South African marine pollution survey report 1974-1975

C E Cloete and W D Oliff (editors)

A Report of the Committee for Marine Pollution
National Programme for Environmental Sciences

SOUTH AFRICAN NATIONAL SCIENTIFIC PROGRAMMES REPORT NO

8

SEPTEMBER 1976

Compiled and issued by the
National Scientific Programmes Unit
Council for Scientific and Industrial Research
P O Box 395
PRETORIA 0001
from whom copies of reports in this series are available on request.

Printed 1976 in the Republic of South Africa
by the Graphic Arts Division of the CSIR

ISBN 0 7988 0194 8

Editors' addresses -

Dr C E Cloete
Coordinator for Environmental Monitoring
National Scientific Programmes Unit
CSIR
P O Box 395
PRETORIA 0001

Mr W D Oliff
Regional Head
NIWR Natal Regional Laboratory
P O Box 17001
CONGELLA 4013

SYNOPSIS

A national marine pollution survey was initiated in 1974 to determine and assess pollution around the coast of South Africa. Impact area surveys, coastal (including estuarine) reference surveys and oceanic reference surveys were undertaken. This report presents the results of the surveys undertaken up to the end of 1975. The impact areas studied were Richards Bay, the Durban area, sites on the Cape Peninsula and Saldanha Bay. Coastal reference transects were undertaken as Umbogintwini and the Fynnlands sewage outfall (both between Durban Bay and Isipingo) and the Umzimkulu and Berg River estuaries were investigated. Results of earlier surveys of Kosi Bay and the Umlalazi, Amatikulu, Umgeni, Ifafa and Umtamvuna estuaries are also given. East coast oceanic reference transects were undertaken quarterly during 1974 and 1975, while the south and west coast transects were sampled on four cruises during 1975. Finally, results are given of some general pollution studies as well as studies of coastal water dynamics north of Cape Town.

SINOPSIS

'n Nasionale seebesoedelingsopname is in 1974 begin om besoedeling langs die kus van Suid-Afrika te ondersoek. Opnames van trefgebiede, kusverwysingslyne (insluitende riviermondings) en oseaanverwysingslyne is onderneem. Die resultate van die opnames wat tot aan die einde van 1975 gedoen is, word aangebied. Die trefgebiede wat ondersoek is, is Richardsbaai, Durban en omgewing, liggings aan die Kaapse Skiereiland en Saldanhabaai. Kusverwysingstudies is onderneem by Umbogintwini en die Fynnlands riooluitlaat (beide tussen Durban en Isipingo) en die Umzimkulu- en Bergriviermondings. Resultate word ook aangebied van vroeëre opnames by Kosibaai en die Umlalazi-, Amatikulu-, Umgeni-, Ifafa- en Umtamvunariviermondings. Ooskus oseaanverwysingstudies was kwartaalliks onderneem gedurende 1974 en 1975, terwyl die oseaanverwysingslyne langs die wes- en suidkuste vier keer gedurende 1975 ondersoek was. Resultate word ook gegee van algemene besoedelingstudies en ondersoeke van die kuswaterdinamika noord van Kaapstad.

CURRENT TITLES IN THIS SERIES

1. A description of the savanna ecosystem project, Nylsvley, South Africa. December 1975. 24 pp.

2. Sensitivity analysis of a simple linear model of a savanna ecosystem at Nylsvley. W M Getz and A M Starfield. December 1975. 18 pp.

3. Savanna ecosystem project - Progress report 1974/1975. S M Hirst. December 1975. 27 pp.

4. Solid wastes research in South Africa. R G Noble. June 1976. 13 pp.

5. Bibliography on marine pollution in South Africa. D A Darracott and C E Cloete. June 1976. 131 pp.

6. Recycling and disposal of plastics waste in South Africa. R H Nurse, N C Symington, G R de V Brooks and L J Heyl. June 1976. 35 pp.

7. South African Red Data Book - Aves. W R Siegfried, P G H Frost, J Cooper and A C Kemp. June 1976. 108 pp.

8. South African marine pollution survey report 1974-1975. C E Cloete and W D Oliff (eds). September 1976. 60 pp.

PREFACE

The National Programme for Environmental Sciences is one of several national scientific programmes administered by the CSIR. It aims at identifying environmental problems in South Africa which lend themselves to solution through cooperative research and at promoting and coordinating research which will contribute to the solution of such problems. The National Programme includes research relating to environmental problems in the lower atmosphere, inland waters, the sea and terrestrial ecosystems. It is designed to meet both national and international objectives and it contributes to the international programme of SCOPE (Scientific Committee on Problems of the Environment), the body set up in 1970 by ICSU (International Council for Scientific Unions) to act as a focus of non-governmental international scientific effort in the environmental field.

The aims of the Marine Pollution Section of the National Programme are to identify scientific problems of pollution of the marine environment along the coast of South Africa and to determine research needs and priorities in this regard, to initiate and coordinate research which would lead to the solution of these problems and to establish a base-line for monitoring future changes of the marine environment. The Committee for Marine Pollution reports to the National Committee for Environmental Sciences on the findings and inplications of the research and advises, through the National Committee, government departments and other official bodies on the scientific aspects and routine monitoring of marine pollution. It also provides for South African participation in the IOC programmes for GIPME (Global Investigation of Pollution in the Marine Environment) and the IGOSS (Integrated Global Ocean Station System) Pilot Project on Marine Pollution (Petroleum) Monitoring.

A National marine pollution survey was planned in 1973 and started in 1974. The Survey has as object the determination and assessment of sources, concentration levels, pathways and consequences of pollutants in impact areas, in estuaries and at coastal and ocean reference stations around the coast of South Africa. The Survey is carried out under the aegis of a Steering Committee, which is responsible to the Committee for Marine Pollution. The present report provides an overview of the work done under the Survey since its inception in 1974 to the end of 1975. In addition, some work which has not been done as a formal part of the Survey but which nevertheless provides relevant information has been included in the report. Such work has been acknowledged where necessary.

The editors would like to thank all the participants whose work is reflected in the report for their kind cooperation. It is of course not possible to provide more than a cursory overview in a report of limited scope such as this. More details of marine pollution work done in South Africa can be found in the bibliography by Darracott and Cloete (1976).

TABLE OF CONTENTS

LIST OF FIGURES

INTRODUCTION

The South African Marine Pollution Survey has as object the determination and assessment of pollution around the coast of South Africa. Two teams have been appointed to execute the survey : one team (based in Durban) for the East Coast from the Mocambique border to Cape Recife at Port Elizabeth, and the other team (based in Cape Town) for the South and West Coasts, from Cape Recife to South West Africa. The various types of surveys undertaken are impact area surveys, coastal reference surveys and oceanic reference surveys.

Impact area surveys

Recognising that pollution initially arises from (a) industrial and urban activities, (b) geological formations, the atmosphere, soils and run-off into rivers and estuaries and (c) accidental or deliberate spillage or discharge from vessels transporting dangerous material, it is felt that the initial prime requirement of any effective monitoring programme is to discover all the major sources of pollution entering the sea along the coastline of the Republic and to determine the concentrations of marine pollutants of interest as a baseline.

This study requires information on, and examination of all industrial and urban wastes entering the sea, including materials dumped at sea and also on materials brought into South African waters by currents. Sampling techniques and storage of samples need investigation and methods of analyses require to be standardised and intercalibrated.

In effect, most polluting effluents are confined to the major cities, ports and industries sited at the coast, and oil discharged from ships around the coast and the ports.

The information required on the wastes ideally includes

- The quantity of waste and seasonal fluctuations in waste input and water flow.

- Bacterial quality, *E coli* I, Salmonellae, Shigellae, parasites, viruses.

- The physical characteristics : T^o, pH, total dissolved solids (TDS), suspended solids (SS), salinity.

- The chemical quality, such as chemical oxygen demand (COD), biological oxygen demand (BOD), oxygen absorbed from permanganate (OA), dissolved oxygen (DO), NH_3, PO_4, the trace metals Hg, Pb, Zn, Cu, Cr, As, Cd, organic pesticides and their residues, and hydrocarbons (including oils).

Reliable, standardised methods should be used to permit meaningful comparison of data. This will be assisted greatly by interlaboratory calibrations and visits to co-ordinate methodology.

An initial survey of all existing discharges is needed. This would be followed by futher checks, say, annually or half-annually to monitor those sources found to be important.

Coastal reference surveys

As it is insufficient to know only the quantity and quality of effluent discharged, it is also necessary to determine the effect of the effluents upon the environment. This can only be done by comparing conditions and marine life in risk areas and naturally untouched areas. It is also necessary to keep in mind the aesthetic and amenity value of coastal areas.

South Africa has only a limited number of estuaries. As estuaries are particularly susceptible to pollution which can affect the nursery areas of many pelagic species of fish life and can spoil the natural aesthetic and amenity values of these unique areas, estuaries must receive adequate attention.

The coastal reference survey programme therefore requires (a) Surveys of the chemistry and fauna and flora of the beach sands and rock encrusting fauna and flora on the beaches near outfalls and remote from them. (b) Surveys of important estuaries. The data would include information required for the impact area studies with, in addition, information on the sediments, and quantitative measurement of the fauna of the water and sediments. (c) Surveys of the near-shore water, plankton and sediments. To limit the amount of work it should be necessary to continue this work only at sites expected to be polluted from the impact area surveys. Current measurements should be included where possible. (d) As marine creatures such as oysters, mussels and limpets are capable of accumulating trace metals and organic pesticides it is especially necessary that such analyses are made of groups of these creatures during baseline surveys and these must be added to the list of data required for baseline coastal surveys.

Oceanic reference surveys

In order to determine any large scale effects of pollution on the environment, sampling must be done at some distance from local sources of pollution. There is a major fishing industry on the whole West coast and minor ones off the East and South coasts. The West coast is under the influence of the cold Benguela Current and is an area of extensive upwelling of deep nutrient rich water to the surface, the East coast is under the influence of the warm tropical Agulhas current and the South coast is in the relatively shallow, variable mixing area between the two current systems. Three oceanic transects (extending out from the coast) have therefore been established to represent extremes in the two oceans.

The East Coast oceanic reference transect is comprised of eight stations extending 100 km offshore on a line bearing about 128^{o}T off Cooper Light (Durban). The West Coast transect extends 100 km due west of Saldanha Bay, and the South Coast transect runs the same distance offshore due south of Cape Infanta.

Data required for this programme includes information on materials at present being discharged, the trace metals (with special reference to Hg, Cu, Cr), organic pesticides, oil and the normal physical and nutrient conditions on a regular seasonal basis (4 times per year) over a number of years.

DURBAN IMPACT AREA SURVEYS

The climate of Natal ranges from the tropical to sub-tropical in the east with temperate mountain ranges to the west. For the particular coastal region shown in Figure 1, the following annual averages apply :

Rainfall	87,4 mm
Temperature	19,9°C
Humidity	76 percent
Evaporation	1724,7 mm

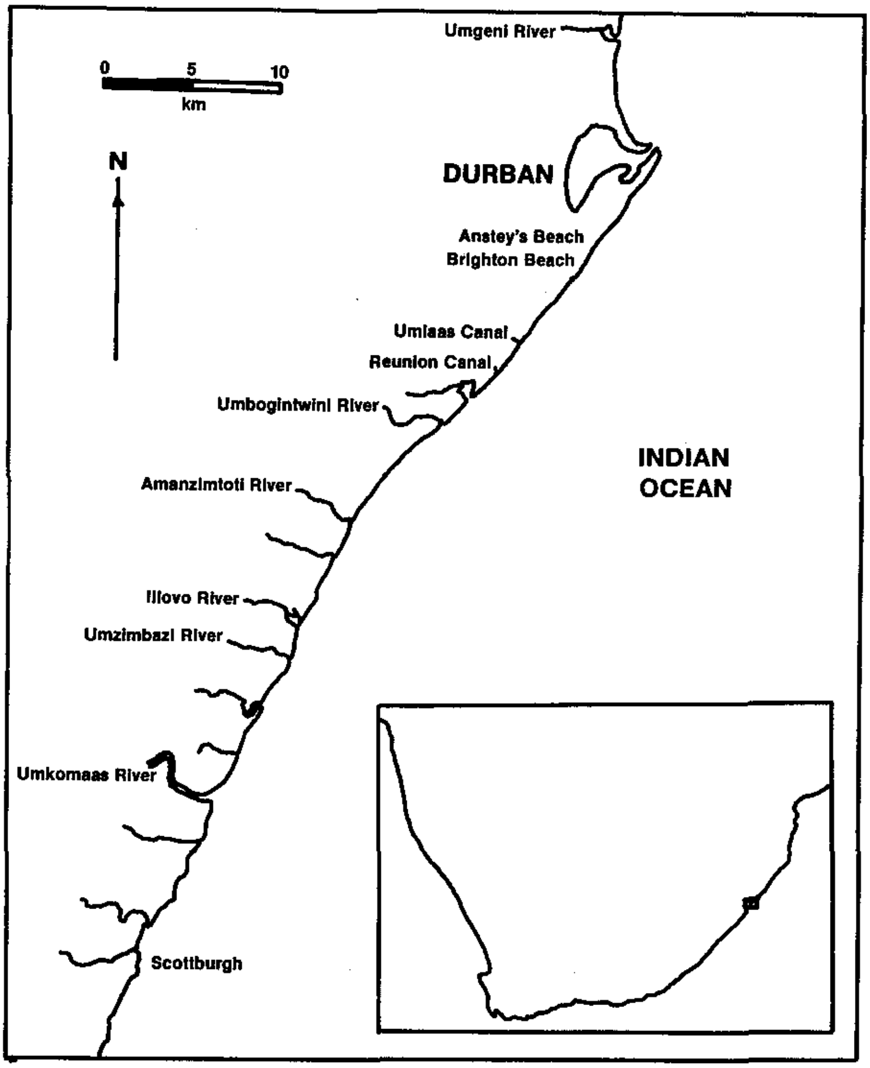

Figure 1. Natal coastline from the Umgeni River to Scottburgh.

Prevailing winds blow roughly parallel to the coast, alternately from the north-east and south-west, with almost equal frequency. In the sea, nearshore currents flow parallel to the coast and reverse direction every one to two and a half days; their average velocity is between 0,03 and 0,18 m/sec. Onshore currents occur 10 to 33 percent of the time. Wave height is normally one to two metres and wave approach is somewhat oblique about 50 percent of the time. Rip currents occur on about 40 percent of occasions; longshore currents flow about 10 percent of the time, their usual coefficient of diffusion being of the order of 5,57 m/min (Stander *et al* 1967).

