoveries in the tagging programmes and estimates of anglers' off-takes. Confidence limits were not possible because of the small number of recoveries.

Table 33. Recoveries of tagged A. berda by sport fishermen.

Programme	No. tagged	No. recovered (R)	Total catch (C)	Estimated % off-take
1st tagging	172	1	447	0,58
2nd tagging	500	3	447	0,60

Estimates for the population of A. berda in the Kosi system may be calculated from the angling recoveries using the same formula as was used for the trap recoveries. The earlier tagging scheme gives 38 528 as an estimate of the population while the most recent one gives 56 000. The mean of these figures is 47 264 and this corresponds closely to the estimate of 45 188 obtained from the intensive tagging recoveries from the fish traps. If both tagging schemes are combined 60 211 is calculated as an estimate of the population of A. berda in the Kosi system. Although not conclusive these calculations produce estimates of the same order of magnitude and suggest that the tagging programmes are producing fair estimates of off-take and population size.

An estimate of the sport angling off-take (c) could be obtained by taking the extrapolated total tourist catch of A. berda and using this together with the 99% confidence limits of the estimates for the population, to give an estimate of the 99% confidence range for catch, a sample of the total population which would equal the anglers' catch :

$$= \frac{447}{102\ 796} \quad \text{and} \quad \frac{447}{28\ 959}$$

$$= 0,43 \qquad\qquad 1,54$$

The estimates for anglers' off-takes from tag returns (Table 33) fall within this range. This second estimate is independent of the first except in that the same value of the total sport angling catch was used in the calculation of the variance of the recovery rate.

A final estimate (d) for sport angling off-take may be made by comparing the total catch of the tourists with that of the traps. This proportion, multiplied by the trap off-take, gives the following :

$$\frac{\text{Total sport angling catch}}{\text{Total trap catch}} \times \begin{array}{c}\text{99\% confidence limits}\\ \text{of \% trap off-take}\end{array}$$

$$= \frac{447}{2\ 168} \times 1,91 \quad \text{and} \quad \frac{447}{2\ 168} \times 7,29$$

$$= 0,39 \qquad\qquad 1,50$$

Table 34 summarises the estimates of sport angling off-takes. It can be seen that the estimate from the earlier tagging programme is very similar to that of the more intensive one and both fall within the 99% confidence limits derived from the other techniques of estimation.

Table 34. Comparison of estimates of sport angling off-takes by different methods.

Method	Estimate of sport angling off-takes
1st tagging (a)	0,58 %
2nd tagging (b)	0,60 %
(c)	0,43 - 1,54 (99% C.I.)
(d)	0,39 - 1,50 (99% C.I.)

(methods as described in text)

This suggests that even the earlier tagging scheme with a smaller number of fish tagged, gave a good estimate of the percentage off-take. The same statistics applied to the earlier tagging scheme give the following results for A. berda :

$$VR = C \frac{R}{C} \left(1 - \frac{R}{C} \right)$$

$$= 2\ 902 \times \frac{9}{2\ 902} \left(1 - \frac{9}{2\ 902} \right)$$

$$= 8,97$$

95% confidence limits for number of recoveries :

$$9 \mp (2,31 \times 2,99)$$

$$= 2,11 \quad \text{and} \quad 15,90$$

95% confidence limits of off-take calculated from these values are 1,83% and 8,64%. This confidence interval is wider because of the smaller number of fish tagged. Since it appears that the smaller number of tagged fish still give a fairly good estimate of the off-take, the same calculations could be made for other species. Table 35 summarises the results from the earlier tagging programme. These results show the confidence limits of the statistical error inherent in the figures used. The limits and figures given are thus for the ideal situation when the six conditions mentioned earlier are met.

Table 35. Summary of percentage off-takes and confidence limits for earlier tagging programmes.

Species	T	R	S.E.	% off-take	95% C.I.
P. commersonni	88	4	2,00	4,54	0,09 - 9,00
A. berda	172	9	2,99	5,23	1,83 - 8,64
R. sarba	191	11	3,30	5,80	2,37 - 9,15
G. rappi	126	3	1,73	2,38	0,00 - 5,07

where - T = tagged ; R = recovered ;
S.E. = standard error (recoveries) ;
C.I. = confidence intervals.

6.4 Discussion

The principal motivation for the tagging programme was to establish estimates for the percentage off-takes by the fish traps. Clearly it was not possible to tag sufficient of all the species concerned and one representative species apparently conforming to the requirements for such an estimate was chosen. The tagging of 500 of these and the efficient recovery system gave an acceptable estimate of the off-take by the traps for A. berda during the year of tagging. The fish trap effort as shown by the numbers of baskets operating yearly (see Appendices 2 and 4) was fairly constant and so the indications are that the off-takes annually should be similar. The earlier tagging scheme, although not as intense, does give similar recovery rates and in the absence of other estimates is useful in indicating the probable off-takes for some other species. The similar recovery rates for A. berda in the two schemes suggest that both may be fair estimates of the percentage off-takes of the traps.

6.5 Conclusions

The accuracy of the results from the tagging of five hundred A. berda should be the highest and therefore should give a good estimate of the population of adult A. berda in the system. The indications are that the off-take calculated for the other species is also fairly accurate, but extrapolations to population size perforce become less accurate when small samples of fish of larger populations are tagged.

The best estimate of the percentage off-take by the fish traps is therefore under 12,0% for all species investigated. Even if these estimates were to be doubled in order to make allowances for a possible high tag loss rate, then in most cases they would still be well under 20,0%.

Four estimates are given for sport angling off-take of A. berda. All are under 2,0% and those for local spear and rod and line fishermen calculated in the same way, were well under 1,0% of the population. It appears that the total off-take of adult <u>A. berda</u> by man from the system is under 10,0%.

Results also indicate that, of the other species for which figures are available, the off-take by man does not exceed 12,0% of the mature stock migrating to the spawning grounds each year. This figure will be discussed in Chapter 7.

7. AN OVERVIEW OF THE KOSI SYSTEM

7.1 Introduction

In the preceeding chapters aspects of the Kosi Bay fisheries were reported upon and discussed. This final chapter is an attempt to collate these data in order to obtain an understanding of the basic functioning of the Kosi Bay ecosystem. Fish exploitation levels will be discussed in the context of their dependence on various food resources, in the light of the recently changing salinity regime and other factors possibly affecting them. In this way statments may be made on the fish resources of the Kosi Bay system, their current exploitation and possible future trends.

7.2 Levels of resource competition and separation in fish utilisation

7.2.1 Human exploitation

Table 36 shows the most important species components of the fish off-takes by man. There is clearly considerable separation in the target species of many of the fishing methods. Figure 33 shows the relative importance to each off-take of various species groupings which are defined as follows :-

1) Muglidae and Chanos chanos. Iliophagous marine species.
2) Rhabdosargus auriventris, R. holubi, Terapon jarbua and Gerres acinaces. Small marine species.
3) Gerres rappi. An estuarine dependent species.
4) Oreochromis mossambicus and Clarias gariepinus. Freshwater species.
5) P. commersonni, R. sarba, A. berda, Caranx species, Sphyraena species, Elops machnata and L. argentimaculatus. Marine and estuarine dependent species. Only this group is of importance to man in the region outside the Kosi system.

The most obvious point to emerge is the separation of approximately 90% of the fish caught by children fishing from that of any other group. Another important separation is clear

Table 36. Most important species by percentage mass of the major human fish exploitation methods at Kosi.

Rank	Fish traps Species	%	Gill nets Species	%	Tourist R & L Species	%	Local R & L Species	%	Spearing Species	%
1.	*P. c.*	32,66	*G. r.*	40,33	*P. c.*	50,90	*R. spp.*	38,90	*G. r.*	32,30
2.	*M. c.*	24,63	*P. c.*	13,03	*R. s.*	29,70	*G. a.*	34,70	*O. m.*	29,39
3.	*L. m.*	10,67	*M. c.*	12,63	*A. b.*	6,70	*T. j.*	17,10	*L. m.*	25,35
4.	*G. r.*	9,14	*O. m.*	7,13	*C.* spp.	2,80	*A. b.*	3,00	*M. c.*	4,04
5.	*A. b.*	6,59	*R. s.*	5,70	*S.* spp.	1,90	*G. r.*	1,40	*P. c.*	2,78
6.	*R. s.*	4,69	*C. c.*	4,48			*O. m.*	1,10	*A. b.*	2,22

where : *P. c.* - *P. commersonni* ; *M. c.* - *M. cephalus* ; *L. m.* - *L. macrolepis*
A. b. - *A. berda* ; *O. m.* - *O. mossambicus* ; *R. s.* - *R. sarba*
C. spp. - *Caranx* species ; *S.* spp. - *Sphyraena* species ; *R.* spp. - *Rhabdosargus* species
G. a. - *G. acinaces* ; *T. j.* - *T. jarbua* ; *G. r.* - *G. rappi*
C. c. - *C. chanos*

in spear fishing catches, where fish groups 3 and 4 constitute 62% of this catch, while the only other noteworthy legal utilisation of these groups is in 9% of the fish trap catches. Group 1 fish are important to both spear fishermen and trap operators, but in fact both methods often benefit the same families. The major apparent competition for a resource is between the fish traps and the sport anglers. Both groups rely heavily on Group 5 fish species. Three factors play important roles here.

a) Spatial separation

Most fish traps are in the region to the north of Mpungwini and as tourist boat fishing is restricted to the lakes the main overlap occurs in Mankawulani.

b) Temporal separation

As has been discussed, the traps principally catch fish leaving the system. This means that sport anglers have an opportunity to attempt to catch fish before they begin to migrate through the area of the fish traps.

c) Relative off-takes

As indicated in Chapter 6 sport anglers caught less than 2% of the estimated standing stock of adults of the species tagged. This meant that the 44% of the trap catch affected by the sport anglers could only have been reduced by this percentage. The overall effect would be a reduction in trap catches of less than 1% by numbers. There was little reciprocal effect, as the level of trap off-take was not sufficient to adversely affect recruitment (Butterworth, pers. comm.). Considerable numbers of fish return to the system, but the results of this study suggest that only a small proportion of returning fish are caught in the traps.

The gill netting fishery was illegal and the results in Figure 33 show data from all areas combined. Clearly gill netting competes with spear fishing, fish traps and the sport fishery.

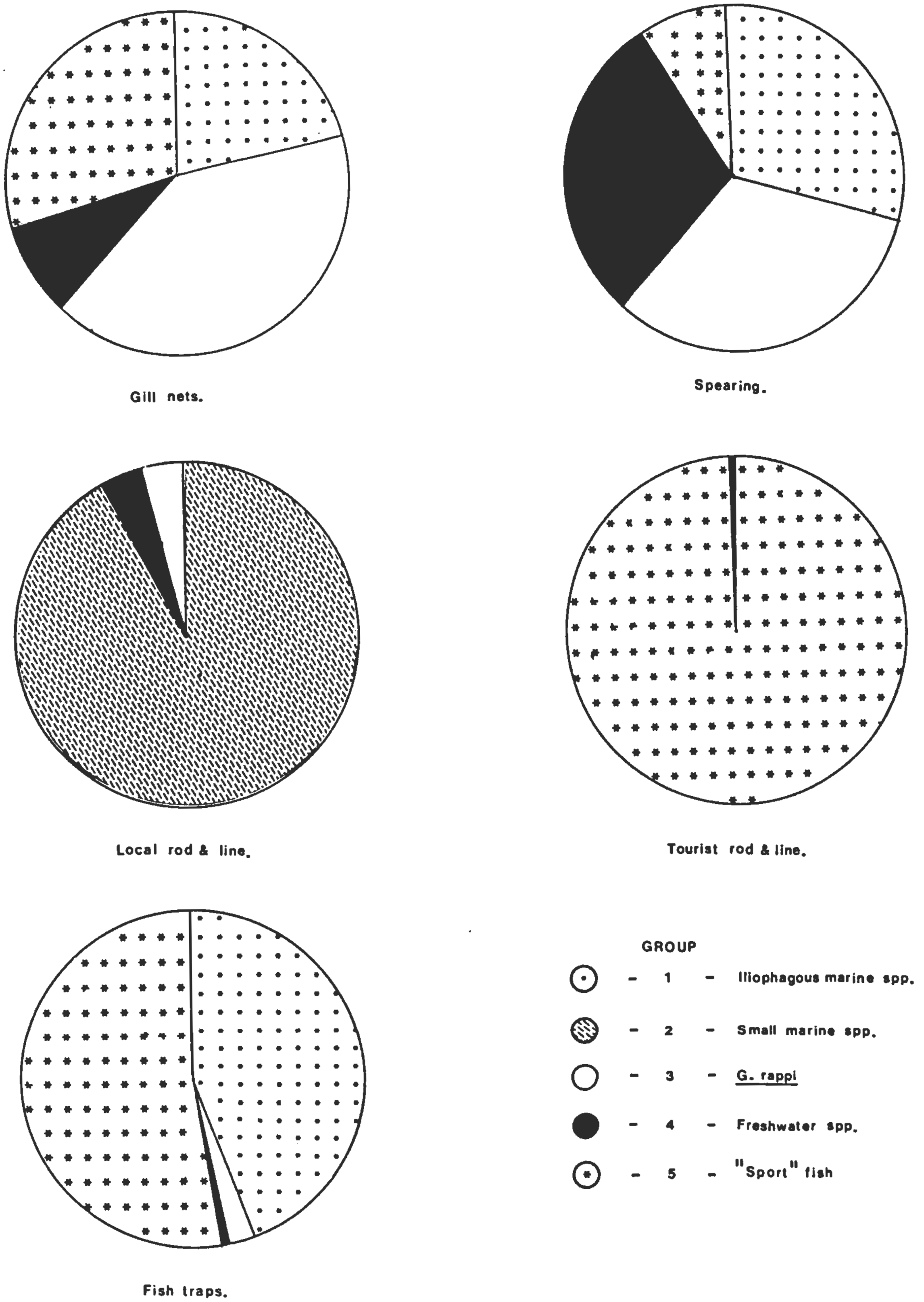


Figure 33. Pie charts showing the importance of different species groupings of fish to the various fisheries expressed in relative percentage by numbers.

It may be possible, however, to re-direct the gill netting effort. The most important increasing fish resource at Kosi is that of the freshwater species, O. mossambicus and Clarias gariepinus (Blaber & Cyrus, 1981). There are also indications that G. rappi is more abundant than the trap catches suggest (this study). The tag recovery rate of 2% in the first tagging scheme and 0% in the second, combined with the small size of the species and obvious abundance throughout Nhlange, suggest that there is potential for man to increase his off-take of G. rappi from the Kosi system without seriously reducing its abundance there. Table 37 shows the species composition of catches by gill netting in different areas. The nets used were seized poachers' nets of 8 - 10 centimetre stretch mesh.

Gill netting in the channels is a questionable practice ecologically, as it disrupts important fish movements, and it is in direct competition with the sport and fish trap fishery. As can be seen from Table 37, if the gill nets were used in the Phragmites beds in Nhlange the effort would be directed principally towards exploiting the least used fish resources. There would also be no interruption of major fish movements. It would therefore appear that gill netting, which by law could be allowed under licence, could be manipulated to minimize competition with other fishing methods and harmful ecological effects while exploiting a large, previously little used food resources. Problems would arise in the management of such a fishery to ensure that no netting occurred in Mthando and other channels. Crocodiles would also be a problem in that very large crocodiles are present in the south and as numbers are thought to be increasing (Kyle, 1985) any intensive gill netting in the reedy margins might result in crocodiles being caught. Large crocodiles would also endanger the gill netters.

7.2.2 Bird predation on fish

Data from this study indicate that the most important natural predation, excluding that by fish, is that of various avian piscivores. Blaber (1973) showed that the population of R. holubi in the Kleinmond estuary, was reduced by 80% by density dependent bird predation. For this reason it was thought

Table 37. Comparison of gill net catches in different areas at Kosi showing their catch compositions in terms of the species groupings described in this section.

Species groups (see pg.)	Channels in north	Nhlange - open water	Nhlange - Phragmites beds
i) Iliophagous marine fish	50,33	29,44	1,54
ii) Small marine fish	-	-	-
iii) *G. rappi*	15,64	48,70	45,38
iv) Freshwater fish	1,36	1,66	51,54
v) "Sport" fish	33,33	20,18	1,54
	n = 147	n = 540	n = 130

important to obtain information on the effects of bird predation on fish in the Kosi system. As can be seen in Table 14, P. carbo clearly takes the largest biomass of fish from the system, accounting for an estimated 46% of that off-take.

As part of this study a platform was erected at a regular roosting site in order to collect regurgitated P. carbo pellets. These were analysed (Jackson, 1984) and results showed that 78% of the energy intake consisted of Muglidae, while the only species of importance to sport anglers, R. sarba, constituted only 4%. In order to establish whether the numbers of P. carbo had changed since first records the literature was surveyed. The earliest quantitative data available were those of Broekhuysen and Taylor (1959) who counted during July 1959 only and obtained a figure of 20 birds. As can be seen in Table 12 in Chapter 3, the mean July count during this study was 40, and that of June was 18. These figures suggest that there has been little change in numbers and therefore off-take since the time of the earlier survey. No other comparable data were found. P. carbo takes large numbers of small fish in the shallows (Jackson, 1984) but sufficient of each species must survive to have kept fish population levels fairly constant.

Fish eagles, H. vocifer, accounting for approximately 7% (see Table 14) of the biomass of off-take, are the only avian predators capable of taking mature fish of the larger species and thus competing directly with man. Data from this study indicate that H. vocifer annually catches in the region of 803 kilograms of fish while the fish traps caught an annual mean during the study of 40 254 kilograms. If the trap catches represented 5% of all fish leaving the system, then H. vocifer would thus be capable of reducing trap catches by only $\frac{803}{40\ 254} \times 5\% = 0{,}1\%$. It was stated earlier that H. vocifer may also play an important role in removing dead and dying fish from the system. It appears that fish predation by H H. vocifer has a minimal effect on trap catches and may well have at least one beneficial effect. Palm-nut vultures (P. angulensis) were not observed preying on healthy fish but were regularly seen eating dead fish. Their diet is generally regarded as being based on vegetable matter and carrion

(Newman, 1983 ; Maclean, 1984), but observations during this study indicate that fish are important to the few birds hunting in the north.

No other avian piscivores are thought to influence human fish off-takes in the Kosi system. The small terns (Sternidae) feed almost exclusively on G. aestuarius (pers. obs.) which are in abundant supply. Jackson (1984) found that 72% of the energy intake of the pied kingfisher, Ceryle rudis, consisted of small estuarine species, principally Ambassis natalensis and G. aestuarius. Other avian piscivores, such as the various types of herons and egrets, feed only in the shallows (Maclean, 1984) and the most common fish there are O. mossambicus and Ambassis species. Both of these are abundant and of no direct importance to man at present. Many of the avian piscivores regularly take food items other than fish (Newman, 1983 ; Maclean, 1984) and as the estimates of off-take are related to daily total food requirements, the figures quoted in this study are over-estimates of the actual effects. According to estimates from this study current levels of off-take by avian piscivores at Kosi have a small effect on human fish exploitation and have not increased greatly since the first available records. A considerable and sustained increase in the numbers of P. carbo would be the only obvious cause for concern in this regard in the future. Whitfield (1977) gave an estimate of overall annual bird predation on fish at St. Lucia as 3,4 $gm/m^2/year$. Lake Mockeln, in Sweden, was estimated as having a rate of 0,8 $gm/m^2/year$ (Nilsson & Nilsson, 1976). If the annual bird predation on fish in the Kosi system is assumed to be 11 562 kilograms (data from Table 14) and the minimum surface area of Kosi is taken as 38,36 km^2 (Begg, 1978) then an estimate of 0,3 $gm/m^2/year$ is obtained. Bird predation rates on fish in the Kosi system appear low relative to available estimates from other systems.

There is little evidence of competition between the avian piscivores. P. carbo is restricted to the northern, clear, saline areas while P. africanus is more common in the more turbid, fresh southern areas (Cyrus & Blaber, 1984a). All the other important avian piscivores are discussed by Whitfield

(1977) who, working in St. Lucia, found considerable resource segregation due to spatial separation and differing catch techniques. Whitfield (1977) found that herons and egrets fished non-selectively but in different zones, and thus caught different sizes or species of fish. He also found that most of the diet of the smaller piscivores consisted of O. mossambicus or other small fish which complete their life cycles within the estuarine environment. A similar pattern is evident at Kosi.

7.2.3 Discussion on reported conflict situation between local fishermen and sport anglers.

It has been shown in Chapters 3 and 4 that the levels of off-take by natural predation plus that of the traditional fishing techniques have been such that recruitment to the system and fish abundance have not been greatly affected. Furthermore these off-takes do not interrupt the major movements of fish between the ocean and the lakes. Since this is the case, the concern expressed by sport anglers seems unfounded. Catch and tag returns from sport anglers show that this off-take can only have a marginal effect on the fish trap catches and the complaint of the trap owners also appears unsubstantiated.

The best estimates of the combined off-takes of the above techniques plus that of natural predation indicate that these are well below levels which would seriously diminish fish stocks or greatly reduce recruitment. It has been shown that the annual abundance of the fish species most important to trap owners and sport anglers in the Kosi system is dependent primarily on exogenous factors. This means that, in the main, the abundance of these species is independent of exploitation levels within the system. The close correlation between annual shore catches of P. commersonni along the Natal coast and those of the traps indicate that abundance along the Natal shoreline and estuaries fluctuates annually in a similar pattern throughout the area. If this apparent correlation is substantiated by further data then it would imply that not only are the catches of both groups independent of each other but that their relative success may be similar each year.

This study was initiated to investigate an apparent conflict situation. Results show that not only is there little conflict, but a potential to increase either or both off-takes.

As long as the immigration of recruits and spent fish and the emigration of mature fish can continue unimpeded the Kosi fishery may be manipulated by regulations to produce more food for the local people and more sport angling for visitors.

Gill netting is probably the most efficient way of increasing the amount of fish caught but this should not be carried out in the channels for the reasons already given.

7.3 Fish species fluctuations and the implications to the major fisheries.

As was shown by the trap catches, few fish species show stable numbers of adults from one year to the next. The main reasons for the changes are varied and Table 38 serves to group species according to these reasons and indicate the level of dependency of the fish traps and sport anglers on these fish types.

It is clear that the stable component of both fisheries is small. The largest proportion of both is based on species whose numbers can fluctuate markedly from one year to the next, irrespective of conditions inside the system. P. commersonni, the most important component in trap catches, increased in numbers by 78,5% from 1981 to 1982, while M. cephalus, the second most important overall, fell by 44,7%. The apparent negative correlation between these important species' trap catch statistics discussed in Chapter 4 was the main factor maintaining trap catch stability over the study period. If this correlation arose by chance, then the trap fishery is clearly susceptible to large fluctuations in catch. Walker (1984) found a similar pattern in Australian estuarine fishing, where total catches remained fairly stable, although species composition fluctuated markedly.

Sport anglers, unlike the fish trappers, can easily change target species. Most are prepared to catch game fish or

Table 38. The dependency of the fish trap and tourist fisheries at Kosi on species groupings indicated by the trap catches.

Description	Species	Fish trap (by mass)	Tourist fishing (by numbers)
a) Stable catches controlled primarily by endogenous factors.	3. *A. berda* 7. *G. rappi*	7,45%	6,67%
b) Declining catches caused principally by falling salinities.	5. *L. macrolepis* 6. *R. sarba* 16. *S. lysan*	6,35%	29,75%
c) Erratic catches controlled by exogenous factors.	1. *P. commersonni* 2. *M. cephalus* 4. *V. buchanani* 10. *L. alata*	76,60%	50,86%
d) Summer visitors dependent on exogenous and endogenous fz factors.	8. *Caranx* spp. 9. *L. argentimaculatus* 11. *C. chanos* 12. *Sphyraena* spp. 13. *E. machnata*	8,65%	12,01%
e) Unimportant species at present	Other species	0,95%	0,71%

benthic feeding fish and select for either group by choice of bait. The fish trap catches tend to reflect the abundance of each species in the system annually.

The abundance of only a few of the species inside the system is seriously affected by man. The major exceptions are the summer visitors. If the channels in the north are kept clear of gill nets, the numbers of these species inside the Kosi system could increase and thus the numbers may be moderated but not controlled by man through gill netting.

As some species decrease in numbers through falling salinities others increase, particularly in Nhlange. Many of these fish, however, are rarely caught in the traps. The small stenohaline proportion of trap catches was decreasing but there was a general increase in the numbers of the euryhaline summer visitors. Since their mean size is much greater than that of the stenohaline group this could result in a slight overall increase in catches in the future.

No general trend is obvious in the Group c species, either over the study period or in living memory (Tembe & Zwane, pers. comm.). Since several species are involved, there is an overall tendency, enhanced by the possible relationship between P. commersonni and M. cephalus, for for the total contribution of this group to remain constant. During the study, the combined mass of these species caught fluctuates by 23%.

The prognosis for the future, barring unforeseen developments, is that no major changes are anticipated. The fish resources at Kosi do not appear to be over exploited and changing salinity patterns are at present not markedly affecting the abundance of the most important species.

7.4 Discussion on trap catch success.

It was shown in Chapter 5 that, for all the important fish species to the fish trap owners, there was a well defined annual cycle in catch abundance. Appendix 9 gives the total monthly catches of the three most important fish species which together accounted for 75% of the mass of fish caught in the traps during the study. From these figures it can be seen that all three species' catches peak in middle to late summer. During the study 48% of P. commersonni were caught during the months of January, February and March while M. cephalus and A. berda catches peaked in May. Since trap catch success is related to fish movement and this occurs in summer for most species the traps tend to catch most fish at that time.

It was also shown that for most species there was a close relationship between trap catches and water height. This serves to amplify the unreliable nature of trap catches. An example of this can be seen in the trap catches of P. commersonni following Cyclone Demoina (see figure 28 on page 135) when 8% of the total catch that year was made in the five days following the heaviest rain and highest water levels. Of all trap caught species M. cephalus showed the most pronounced annual peak of abundance which occurred during high water in the new moon phase nearest the middle of May each year.

Trap catch success is governed by fish abundance and movement and not necessarily by the effort put into the fishing technique. The marked seasonal fluctuations in catches render the trap fishery unsuitable for commercialisation as these enterprises generally only succeed on a sustained and predictable production basis.

Most fishing techniques may be modified or carried out in different areas on a daily basis in order to increase catches. The fish traps will not catch many fish when no important species are migrating and water levels are low. They may be regarded as a "passive" fishing method in that they are reliant on the abundance and movement of fish and these are dictated, on a daily and annual basis, by factors outside the control of the fish trap owners.