Changes in the bacteriology of the Durban impact area 1964-1975

Durban, with a population of more than 800 000 people, is the principal port and also most popular holiday resort of South Africa. More cargo is handled in the Durban harbour than in all the other South African harbours combined. The main industries include two oil refineries, a large sugar terminal, chemicals, textiles, food-processing, footwear, tire-manufacture and printing and paper board.

A determined attack on sewerage- and waterborne-waste disposal problems has been initiated by certain Natal municipalities and industries. This has involved waste-water reclamation projects, increased industrial re-use of water, larger and more efficient treatment plants to keep pace with expansion and, most recently, two submarine pipelines to carry presently irretrievable water in the form of waste, far out to and under the sea thereby utilising the ocean for effective dilution and dispersal of pollution. Surveys were made of the changes in the bacteriology of the Durban impact area. The occurrence and distribution of coliforms and pathogenic indicators of pollution were used to formulate a bacteriological standard for classifying water qualities (Tables 1,2).

Table 1. Evaluation of indicators

Indicator	Degree	Value
E coli I per 100 ml	0 - 10	1
	11 - 100	2
	101 - 1 000	4
	> 1 000	8
Parasite units per 250 ml	1 - 7	4
	> 7	8
Coagulase and mannitol positive staphylococci per 50 ml	Present (+)	4
Salmonellas per 250 ml	Present (+)	4
Salmonella typhi per 250 ml*	Present (+)	4
Shigellas per 250 ml	Present (+)	4
Salinity, in ^{o}/oo	< 34^{o}/oo	4

* *S typhi* if present would therefore contribute a total value of 8, scoring 4 under salmonellas and 4 under *S typhi*.

This method of appraisal proved of value in monitoring changes in the water quality before (National Institute for Water Research 1968a; Livingstone *et al* 1968; Livingstone 1969) and after (National Institute for Water Research 1972a, 1974, 1975a; Livingstone 1976) the submarine outfalls became operational.

Table 2. A system of classifying sea-waters by indicator values

Indicator values	Class
1 - 4	I
5 - 8	II
9 - 16	III
> 16	IV

On the 22nd November, 1968, the submarine pipe at Umlaas was put into service; and one year later, on the 24th November 1969, the submarine outfall at the Bluff started to discharge - the complex of pipes at the harbour mouth which had ejected 80 Ml/d untreated sewage with every outgoing tide ceased to function on that date. Before the submarine pipeline became operational, the worst station was at the harbour mouth. Counts of *E coli* I/100 ml usually exceeded 5 million, whilst parasite ova, coagulase + mannitol + staphylococci and salmonellae were invariably recovered from its waters. Not infrequently *Salmonella typhi* was isolated (National Institute for Water Research 1968a, Livingstone *et al* 1968, Livingstone 1969). Along the rest of the coast more than a score of minor outfalls existed, the main rivers and canals were polluted, and of the other stations all except the two stations just south of the harbour mouth yielded salmonellae at least once. After the submarine pipes started to operate and the discharges ceased at the harbour mouth, there occurred a dramatic abrupt cessation of salmonellae isolation, a great fall in *E coli* I numbers, and staphylococci were rarely to be found at this station. The improvement effected favourably the neighbouring stations immediately to the north. Despite the year-long failure at the Central Works at the Bluff during which untreated sewage was pumped out to sea there was little or no effect on the surf stations.

By November 1971, all the surf stations from just south of the Umgeni river mouth to just north of the Fynnlands outfall reflected a Class I in water quality. This is a formidable achievement for a stretch of coast that includes an industrial port and several of the country's year-round most popular bathing and beach amenities.

The Umgeni river itself reflected little change, fluctuating between Class III and Class IV, although the frequency of isolation of salmonellae from its waters is beginning to show a downward trend (National Institute for Water Research 1974, 1975a).

A marked improvement was also found in the area south of the Fynnlands outfall. However, the terrain includes three bathing beaches (Anstey's Beach, Brighton Beach and Treasure Beach), the complex of canals at Umlaas, the Reunion canal and the Isipingo river. In this region the rate of improvement has not been as steady. At times, temporary deterioration in the water-quality have occurred and these have been attributed to breaks in minor sewers inland and upstream of canals. The Umlaas canal is also a significant contributor in times of heavy rains and flooding. Nevertheless, by November 1971, this section of the coast had attained Class I water quality at most locations and no worse than Class II for the remaining stations, under normal weather conditions, and this improvement has been steadily maintained (National Institute for Water Research 1974, 1975a).

To conclude, the overall picture is incontrovertibly one that shows a notable bacteriological improvement in the sea-water quality of the region. This improvement can be attributed to the treatment and diversion of the region's sewage via the submarine outfalls for discharge out to and under the sea, and to the closing down of the harbour outfalls and of the various pipes and drains on the beaches. All recognised bathing beaches now fall within Class I of the system of water-quality gradation. Where the surf water-quality does not attain a Class I gradation, this is compatible in *every instance* with the presence of sewer pipes, or drainage features (canals, rivers, effluent pipes) contaminated with sewage.

Pollution survey of the Durban area

To initiate the work under the monitoring programme on demarcation and classification of impact areas on the east coast, various drains, canals and outfalls in the vicinity of Durban have been examined during the first half of 1974 (Turner and Livingstone 1974). These were: the pipe which drains the Bluff bird sanctuary and ejects at Ansteys Beach, the Umlaas canal complex, the Reunion canal, the Isipingo river and the three Durban sewage outfalls - Bluff, Umlaas and Fynnlands. These last three were not, of course, sampled at the point of emergence but at the respective works which supply them. The Durban outfalls were analysed for total mercury only while all other samples were analysed for total mercury, copper, cadmium, lead, chromium, total nitrogen, oxygen absorbed from permanganate (OA), pH and dissolved oxygen (DO). In addition, various drains and streams which eject into Durban Harbour were examined for total nitrogen, OA, pH and DO as was the harbour itself.

The Umlaas and Reunion canals were highly polluted organically. This is particularly so for the Reunion canal which also had an unpleasant appearance aesthetically and requires investigation in much greater detail. All four of the samples from the harbour exhibited evidence of gross faecal pollution. However, in view of the absence of parasite ova and the paucity of salmonella isolations (only one instance from the Umbilo River), it may be reasonably inferred that such pollution occurs a considerable distance upstream of these sampling points.

The highest mercury level found along the shore was in the Bluff outfall sample at 0,88 ug/1 000 cm^3. Low levels were found in the Fynnlands outfall and the Bird Sanctuary drain samples. The other samples contained somewhat elevated levels ranging from 0,23 to 0,55 ug/1 000 cm^3 and probably deserve closer scrutiny. Copper, lead, cadmium and chromium results were satisfactorily low and probably typical of the normal drainage in this area.

Mercury analyses were carried out on samples from the Southern sewage works, effluent from an industrial operation on Maydon Wharf which discharges into the Maydon Channel, and the Maydon Channel itself. The

Southern sewage works sample contained 0,85 ug Hg/1 000 cm^3, a similar level to that reported previously (Turner 1974) and the industrial effluent 0,59 ug Hg/1 000 cm^3. Neither result is considered excessively high.

Four water samples were taken in the Maydon Channel, approximately equally spaced, from the yacht-mole to the fish jetty. These contained 0,126 to 0,159 ug Hg/1 000 cm^3 expressed as total mercury. Based on present evidence, these values are abnormally high and indicate the need for more detailed investigations.

Of all the species of fish analysed, only the perch *(Acanthopagrus berda)* showed promise as an indicator species for future work. A specimen, taken from the Umzimkulu Estuary, contained 0,207 mg Hg/Kg. The highest lateral muscle mercury result so far obtained in the survey is 0,211 mg Hg/Kg from a specimen of *Coracinus multifasciatus* - a marine reef fish.

Mercury analyses were carried out on specimens of *Panulirus homarus*, *Panulirus versicolor*, *Emerita austroafricana* and *Perna perna*. The exceptionally high levels found in *Panulirus homarus* from the Fynnlands outfall area confirm previous work. Specimens of *Emerita austroafricana* and *Panulirus homarus* were obtained from the Umbogintwini area, both of which contained relatively high levels of mercury - a not unusual result for this area. The *Emerita austroafricana* result was, however, satisfactory in that this and related species are widely distributed along the east coast of South Africa and they may be of use as alternate indicator organisms in places where *Panulirus homarus* is not readily available.

RICHARDS BAY IMPACT AREA SURVEYS

Richards Bay was first studied during 1969-1970 under the estuarine survey programme which the research group of the National Institute for Water Research in Durban undertook under the Natal Rivers Research Fellowships. The bay was at that time already earmarked for development as a major deep-water harbour, with the result that the project on this particular estuary naturally developed into a before and after study of the effects of the harbour developments on the Southern Bay Sanctuary area. During the initial study stations were scattered over the whole bay. Emphasis was on biological and chemical parameters, studies being made of the zoobenthos and zooplankton, the macrocrustaceans and fish species present, and the chemistry of muds and the bay water. During follow-up studies after construction of the berm wall, research was confined to the Southern Bay Conservation Area.

Pre-development survey of 1969 - 1970. (Hemens *et al* 1970)

Richards Bay lies approximately 190 km north of Durban by road and consists of a wide bay connected to the sea via a narrower channel as shown in Figure 2. The seaward channel and the main bay itself together cover an area of approximately 2 890 hectare. There are three fresh water discharges into the bay which cause the salinity in most of the bay to be below that of normal sea water. By far the largest freshwater volume discharges from the Umhlatuzi river through a delta mouth on the northwest shore of the bay. This river receives the Mfule and Enselini rivers as major tributaries and the combined mean annual run-off from the Umhlatuzi and Enselini catchments has been estimated as 5 356 x $10^8 m^3$. The remaining freshwater inflow is from the Mzingazi river which drains the Lake Mzingazi and the Mthantathweni river draining Lake Icubhu. Both are freshwater lakes lying respectively north and south of Richards Bay and the contribution of each is of the order of 3,7 x $10^6 m^3$ per annum.

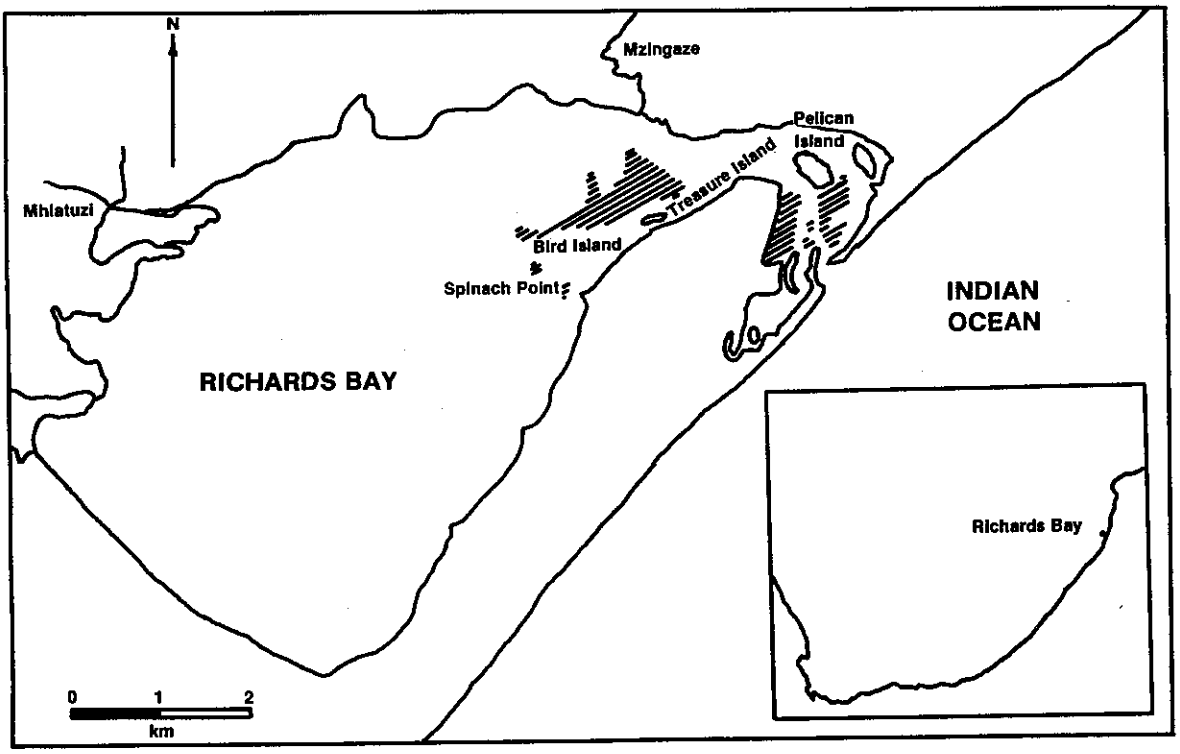

Figure 2. Richards Bay before development.

At present (1970) Richards Bay is the last remaining large estuary on the Natal coast that is little affected by human activities. It is a popular holiday resort for aquatic recreation, particularly boating and angling, and supports a large and varied population of water birds, fish and aquatic invertebrates, particularly prawns. It acts as a nursery area for the early stages of several species of marine fish and a feeding area for adults. The bay itself and the land on the perimeter of the bay is either State Land or Native Trust Land, control of some of which is vested in the Natal Parks Board, and the whole area is controlled as a wild life sanctuary.

Richards Bay has been developed as a major industrial harbour complex and, in consequence, changes in the bay environment must inevitably result.

Although quantitative study of the free-swimming species diversity and abundance is in an early stage and only the northern shore has been examined in any detail, the indications are that the river borne sediments deposited in the Umhlatuzi delta area provide conditions favoured by penaeid prawns and juvenile fish of several species and that their density is generally greater in this area than anywhere else in the bay. There is evidence of industrial pollution in this area in the form of layers of fibrous material, probably derived from sugar cane and wood processing activities up stream. However, under normal conditions this pollution does not appear to be harmful and may, in fact, contribute to the fertility of the area. Nevertheless, disturbance of the deep anaerobic organic sediment in this area, much of which appears to contain fibrous material, could result in general mortality among the local population.