7.5 A summary of and discussion on major fish movements and energy pathways.

Figure 34 serves to summarize the major fish movements and energy pathways described in this study. In spite of trap

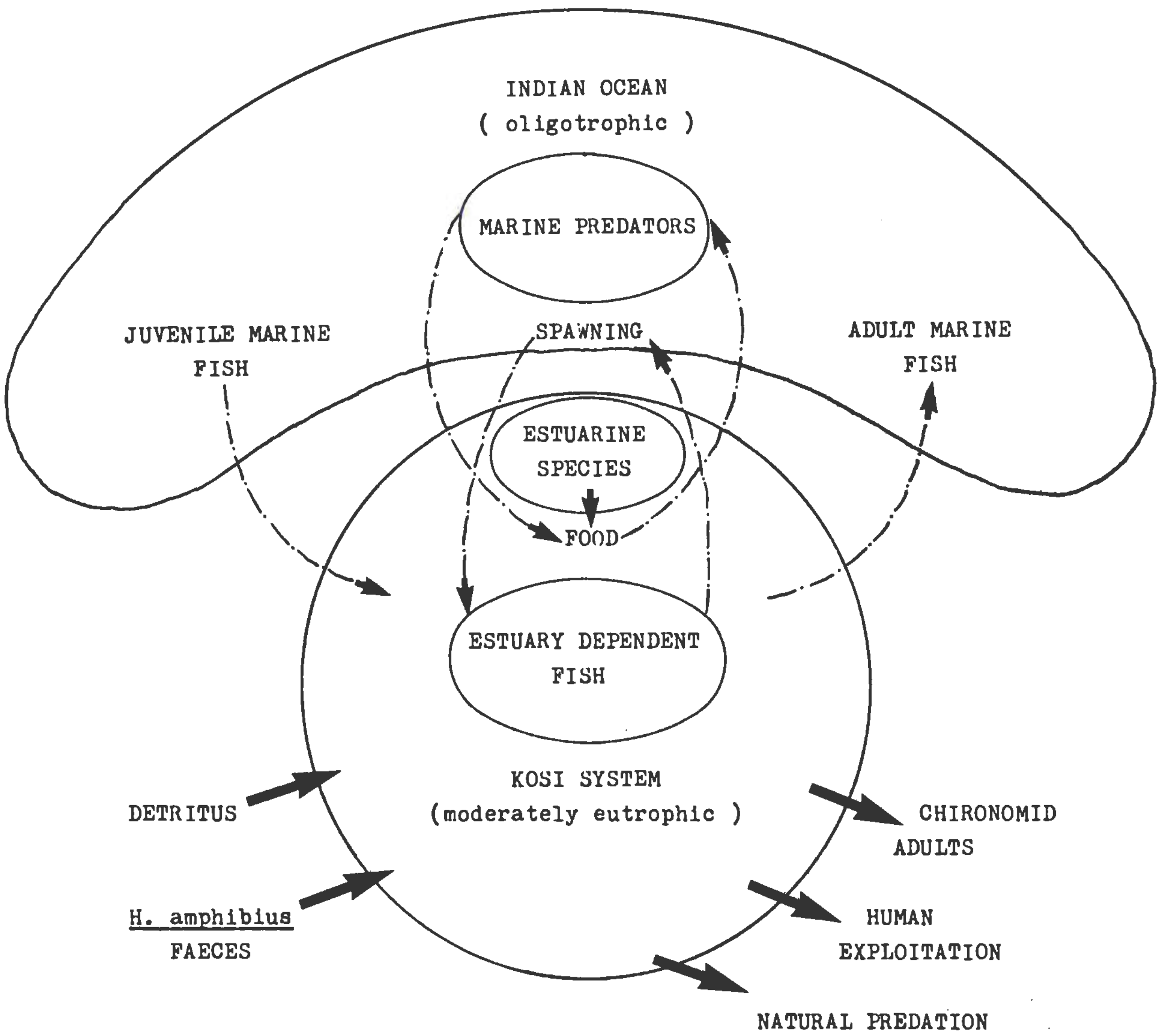


Figure 34. A summary of major fish movements and energy and nutrient pathways in the Kosi system and adjacent ocean.

catches showing individual species fluctuating in numbers there are indications of some stability in the total larger fish biomass. Current levels of off-take do not markedly affect the populations and overtly, as yet, man has not greatly influenced the area.

From Figure 34 it is clear that the links between the Kosi system and the Indian Ocean are of paramount importance in maintaining current species composition. Each year there are migrations of mature fish to the ocean to spawn and of recruits entering the system as well as immigration and emigration of summer visitor species. These links are usually broad, shallow channels which have changed little in living memory (Zwane, pers. comm.). Mthando channel, joining lakes Mpungwini and Nhlange (see Chapter 1) is quite different. Begg (1978) and Moll (1978) stressed the danger of boats passing through Mthando channel causing banks to collapse and changing the morphology and it would be unfortunate if the tenuous link between the largest lake and the ocean was upset unknowingly by tourists. Blaber (1978) focussed attention on the link between Nhlange and the marine environment and commented that small changes in drainage patterns could radically alter the degree of isolation of Nhlange. The destruction of the swamp forests is receiving attention, but several large scheme to plant trees and rice in the catchment area are underway or being considered (Steele, pers. comm.).

There is clearly an annual loss of a considerable amount of energy through emigration of adult marine fish. Small fish enter the system, feed and leave for the ocean again. Many of these fish will not return and thus the off-take of these fish by man does not represent an additional loss. The capture of "summer visitor" fish by sport fishermen will similarly not represent an extra loss of energy as these fish would also leave before winter.

The harvesting of <u>J. kraussi</u> and various crabs by the local people may represent an increasing energy loss and this should be monitored. The tourist bait fishery is on a small scale compared with St. Lucia (Bond, 1973). It is possible that salinities are becoming critical to C. kraussi (Forbes, 1979) and that the resource itself may be decreasing. By the end of this study the gill netting in the northern channels had been reduced to levels where it did not appear to interfere with the annual immigration of the "summer visitor" species. The large scale export of gill netted and fish caught by sport anglers had virtually ceased and illegal fishing methods, such as jigging, were discouraged.

Over 99% of the catch of the fish traps during the study period was of marine fish species, in spite of the shallow and sometimes narrow nature of the channels between the ocean and the lakes. Clearly the higher trophic levels within the system are dominated by marine species while the lower levels are characterized by estuarine or freshwater species. The closure of Kosi Mouth has only been recorded once (Begg, 1978) but if this were to occur more regularly or for a protrated period it would have serious implications to the Kosi Bay fishery.

The channels and particularly Kosi Mouth remaining open are of critical importance to the current fish (this study) and plant (Breen & Hill, 1969) communities at Kosi. The two most important fisheries at Kosi, the fish trap fishermen and sport anglers, are dependent on marine fish species each of which currently recruit and emigrate annually through Kosi Mouth. Clearly the basic functioning of the Kosi Bay ecosystem, as it is at present, is dependent on the mouth and channels remaining as they are. Any development plans which could alter these in any way must be considered in this knowledge. If the mouth should close again as it did in 1965 (Begg, 1978) serious consideration should be given to its being reopened again as soon as possible in order to maintain the current fish and plant communities there.

7.6 Major trophic relationships and energy pathways.

7.6.1 Introduction.

Data from catch monitoring have shown that many of the fish of the Kosi system are dependent on the food resources in the system. Trap catches and other off-takes will thus be affected by major changes in these resources. In this section these are examined and major food webs are identified and described.

The water bodies of importance to the larger fish species of the Kosi system may be divided into two zones:

Zone 1; this comprises lakes Nhlange and Amanzimnyama and was essentially a freshwater system during the study and the lower trophic levels were typical of such systems. Chironomid larvae were the dominant benthic infaunal organisms here (Cyrus & Blaber, 1982).

Zone 2; this zone, comprising lakes Mpungwini and Mankawulani, was more typically estuarine with salinities between 1 p.p.t. and 28 p.p.t.. The infauna was dominated by Callianassa kraussi (Forbes, 1979) which is principally an estuarine species (Branch & Branch, 1981).

This results in two markedly different food webs and these are summarized in Figures 35 and 36. The surface area of Zone 1 is approximately ten times that of Zone 2 and the mean depth is approximately 7 metres whereas that of Zone 2 is 8 metres (Begg, 1978). Forbes (1979) found that C. kraussi was absent below depths of 7 metres in Mankawulani, whereas Boltt and Allanson (1975) found Chironomid larvae in Nhlange as deep as 30 metres, although more common in water less than 15 metres.

The relative sizes of the two zones together with the proportion of each zone capable of supporting the main infaunal organisms indicate the relative importance of each food web at Kosi. The area in which fish may feed on Chironomid larvae was approximately twenty times larger than that for C. kraussi. It was also clear that only P. commersonni ate large numbers of C. kraussi, whereas many species fed on Chironomid larvae and pupae. Although they spend much time in tubes in the substrata, Chironomid larvae occasionally swim freely (Skaife, 1979) and pupae must pass through the water column to the surface before the adult can emerge and so no specialised feeding mechanism is necessary to prey on these animals.

The tagging programme indicated that the traps caught approximately the same proportion of all the larger marine species. The relative mass of each species caught could thus be used to indicate the percentage of the total large marine fish biomass represented by each species in the two zones. This has been used in Figures 35 and 36 to indicate the importance of the various food chains within each web. Since O. mossambicus and C. gariepinus do not migrate to the ocean no estimate of these or other freshwater fish is possible. O. mossambicus is abundant in Zone 1 and its numbers, monitored by gill net catches, have increased steadily during this study. C. gariepinus was restricted to the shallow margins and the biomass of this species plus the other freshwater species was small.

7.6.2 The food web in Zone 1.

It can be seen in Figure 35 that the food web in Zone 1 is simple compared with those given for other systems such as the Pongolo floodplain pans (Heeg & Breen, 1982), Mhlanga estuary (Whitfield, 1982) and Lake Sibaya (Minshull, 1969 ; Bruton, 1980). There are two main energy pathways evident which together directly sustain approximately 88% of the trap caught fish.

Detritus, or associated micro-organisms, is the major food source of Chironomid larvae (Skaife, 1979) and these in turn are the principal prey item of P. commersonni, G. rappi and R. sarba in this zone (Cyrus & Blaber, 1983a ; this study). Together these fish species constituted an estimated 49% of the larger marine fish biomass there.

Members of the Muglidae feed almost exclusively on detritus (Odum, 1970) and diatoms (Blaber, 1976). The two most abundant species, M. cephalus and L. alata, together form an

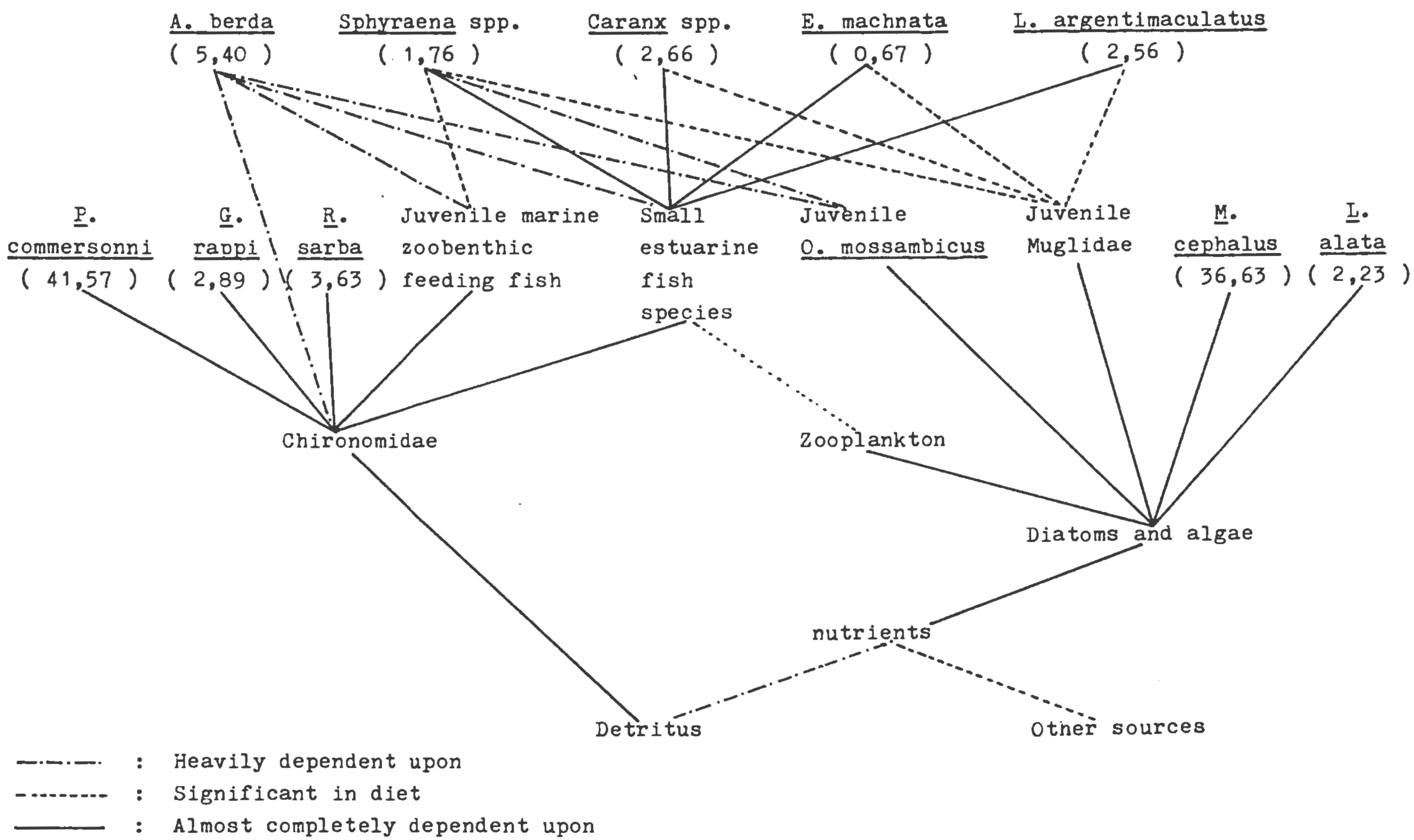


Figure 35. Simplified food web in Nhlange and Amanzimnyama using percentage mass in trap catches to indicate biomass of larger marine species.

estimated 39% of the biomass of the larger marine fish in this zone. O. mossambicus also feeds predominantly (Bruton & Boltt, 1975) or almost exclusively (Bowen, 1978) on diatoms and since this species forms the bulk of the remainder of fish biomass the importance of diatoms is greater than that indicated in Figure 35.

The remaining fish species, constituting an estimated 11%, are either heavily dependent upon Chironomid larvae, or dependent on fish which themselves feed principally on Chironomid larvae or diatoms (this study). Blaber and Cyrus (1983) found that Gilchristella aestuarius provided 58% of the energy intake of immature Caranx papuensis, the most abundant Carangid in the Kosi system. E. machnata was also found to feed principally on this species (this study) and Blaber et. al. (1981) found that in Nhlange Chironomid larvae were the most important food item in the diet of G. aestuarius, providing 47% of their energy intake. Blaber (1982) showed that Sphyraena bleekeri and S. qenie fed principally on Ambassis species and Martin and Blaber (1983) showed that the main food item of these in Kosi system was insects, with Chironomid larvae and pupae predominating. S. jello was shown by Blaber (1982) to feed principally on Muglidae.

It is clear that nearly all the biomass of fish in this zone and thus most of the fish caught in the fish traps and by other fisheries are dependent, directly or indirectly, on either Chironomid larvae and pupae or diatoms. The former depends on detritus (Skaife, 1979) and the latter on plant nutrients in the water (Blaber, 1976) derived principally from detritus (Hemens et. al., 1971). A similar detritus based food web was found in Mhlanga estuary (Whitfield, 1982).

The benthos of Nhlange was first recorded in detail by Boltt and Allanson (1975) and again by Cyrus and Blaber (1983a). Begg (1980) draws attention to a general decline in species diversity in the benthos in Kosi and clearly several species such as Musculus virgiliae have disappeared between the two recent surveys. Although the species diversity was decreasing, probably reflecting falling salinities (Blaber & Cyrus, 1981), the zoobenthos biomass has not declined. Boltt and Allanson (1975), whose sampling was carried out in 1968 and 1969, produced a mean figure of 2 222 Chironomid larvae/m^2 , while Cyrus and Blaber (1983a), working at Kosi during 1978 - 1980 gave a figure of 3 088 larvae/m^2 . Densities as high as 108 100 larvae/m^2 were recorded in the shallows of the Phragmites beds during this study, although in the deeper water of these beds a mean density of 21 195 larvae/m^2 with a standard error of 6 285 larvae/m^2 was found. Cyrus and Blaber (1983a) gave an energy value of 6,676 J/Chironomid larva which indicates that energy values of at least 721 027 J/m^2 are attained in Nhlange with a mean of 141 498 J/m^2 in the deeper Phragmites beds. This compares with an energy value of 27 400 J/m^2 for the zoobenthos in Mhlanga estuary (Whitfield, 1982) and 161 000 J/m^2 for the detritus itself. Chironomid production of 240 - 1 050 kg/ha /year has been found in Bohemian pools (Lellak, 1961) where they were estimated to supply a third to one half of the fish food requirements.

The highest densities of Chironomid larvae in the Kosi system were found in the shallows of the extensive Phragmites beds. At localities where the higher densities occurred, the lake floor was almost exclusively covered in Phragmites stalks and Chironomid tubes. Densities decreased in deeper water, but still remained well above the value found by Cyrus and Blaber (1983a). Oligochaeta were very numerous in the benthos (Cyrus & Blaber, 1983a), but they were extremely small and not recognised in any of the larger fish stomachs.

Stomach content analyses for this study were carried out using a binocular stereo-microscope and so it is possible that oligochaeta remains were present but were not recorded. Cyrus and Blaber (1983a) found that, although numbers of oligochaeta were present in the stomachs of G. rappi, the species did not select for this prey item and the energy contribution was small. The larger benthic feeding fish appear to feed on much larger individual prey items. Hymenosoma orbiculare, another important component of the zoobenthos, according to Cyrus and Blaber (1983a), had almost disappeared from this zone by the end of the study as had the isopod

Cirolana fluviatilis, and polychaete worms. It appears that Chironomid larvae now dominate the macro-zoobenthos in this area. In Zone 1 there are only two important and very short food chains.

7.6.3 The food web in Zone 2.

As can be seen in Figure 36, the food web in the more saline areas is more complex than in Zone 1. This is principally due to the increased diversity of zoobenthos and the specialisation of certain fish species in exploiting these resources.

Forbes (1973) showed that detritus was the main food source of C. kraussi and Forbes (1979) reported that this crustacean was the dominant zoobenthic organism in Zone 2. Evidence from this study shows that C. kraussi is the most important food item to P. commersonni in this area and this fish species is estimated at 40% of the biomass of the larger marine species here.

The iliophagous species, with the addition of V. buchanani and C. chanos are estimated at 43% of the larger marine fish biomass, but O. mossambicus is much less common in this zone than in the previous one. No other freshwater species of importance occur here.

Other zoobenthic organisms in this zone are also directly or indirectly dependent on detritus (Skaife, 1979 ; Branch & Branch, 1981). The bivalve Hiatula lunulata, was found to be the major food source of G. rappi (Cyrus & Blaber, 1983a) and Rhabdosargus sarba (this study). Juvenile Gerres species were also shown to feed on H. lunulata (Cyrus & Blaber, 1983b) while juvenile Rhabdosargus species, which were abundant in this zone, were also found to utilise this resource (this study). Chironomid larvae were present in the less saline margins of this zone and played a role in the diet of all zoobenthic feeders. R. sarba and A. berda were found (this study) to eat small quantities of Brachyura, of which Hymenosoma orbiculare was the most important species. Blaber et. al. (1981) found that G. aestuarius fed almost exclusively on

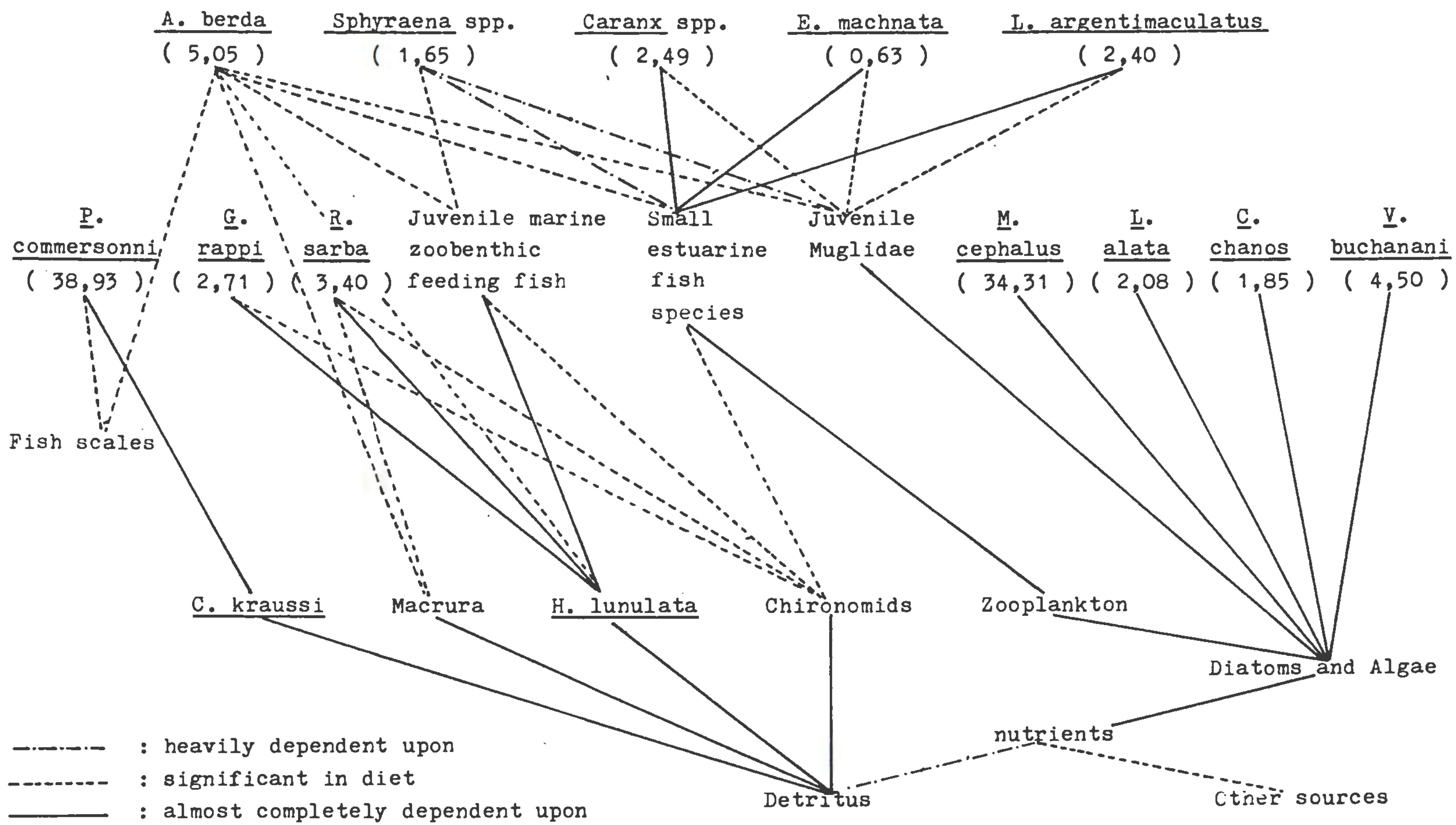


Figure 36. Simplified food web in Mankawulani and Mpungwini using percentage mass in trap catches to indicate biomass of larger marine species.

small zooplankton in Mankawulani while Marin and Blaber (1983) found that Pseudodiaptomous stuhlmanni was the dominant crustacean prey of Ambassis species. Croilia mossambica, another small estuarine species eaten in numbers by piscivores at Kosi (Blaber & Cyrus, 1983) was found to feed principally on zooplankton.

7.6.4 General discussion.

The most important food chain in the Kosi system is from diatoms to iliophagous fish. This feeds directly approximately 45% of the catch by mass of the fish traps and thus roughly the same percentage of the biomass of the larger marine fish at Kosi. Since the area in which Chironomid larvae predominate in the benthos is approximately twenty times greater than that for C. kraussi, and G. rappi is found principally in Nhlange, approximately 40% of the biomass of economically important fish are dependent directly on Chironomidae. Of the remaining 15%, it has been shown that many of these fish are piscivorous and much of their prey is in turn dependent on Chironomids or diatoms.

In both zones much of the fish predation is on small estuarine species. Table 39 summarizes data on fish prey species from this study. The dependency by numbers on small estuarine species can clearly be seen (87% of the 245 prey fish identified were of this group). The non-estuarine species do, however, tend to be much larger and are important in the diet of the larger Carangids, L. argentimaculatus and Sphyraena species. Blaber (1978) comments on a scarcity of estuarine species, stating that G. aestuarius was uncommon, and Blaber and Cyrus (1981) recorded it as absent from Mankawulani. In 1983 a dense shoal of these small fish, approximately 100 metres by 100 metres was driven into the shallows on the eastern shore of Mankawulani, indicating that at that time G. aestuarius was present in large numbers. During summer, throughout the study, large shoals of G. aestuarius were obvious in Mpungwini and Nhlange as game fish disturbed the water in the region of the shoals during intense feeding activity. When Mthando channel reversed flow and clear saline water was flushed in, up to 45

Table 39. Prey species identified from stomach contents expressed as a percentage of total fish prey.

Species	Prey species								
	G. aestuarius	Ambassis spp.	Gobidae	Gerreidae	Rhabdosargus spp.	Muglidae	P. commersonni	A. berda	No. of fish
P. commersonni	70,37	7,40	22,22	-	-	-	-	-	27
A. berda	-	18,18	72,72	9,09	-	-	-	-	22
R. sarba	83,33	-	-	-	16,67	-	-	-	6
C. papuensis	95,45	-	4,54	-	-	-	-	-	44
C. sexfasciatus & C. ignobilis	55,55	8,64	29,63	1,23	3,70	-	1,23	-	81
L. argentimaculatus	-	17,86	17,86	32,14	7,14	25,00	-	-	28
E. machnata	100,00	-	-	-	-	-	-	-	22
Sphyraena species	-	66,67	-	-	-	20,00	-	13,22	15
Total no. of fish	133	28	53	12	6	10	1	2	245
% of total	54,29	11,43	21,63	4,90	2,45	4,08	0,41	0,82	
Approx. mean total length	70 mm	90 mm	85 mm	160 mm	170 mm	250 mm	180 mm	160 mm	

% estuarine species = 87,35
% non-estuarine species = 12,66

dense shoals of G. aestuarius and 3 large shoals of Ambassis species were observed.

G. aestuarius is now common throughout the lakes of the system, principally in the open water. Ambassis species are common in the Phragmites beds around the margin of Mpungwini and Nhlange, where densities of 200 g/m^2 were recorded from cast netting, compared with a mean of 0,28 g/m^2 for Mhlanga estuary (Whitfield, 1982). Stomach content analysis of Ambassis species in Nhlange (this study) indicated that at sizes from 30 - 90 mm (T.L.), Chironomid larvae made up 92% of the diet. For larger Ambassis species, 63% of the diet was fish, with G. aestuarius accounting for 86% of the fish identified (n = 28). During this study large numbers of Gobidae were found on the sandy floor of Mankawulani and Nhlange, and many piscivorous fish and P. commersonni were found to eat these. Whitfield (1982) comments on the presence of Gobidae in the stomachs of the Carangidae at Mhlanga estuary in larger numbers than their relative abundance shown in seine net catches. He ascribed this to a sampling artefact, but Blaber and Cyrus (1983) also recorded Carangids at Kosi eating numbers of Gobidae and Kok (1980) found gobies to be the most important prey item of piscivorous fish in the Pongolo floodplain system. Of 81 fish identified from Carangid stomachs (excluding C. papuensis) caught by sport anglers and examined for this study, 23 were members of the Gobidae. These small estuarine fish are an important segment of the diet of Carangids at Kosi and their importance in the food webs in other systems may be greater than previously recognised.

The stomach contents of 20 Glossogobius giuris, the most common goby in the margins of Nhlange, were examined and only Chironomid larvae and pupae were identified.

An eel, Anguilla marmorata, was also found to be common in the Phragmites beds although rarely caught by man. Stomach content analysis showed it to be piscivorous with Ambassis species the principal prey. Although not discussed in previous fish surveys of the Kosi system, this large piscivore is an important predator on small fish. Many of the piscivorous fish of the system feed principally on estuarine species which are clearly in abundant supply. The larger piscivorous fish, possibly excluding E. machnata, eat fairly large numbers of juvenile marine species as well as estuarine species and since the mean length of the former group is greater than the latter (see Table 39) they are the most important part of their energy intake.

Few penaeid prawns were found in the Kosi system by Champion (1971) in spite of the fact that St. Lucia estuary supports a bait fishery which produced 30 000 kg of prawns in 1973 (Bond, 1973). No fish in the Kosi system have been found to feed predominantly on penaeid prawns, although juvenile Caranx species eat considerable numbers in the northern channels (Blaber & Cyrus, 1982).