Examination of the water and sediments so far carried out indicate that, although unpolluted to any significant extent by industrial or agricultural activities in the catchment of the Umhlatuzi river, the water and sediments are considerably more fertile in terms of nutrient content than are those of the open sea. Much of the nutrient content of the bay must have been derived from the catchment of the Umhlatuzi and it seems that the bay acts as a "nutrient trap". Mineral nutrients, such as nitrogen and phosphe-rous, that enter the bay in solution are incorporated into the production of new living material by photosynthesis. This solid material tends to be retained within the bay in various ways, and a reduced amount of nutrients is eventually discharged to the sea. This nutrient trapping effect is frequently observed in inland lakes through which streams flow and, due to constricting effect of the narrow mouth, an analogous situation appears to exist in Richards Bay in which photosynthetic activity has been shown to occur. There is also some evidence that biological activity in the extensive mangrove shorelines may contribute to the general nutrient level in the bay, particularly as regards nitrogen. This element can be fixed from atmospheric nitrogen by blue-green algae and several species that are active in the nutrient cycle of mangrove fish culture ponds in Java are listed by Schuster (1952). There seems no reason why similar species should not be active in mangrove areas on the African coast.

The unusual uniformity in the physical and chemical characteristics of the sediments covering the bottom of the main bay can only be due to the dispersive effects of wind-induced turbulence in this part of the bay for a large part of the year. This is a factor which may require con-sideration when dredging of a deep shipping channel is undertaken.

Continuation of pre-development survey : June - November 1970. (Hemens *et al* 1971a)

The southern area of the bay provides a more stable environment than the northern and eastern bay mouth areas which are subject to tidal effects. In the southern bay the sediments are usually homogeneous consisting almost entirely of fine silt and clay and are not less than 5 m deep. These sediments are not influenced by tidal currents and no significant changes in composition have been detected during the study and seem unlikely to occur, except, perhaps, under exceptional flood conditions in the Umhlatuzi catchment. During extended periods of low rainfall the water of the southern bay gradually reaches seawater salinity but the salinity is reduced after rainfall in the river catchment over a period of a few days. The whole area supports a permanent population of bottom-living molluscs and crustacea with largely sedentary habits and is ranged by mobile species such as the prawns and various fish species. Planktonic photosynthesis in the area is continuous throughout the year, reaching a maximum in summer, and it is considered that most of the plankton is utilized by other animals after it has sunk to the bottom, since there appear to be few if any suspended plankton feeders in the bay. Evidence for the incorporation of photosynthetic productivity into the trophic structure of estuaries in this way is increasing and is becoming generally accepted. This phenomenon would be in agreement with the generally high nutrient levels found in the bottom muds and accounts for the function of the bay as a nutrient trap.

Although the mangrove and shoreline marsh areas are undoubtedly important in providing grazing for herbivorous forms and shelter for smaller species and juveniles of larger species it does not seem that the mangrove areas contribute significantly to the nutrient levels in the bay. Future changes in tidal range in this part of the bay can be expected to alter the present configuration of the mangrove and marsh areas.

It is now clear that the *Zostera* beds do not exist south of the line Spinach Point - Umhlatuzi delta. These areas are particularly productive feeding areas and adults and juveniles of many invertebrate and fish species are concentrated in the *Zostera* during the warmer months from August to April. The consequences of destruction of these *Zostera* beds during harbour construction on the structure of the bay faunal community is difficult to predict but cannot be other than adverse unless development of similar *Zostera* growth can be encouraged in the southern part of the bay.

There is evidence that Richards Bay has an important function in the maintenance of certain fish and invertebrate populations along the Natal coast.

The Southern Bay conservation area before dredging of the new mouth to the Southern Bay

In November 1974 the northern section of Richards Bay was being developed into a modern port, while the southern bay, receiving the waters of the Mhlatuzi river, was being isolated by a berm wall across the width of the day, and a new opening to the sea was being constructed, cutting through the coastal sand dunes (Figure 3).

A survey was carried out in the last week of October 1974 and the second week of November 1974 (Hemens and Connell 1975).

Salinities were high in the bay, due to an unusually low flow in the Mhlatuzi river for that time of the year. Water temperatures were quite high but were comparable to those previously recorded in November 1970 and pH values were similar (Hemens *et al* 1971a).

The bay water concentration of both nitrogen and phosphorus were higher than the values previously recorded for the undisturbed conditions in August and November 1970. The sediment phosphorus concentration at comparable locations were also higher than before but the nitrogen in the sediment was the same or slightly lower. It is suggested that these changes have been caused by the distribution of anaerobic silt dredged from several metres below the mud surface and sprayed into the bay water for removal by tidal action. At sample locations comparable with data obtained in 1970 the general pattern of the other water and sediment parameters remained unchanged, except where changes in particle size distribution made it obvious that dredging operations had changed the

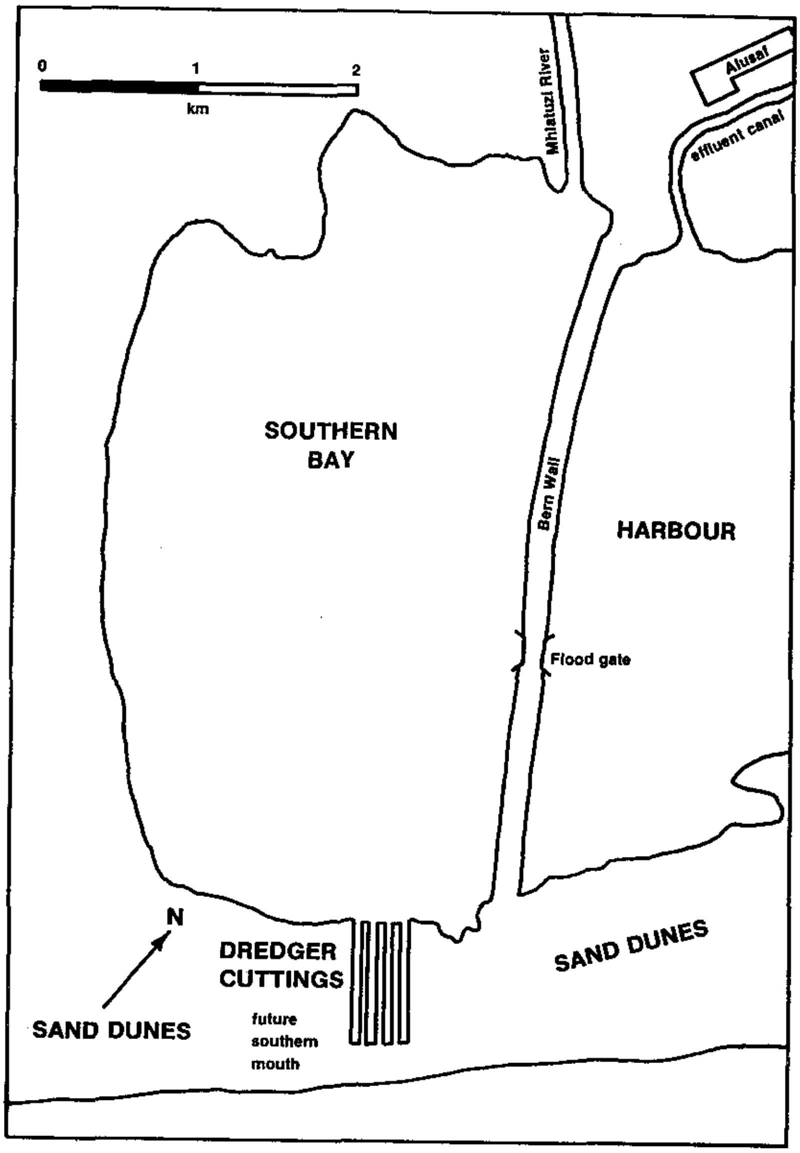

Figure 3. Richards Bay, November 1974.

character of the bottom by addition of silt or sand. The concentration of Kjeldahl nitrogen in suspended material in the water was high, approaching 6 000 ug N/l in places.

The bacteriological picture of a transect of the Southern Sanctuary suggested that these waters were comparatively unpolluted by sewage. Some evidence of moderate pollution was found, but the pollution was neither widespread throughout the bay waters, nor of serious proportions.

Analysis of both species and numbers of the benthic fauna showed the results generally comparable with those reported previously, the only difference being that a small unidentified species of sipunculid worm was found in relative abundance at two stations.

In comparison with the Umzimkulu estuary, the zooplankton of Richards Bay is rich, with a far greater biomass. Detritus in the Umzimkulu samples made settled volumes determinations impossible, but counts of the animals yielded total numbers of around 2 000 per sample compared to 22 000 to 82 000 in the samples from Richards Bay.

Analyses of some of the sediment samples, fish and prawn for chlorinated hydrocarbon residues showed that small quantities of DDT and dieldrin had occurred in all fish samples. Virtually none of the most common chlorinated pesticides (DDT, DDE, dieldrin, lindane, aldrin, etc) were detected in the prawns or sediments.

In the water, mercury concentrations ranged from 0,010 to 0,378 ug/l; copper from 0,25 to 3,08 ug/l; cadmium from < 0,001 to 0,025 ug/l and lead from 0,53 to 3,94 ug/l. In the sediments, mercury concentrations ranged from 0,017 to 0,029 ug/gm; copper from 8,3 to 12,0 ug/gm; cadmium from 0,46 to 0,76 ug/gm; lead from 20 to 32 ug/gm; zinc from 66 to 175 ug/gm and iron from 19,02 to 28,9 ug/gm (on a dry weight basis). Most of these results are well in line with what had been measured in other Natal estuaries.

Mercury concentrations in biological materials were also well within the range of concentrations found in uncontaminated areas. The high level of lead found in the crustaceans, however, were a serious feature. All other results appeared to be within the expected range of normal concentrations for biological materials.

CAPE PENINSULA IMPACT AREAS

Due to the large number of impact areas in the vicinity of Cape Town, it was decided initially to confine activities to the Cape Peninsula and surroundings (Fricke *et al* 1975). Five sites, viz Salt River Mouth, Camps Bay, Dido Valley Beach, Zandvlei and Strandfontein were investigated during the course of 1975 (nos 1 - 5 respectively on Figure 4). As no beach reference areas in the Cape have been suveyed at this stage, the baseline figures used for comparison are those considered as being normal for Natal beaches (Oliff *et al* 1967a, 1967b). The results of the Zandvlei investigation have not yet been finalised.

Salt River Mouth

The Salt River represents the final discharge of a number of tributaries, viz Liesbeeck, Black, Vygieskraal and Elsieskraal Rivers, which converge further upstream. The river system is essentially located in the flats of the Cape Peninsula and drains some hundreds of square kilometers of the densely populated northern suburbs and Cape Flats. Along its course, the Salt River, as we shall call the ultimate stream, flows through the Paarden Eiland industrial area and enters the sea just north of Table Bay Harbour. In its totality, the Salt River and its tributary system may be considered polluted since the river carries over its short course large amounts of organic and inorganic wastes from industrial and residential sites (Banks 1971; Scarfe 1972). To date little has been done towards a thorough

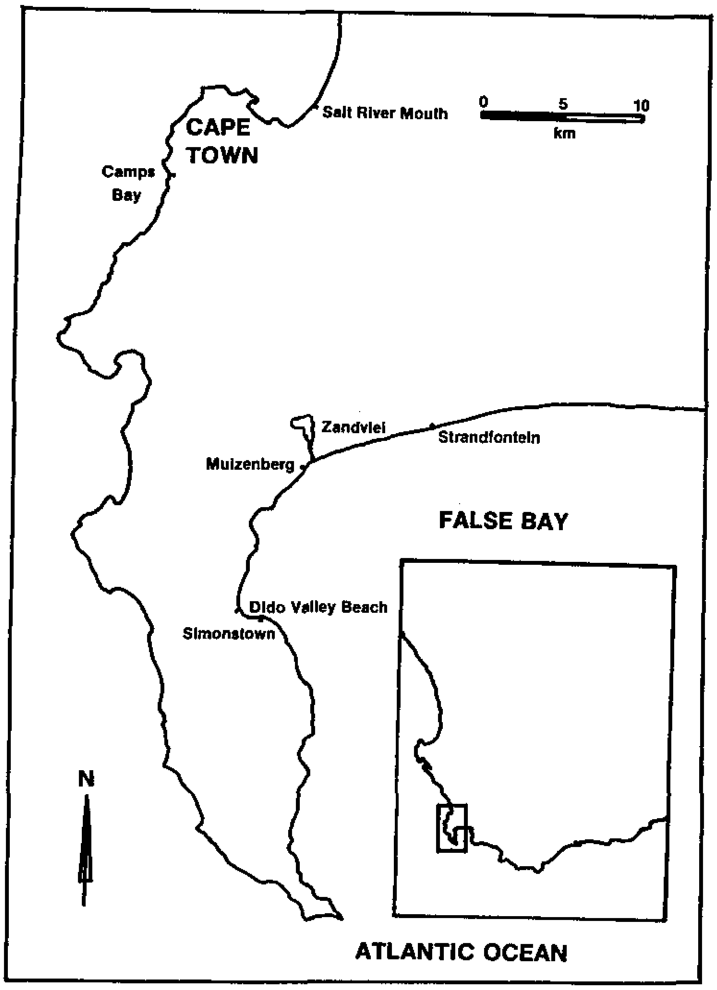

Figure 4. Impact sites on the Cape Peninsula investigated during 1975.

study of the river system. The Cape Town Municipality is planning that such work be done in the near future. Seasonal fluctuations occur, depending on the rainfall as well as the nature and volume of discharged effluent. The plume of the river can generally be clearly seen and flows northwards along the coast for a few hundred metres and then moves offshore. Salinity measurements showed that the plume was noticeable 500 m north of the mouth, the salinity being less than 34% at this point. Nutrient concentrations were high in the mouth but tended to drop off with distance from the mouth. OA values were high, values of up to 0,03 mg/g for water (thirty times higher than normal) and 0,25 mg/g for sediments (four times higher than normal) were obtained. Dissolved oxygen content of water was low, interstitial water having only one-tenth normal concentration at some points. Mercury levels in sediments were low and can be considered normal.

Although a polluted site, the faunal content of beach samples is nevertheless richer than those taken on apparently clean beaches. The fineness of the beach sediment near the river mouth, when compared with that, say, at Camps Bay, may be an underlying cause. Two suction samples were obtained with the apparatus modified by Christie and Allen (1972) just outside the surf zone 100 m on either side of the river mouth, at a depth of 6 m, and a distance from shore of approximately 150 m. The noticeable difference between the two samples in numbers of animals collected and species distribution may be caused by the fact that the discharge plume of the river turns north sharply at the mouth only to veer offshore some hundreds of meters along the beach. The spionid polychaete *Prionospio sexaculata* which is tolerant of low O_2 conditions is noticeably absent.