Zooplankton levels in the Kosi system are generally regarded as low (Champion, 1971 ; Oliff et. al., 1977 ; Begg, 1978) although Blaber and Cyrus (1981) described Mankawulani as having a fairly high density. They pointed out, however, that the low salinities excluded marine filter feeding fish and G. aestuarius, as the only common planktivore, was the only abundant species capable of utilising this food source. Blaber et. al. (1981) regarded G. aestuarius as principally a filter feeder in Mankawulani, whereas in Nhlange it fed on individual prey items because of low zooplankton densities. Throughout the study there were between 100 and 400 greater flamingoes (Phoenicopterus ruber), resident in the shallow margins of Mankawulani and the channels north of this lake. These were possibly exploiting the relatively high zooplankton and benthic fauna levels of this region (Blaber et. al., 1981 ; Cyrus & Blaber, 1984b) . Taylor (1981), however, reported the discovery of large bivalves and macroplant material from the stomach of an apparently healthy P. ruber shot in St. Lucia. It is not known what these birds eat at Kosi, but their continued presence indicates a substantial food resource.

Table 40 summarises data on food dependency of fish communities in some estuarine systems and this can be compared with that of the trap caught fish at Kosi. Data from Kosi are only from the

Table 40. The percentage dependency of trap caught fish on various food resources at Kosi and data from other estuarine systems snowing the dependencies of the fish communities there.

Food source	% Biomass					
	Kosi **	Mhlanga *	Swartvlei *	St. Lucia ***	Cockburn Sound ****	Peel-Harvey est. ****
Detritus and associated micro-organisms	44,45	93,16	28,54	20,13	3,10	14,10
Zoobenthos	43,53	1,52	23,29	24,11	60,40	48,50
Fish	12,02	0,10	10,26	16,66	13,50	0,10
Zooplankton	-	1,80	12,90	36,70	18,10	35,50
Aquatic plants and associated organisms	-	3,19	25,01	2,40	-	-

where : * = Data from Whitfield (1982) : ** = Larger marine species only
*** = Data from Whitfield (1977) : **** = Percentage by numbers from Potter et. al. (1983)

larger species but although no direct comparisons may be made some interesting points are clear. The Kosi system fish community is clearly not as dependent directly on detritus and associated micro-organisms as that of Mhlanga, but is more so than some other estuaries. Few of the smaller fish in the Kosi system graze on aquatic macrophytes and so this food source is relatively unimportant. Many of the smaller fish in the system feed on zooplankton and so this value in the table is not a reflection of the whole fish community. Estuaries support dissimilar species compositions of fish with different food sources. The fish fauna probably reflect relative sizes of the food sources, modified annually by the levels of recruitment for the major species and other factors such as turbidity.

7.7 Factors influencing the fish food resources of the Kosi system.

Parsons (1979) described and contrasted two zones in the world's oceans. The coral seas, including the ocean adjacent to Kosi, were described as having low primary productivity and were characterized by flagellates dominating the lower trophic levels. The other extreme, the areas of upwelling, Parsons (1979) described as areas of high primary production characterized by a diatom-dominated ecology. The coral seas he distinguished by having high species diversity and low fish biomass while the upwelling areas have low species numbers but high fish biomass.

The ocean near Kosi mouth is typical of the coral sea type and is oligotrophic. Inside the Kosi system the situation changes rapidly and progressively. Species diversity decreases (Blaber & Cyrus, 1981) and relative biomass of fish increase. The stable water conditions of the ocean are replaced by shallow lakes where "turnover" and upwelling of the lower layers of water are thought to occur regularly (Hemens et. al., 1971). This results in the mixing of the nutrient rich lower layers with the upper layers (Heydorn, 1972). The abundance of diatoms has been commented upon (Hemens et. al., 1971) and this is reflected in the large biomass of iliophagous fish. O. mossambicus, which feeds principally on diatoms (Fryer &

Iles, 1972), is common in the Kosi system. They grow quickly and to much larger sizes than elsewhere in the region (Bowen, 1979) indicating an abundant food supply. Fish trap catch statistics suggest that 2,5% of O. mossambicus are larger than the current Natal record (Coke, 1981).

Parsons (1979) reported that diatoms, since they contained an accessory pigment system (chlorophyll c and fucoxanthin), were capable of efficient photosynthesis at low light intensities. Diatoms also have a greater growth potential than flagellates as they do not have to expend energy through actively swimming. In the stable water of the coral seas diatoms do not compete well with flagellates which are more mobile. Inside the Kosi system, however, the regular "turnover" (Heydorn, 1972) and large areas of shallow water serve to mix the diatoms with nutrients. In this way the disadvantages of diatoms is overcome and they are able to photosynthesize aided by the clarity of the water.

Parsons (1979) characterized the productive upwelling areas with the short food chain ; diatoms to large zooplankton to fish. At Kosi the iliophagous fish shorten this chain even further. Oliff (1976) and Robarts (1976) showed that phytoplankton production was not generally of great importance in South African estuaries. The phytoplankton of Kosi is not particularly rich (Shaw & Breen, 1974) but full stomachs in M. cephalus throughout the year (this study) indicate that diatoms in the bottom sediments are abundant at all times.

In the St. Lucia system, which is markedly more turbid than Kosi, Blaber (1976) found that diatoms were the most important component of the diet of the large numbers of Muglidae there. This was possible because the shallow nature of that system allowed diatoms to enter the euphotic zone during wind induced turbulence. At Kosi the euphotic zone in considerably greater than at St. Lucia (Begg, 1978) and thus diatoms are able to photosynthesize for a greater proportion of the time.

It has been shown that some estuarine invertebrates and fish utilise detritus and associated organisms directly as a food source (Adams & Angelovic, 1970 ; Bowen, 1976). Some, such as O. mossambicus, rely on the chemical breakdown of materials, whereas others, such as M. cephalus, have a muscular gizzard type structure which uses sand grains to grind and crush material (Thomson, 1966 ; Blaber, 1976) and a long gut in which to digest it (Odum, 1970).

As has been stated approximately 45% of the biomass of fish at Kosi is dependent on benthic diatoms, detritus and detritus associated organisms. If Kosi is regarded as nutrient poor and silt free relative to other Natal estuaries (Begg, 1978), then from where do the detritus and nutrients come ?

Whitfield (1982) found that in Mhlanga estuary, where more than 90% of the fish biomass was dependent on detritus, much of it entered the system from the fringing Phragmites swamp. He stated that the biological productivity of that system was closely related to that of the reed beds. Westlake, (in Welcomme 1979a) considered tropical reed swamps one of the most productive plant communities in Africa. Approximately 30 kilometres of the shoreline of the Kosi system comprises dense Phragmites beds and there are extensive swamps to the west and south of the Kosi system. Readings from the water level recorder on the shore of Nhlange show that the level of this lake rose and fell repeatedly over a range of 1,5 metres. Whitfield (1982) regarded the repeated innundation of the surrounding areas as a major source of nutrients and detritus while Welcomme (1979) regarded the repeated inundation of floodplains as the major source of nutrients there. Together this inundation combined with the large areas of Phragmites produced considerable amounts of autochthonous plant debris and detritus. Cyclic destruction of aquatic macrophytes is also considered to increase the detritus available (Hutchinson, 1977).

Submerged aquatic macrophytes were not abundant in the Kosi system during the study. The main emergent macrophytes, Phragmites species, are important as producers of detritus, but no major fish species are directly dependent on macrophytes for food. Whitfield (1982) described the main role of aquatic macrophytes in an estuary as transient stores for primary products which are eventually released to the system through detritus.

Detritus also plays an important role in the Kosi system. Mention has been made of nutrients entering the waters following the degradation of detritus, although the details of detritus dynamics are still being investigated (Roman & Tenore, 1984).

Hemens <u>et</u>. <u>al</u>. (1971) and Begg (1978) considered that plant nutrients in the water of the Kosi system were derived principally from the chemical breakdown of detritus on the lake floor but it could also be released through the activity of bacteria and fungi on these materials (Perkins, 1974 ; Wetzel, 1984). It has been reported that many mud and detritus eating organisms, such as Chironomid larvae, probably feed on bacteria rather than the detritus itself (Perkins, 1974).

Wetzel (1984) stressed the importance of detritus as an energetic store upon which the metabolism of ecosystems depends for stability. He considered that the slow utilisation rate of the detrital reservoir (estimated at between 1% and 5% per day by Saunders <u>et</u>. <u>al</u>. 1980) imparted stability to aquatic systems. He also considered that benthic bacterial metabolism dominated in shallow coastal regions and so it is likely that much of the nutrient released from detritus in the Kosi system is released through bacterial action.

Wetzel (1984) reported that a large proportion of the energy and nutrients of aquatic systems is to be found in detrital dissolved organic carbon. In the Kosi system, because of the depth of the lakes and small stream size, this material is retained inside the system. Similarly zooplankton, which is often lost to floodplain systems during floods (Welcomme, 1979), is not easily lost from the Kosi system.

It is reported in this study that dense concentrations of Chironomid larvae were found in the <u>Phragmites</u> beds. Energy values of 721 675,6 J/m^2 were recorded for these larvae indicating that the areas of <u>Phragmites</u> beds are rich in zoobenthos as well as detritus. There are strong indications that the falling salinities, particularly in Nhlange (see Figure 4), have led to increasing densities of Chironomids, thus increasing the benthic standing crop in the lake. The production of large numbers of adult Chironomids will, however, lead to a loss of biological material from the water of the system as many adults die while over the surrounding land.

The Nkanini and Sihadla rivers drain through extensive swamps which filter out much particulate material. Regular cyclones and periods of extremely heavy rainfall, however, serve to flush large amounts of allocthonous plant debris into the system. Allanson and van Wyk (1969) reported a large influx of plant debris into Nhlange which temporarily caused reduced oxygen levels in the substratum. Boltt and Allanson (1975) regarded Amanzimnyama as acting as a settling pond but concluded that in times of flood this southern area would be an important source of particulate matter.

Together the known sources of autochthonous and allocthonous detritus could account for the considerable quantities of nitrogen in the waters of the system (Hemens et. al., 1971). An obstacle to incorporation of the nutrients into biological material may have been the P : N ratio discussed in Chapter 1.

The input of detritus from the above sources has probably remained fairly constant for many years. Table 41 summarizes the available data on H. amphibius numbers and they indicate a steadily growing population. Hippopotami are readily seen by boat, aeroplane or helicopter in the Kosi system and it is likely that the figures in Table 41 represent an actual increase and not a function of the different counting methods. The input of detritus and nutrients from this source must have increased proportionately. The importance of the translocation of nutrients from surrounding lands to aquatic systems by H. amphibius has been recognised (McLachlan, 1971) and Viner (1975, in Bruton 1979) suggested that the fisheries industry on Lake George, in Uganda, was dependent on this source of nutrients. Taylor (1980) studied the transfer of nutrients to the St. Lucia system by H. amphibius. Using figures from

Kyriacou (1980) on the chemical composition of dung and estimates of dung production from Laws and Field (cited in Arman & Field, 1973), Taylor (1980) estimated the quantities and proportions of materials deposited in St. Lucia by H. amphibius. These values have been used to calculate the input of chemicals and plant materials to Kosi and the results are summarized in Table 42.

Table 41. Available records of H. amphibius counts in the Kosi system.

Year	Authority	Type of count	Total number
1958	N.P.B.	Boat	19
1979	N.P.B.	Boat	32
1980	N.P.B.	Aeroplane	36
1981	N.P.B.	Aeroplane	34
1982	N.P.B.	Aeroplane	35
1984	KwaZulu	Helicopter	47
1985	KwaZulu	Helicopter	60

where N.P.B. represents Natal Parks Board
KwaZulu represents KwaZulu Bureau of Natural Resources

Tinley (1958) recorded only one hippopotamus in the northern reaches with a total of 19 for the whole system. The latest count indicates 35 resident in the northern areas and a total of 60 including those in the surrounding pans. H. amphibius has been responsible for a large increase in the input of detritus in recent years. From data available the ratio of P : N in H. amphibius dung is 1 : 6,4. A sustained increase in dung input to the Kosi system might locally improve primary productivity through increasing the P : N ratio. The implications of this go beyond the simple deposition of nutrients into the system and form a further argument for protecting the animals in areas such as Kosi.

The substantial increase in H. amphibius in Mankawulani and Mpungwini and thus in nutrient transfer into those lakes may

Table 42. Chemical composition of *H. amphibius* faeces and estimates of the dry mass of dung transferred to the Kosi system (after Taylor, 1980).

		Values for 1958		Values for 1985	
Chemical composition	gm/kg - dry mass	Northern area 1 animal kg/year	Total 19 animals kg/year	Northern area 35 animals kg/year	Total 60 animals kg/year
Organic material	666,70	1 467,00	27 873,00	51 345,00	88 020,00
Inorganic material	333,30	733,00	13 927,00	25 655,00	43 980,00
TOTAL	-	2 200,00	41 800,00	77 000,00	132 000,00
Nitrogen	9,50	20,90	397,10	731,50	1 254,00
Sodium	2,65	5,83	110,77	294,05	349,80
Magnesium	2,23	4,91	93,29	171,85	294,60
Phosphorous	1,48	3,26	61,94	114,10	195,60
Calcium	0,765	1,69	32,11	59,15	101,40
Potassium	0,58	1,28	24,32	44,80	76,80

well have a localised effect on eutrophication. At current levels, however, the number present in Nhlange is too low to have a marked influence. Until 1982 poaching had been controlling H. amphibius numbers (Steele, pers. comm.), but since that time poaching activity has declined appreciably. If the apparent 1984/5 increase of over 25% in H. amphibius numbers was correct and if it continues then in future these animals may have a greater effect on the productivity of the whole system.

The numbers of H. amphibius in Lake Sibaya have increased from 40 (Tinley, 1976) to 146 (Ward, 1985). There are indications that the stunted populations of O. mossambicus there, caused by nutritional constraints (Bowen, 1979), may be increasing in size (pers. obs.).The importance of H. amphibius in otherwise nutrient deficient systems is recognised (McLachlan, 1971) but little quantitative evaluation has yet been attempted.

Hellier (1962) determined that in Laguna Madre in Texas there was a correlation between fish biomass and the amount of plant material present. This would mean that any increase in H. amphibius numbers at Kosi, resulting in more faeces entering the system, would produce an increase in fish biomass thus benefitting the fishermen.