Bacteriological measurements indicate that although the Black River carries an extremely high bacterial load, the presumptive *E coli* organisms die off rapidly in a salt environment. This would support the view that coliforms do not present any threat in the marine environment due to their low salt tolerance. However, a count of 200 presumptive *E coli* bacteria/100 ml indicated substantial sewage pollution with its attendant dangers.

Dido Valley Beach, Simons Bay

This beach in Simons Bay represents an impact area since an oil refinery (an edible oil hydrogenation plant) discharges an apparently insignificant volume of effluent into the sea via an open rivulet. The beach is approximately 400 m long and the outfall enters the sea about 270 m from the southern end of the beach.

OA and nutrient values of both water and sediments showed dramatic increases in the river mouth, OA of water being nearly 40 times normal, and of sediment being more than 10 times normal. Phosphate and silicate concentrations in the outfall were 8 and 90 ug atoms/l respectively, and the dissolved oxygen content of the water showed a corresponding decrease to below 2 ml/l. Mercury levels in the sediments were not unduly high, being below 12 ng/g at all parts.

Since the faunal content of the sediments along this beach is very poor, quantitative samples were taken (0,1 m^2) from scattered rock outcrops along the stretch of the beach on both sides of the factory outfall during low tide. It appears that proximity to the discharge rivulet causes a diminution in the total number of individuals (all Polychaete species) as well as in the ash-free dry mass of all individuals per station. The number of Polychaete species shows a similar, though less pronounced, response to the source of pollution. Bacteriological measurements (Orren 1975) indicated a total coliform count in the order of 10^3 - 10^5 organisms per 100 ml and a presumptive coliform count of about 4 to 120 organisms per 100 ml. Differential counts showed no *E coli* I.

Camps Bay

The beach at Camps Bay is just over 500 m long, running approximately north-south. This survey was planned in order to obtain background levels before the sewage discharge pipe, at present under construction in the middle of the beach comes into operation. It appears that the new outfall has been well sited. The mouth of the outfall is at a depth of approximately 23 m and the terrain near the outfall is relatively barren. It is scoured by an appreciable current which apparently flows parallel to the coast.

Camps Bay has been found to be the least polluted beach sampled in the Cape Peninsula and surroundings. Levels of all parameters measured compared favourably with those considered normal for Natal beaches. As macrofaunal sampling at 100 m intervals did not yield any organisms at all, 0,1 m^2 rock scrapes were performed at the southern flank of the beach. The identification of the specimens collected is under way.

Strandfontein, False Bay

Strandfontein is part of a long stretch of beach running approximately east-west along the northern coast of False Bay. Zeekoeivlei discharges into the sea along this stretch of beach. The sewage works at Strandfontein has been undergoing extensive development since 1960 and it now consists of a chain of 27 shallow pans covering an area of about 800 ha. Fresh sewage enters at the northern end of the works and decomposed sewage flows into False Bay via the Zeekoeivlei outlet. Sampling was conducted in the outfall and then eastwards along the beach, this being the direction in which the plume appeared to be carried.

Salinity measurements showed that the plume was noticeable as far as 600 m from the mouth, salinity being 33,3^{o}/oo at this point. OA values decreased with distance from the mouth, but even at 600 m the value was ten times normal level. Dissolved oxygen concentration was low in the outfall, but increased to normal levels 200 m from the mouth. Nutrient levels were high in the mouth, but tended to decrease with distance away. Mercury levels in the sediments were low at all points.

A rough analysis of the organisms obtained in seven equally spread bucket samples has been made. The overall picture presented is one of increased numerical abundance of polychaete worms and copepods with distance away from the vlei discharge stream. Ciliates on the other hand are obviously intolerant of marine salinity conditions. The modal distribution of Nemertines in terms of numbers is puzzling.

Bacteriological sampling at False Bay

During 1974, bacteriological samples were collected at the following sites (Orren 1975) : (a) Municipal sewage outflow (Strandfontein) (b) Muizenberg Beach to the east of the lifesavers' hut (c) Zandvlei outfall (d) Marine Oil Refinery, Simonstown (e) Boulders Beach, on an exposed, well-fulshed outcrop.

The provisional results are set out in Table 3. Differential counts gave the results in Table 4.

As a guide to interpretation, potable water standards (Department of Health and SABS) require that not more than 10 presumptive coliform organisms be present in 100 ml water, and that no *E coli* I is present at all (Department of Health) or that no *E coli* I is present in two consecutive samples (SABS).

Table 3. Provisional results of bacteriological sampling at various sites in False Bay

Station	Total Coliform count		Presumptive Coliform count	
	October	November	October	November
a	$20 - 36 \times 10^3$	$1,8 - 24 \times 10^2$	$22 - 120 \times 10^2$	$40 - 20 \times 10^2$
b	Nil	12	Nil	4 - 20
c	24	34 - 100	Nil	6
d	$3 - 4 \times 10^3$	$8,2 - 14 \times 10^4$	70 - 100	6 - 120
e	Nil	18	Nil	4 - 20

Note (1) Stations a to e as listed above
(2) All counts expressed as organisms per 100 ml

Table 4. Differentiated *E coli* counts, October 1974

Station	*E coli* I/100 ml	*E coli* II/100 ml	*E coli* VI/100 ml
a	$19 - 104 \times 10^2$	-	$3 - 16 \times 10^2$
e	-	28 - 40	42 - 60

Note (1) *E coli* type I - faecal origin
(2) *E coli* Irregular II - doubtful habitat
(3) *E coli* Irregular VI - usually non-faecal origin

SALDANHA BAY IMPACT AREA SURVEY

Saldanha Bay, situated on the west coast of the Republic some 100 km north of Cape Town is the only large natural harbour on the west coast of South Africa (Figure 5). The Langebaan Lagoon, which forms part of the Bay, is a shallow tidal body of water of spectacular scenic beauty. The southern part of the Lagoon is characterised by salt marshes, and is ecologically unique in South Africa.

Saldanha Bay is a fishing harbour and as such has been subjected to a fair amount of organic pollution, emanating from the various fish-processing factories which are situated in the Hoedjies Bay area. Various ad hoc surveys were made prior to April 1974 in connection with this pollution, and improvements in off-loading and processing techniques implemented by the factories during 1974 have resulted in a marked improvement of the water quality in Hoedjies Bay (Shannon 1975).

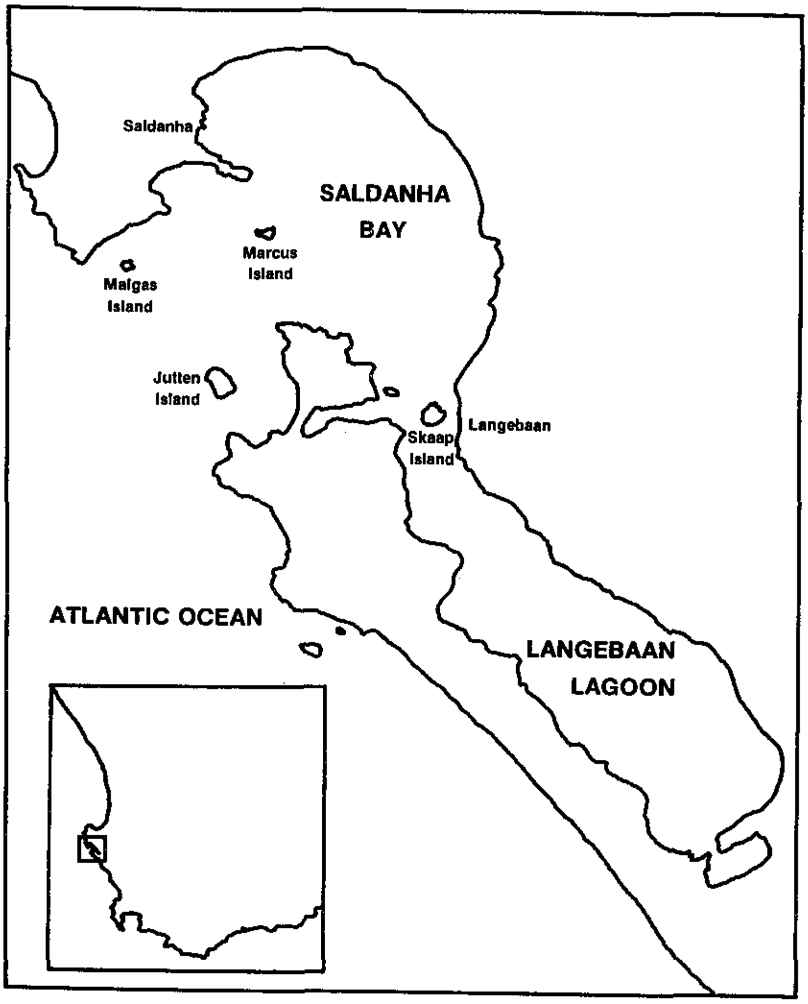

Figure 5. Saldanha Bay and Langebaan Lagoon.

In April 1974 a detailed survey of the physical and chemical characteristics of the water in Saldanha Bay and Langebaan Lagoon was commenced to establish baseline conditions in the region prior to the development of the Bay as a major port and industrial centre (Shannon and Stander 1976).

The thermohaline characteristics of the water resemble those of the Benguela current, although in summer surface heating and evaporation tend to raise the temperature and salinity somewhat. This is most marked in the Langebaan Lagoon where surface temperatures and salinities in excess of $24^{o}C$ and $37^{o}/oo$ have been recorded during the latter part of summer. A variety of chemical parameters have been measured. These include a number of heavy and transition elements, dissolved oxygen, nitrate/nitrite, Kjeldahl nitrogen, inorganic phosphorous, total phosphorous, reactive silica, pH, chlorophylls, chemical oxygen demand and oxygen absorbed. Available data indicate that the Bay is at present relatively unpolluted.

The circulation pattern in Saldanha Bay is complex. The Bay and Lagoon are tidal and currents in the upper 5 m are highly dependent on wind speed and direction. Surface currents in the region have a magnitude typically in the range 10 - 20 cm/sec. Currents in the mouth of the Bay are tidal and are not appreciably influenced by wind. Tidal currents of up to

1 m/sec have been recorded at the entrance to Langebaan Lagoon. The construction of the jetty and breakwater is altering the circulation pattern.

The dissolved oxygen content of the water in the Bay and Lagoon showed variations typical of a highly productive West Coast type environment. The typical range of surface oxygen values in Saldanha Bay/Langebaan Lagoon was 4 - 8 ml/l, the average being about 6 ml/l.

The pH of Saldanha Bay water was generally high, values in excess of 8,4 being recorded on a number of occasions. The implications of the high pH values should be kept in mind should ammonia pollution in the Bay take place at some future date (the toxicity of ammonia is highly dependent on pH and at a high pH can become lethal).

The mean concentrations of the nutrients, viz nitrate, inorganic phosphorous, total phosphorous and reactive silica during the period under discussion in the upper 10 m layer were 7,5, 1,4, 2,0 and 19,2 mg at/m^3 respectively. The mean level of total chlorophyll in the surface water was 11,5 mg/m^3. The chlorophyll concentrations in the Langebaan Lagoon were significantly lower than in Bay water, averaging about 6,3 mg/m^3. More details about the chlorophyll distribution are given by Henry *et al* (1976).

The mean values of COD and OA in the upper 10 m layer were 8,1 and 1,6 mg/l respectively. These can be considered as base-line values for the area, and any future discharge of organic or other oxygen demanding effluents into the Bay should be viewed in the light of the above (and the nutrient) data.

The physical and chemical data indicate the existence of three systems viz Bay System, Lagoon System and Benguela System. The interchange between the Bay and the open sea is small and on the basis of a simple model the removal time of pollutants from the Bay has been calculated as 20 days. The available data indicate that the discharge of noxious and toxic effluents into the Bay should be discouraged. The beach near the residential area of Saldanha Bay and the Donkergat Peninsula will probably be polluted on occasions once the harbour comes into operation, and it is not impossible that the Langebaan Lagoon will also become polluted.

Results given by Fourie (1976) and Watling and Watling (1974, 1975) indicate that the levels of metals in marine organisms from Saldanha Bay and Langebaan Lagoon, prior to harbour development and industrialization, are consistent with an unpolluted environment.

The oysters *C gigas* and *C margaritacea* have proved to be most suitable for use as indicator species and accordingly will be used as such to monitor pollution during the development and industrialization of Saldanha.

Although it is generally accepted that mussels do not accumulate metals to the same extent as oysters, *Choromytilus meridionalis* could be very useful as a test organism and, because of its abundance, will be used as such for future studies.

COASTAL REFERENCE SURVEYS

Impact area studies between Durban Bay and Isipingo revealed two locations which warranted further investigation and characterization. These were the beaches at Umbogintwini and around the Fynnlands sewage outfall, where beach transects were conducted in July, 1974.

The research group of the National Institute for Water Research in Durban has been involved in estuarine surveys since 1969. Initially research was conducted under the Natal Rivers Research Fellowships, with the object of characterising the estuaries, particularly on the South Coast of Natal, in terms of biological communities, water quality (chemical and bacteriological) and recreational potential. Six estuaries were studied; these were Kosi Bay and the Umlalazi, Amatikulu, Umgeni, Ifafa and Umtamvuna estuaries.

The Ifafa estuary became another focal point of research with the construction of a marina on the south bank of the estuary. After the initial survey mentioned above, the study was expanded to monitor the eutrophying effects of the planned release of effluents, from a proprietary sewage treatment plant on the marina site, into the estuary.

During 1974 estuarine research emphasis changed slightly with the launching of the National Marine Pollution Survey. The importance of estuaries as routes for the entry into the sea of heavy metals and insecticides from industry and farming, led to the search in estuaries for these contaminants, in muds and waters, and at various levels of the estuarine food web. Two estuaries were surveyed in this way, namely the Umzimkulu and Richards Bay.

The Umbogintwini Transect

The oxygen absorbed and Kjeldahl nitrogen values indicate normal levels of easily oxidizable and nitrogenous material according to the values established by Oliff *et al* (1967a) as typical for Natal sandy beaches. The faunal analyses indicate the likely presence of a toxic factor in the environment. The two lower transect stations yielded a complete absence of an interstitial fauna and the upper two yielded a very limited fauna.

An improvement in total numbers and diversity was evident 100 metres north and south of the transect line indicating that the effect is not very widespread. Although it is possible under normal conditions to have a low interstitial faunal count (Oliff *et al* 1967a) the consistently low figures strongly indicate toxic conditions.

The Umbogintwini results reflect very high concentrations of ammonia and nitrate and also, abnormally high pH values. A combination of these factors may well be responsible for the toxic conditions detected by the faunal analyses. Ammonia, in particular, is known to increase markedly in toxicity above a pH of about 8,2 and the sample taken 1,0 metre above the chart datum line contained 1 550 ug NH_3 - N/1 000 cm^3 at pH 8,81. Samples of the Natal Crayfish *Panulirus homarus* and the sand louse *Emerita austroafricana* contained abnormally high levels of mercury.

The Fynnlands Sewage Outfall Transect

There is ample evidence in the faunal analyses to indicate a considerable degree of organic pollution. The two lower transect stations yielded faunal count well in excess of the levels suggested by Oliff *et al* (1967a) as being normal for unenriched conditions. This effect decreases with height above low water springs. Samples taken 100 metres either side of the transect indicate that the effect is not very widespread.

Chemical analysis of interstitial water samples showed no exceptional values of any parameters even though the surf-water results indicated a fairly high load on the beach. However, toxic conditions were not indicated by the faunal analyses. Analysis of the Natal Crayfish showed that it contained abnormally high levels of mercury and indicate the need for a more detailed investigation.

Kosi Bay

The Kosi system of estuarine lakes lies on the Tongaland coastal plain on the north eastern border of Natal and consists of a series of five lakes connected by channels. The whole system from Lake Manzamnyama in the south to the mouth of the tidal basin in the north extends over a distance of approximately 16 km and is separated from the Indian Ocean by a ridge of forested sand dunes rising to 100 m in places (Figure 6). The system is normally open to the sea and some tidal movement reaches as far as Lake Hlange but closure of the mouth can occur, as was the case from August, 1965 to January, 1966. The area is entirely undeveloped and is unique among Natal estuaries in that its waters are normally clear and blue and reach a depth of 30 m in places.

Due to the relative inaccessibility of the area technical publications on the system are not numerous but several have appeared during the last twenty years, notably by Broekhuysen and Taylor (1959) and Campbell and Allanson (1952) on the biology of the lakes, particularly the fishes, Breen and Hill (1969) on the mangrove community, Hill (1969) on the bathymetry and possible origin of the lake system and Allanson and van Wyk (1969) on some aspects of the physics and chemistry of Lakes Sifungwe and Hlange.

A survey of certain aspects of the chemistry of the waters and sediments, of the invertebrate fauna of the bottom sediments and marginal vegetation and of the rate of photosynthetic primary production in the lakes and the associated planktonic organisms was carried out in August 1971 (Hemens *et al* 1972a). The Kosi system can be conveniently divided into three main ecological regions based on the chemistry and biology of the water and sediment.

The first of these regions comprises the tidal basin from the mouth to the lower end of the channel to Mpungwini but excluding the Kukulwe creek. This area is typified by clear water of mainly marine origin with mixed marine and estuarine plankton populations. The primary productivity is in the same range as coastal marine water. The region experiences considerable tidal rise and fall and the bottom harbours a rather sparse population of mainly marine benthos in sand containing comparatively low concentrations of organic material and mineral nutrients.

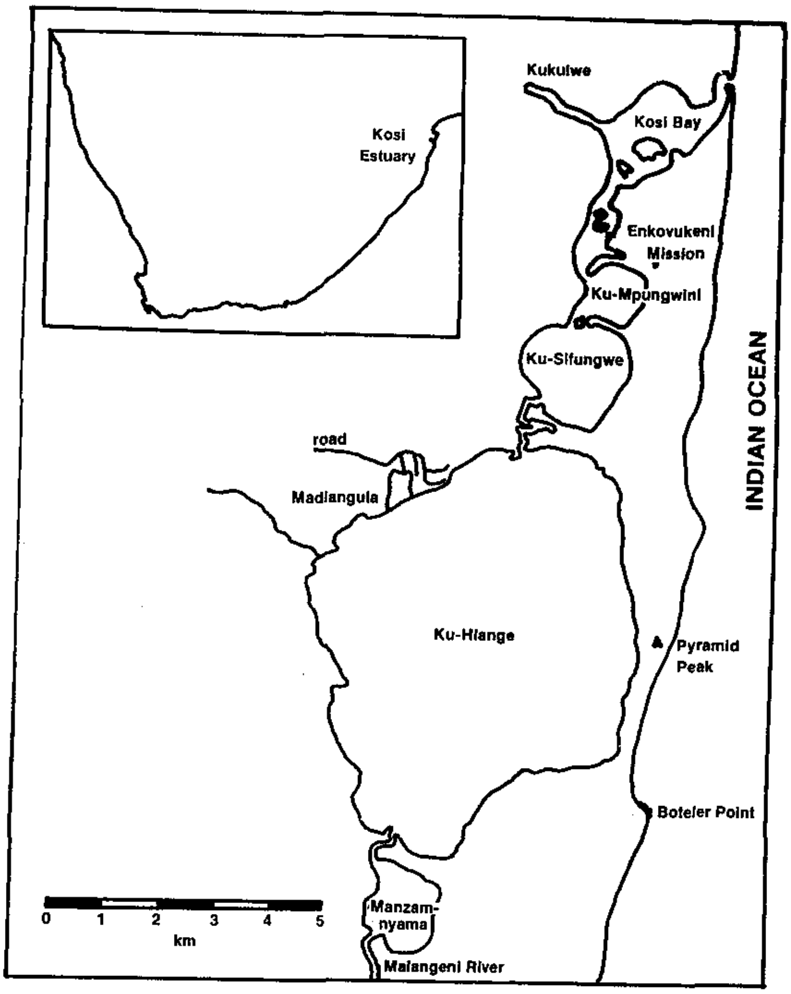

Figure 6. The Kosi Bay estuarine lakes.

The second region is the largest of the three and covers the area where the salinity changes from near that of seawater in the north to nearly freshwater conditions in the south with the channels between the lakes acting as barriers and causing stepwise changes in salinity between Mpungwini and Hlange.

The remaining region is the smallest of the three and is represented by the freshwater environment of Manzamnyama and the Malangeni river. Here conditions are typical of a moderately eutrophic freshwater lake and a slow flowing river, although it seems probable that the amount of organic detritus on the river bed was greater than during the wetter months of the year.

In terms of biological production the second region comprising the area between the channel below Mpungwini to the southern end of Hlange is the most important. The water in this region has a higher concentration of mineral nutrients such as nitrogen and silica than elsewhere in the system, the former being partially derived from decomposition of organic material accumulated in the deeper parts of the lakes.

At the time of the survey plankton primary production rates in the surface waters were in the region of 60 mg C/m^3/day mainly due to the activity of a species of *Microcystis*. Production at this rate, while higher than the average for coastal waters, is not as high as rates of 100 mg C/m^3/day or more than have been measured in Richards Bay. Whether this rate is maintained at all seasons is not known but the fact that detritus feeders are predominant in the sand bottom areas which constitute the major area of the lake floors and the fact that these sand bottoms are not very rich in nutrients, containing not more than 300 ug/g dry wt of nitrogen compared to 1 000 - 2 000 ug in silt bottomed estuaries such as Richards Bay, tends to suggest that these detritus feeders are dependent upon continuous fall-out of planktonic material for their nutrition. On this basis the lakes could be classified as moderately eutrophic with some primary production at all seasons.

A further indication that the system is moderately eutrophic lies in the fact that the fauna tends to consist of a relatively small number of species some of which are present in very large numbers. This tendency toward low species diversity with high species abundance is typical of eutrophic conditions and becomes more marked with increasing degrees of eutrophication. On this basis the fauna indicates that the degree of eutrophication of the system is not very great.

The occurrence of deeper water on the eastern sides of Lakes Mpungwini, Sifungwe and Hlange appears to have an important effect in the retention of mineral nutrients within the system since these deeper areas are separated to varying extents from the course of main water movement and are not subject to strong flushing action under normal conditions.

It seems probable that some of the nutrients entering the system from the catchment are incorporated into biological production and eventually accumulate in the deeper areas in the form of dead plankton etc, together with other organic debris that may enter the system and eventually gravitate to the bottom. Subsequent decomposition of this material provides a source of soluble nutrients that can either slowly diffuse upward into the overlying water as apparently is the case in Sifungwe or can be mixed with the overlying water by upwelling and turn-over of the lake under wind action as appears to have been the case in the larger Lake Hlange at the time of the survey. Much of the nutrient material will thus be recycled many times and nutrient gains by the system must exceed the losses if a steady increase in nutrients in the system is to occur over the years. Since there are no abnormal nutrient additions to the system in the form of sewage or industrial wastes and the present nutrient level is still relatively low it is concluded that natural eutrophication of the Kosi system is a slow process.

The recycling of nitrogen derived from organic material accumulating in the lakes appears to be strongly assisted by anaerobic reduction of organic nitrogen to soluble ammonia nitrogen in the anoxic layers of the deep water bottom sediment. It is suggested that this is the reason for the higher proportion of the total nitrogen that is present as ammonia nitrogen in the Kosi system compared to shallow estuaries such as Richards Bay where anoxic zones are not encountered.

There seems little doubt that a substantial amount of oxidizable material accumulates in the deeper areas which is sufficient to cause complete oxygen depletion in the deeper areas at times, particularly in Lake

Sifungwe. The phenomenon must considerably reduce the area of lake bottom that is able to support a permanent bottom fauna.

The Kosi lake system appears to be in an early stage of eutrophication and its biological productivity may be limited by a shortage of phosphorus. If development of the area is undertaken it should be borne in mind that any activity that will increase the concentration of plant nutrients in the water, such as sewage discharge, factory wastes, agricultural fertilizers etc, could increase the capacity of the system to support algal blooms and so destroy the present aesthetic charm of its unique clear blue water.

The Umlalazi Estuary

The Umlalazi river rises near Eshowe and receives a number of small streams as it passes along the eastern side of the Ngoya ridge. As it leaves the hill country it is joined by the Umkukuze river as its main tributary and flows across the coastal plain to discharge to the sea through a permanently open mouth near the village of Umtunzini. The Umlalazi is about 40 km in length and drains a catchment of approximately 415 km^2. Most of the upper catchment crosses rocks of the Table Mountain series and Archaean Granites while the lower catchment lies on strata of the Ecca series and on the unconsolidated crescent Miocene Beds of Zululand. The average annual rainfall over the catchment varies between 1 016 to 1 270 mm in the south and 1 270 to 1 524 mm in the north and west along the Ngoya ridge.

The estuarine reach of the river is approximately 11,5 km long, reaching upstream to the National Road Bridge (Figure 7).

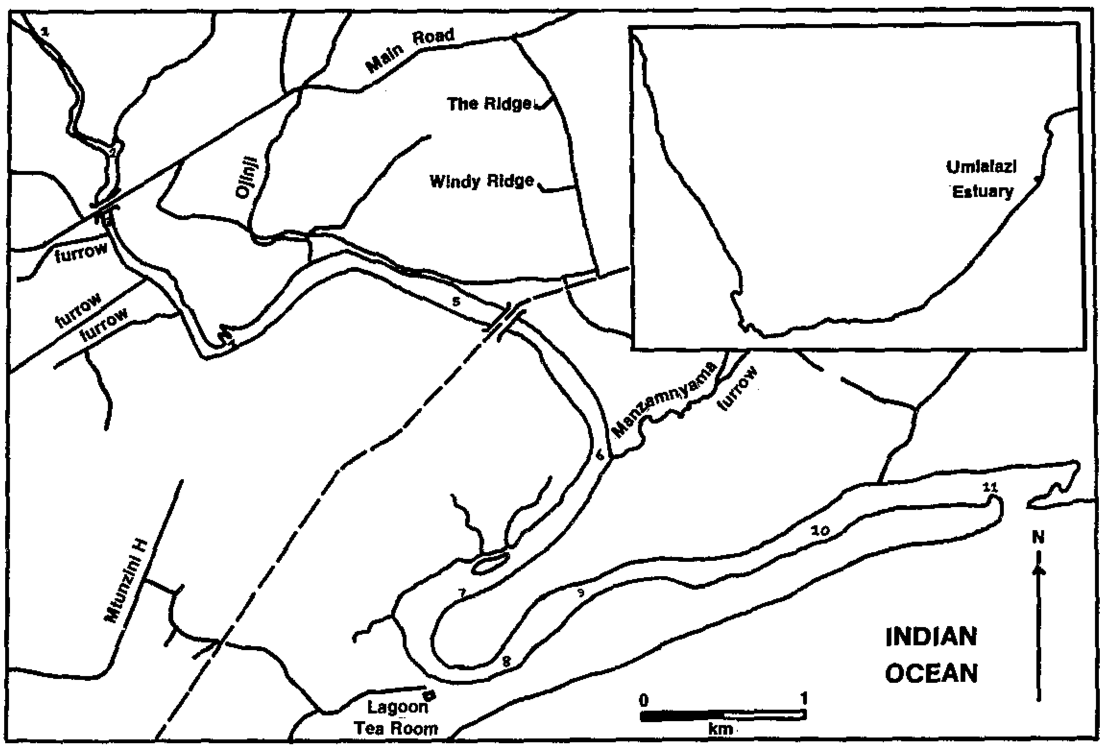

Figure 7. The Umlalazi estuary.

A survey (Hemens *et al* 1971c) was carried out during May and June, 1971 at a time of somewhat atypical conditions resulting from abnormal flooding of the estuary 2 to 3 weeks previously. Salinity stratification was evident in water more than 1,5 m in depth with the fresh water tending to move downstream as a surface layer over the bottom saline water. Above the limit of the salt water intrusion the fresh water was suitable for potable supply after conventional treatment. Any water extraction points should be located well above Station 2.

Low tide water samples indicate that the estuary could not be considered bacteriologically "clean" since faecal contamination was indicated by the isolation of *Salmonellae* and *Streptococci* between Stations 1 to 7. The contamination was not considered excessive since all *E coli* counts were well below 1 000/100 ml sample. Due to lack of clearly defined criteria the suitability of the water for body contact water recreation was uncertain.