It has long been known that the introduction of organic waste and ruminant faeces to water systems results in increased fish production (Hoffman, 1934). In recent years this has led to daily fish production rates as high as 20 - 40 kg/ha/day (Hepher & Schroeder, 1975). Although they are not true ruminants H. amphibius retain food in the gut where microbial action breaks down cellulose (Van Hoven, 1974 ; Langer, 1976) and the efficiency of H. amphibius digestion has been compared with that of sheep (Arman & Field, 1973).

Schoonbee et. al. (1979) working on the introduction of cattle manure to fish ponds found a clear correlation between the amount of manure added and the amount of zoobenthos. They found that the quantity of manure added strongly influenced the density and biomass of the benthic macro-invertebrate organisms and the dominant group in most ponds investigated was Chironomid larvae.

From the above it would appear that a direct comparison between the activity of H. amphibius at Kosi and the enrichment of artificial ponds with cattle manure is valid. Not only does the H. amphibius dung increase the amount of detritus and nutrients in the system, it will increase the benthic standing crop and in some areas may modify a factor limiting primary production.

Another locally important source of nutrients and particularly phosphates, is the guano of the fish-eating birds. This is one of the purest sources of phosphates exploited by man (Branch & Branch, 1981). It has been estimated that fish-eating birds return 20% of the food taken from the water in the form of faeces (Fitzpatrick, 1975). Numbers of fish-eating birds feeding in the Kosi system appear to have remained steady over at least the past 20 years (this study). From the birds feeding in the system there will be a net loss of phosphates and nutrients, however, many birds roost in the reedy margins of the Kosi system each night although they feed elsewhere. Clearly the defecation of these birds in the water of the system constitutes a gain of nutrients. Regular counts indicate that approximately 250 egrets and 125 P. africanus roost at night on old fish trap stakes and Phragmites reeds in the north of Nhlange. If figures are calculated from Whitfield (1977) and this study, an estimate of defecation of approximately 3 440 kg/year is obtained. Much of this will be deposited in the Kosi system at night and again this will increase the P : N ratio. It is not known if the numbers of these birds are increasing or decreasing.

Comparisons with other systems can be misleading. Whitfield (1982) uses the estimated biomass of fish per square metre. In this assessment the coral reefs had the greatest fish biomass but this is deceptive as the overall productivity of the coral seas is regarded as low (Parsons, 1979). Sampling fish by cast net at Kosi produced different figures dependent upon the time of day and the area sampled. The fish biomass/metre^2 in the Phragmites beds was much greater than that for the open water and it was not possible to sample sufficient areas to obtain an acceptable estimate using this method. Similarly any comparison of energy values/metre^2 has limited value. An indication of the relative benthic food resources of the Kosi system may be obtained by comparing its benthic standing crop with that of other areas. Table 43 lists the available data for some other systems and gives values obtained in this study.

Table 43. Comparison of macrobenthos standing crop according to available published data and that from this study.

System	gm/m^2 (dry mass)	Authority
1. Lagoa Poelela	0,007 - 2,618	Boltt (1974)
2. St. Lucia	0,68	Boltt (1975)
3. St. Lucia	2,63	Blaber et. al. (1983)
4. Mhlanga	1,50	Whitfield (1982)
5. Pongolo pans	4,44	Kok (1980)
6. Swartvlei	6,43 - 132,46	Whitfield (1982)

Data from this study :

Kosi Mankawulani - *C. kraussi* mean = 22,71 gm/m^2 (S.E. = 13,53 and n = 50)

Nhlange reed beds - Chironomids mean = 8,57 gm/m^2 (S.E. = 2,53 and n = 15)

It can be seen that some areas of the Kosi system have relatively high benthic standing crops. An important feature of *C. kraussi* is that it releases submerged detritus and makes it available to benthic organisms in the faeces pellets deposited on the substratum outside the burrow hole (Forbes, 1977). It is clear that the Kosi system has a much higher trophic status than the adjacent ocean and it appears that the slow eutrophication reported by Hemens et. al. (1971) may be accelerating due partially to falling salinities and additional nutrient input from increasing hippopotami numbers.

Whitfield (1982) concludes that it is because estuaries act as detritus traps that they have high nutrient levels and high productivity. The fact that the Kosi system is the best example of segmentation in South Africa (Orme, 1973) indicates that it is probably the most efficient detritus trap. This will also mean that phosphorus, although at low levels, will tend to be retained in the system and be repeatedly incorporated into and released from biological material. Cyclones flush large amounts of detritus into the lakes where it settles and is eventually broken down (Wetzel, 1984). In most Natal estuaries heavy rains flush vast amounts of detritus into the ocean whereas at Kosi, due to the narrow channels, little material is lost to the ocean.

Two trends are obvious in the system. The slowly falling salinities which were considered (Blaber & Cyrus, 1981) to be either representing a long term increase in isolation from the ocean or an oscillation due to climatic cycles, and slow eutrophication. The salinity is at present outside the control of man and may at current levels be increasing the productivity.

An increase in salinities caused by a reduction in fresh water entering the system, following major afforestation or agricultural schemes, would not greatly affect the Kosi Bay fishery. Similarly a further reduction in salinities, caused by swamp forest destruction allowing greater run off following precipitation, would not necessarily be detrimental to the fishery. Afforestation and agricultural schemes would also involve the use of large quantities of fertilizer in the Kosi catchment. During the study period fertilizer was not used locally to any great extent (pers. obs.) and such future use could greatly accelerate the eutrophication of the Kosi system. The more rapid run off of water following rainfall caused by the destruction of the swamps would lead to greater sand deposition in the lakes. Clearly all the implications of development schemes should be considered and balanced before decisions are made.

7.8 Why and how do marine fish enter the Kosi system ?

It is clear from this and other studies that many primarily marine fish species enter estuarine systems in large numbers in spite of the restricted openings to the ocean which most of these have (Begg, 1978). This recruitment is often as juveniles (Wallace & van der Elst, 1975) but can also be an annual recruitment of larger individuals, often following spawning, or a warm month entry and exit by summer migrant species (this study). Several, such as A. berda and G. rappi, have developed life cycles closely associated with estuaries (van der Elst, 1981 ; this study). The questions now asked are why such numbers of marine fish do enter estuaries and what factors control this movement ?

It has been postulated that estuaries provide advantageous conditions such as reduced predator pressure (Whitfield & Blaber, 1978), suitable and sufficient food (Blaber & Whitfield, 1977 ; Blaber & Blaber, 1980) and reduced turbulence and shallow water (Day, 1951 ; Blaber, 1974). Blaber (1981) considered that it was not the estuaries themselves which were important but certain features commonly occurring in them. He pointed out that in areas such as the Bay of Bengal conditions similar to those inside estuaries were exhibited in the open ocean. Blaber (1981) postulated that the evolutionary pressures which led to many fish species entering estuaries on the south-east coast of Africa may have developed in these open ocean areas. He considered that these may have developed as escapes from predation or moving to areas of higher productivity. Heydorn (1978) pointed out that the circulation of surface waters in the Indian Ocean facilitated the dispersal of fish in a southerly direction and Blaber (1981) considered that this would lead to the mechanism that fish had developed to enter turbid inshore zones manifesting itself on the Natal shore as an entry into estuaries.

Many fish species whose juveniles are usually associated with estuaries do not spawn in the immediate vicinity of estuary mouths (Wallace, 1975b). It is thus probable that only a small proportion of juveniles enter estuaries, but the higher predation pressure in the coral seas (Blaber, 1981) leads to few of those outside surviving. Another factor of possible relevance to the apparent absence of the juveniles of some marine species from the marine environment was identified by Blaber and Blaber (1980). They found that in the south-east African coastal area, it was only estuaries that provided sufficient and suitable food for the juveniles of several marine species, including ten members of the Muglidae.

Although the coral seas are generally regarded as areas of low productivity (Parsons, 1979), Blaber (1981) pointed out that, within these areas, there are zones of higher productivity such as shallow, turbid coastal zones, coral reefs and estuaries. The migration of fish to these zones would result in increased food availability. Coral reefs and shallow, turbid coastal zones are widespread and extensive around most of the shore of the Indian Ocean, but along the south-east coast of Africa there are no turbid coastal areas (Cyrus, 1984), few coral reefs and the area of estuaries suitable for juvenile fish is small and diminishing rapidly due to the activities of man (Begg, 1978).

The proximate factors by which fish are guided to enter the estuarine environment are not yet clearly understood, although it is generally thought to be by following a salinity or turbidity gradient (Blaber, 1981 ; Cyrus, 1984). Recent work, however, has suggested that other factors may also play a part (Blaber *et. al.*, 1985).

Turbidity was found by Cyrus (1984) to be an important factor controlling the distribution and species composition of juvenile fish in Natal estuaries. In general he found that there was a tendency for fish species numbers, though not necessarily density, to increase with turbidity. The Kosi system, as the only extensive estuarine system on the Natal coast with low turbidities (Begg, 1978) is thus probably of particular importance in the recruitment of some fish species intolerant of higher turbidities. Cyrus (1984) expressed the fear that the St. Lucia system might, through dredging

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Appendix 1. Summarized monthly weather data collected during the study period.

	Rainfall (mm)				Minimum air temperature			Maximum air temperature			
Months	1981/2	1982/3	1983/4	1984/5	1981/2	1982/3	1983/4	1981/2	1982/3	1983/4	1984/5
Apr	97	160	12	28	N/A	18,4	19,5	N/A	26,3	30,5	28,4
May	217	50	52	59	N/A	16,2	15,3	N/A	24,1	26,7	26,8
Jun	32	17	59	57	N/A	12,3	13,3	N/A	22,5	24,3	22,1
Jul	13	41	87	123	N/A	12,5	11,7	N/A	22,6	23,7	23,5
Aug	87	14	105	82	N/A	13,7	12,0	N/A	23,7	23,8	24,4
Sep	131	27	29	28	14,2	15,7	15,4	27,6	25,6	28,2	27,1
Oct	126	87	40	34	16,2	16,9	16,6	26,6	27,6	30,9	30,2
Nov	162	74	178	30	20,3	18,3	19,7	29,5	29,5	33,2	33,4
Dec	32	83	208	18	20,4	20,5	20,2	31,8	32,6	38,6	36,1
Jan	108	42	136	9	22,5	21,5	20,6	34,6	38,5	37,7	38,2
Feb	170	36	365	641	21,1	20,9	20,5	32,5	35,0	34,6	36,4
Mar	106	164	234	76	20,0	20,0	19,1	30,3	32,7	32,0	32,6
Total	1 281	795	1 505	1 185							
Mean	106,75	66,25	125,42	98,75							

Minimum air and maximum water temperatures for 1984/5 were not used in this study, but were recorded.

N/A = Data not available.

Appendix 1 (cont.).

Months	Minimum water temperature 1981/2	1982/3	1983/4	1984/5	Maximum water temperature 1981/2	1982/3	1983/4
Apr	N/A	23,4	24,9	21,7	N/A	25,2	27,2
May	N/A	21,2	21,6	20,0	N/A	23,7	23,5
Jun	N/A	19,0	19,6	17,4	N/A	20,6	21,0
Jul	N/A	18,5	17,0	18,1	N/A	20,7	19,0
Aug	N/A	20,1	17,5	18,2	N/A	21,9	19,6
Sep	18,3	21,0	20,7	19,2	20,9	22,2	22,9
Oct	19,3	22,1	21,1	21,2	21,6	24,8	24,2
Nov	22,8	23,2	23,1	21,6	25,7	25,0	26,4
Dec	23,9	24,0	25,3	23,0	27,1	28,1	28,3
Jan	25,7	26,4	25,5	24,9	28,7	29,5	28,9
Feb	25,6	25,7	24,6	26,1	27,3	28,1	26,8
Mar	24,7	24,5	24,4	24,8	27,6	30,0	26,6

Appendix 2. The Kosi Bay fish traps.

The survivors of the Portuguese ship Sao Bento, which was wrecked off the Natal coast in 1554, called one of Natal's estuaries Pescaria. Bulpin (1966) placed this in Durban Bay, but Stuckenberg (pers. comm.) considers it more likely that it was Richards Bay. It is suggested (Bulpin, 1966) that the place was so called because of the presence of fish traps. It is probable that in the past several of Natal's estuaries contained fish traps, but at the present day only Kosi Bay contains significant numbers.

Tinley (1964) described the traps and how they functioned and the design has not changed in living memory (Tembe & Zwane, pers. comm.). The fence of the traps is usually begun at the edge of the channel, curving towards the middle and then usually turning upstream, forming an open figure 6. At the end of the guide fence is a fish-catching basket with a valve which allows fish to enter freely but inhibits escape. From the baskets another fence continues a short distance back towards the bank forming a funnel to guide fish into the valved basket.

Fish moving through the channels encounter the fence and are guided then funneled into the basket during the night. The trap owner spears them and takes them away the following day.

The traps are made exclusively of indigenous plant materials (Tinley, 1964 ; Balfour-Cunningham, 1985) and approximately 1 100 kilograms of wood is needed for an average trap (this study). They need constant maintenance and much of the work is skilled and time consuming.

The position, size and structure of the traps have evolved over many years. The local people have always tried to catch as many fish as possible at all stages of the tide. For this reason traps are usually positioned in the deeper water and are submerged at nearly all high tides. The structure of the valve is such that fish may enter even if the water is shallow and so the traps are capable of catching fish moving at low water as well as high. Some species of fish try to escape by jumping out of the basket and so the baskets extend 1 000 - 1 500 mm above the usual high water mark of the spring tides. Because of the positioning of the traps and the high baskets, the traps are capable of catching and holding fish throughout the usual tidal range and also in most cases even during exceptionally high water.

Figure 2a shows the position of the important traps during the study period. Table 2a from Kyle (1980) gives figures for fish traps in the Kosi system from 1959 as estimated from aerial photographs.

Table 2a. Estimates of numbers of fish traps and baskets from Kyle (1980) in the Kosi system from aerial photographs.

Year	Number of traps	Number of baskets
1959	76	193
1970	110	253
1978	84	240
1980	85	238
1985	67	200

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Appendix 2 (cont.)