The bottom sediments of the estuary showed variation in texture and composition that appeared to be mainly dependent on channel width and depth and distance from the mouth. Abnormal river flows tended to scour fine sediments from the reaches above Station 4 and to deposit coarse river sand and gravel brought down from upstream. The glutinous mud between Stations 4 and 5 was resistant to erosion and appeared to be a permanent feature of the estuary bottom. Stations 5 to 6 appeared to be a section of unconsolidated sandy silt subject to redistribution during strong river flows. From Station 7 to the mouth flood induced changes were less noticeable, probably due to increasing channel width.

Biologically the estuary appeared to be moderately productive but extensive areas of productive tidal mud flats were absent. No evidence of the growth of the ecologically desirable eel grass *Zostera* was found apart from small patches near the banks between Stations 9 and 10, although this was reported as present in the marginal shallows from Stations 7 to 10 in 1963. Its absence may have been the result of dredging operations in the estuary since 1965, or, possibly the consequence of flooding that had preceded the survey.

The estuary supported a moderate population of smaller estuarine fish species which exploited the food production of the system in the form of algal and other micro-organism growths and the invertebrate population of the bottom and marginal vegetation. This permanent population was, in turn, exploited by larger predatory fish which move in from the sea at various seasons of the year. Some of these larger species, such as the Natal Salmon *Johnius hololepidatus* move far up the estuary into low salinity water in search of food. The presence of the shark, *Carcharhinus leucas* is worthy of note in the water sport context.

Tidal exchange of water appeared to be quite effective up to about Station 5 and it seemed that undesirable eutrophic effects due to the discharge of treated sewage would be unlikely provided the estuary mouth remains permanently open. Dredging operations to provide increased water surface in the region of Station 7 would reduce current velocity in this area and sediment deposition would be likely to occur. This could increase the secondary productivity of the estuary with consequent increases in resident fish population, particularly if *Zostera* became established in the area. If constant dredging is required to maintain open channels the reverse is likely to be the case.

The marsh shoreline opposite Station 7 had been raised by deposition of material dredged from the channel and very little tidal flooding of the marsh appeared to occur under normal circumstances. It was considered that the contribution of this area to the productivity of the estuary was not very important and that filling of this area for development purposes would have no marked effect on the estuarine ecosystem.

In general it appeared that serious adverse changes in the estuarine ecology of the Mlalazi need not occur if due consideration was given to prevention of water pollution and the maintenance of a stable bottom in all areas where dredging was not essential for development.

The Amatikulu Estuary

The Amatikulu river rises on the slopes of Esungslweni about 27 km west of Eshowe at an altitude of 760 m. The catchment covers an area of approximately 900 m^2, mostly in an area of moderately high rainfall (1 016 - 1 270 mm) under sugar cane cultivation. The river follows a course approximately 80 km in length before reaching the Zululand coast where it turns north for about 4 km parallel to the coast behind a narrow dune ridge 5 - 15 m in height before discharging to the Indian Ocean at 29^o 05' S, 31^o 39' E. The whole of the estuarine section of the river lies within the Bantu Reserve No 8.

A smaller river, the Nyoni, which drains the coastal area south of the Amatikulu, reaches the coast about 10 km south of the Amatikulu and also turns north for the final 7 km of its channel before discharging to the sea through a break in the coastal dunes. This mouth was frequently closed during periods of low rainfall until, during a time of exceptionally heavy rainfall in May, 1971 flood conditions caused erosion of a 1 km section of land lying between the mouth of the Nyoni and the point at which the Amatikulu reaches the coast. This resulted in capture of the Nyoni by the Amatikulu and closure of the Nyoni mouth and at the time of the survey the contiguous sections of the two rivers formed an almost straight channel behind the coastal dune ridge some 14 km in length, as shown in Figure 8.

Although the estuary channel water consisted almost entirely of fresh water at the time of the survey due to high river flow, it is probable that marine influence can extend upstream, perhaps as far as Station 9, during periods of high tides and low river flows provided the mouth does not become closed at such times (Hemens *et al* 1972b).

The chemical quality of the fresh water reaching the mouth at the time of the survey was good, being suitable for potable supply after conventional treatment and disinfection and no evidence of industrial pollution further upstream was obtained. The bacterial quality of the water, however, indicated fairly heavy contamination by domestic sewage, with pathogenic organisms present at all stations except at the mouth. Comparison with results from previous years and with those obtained from a second survey five months after the main survey indicate that dry season water quality remains unchanged from values obtained in 1967 - 1968. There is evidence that some faecal contamination of the river occurs during passage through the environs of Amatikulu but worse conditions appear to occur during

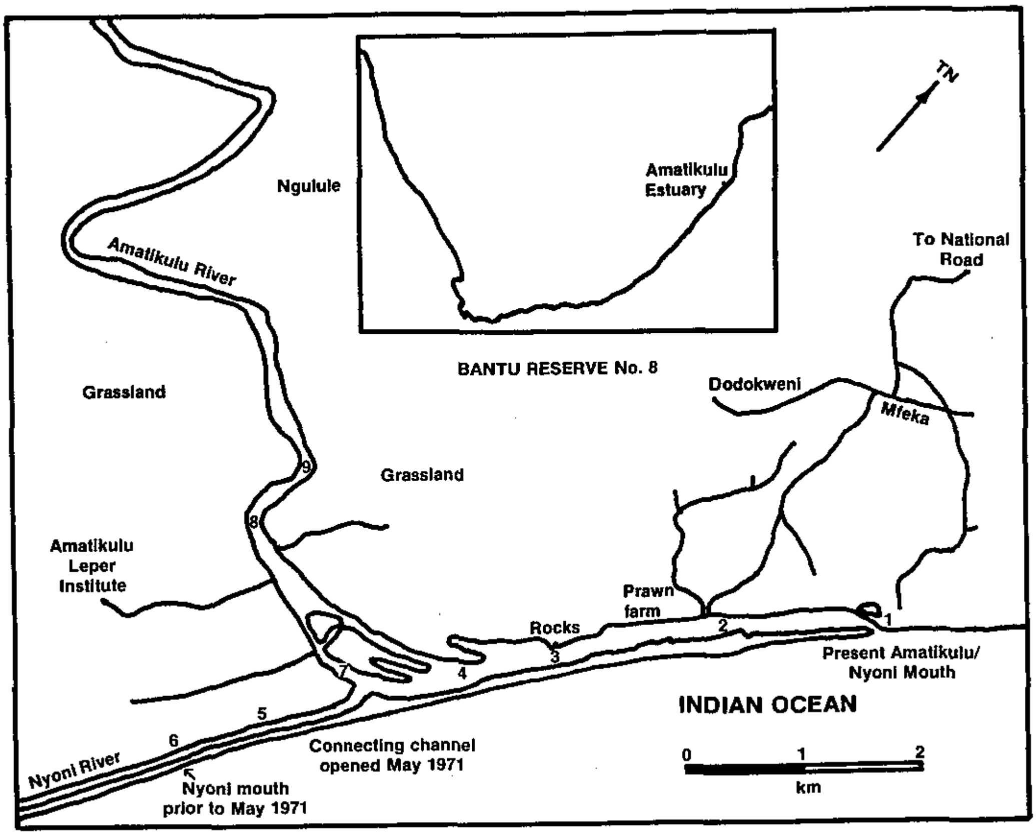

Figure 8. The Amatikulu estuary.

periods of high river flow. It is presumed that this is the result of surface run-off during high rainfall periods but the sources of pollution during such periods were not determined.

The composition and particle size distribution of material forming the bed of the estuary channel appears to be dictated by the morphology of the channel and its effect on velocity of water movement. In regions where the channel is narrow but not deep and where it is wide but shallow the water velocity is sufficient to prevent deposition of finer particles and the bottom consists of sand or sandy gravel. Fine particulate material is generally absent from the estuary except in a short section of channel near Station 8 and in the final 2,5 km of channel near the mouth. In these areas the velocity is low enough to allow the deposition and accumulation of fine particle sediments and organic detritus.

The factors governing the sediment character also appear to govern the abundance and distribution of the bottom fauna to a large extent since coarse sediments containing very little silt and organic material that are subject to shifting by water currents are not conducive to the development of dense benthic animal populations. This was evident from the rather sparse invertebrate population inhabiting the bottom in the sand and gravel sections of the channel. Dredge samples taken from the bottom of the deeper areas near the mouth revealed few, if any, animals to be present, possibly due to the presence of sulphide in the sediment, but it seems probable that these areas are normally more productive in view of the presence of penaeid prawns in the gut of several fish captured in the area and the supply of live prawns usually obtained in this section of channel by the prawn farm operators.

In view of the absence of eel grass beds *(Zostera capensis)* and their associated populations of invertebrate food organisms anywhere in the estuary and the lack of tidal mud flats or salt marshes due to the topography of the land surface the fish population is surprisingly numerous for an estuary with a poorly developed benethic population and limited areas of marginal vegetation.

From the scenic and amenity viewpoint the Amatikulu estuary compares favourably with many smaller estuaries on the Natal coast that have been developed to varying degrees as holiday resorts. The area is dominated by the high forest-covered ridge on the south bank which was observed to possess a varied bird population and is doubtless inhabited by small mammals of various kinds.

The contrast between the grass covered hills with occasional stands of trees on the north bank and the heavily forested south bank is marked and it seems probable that the survival of this forest and its animal population, including the crocodiles which are reported but were not seen to be present, is due to the fact that the whole area is within the boundary of the Amatikulu Leper Institute and that access to the public and to the inhabitants of Bantu Reserve No 8 is restricted. Apart from the presence of the small experimental prawn farm near Station 2, which consists of several concrete ponds containing water pumped from the estuary and a number of small buildings, no commercial development of the estuary of any kind has occurred. In view of the amenity potential of the area there is no doubt that this lack of development results from its location in the reserved area.

The Umgeni Estuary

The Umgeni river is 235 km long and drains a catchment of 5 850 km^2. The water is of reasonable good quality, but a considerable load of silt is carried during the summer rains. The river enters the sea through the urban area of the city of Durban and receives some load of industrial waste and sewage at the head of the small estuary, about 1,6 km from the sea (Figure 9).

A detailed environmental survey of the estuary was made during May, July and August 1972 (Simpson *et al* 1972). In comparison with an earlier analysis (Oliff *et al* 1970) there had been a significant change for the better in the sediment quality; the OA, phosphorus, sulphide and nitrogen values have decreased significantly. Whether this improvement in the sediment qualities had been brought about by natural means or by the removal of certain effluents from the river is not known. The relative degree of pollution of the Umgeni estuary may be obtained by comparing the Umgeni sediment with those from the Richards Bay area, if it is assumed that the Richards Bay samples represent natural silt. Comparison with samples from the main bay area of Richards Bay shows that the Umgeni silt is highly enriched in nitrogen and phosphorus and has a sulphide content of

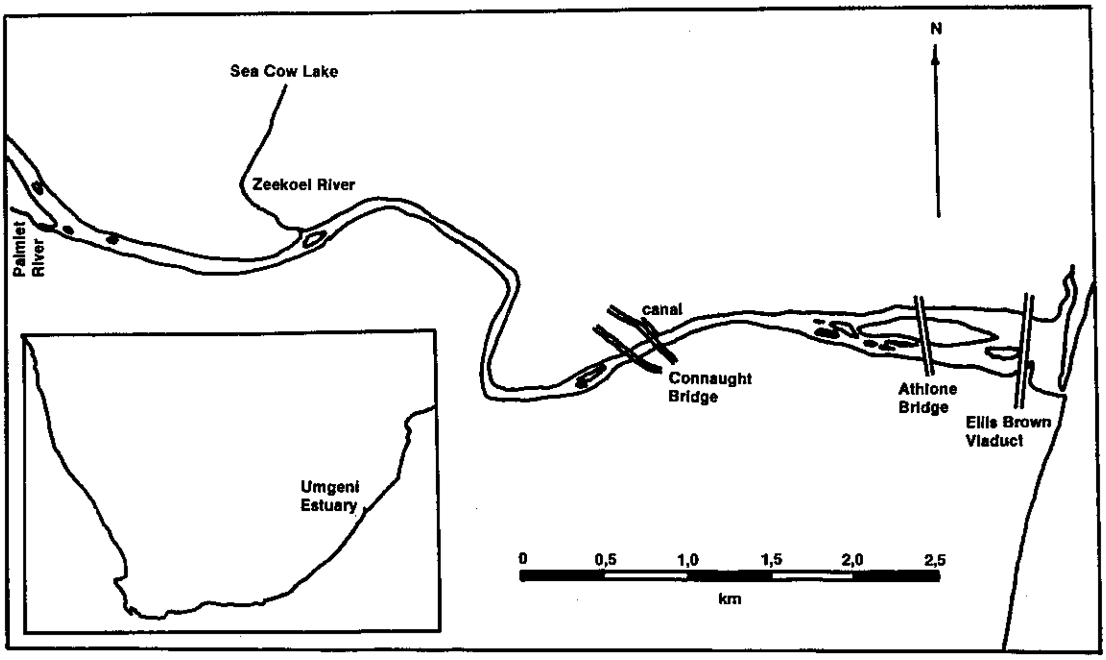

Figure 9. The Umgeni estuary.

more than ten times that of Richards Bay. An interesting fact is that the OA's are not significantly different, yet the volatile content of Richards Bay silt is significantly higher than that of the Umgeni; the inference here is that the organic matter in the former is more stabilised than that of the Umgeni. The Umgeni - Richards Bay - Mhlatuzi area comparison gives a somewhat different picture: apart from nitrogen and phosphorus values there are no significant differences in the other parameters. The difference in nutrient value may possibly be explained by the fact that, as far as is known, the Mhlatuzi river is mainly polluted by sugar mill effluent which is low in nitrogen and phosphorus whereas the Umgeni refuse has among other things, sewage effluence which are generally high in nitrogen and phosphorus. Clearly different types of effluent lead to different sediment characteristics.

Comparison with Kosi Bay results (Kosi bay is entirely undeveloped and therefore unlikely to have been subjected to man-made pollution)indicates that the Umgeni sandy sediments cannot be considered as being enriched. The materials used for comparison is not ideal, however, as the Kosi bay sands generally exhibited a far more normal particle size distribution, ie uni-modal distribution.

The salinity of the river water was low. Oxygen saturation values in excess of 90% were found above the Sea Cow Lake discharge, while values recorded below the discharge ranged from between 80 - 90%, indicating some depletion in dissolved oxygen. The Sea Cow Lake effluent has, in fact, a dominant influence on the river chemistry, masking the effects of any other smaller discharges. The Sea Cow Lake effluent represents a considerably flow and reflects values which are typical of a diluted sewage works outfall, being rich in nitrogen and phosphorus and having a fairly high OA. There is a significant rise in all the cehmical parameters below the Sea Cow Lake discharge, especially in the case of phosphorus which rose from 16 to 270 ug/l.

Biological analyses support the chemical results in that the Umgeni estuary can be regarded as moderately polluted. Since the pollution in this estuary is caused by the Sea Cow Lake effluent - resulting in an increased nutrient load - it can be assumed that the governing factor for presence or absence of organisms is represented by a low oxygen content of the interstitial water of the sediments. The lack of a well developed estuarine crustacean fauna and the abundance of *Polychaetae* indicate that the *Polychaetae* are more tolerant to low oxygen conditions than crustacea. From the biological point of view the Sea Cow Lake effluent does not have a very significant effect on the system.

Bacteriological analysis show that the river was moderately polluted with faecal material before it reached the highest point upstream that were sampled. While the Palmiet was also contaminated, this tributary was a relatively minor contributor. Downstream of the Sea Cow Lake discharge, the *E coli* I/100 ml numbers increased by about 100 and salmonellae were recovered. Despite the expected variabilities of nature and flow in a sewage contribution and within the recipient body of water, it appears that the Sea Cow Lake discharge is a considerable contributor of sewage. Further sources of contamination below this discharge do not materially alter the general river qualities.

The Ifafa Lagoon

The Ifafa river rises near Jolivet and is approximately 65 km long, having no tributaries of any consequence. The Ifafa has a mean annual flow of about one to 1,5 cubic metres/sec. The lagoon lies approximately 100 road km south of Durban.

The coastal lagoon is here considered as the body of water stretching from the beach sandbar upstream to a point where the normal depth decreases to less than 0,5 m (Figure 10).

The valley sides of this section of river rise quite steeply to the 60m contour, the steepest section being on the north bank. The vegetation consists of a strip of luxuriant mangrove growth, timber plantations, cane fields and a strong growth of mixed indigenous trees and shrubs. The area of the lagoon is approximately 32,4 hectares with a length of 2,8 km and is uninterrupted by islands and sand-bars. The Ifafa lagoon is characterised by a low sandbank which stretches across the mouth of the lagoon from the north bank to an artificial weir on the south bank. The extent and height of the sandbank varies throughout the year. There is no tidal effect in the lagoon except on rare occasions when the sandbank is breached and then only if the water level in the lagoon drops rapidly below sea level. Under such circumstances there may be a movement of sea water into the lagoon at high tide only. The stability of the lagoon is dependent on the sand-bank but breaching of this barrier may be effected in one of three ways: flooding of the lagoon by the Ifafa river, wave action from the seaward side of the sand-bank by high seas and man-induced breaching of the sandbank for flushing purposes.

An environmental survey was made over the period 6 - 13 December 1970. (Hemens *et al* 1971b). This period had been preceded by several days of heavy rainfall and at the time of sampling the entire lagoon consisted of

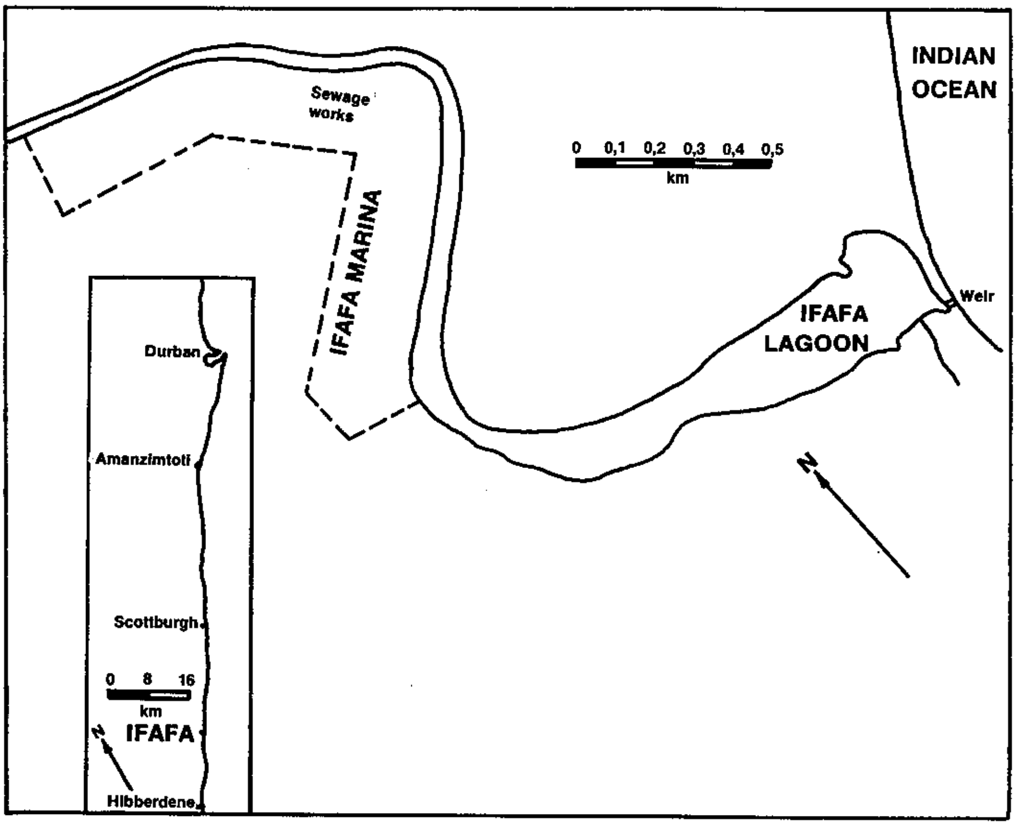

Figure 10. The Ifafa estuary.

completely fresh water. The conductivity measurements indicating salinities of less than 0,08 parts/thousand. It seems, therefore, that at times of flooding the Ifafa lagoon must be considered as a freshwater lagoon with the chemical characteristics of the Ifafa river. Comparison of the lagoon water analysis with the river water analysis showed this to be the case and that the water is of very good quality, but possesses the corrosive tendencies common to most Natal waters.

Classification of bacteriological analyses according to a method evolved by the NIWR Marine Bacteriology Group (Livingstone 1969) indicate either a class I or Class II, according to the sampling site. Use of the classification for river waters developed by Brandt *et al* (1967) indicates a Class II water, described as of medium quality suitable for drinking after conventional treatment (provided the accepted specifications for trace elements, etc are fulfilled) and suitable for most other uses.

Sediment analysis show the lagoon bottom to consist largely of river sand and gravel. The proportion of sediment with a particle size of less than 125 microns did not exceed 17,4%. This is in contrast to many of the Natal estuaries, notably Richards Bay and the St Lucia lake, where the fraction smaller than 125 microns normally exceed 95%. The sands and gravels themselves are poor in organic matter and the nitrogen and phosphorus content are respectively about 1/10th and 1/4 of the values found in silt bottom estuaries.

The number of fish species taken in the biological survey is not large, being only 10, compared to over 80 for a body of water with a variety of ecological niches and a range of salinities, such as the St Lucia lakes (Millard and Broekhuysen 1970). All the species appeared to be those that are able to exist by utilising films of micro-organisms developed on organic detritus or algal films on harder surfaces such as rocks, immersed mangrove trunks and roots. As some species of fish are typically estuarine, it is evident that the lagoon water must be saline to some degree for most of the time if an estuarine community is to develop. It is not clear how sufficient sea water to provide an estuarine environment is able to enter the lagoon and this aspect requires further investigation. Particular attention was given to the possible presence of vector snails of the forms of schistosomiasis endemic to this area. No specimens of vector snails were found, possibly because of the flood conditions which preceded the survey.

One cause of deterioration of the Ifafa lagoon could be the rapid eutrophication of the lagoon water, particularly in the dry season when there may be little or no overflow at the mouth and settlement of silt increases the water clarity. Increase of the nutrient content of the water as a result of the discharge of treated effluent from the Ifafa Marina could establish conditions well within the range in which excessive growth of photosynthetic organisms, such as algae, is likely to occur.

In 1971 a survey was conducted of aspects of the limnology of the Ifafa lagoon in relation to its possible eutrophication (Archibald 1971). Physical, chemical, biological and bacteriological variables were observed.

In the Ifafa lagoon the mean depth is low thus enabling mixing of the water which prevents stratification. Surface and bottom temperatures show only very small differences even in the deeper regions of the lagoon. The mean temperature values of the whole lagoon show a seasonal trend with the onset of summer, except in December 1971 when the breaching of the sandbank caused lower temperatures comparable to the colder running river water above the marina. Values obtained from the pH of the water did not vary a great deal over the whole lagoon or seasonally and together with alkalinity values indicated a slightly alkaline nature for the greater part of the year. The area and volume of water retained in the lagoon can be extremely variable. The mean depth of the lagoon was calculated at 1,60 metres except when the sandbank was breached on two occasions and values of 1 metre or less were recorded.

Observation of changes in the transparencies of water indicated considerable variation of the demarcation between the euphotic zone, the limnetic zone and the profundal zone. Highest turbidity values (up to 72,99 mg SiO_2/l) were recorded during December when the lagoon was a shallow turbid body of water. Lower values were obtained during the drier months from June to September. Conductivity and salinity measurements indicate that the Ifafa lagoon generally contain entirely fresh water even when there is no flooding by the river.

Measurement of dissolved oxygen showed that the percentage saturation values of oxygen lay between 80 - 100% in most cases. The alkalinity and total inorganic carbon values in the Ifafa lagoon are consistent with conditions in which it would appear that carbon is not a limiting factor in this oligotrophic system.

The concentrations of nitrate in the Ifafa lagoon rarely exceeded 1,0 mg/litre throughout the entire sampling period, with nitrates always the most abundant form of nitrogen. In December 1971 there was an appreciable increase in the nitrate concentration, probably as a result of the increased drainage from the immediate geographical area and the subsequent effect of the nutrient increase being introduced into the empty lagoon. Ammoniacal nitrogen varied between 0,2 and 0,8 mg/litre despite the fact that large water bodies with a low production rate usually have concentrations lower than the nitrate-nitrogen values. No known waste waters reach the lagoon at present in large amounts and therefore the ammoniacal-nitrogen results, as expected, are generally lower than the nitrates.

The concentrations of phosphorus in the Ifafa lagoon varied from 0,01 mg P/litre to 0,14 mg P/litre while the average concentration over the entire sampling period was 0,058 mg P/litre. Although the concentration of phosphorus might be sufficient to sustain an algal bloom it did not appear to be the case. Silicon measurements indicated that there was little variation in the concentration of silicon throughout the sampling period. No noticable increase in the diatom population was therefore expected under the prevailing conditions.

Algal counts were made on samples and the results indicated only slight differences over the sampling periods. The counts were less than 40 organisms/ml, compared with an algal count of approximately 8000 organisms/ml obtained from a typical sewerage maturation pond. Chlorophyll results were generally low through the entire sampling period. There was a slight upward seasonal trend from the head of the lagoon to the mouth and the maximum level obtained was 4,07 mg chlorophyll/m^3. Maximum values were obtained during the September - November period.

Both the oxygen method and the carbon-14 method were used in the determination of the primary production of the Ifafa lagoon. In June the values were comparatively low but these increased with the onset of the summer period especially in the lower stations which always showed higher results than those measured in the upper parts of the lagoon. The maximum figure obtained was 29,93 mg/m^3/hour and 6,55 mg/m^3/hour for the mouth of the lagoon using the oxygen and carbon-14 methods respectively. A typical sewerage pond gave values of 538 mg C/m^3/hour and 117 mg C/m^3/hour, respectively, for the two methods. The bacteriological results show that the Ifafa water is faecally contaminated before it enters the area under survey.

Further eutrophication studies of the Ifafa lagoon (which received no allocthonous material) were conducted during 1972 (National Institute for Water Research 1972b). The results were compared with that of the Amanzimtoti lagoon, which receive a treated sewage effluent.

Chemical and physical parameters in the Ifafa lagoon are consistent with an oligotrophic system with low concentrations of nutrients and high dissolved oxygen content of the water, except where large increases in salinity were observed. During the period of investigation, emphasis has been placed on the characteristics of the phytoplankton and the part played by these features in the assessment of eutrophication. The low density (organisms/millilitre) high species diversity and the species composition of the samples throughout the lagoon during the period of investigation strongly accentuate the oligotrophic condition of this system. The effects of the introduction of a treated sewage effluent directly into a system are selfevident from the chemical, physical and biological results obtained from the Amanzimtoti lagoon.

High nutrient concentrations (especially phosphorus and nitrogen values) together with reduced oxygen content of the water, which is very often accentuated where increased salinities were observed, are direct changes brought about by the effluent. Persistently high algal densities in the lagoon (organisms/millilitre) is an indirect response to a nutrient charged system and together with the low species diversity and different species composition, are biological manifestations of the eutrophication which has occurred in the Amanzimtoti lagoon.

Although it is accepted that the Ifafa regime is not exactly the same as that which prevails at the Amanzimtoti it is suggested that unless the Ifafa system is capable of tolerating a sewage effluent at the concentration which is planned by the marina complex, eutrophication must occur. The extent of the eutrophication and therefore the deterioration of the water quality will depend on (a) the development and the progress made in the construction of the marina complex and the rate of increase of the concentration of the sewage effluent discharged to the system, (b) the morphological and biological features of this lagoon and its inherent capacity to tolerate concentration of this effluent and (c) the environmental regime of the Ifafa lagoon.

Six follow-up eutrophication studies were undertaken during the period from December 1973 to July 1975 (National Institute for Water Research 1975b). By mid 1975 the marina was still very much incomplete and has not reached maximum operating capacity. The sewage works has not yet come into operation and all wastes were handled by soak pits and septic tanks.

Since there is no discharge of effluent the change in temperature from survey to survey was a seasonal effect.

Conductivity values in the upper reaches of the lagoon were very similar to the values obtained in the river itself, and as expected the water in the upper lagoon region was fresh. However, in the lower reaches the conductivity increased considerably, both in the surface and bottom water. It was established that the water system would be controlled at the mouth so that changes in salinity would not necessarily be a natural phenomenon. The water retained in this system will very likely be almost totally fresh for the greater part of the year.