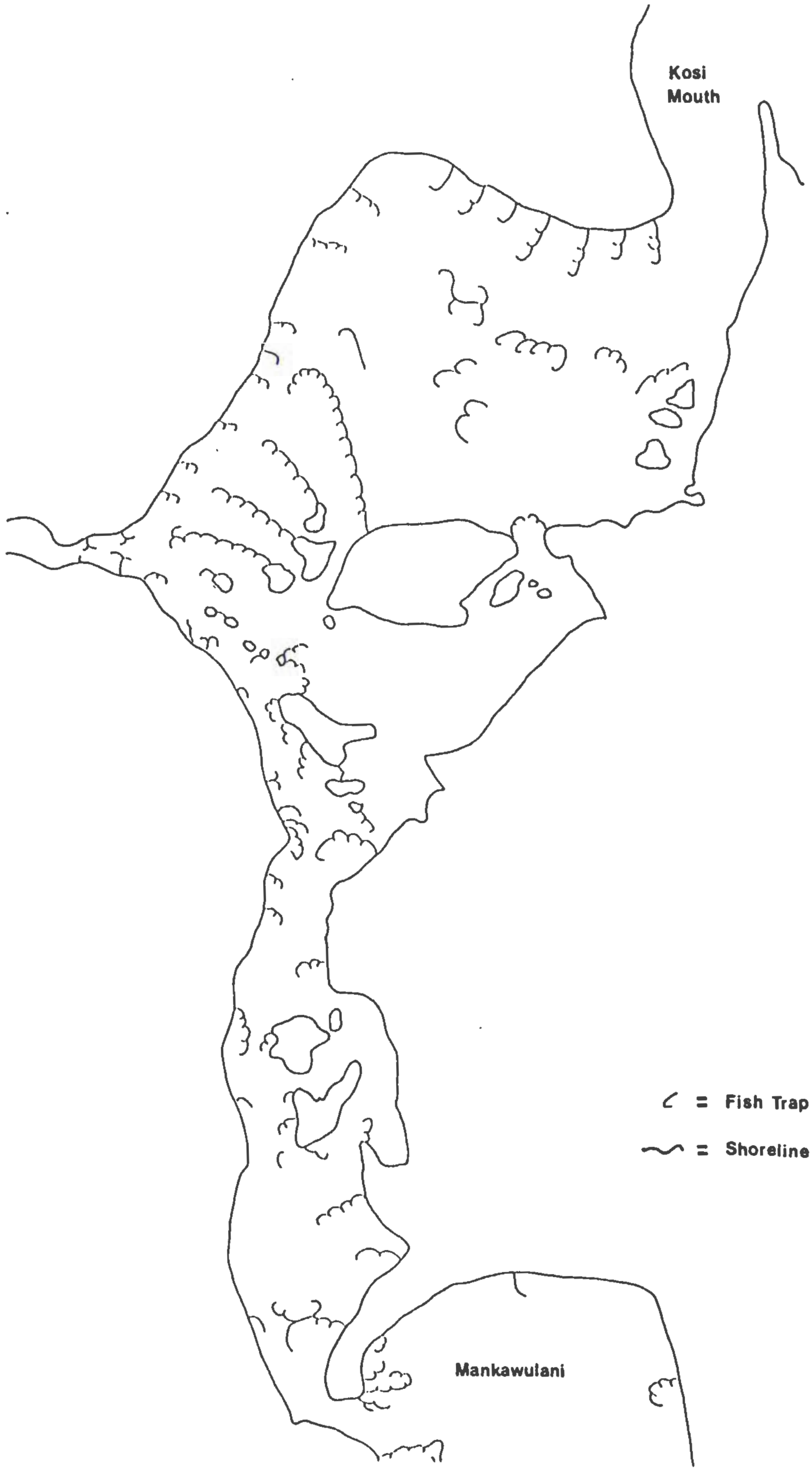

Figure 2a. Map of northern reaches of the Kosi system showing the position of the important fish traps during the study period.

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ZWANE, C. Fish trapper. Tembe Tribal Authority, P.O. KwaNgwanase, Natal, Republic of South Africa, 3973.

Appendix 3 . The Scientific, Zulu and English names of the fish caught in the Kosi Bay fish traps.

Smith (1977) No.	No.	Scientific Name		Zulu Names	English Names
679	1	Pomadasys commersonni	Lacépède 1802	Inkolonkolo	Spotted grunter
877	2	Mugil cephalus	Linnaeus 1758	Intulo	Flathead mullet
707	3	Acanthopagrus berda	Forsskål 1775	Ikula	Perch
888	4	Valamugil buchanani	Bleeker 1853	Imbulakazi	Blue-tail mullet
710	6	Rhabdosargus sarba	Forsskål 1775	Ipendesi/Isigobolo	Yellow fin bream
886	5	Liza macrolepis	Smith 1846	Ucushane/Umacijane	Largescale mullet
632	7	Gerres rappi	Barnard 1927	Inshuludla	Pouter
511	8	Caranx spp		Ikhomane	Kingfish
664	9	Lutjanus argentimaculatus	Forsskål 1775	Umwali	Rock salmon
881	10	Liza alata	Steindachner 1892	Ibangwa	Diamond mullet
105	11	Chanos chanos	Forsskål 1775	Umnonzi	Milkfish
	12	Sphyraena spp		Indobolo/Umsephuku	Sea pike
100	13	Elops machnata	Forsskål 1775	Ishange	Springer
	14	Oreochromis mossambicus	Peters 1852	Ikhwamba	Tilapia
1063	15	Platycephalus indicus	Linnaeus 1758	Umkhokhoba	Sand gurnard
545	16	Scomberoides lysan	Forsskål 1775	Umkwandla	Queenfish
631	17	Gerres acinaces	Bleeker 1854	Isihlengane	Pouter
547	18	Pomatomus saltatrix	Linnaeus 1766	Umuyende	Elf
	19	Clarias gariepinus	Burchell 1822	Ubabule/Ntakanzima	Barbel
447	20	Epinephelus tauvina	Forsskål 1775	Igolomba	Rockcod
	21	Epinephelus spp		Ilondwa	Rockcods
401	22	Terapon jarbua	Forsskål 1775	Imata	Pest of St. Lucia
890	23	Myxus capensis	Valenciennes 1836	Umsiva/Isiliva	Freshwater mullet
580	24	Monodactylus spp		Isiphasi	Moony
228	25	Tylosurus leiurus	Bleeker 1851	Umhlanga/Umhlomololo	Garfish
690	26	Gaterin niger	Cuvier 1830	Isibubulungu/Iphangane	Harry hotlips
878	27	Valamugil robustus	Gunther 1861	Ithefa	Robust mullet
552	28	Argyrosomus hololepidotus	Lacépède 1802	Uhlonzi	Salmon
528	29	Alectis indicus	Ruppell 1828	Imbokoda	Indian mirrorfish
	30	Scylla serrata		Inkalankala	Crab
659	31	Lutjanus fulviflamma	Forsskål 1775	Isigilajozi	Blackspot snapper
938	32	Eleotris fusca	Bloch-Schneider 1801	Isimumumu	Dusky sleeper
	33	Unidentified		Ithago	Unknown
691	34	Gaterin plagiodesmus	Fowler 1935	Ifole	Barred rubberlip
	35	Anguilla marmorata	Quoy & Gaimard 1824	Ibalane/Mbokwan	Mottled eel
880	36	Crenimugil crenilabis	Forsskål 1775	Isithonga	Fringelip mullet
709	37	Rhabdosargus holubi	Steindachner 1881	Inyundu	Stumpnose bream
628	38	Gerres filamentosus	Cuvier 1829	Isithelezi	Longfin pouter
520	39	Caranx ignobilis	Forsskål 1775	Isikholwa	
	40	Thalassoma spp		Mazinyo/Mekhuhlwini	Wrasses

Other fish reportedly caught occasionally are the following ;

63	41	Rhinobatos annulatus	Muller & Henle 1841	Ifungwe	Sand shark
882	42	Liza tricuspidens	Smith 1935	Udakwa	Springer mullet
	43	Tetraodontidae spp		Isabova	Puffer
101	44	Megalops cyprinoides	Broussonet 1782	Ubukala/Ikali	Oxeye tarpon
1047	45	Pterois volitans	Linnaeus 1758	Ugesi	Devil firefish

Appendix 4. Details of the number of fish traps and baskets working on a monthly basis during this study.

Total number of traps working each month

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1981	-	-	-	60	59	61	66	68	68	70	73	73
1982	73	75	77	76	73	78	74	74	75	74	74	73
1983	73	74	74	74	74	77	75	72	66	65	66	66
1984	68	64	66	68	70	70	69	69	67	66	66	69
1985	69	68	67	-	-	-	-	-	-	-	-	-

Total number of baskets working each month

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1981	-	-	-	173	168	171	180	187	176	184	193	192
1982	197	201	210	213	216	219	216	221	211	209	203	205
1983	200	201	201	201	203	216	205	187	187	187	183	184
1984	185	182	190	196	201	198	194	181	181	177	181	190
1985	190	202	199	-	-	-	-	-	-	-	-	-

Throughout the study the traps which caught most fish remained virtually unchanged and in constant use. Nearly all the fluctuations in trap and basket numbers were accounted for by the less successful trap owners trying new sites, new owners building traps and old, unsuccessful traps being abandoned.

n = 48 months

$\bar{x}$ = 194,7 traps/month or 71076 trap.days/year

SE = 1,94

Σx = 9347 traps

Appendix 5a. Example of computer print-out of summary of one year's fish trap catch statistics for Species 1 - <u>Pomadasys commersonni</u>

KOSI BAY FISH CATCH ANALYSIS FOR THE YEAR 1981   file name = KB1100

Kraal range   1 to 200

Species in this analysis:
1

***** Number of fish caught in each month

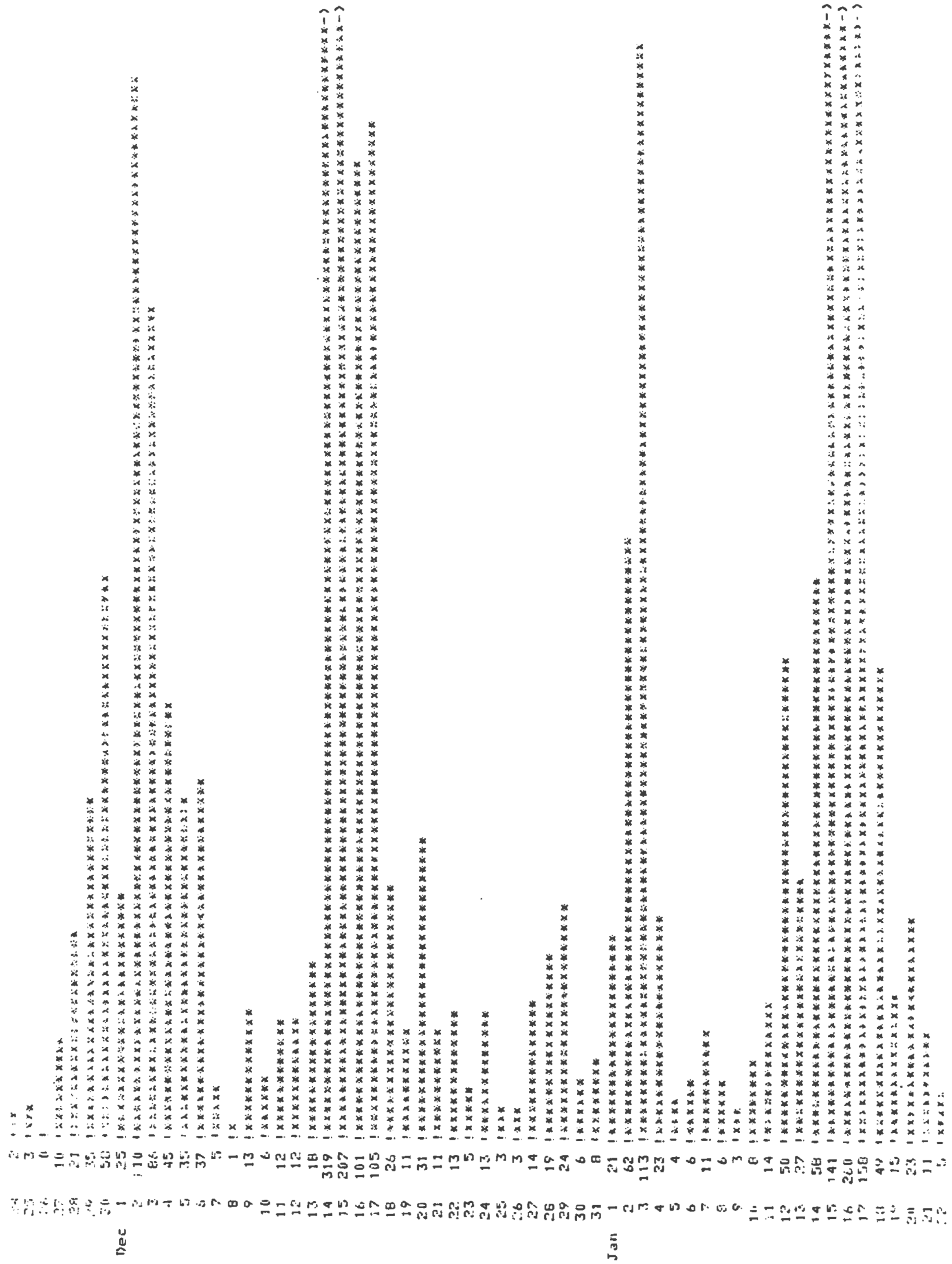
Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	TOTAL
689	815	335	318	483	616	547	309	1092	751	1344	1475	8774

***** Length distribution

% in each class

	Mean	Min	Max				32				64				96				128
Apr	44.9	13.0	93.0		0.87	2.2	14.7	19.9	19.3	20.6	16.5	3.2	1.5	0.87	0.44				
May	49.1	15.0	79.0		0.12	0.37	6.0	11.4	21.1	31.5	25.8	2.6	1.1						
Jun	48.0	25.0	75.0				6.3	14.6	27.8	28.1	17.0	6.0	0.30						
Jul	48.9	24.0	92.0				6.9	14.2	18.9	32.1	21.7	4.4	1.6		0.31				
Aug	44.8	21.0	86.0			1.7	19.9	21.3	17.6	14.9	13.9	7.0	1.0	2.7					
Sep	36.6	18.0	86.0			7.8	43.7	16.7	10.6	10.9	5.5	2.4	0.32	2.1					
Oct	45.1	19.0	85.0			2.4	14.8	16.1	18.8	28.0	13.9	5.1	0.37	0.55					
Nov	45.9	21.0	75.0			1.9	10.0	15.9	23.9	26.5	18.1	2.6	0.97						
Dec	41.4	18.0	78.0			2.4	9.6	39.3	20.0	16.9	11.3	0.37	0.18						
Jan	45.5	12.0	82.0		0.13	1.7	8.0	22.9	17.0	32.1	16.8	0.93	0.27	0.13					
Feb	45.8	17.0	87.0			2.5	5.1	19.9	20.9	35.3	15.3	0.74	0.07	0.15					
Mar	43.5	20.0	73.0			0.47	4.3	39.3	18.5	25.0	11.9	0.47	0.07						
TOTAL	44.5	12.0	93.0		0.09	2.0	11.0	24.1	19.2	25.5	15.0	2.2	0.49	0.43	0.05				

Appendix 5b.



Example of computer print-out of total daily trap catch for one species (P. commersonni) during the period 24/11/83 - 22/1/84.

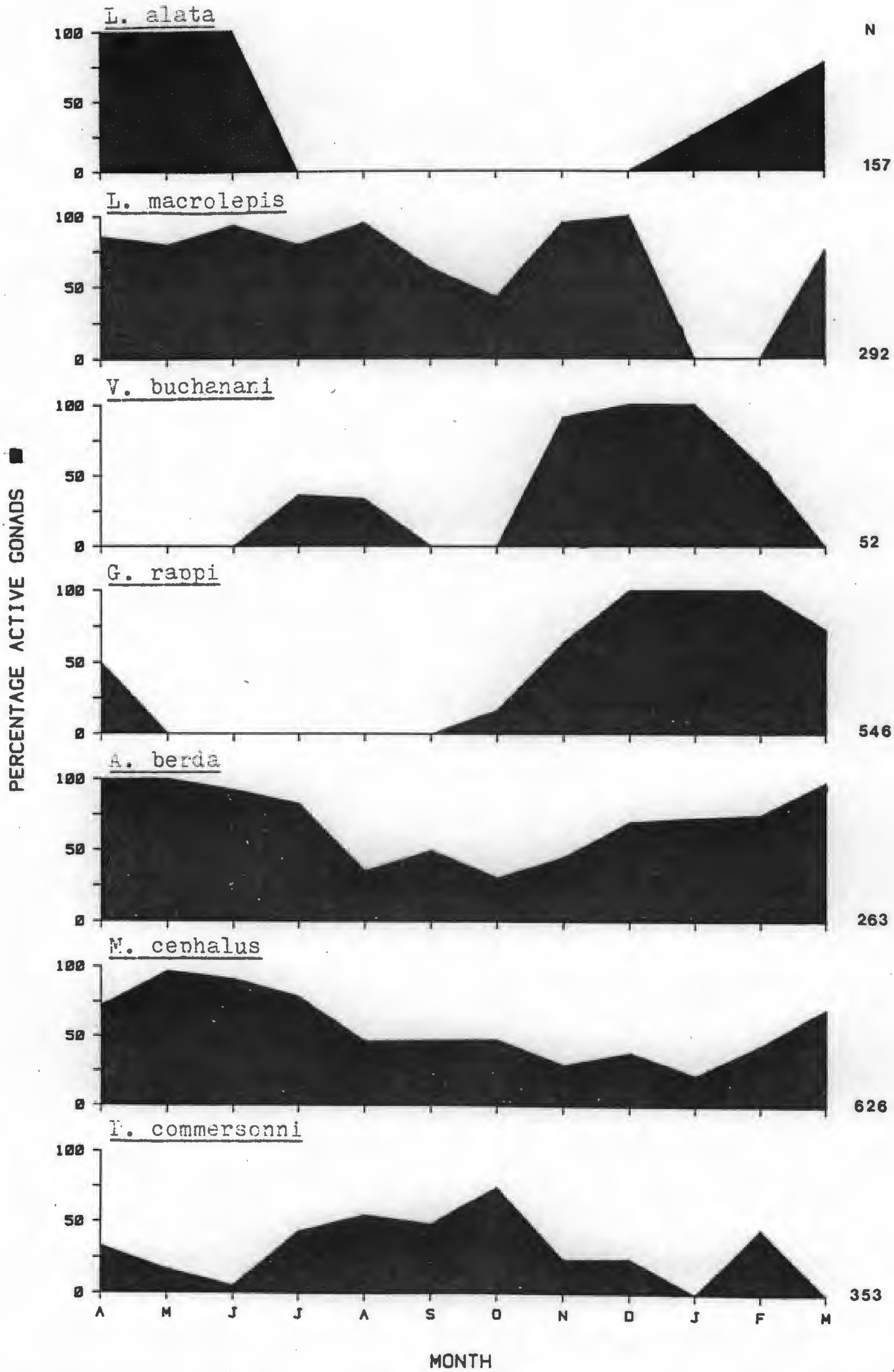
Appendix 6. Data on gonad condition.

Estimates of length of fish at maturity and sources of these estimates.

Species	Length at maturity (T.L.)	Source
1. *L. alata*	440 mm	5
2. *L. macrolepis*	260 mm	1
3. *V. buchanani*	440 mm	1
4. *G. rappi*	140 mm	4
5. *A. berda*	200 mm	1
6. *M. cephalus*	480 mm	1
7. *P. commersonni*	420 mm	1
8. *R. sarba*	240 mm	1
9. *Caranx* spp.	500 mm	2
10. *L. argentimaculatus*	450 mm	2
11. *C. chanos*	900 mm	2
12. *Sphyraena* spp.	500 mm	2
13. *E. machnata*	650 mm	5
14. *C. mossambicus*	150 mm	3
15. *P. indicus*	400 mm	1
16. *S. lysan*	500 mm	5
17. *G. acinaces*	110 mm	
18. *P. saltatrix*	250 mm	2
19. *C. gariepinus*	190 mm	3
20. *E. tauvina*	500 mm	5

where - 1 = Wallace (1975)
2 = van der Elst (1981)
3 = Pienaar U de V (1978)
4 = Cyrus D.P. (1980)
5. = estimated from examination during this study

Appendix 6. (cont.)



Data on reproductive cycle of several fish species showing percentage each month with active gonads.

Appendix 6 (cont.). Gonad conditions.

Species	No. examined	Gonads inactive	Gonads active
R. sarba	43	31	12
Caranx spp.	27	27	-
L. argentimaculatus	27	25	2
C. chanos	35	35	-
Sphyraena spp.	21	21	-
E. machnata	24	24	-
O. mossambicus	86	43	43
P. indicus	4	3	1
S. lysan	6	6	-
G. acinaces	22	2	20
P. saltatrix	8	8	-
C. gariepinus	5	3	2
E. tauvina	2	2	-

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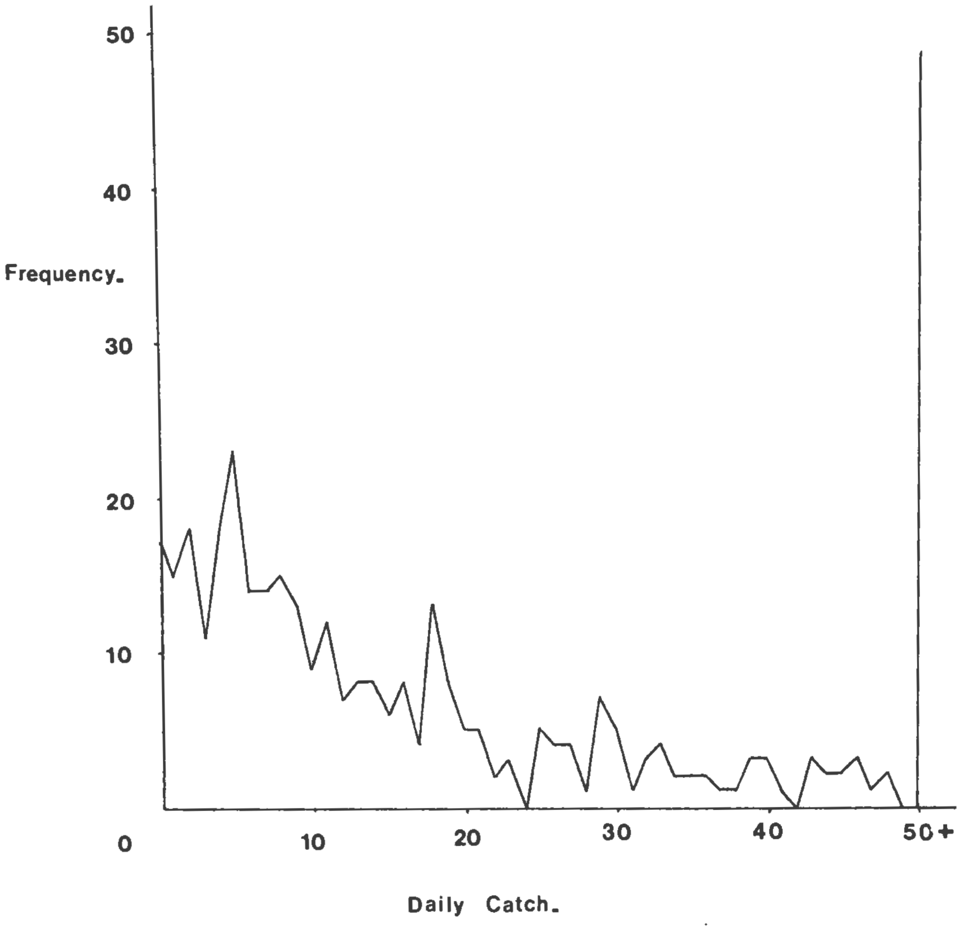
Appendix 7. Yearly catch statisitics for the Kosi Bay fish trap monitoring programme.

Species	1981	1982	1983	1984	Total
21. *Epinephelus* spp.	16	20	16	2	54
22. *T. jarbua*	10	4	17	9	40
23. *M. capensis*	17	32	230	263	542
24. *Monodactylus* spp.	9	4	30	25	68
25. *T. leiurus*	5	33	46	102	186
26. *G. niger*	11	6	3	8	28
27. *V. robustus*	-	7	187	574	768
28. *A. hololepidotus*	1	4	49	11	65
29. *A. indicus*	3	29	-	-	32
30. *S. serrata*	20	32	17	7	76
31. *L. fulviflamma*	2	4	12	2	20
32. *E. fusca*	1	13	6	7	27
33. Unidentified	9	9	8	-	26
34. *G. plagiodesmus*	2	4	-	4	10
35. *A. marmorata*	-	4	3	7	14
36. *C. crenilabis*	-	-	33	27	60
37. *R. holubi*	-	-	22	1	23
38. *G. filamentosus*	-	-	1	-	1
39. *C. ignobilis*	-	-	-	-	-
40. *Thalassoma* spp.	-	-	23	19	42
TOTAL	106	205	703	1 068	2 082

Appendix 8.



where : mean = 24,04; range = 0 - 257; modal catch = 5

Distribution of total trap catches of P. commersonni during the period 1/4/81 - 31/3/82.

Appendix 9. Monthly trap catches of three species of fish.

Year	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Pomadasys commersonni												
1981/2	689	815	335	318	483	616	547	309	1 092	751	1 244	1 475
1982/3	573	393	174	338	479	466	909	1 701	1 324	1 301	3 957	4 044
1983/4	713	1 268	527	1 244	1 117	1 968	2 388	677	2 247	2 009	3 648	341
1984/5	117	67	35	71	502	784	520	804	1 296	1 867	4 156	862
Mugil cephalus												
1981/2	1 956	3 082	3 666	1 069	381	381	300	242	412	288	453	372
1982/3	920	1 538	817	427	289	209	157	347	658	351	293	966
1983/4	903	1 844	633	1 530	490	427	650	470	785	1 129	2 082	710
1984/5	954	2 622	1 594	568	505	517	426	599	323	523	856	757
Acanthopagrus berda												
1981/2	784	832	346	163	105	64	27	19	40	99	140	283
1982/3	970	626	448	357	133	53	15	17	23	34	35	142
1983/4	598	810	423	357	42	22	15	37	58	105	108	335
1984/5	473	673	444	248	96	46	19	13	31	35	32	58

Appendix 10. The capture of 500 *Acanthopagrus berda* for tagging.

Introduction

In order to determine the percentage off-take of the fish traps it was decided to tag and release 500 *A. berda*. These fish were found to be difficult to catch but proved very hardy when caught and tagged. The fish were caught throughout the system but all were released in the lakes.

Material and methods

Initially large seine nets were used to capture the fish, but experience showed that in clear water *A. berda* nearly always escaped. They were even seen forcing passage under the bottom line of the net. Gill netting was attempted in areas where there were many *A. berda*, but few were caught and the fish were seen to avoid the nets. Rod and line fishing was most productive, but *A. berda* is generally a solitary fish and feeding habits varied resulting in very erratic catches. Occasionally *A. berda* which had entered fish traps were bought, netted, tagged and released in the lakes. Other fish were bought from local fishermen and tourists and several people were employed to catch fish by rod and line to tag. One *A. berda* tagged was caught by a local child by hand.

Table 10a summarizes the numbers of fish caught by the different methods.

Conclusions

Netting of *A. berda* in clear water is not productive. Numbers can be caught by rod and line, but the catches per rod hour varied between 0,29 and 1,95 with a mean of 0,66. For the reasons given in Chapter 6 *A. berda* is a suitable species to tag, but capture of sufficient numbers is a problem.

Table 10a. Capture methods and numbers of *A. berda* caught.

Method	Number caught
a) Rod and line	279
b) Buying fish from local fishermen	83
c) Buying fish from trap owners	74
d) Seine netting	34
e) Gill netting	15
f) Buying fish from tourists	14
g) Catching fish by hand	1
TOTAL -	500