The nutrient concentrations in this sytem have remained constantly low over the period of investigation. Nitrogen and phosphorus values have not increased at all, over and above the concentrations which enter via the Ifafa river. Since the Ifafa river is the only major source of water and since there is no change within the system it is reasonable at this stage to assume that the development of the Marina thus far has had little direct effect on the lagoon water.

Algal growth potential values remained constantly low and uniform throughout the system and phosphorus was identified as the growthlimiting nutrient. Chlorophyll "a" concentrations were low throughout the system confirming the low nutrient status of the water.

The Umzimkulu Estuary

The Umzimkulu river rises at 2 000 metres near Drakensberg gardens and with its tributaries, drains a 70 km section of the Drakensberg, from Sani Pass in the north to the Bushman's Nek Pass in the south. The total catchment area of this system is about 6 750 sq km and with an average rainfall of 1 000 mm, its run-off is the second biggest in Natal (after the Tugela).

In Natal the Umzimkulu is almost exclusively occupied by European farms. In the last 20 km to the coast, sugar cane is grown extensively, while in the Harding area fairly extensive areas of cultivated forest occur. Further details of the river are given in National Institute for Water Research (1968b).

The estuary was investigated from 5th to 7th August 1974 (Connell *et al* 1975). At the time of sampling, the estuary was open to the sea via a constricted mouth on the south bank, confined on the south side by a concrete wall. The mouth was narrow, being only about 10 metres across at its narrowest (under the road bridge) but was fairly deep, 4 metres at low tide (Figure 11). Depth profiles indicate that the estuary is generally shallow.

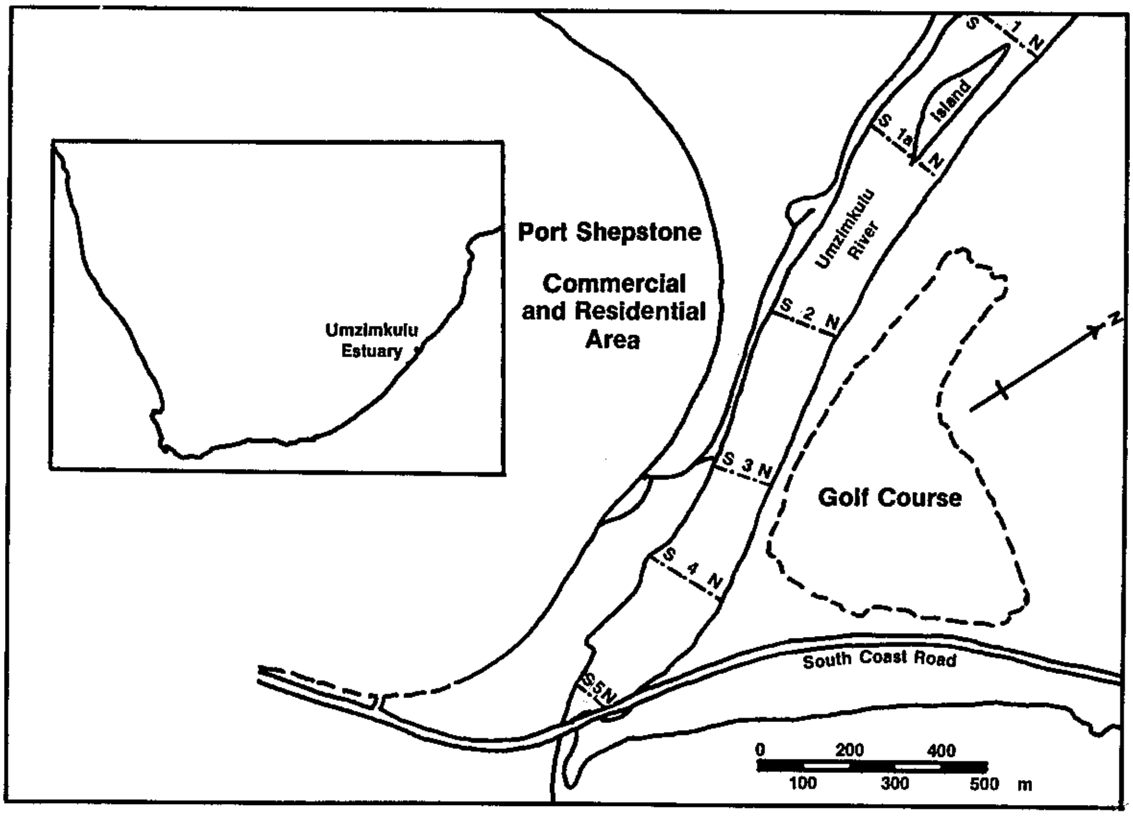

Figure 11. The Umzimkulu estuary.

Salinity readings indicated that the penetration of sea water at high spring tide was far higher than the northern end of the island. Surface temperature readings yielded a temperature of 16,3 to 16,4°C for all stations, but the low surface salinities of surface waters show this to be the temperature of the fresh water coming down the river.

Water analyses indicate a source of organic enrichment upstream. Ammonia levels were fairly high, the higher levels generally being associated with sea water entering the estuary. This possibly due to contamination by the Port Shepstone sewage discharge which is quite near the estuary mouth. Nitrate and phosphate results were in the range expected for estuarine waters. The bacteriological picture shows that the estuary is remarkably clean from faecal pollution.

The low species diversities of the fauna together with the frequent occurrence of high counts of single species is indicative of organically enriched conditions. This conclusion is largely supported by the sediment analyses, where both the oxygen absorbed and Kjeldahl nitrogen values indicate a patchily high organic content. Reference to data for the Umgeni, Amatikulu and Umtamvuna estuaries (Simpson *et al* 1972, Hemens *et al* 1972b, 1973), emphasises the high density of a few species in the sediments of the Umzimkulu estuary. This is probably caused by the sugar mills situated on the river about 4,5 km from the mouth and 1,5 km above the limit of tidal influence.

Sampling was unfortunately not extended past the islands (Figure 9) although more than a metre of water covered the sand banks above Station 1 at high tide. As a result, the zooplankton data recorded shows the typically estuarine copepod *Pseudodiaptomus hessei* to be common only at Station 1. The high numbers of the oligochaete *Paranais frici* was probably a result of disturbance by the current of clumps of detritus containing these worms. They were more common at the upstream stations, as also indicated by the benthic fauna. The small calanoid copepod *Paracalanus crassirostris* was well distributed throughout the sampled portion of the estuary, and is a common species in many estuaries. The species tentatively described as *Diaixis* sp appears to be new.

The absence of mysidacea from the catches in the estuary is remarkable since they are normally collected in sled nets in estuaries, while the absence of the copepod *Acartia natalensis* (Connell and Grindley 1974) and to a lesser extent, amhipods, isopods, tanaidaceans and cumaceans is possibly indicative of a disturbed estuarine environment.

Sediment samples and some fish were analysed for chlorinated hydrocarbon residues. A small concentration of DDE was found in the fish examined, ranging from 0,017 ppm in Mullet to 0,004 ppm in perch. DDT was found only in the perch. The concentration levels are considerably lower than those found in similar fish in Durban Bay and the Umgeni estuaries. The muds did not contain any of the most common chlorinated pesticides such as DDT, DDE, dieldrin, aldrin and lindane.

Water samples and sediment samples were analysed for mercury, copper, cadmium, lead and zinc. Sediments were also analysed for iron.

The results of the water sample analyses appear to indicate a source of metallic contamination between Stations 1 and 3. This is particularly so for lead and may, therefore, be a result of drainage from Port Shepstone. Mercury levels were much higher than was expected for an estuary in this situation and may indicate the need for further investigation.

From experience with oceanic samples, levels of all the metals measured in the sediments, except zinc, appear to be fairly low. Zinc concentrations were extremely high, particularly at Station 1, but this may simply be a geological peculiarity.

Four samples of fish tissues were analysed for mercury content. The Mullet samples contained typically low values. The normal background concentration for the perch is not known but the level found in the one specimen (0,207 ug Hg/gm) is common in oceanic predators and some species of reef-dwellers.

The Umtamvuna Estuary

The source of the Umtamvuna lies at an altitude of 1 900 m about 15 km south east of Kokstad and the river follows a winding course approximately 160 km in length to reach the Indian Ocean a short distance south of Port Edward. For most of its length the river marks part of the Natal-Transkei border and it drains a catchment area of approximately 1 630 km^2. The headwater streams down to and including the Weza tributary are scheduled as waters to which the Special Standard for industrial effluents apply under the Water Act of 1956.

For much of its lower course the river flows through a narrow valley some 250 - 300 m deep and 500 - 700 m wide which it has cut into a dissected plateau with an average elevation of about 400 m. The edge of this plateau is reached some 3 km from the coastline and the sides of the final 4 km of river valley are less steep, except where the channel has cut through a 90 m high coastal ridge to reach the ocean.

The estuarine section of the river extends approximately 5,25 km upstream from the mouth into the steep sided valley to a point where a barrier of boulders across the channel forms a 50 m section of shallow rapids about which salt water penetration does not occur. There are no tributaries of any consequence in the estuarine section apart from a small stream draining a steep walled valley about 1 km in length extending from the southern side of the main river valley (Figure 12).

The Umtamvuna estuary differs from other Natal estuaries in that there is no intermediate transition stage between marine and freshwater at the head of the estuary, due to the presence of a section of rocky rapids, and the average channel depth is 3 - 4 m, reaching to ten metres in one section. Depths of this magnitude have been encountered only in the St Lucia Lakes and at Kosi Bay. This combination causes the estuary to have a marine character over the whole of its length and periodic closure of the mouth by a sand bar has a number of physicochemical and biological consequences that are not encountered elsewhere in Natal in estuaries without lake systems.

Measurements made with the mouth closed and subsequently open (Hemens *et al* 1973) showed that there is a progressive accumulation of marine water on the floor of the estuary which causes the less dense freshwater from upstream to move downstream in the top 2 - 3 m from the surface and

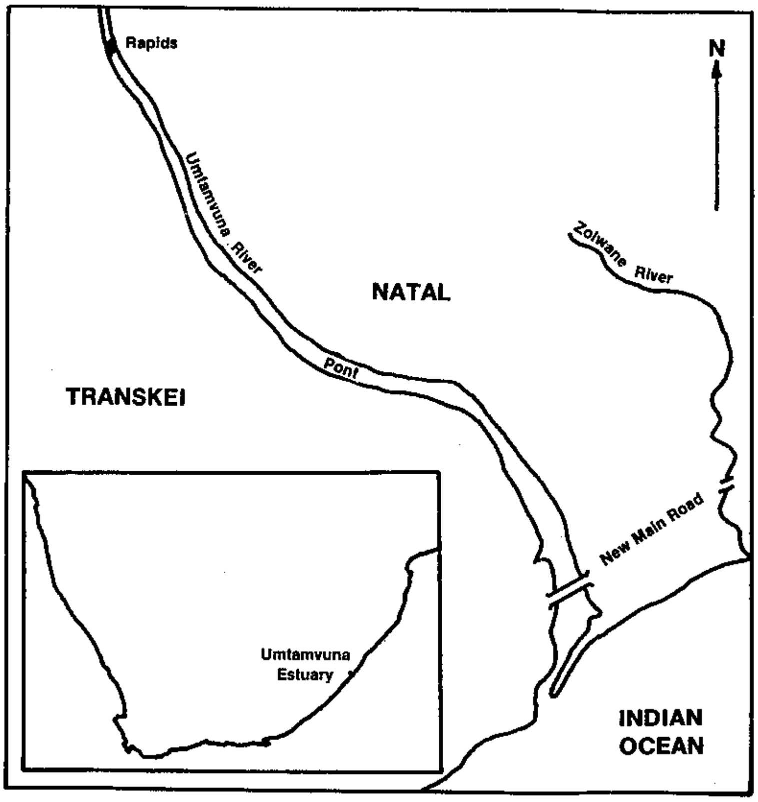

Figure 12. The Umtamvuna estuary.

vertical mixing of fresh and saline water is incomplete. In consequence marine water of high salinity (30 - 34^{o}/oo) fills the whole of the channel at depths below 2 - 3 m from the surface and this situation extends from the mouth to the rapids which mark the abrupt change from estuarine to freshwater conditions.

During periods of more than a few days when the mouth is closed dissolved oxygen in the lower water layers is depleted due to bacterial and chemical oxydation of soluble compounds diffusing from the bottom sediments. After 7 - 10 days of this condition the dissolved oxygen level in the deeper water may fall to 3 mg O_2/l or less and fish may be denied the use of this water volume and the food content of the estuary sediment lying below it. It is suggested that periodic repetition of these conditions is responsible for the unexpectedly sparse fish population observed and that in consequence the considerable biological production capacity of the system is not fully exploited.

The quality of the freshwater input to the system is high and there is no evidence of human faecal pollution of any consequence. The water chemistry is as would be expected from various mixtures of good quality freshwater and clean marine water.

Apart from the area in the vicinity of the mouth the bottom sediment over the whole of the estuary consists of fairly homogeneous silt containing nutrient concentrations intermediate between those of Richards Bay and the polluted silts of the Umgeni estuary. It is suggested that under conditions such as occur in the Umtamvuna when the mouth is closed mineral components of the silt may be enriched by adsorbtion and adsorbtion of the soluble products of decomposition to the extent that it may not be possible to distinguish between a rich silt and a silt that has been moderately contaminated by organic urban or industrial discharges unless methods other than those employed can be developed.

The Berg River Estuary

The Great Berg River is one of the two largest rivers opening into the sea along the west coast between Cape Town and the Orange River. It represents a contrast to the barren Orange River estuary, but is also different from the richly populated rivers of the south and east coasts.

The river system drains a large area of the south-western Cape Province which falls in a winter rainfall belt. The Berg River enters St Helena Bay at Laaiplek. In 1968 a new mouth to the River was opened and it now enters the sea about 1 km north of the original mouth.

Breakwaters have been constructed, enabling fishing vessels to offload catches in the sheltered upper reaches of the river. The original mouth of the estuary (Die Mond) has since silted up and now forms a lagoon running parallel to the coast. The river flows between steep banks, but has extensive flood plains, with mud predominating on the banks of the river. The estuary is extremely rich in bird and marine life and can be considered unpolluted.

An extensive survey was undertaken at the end of October 1975 (Fricke *et al* 1975). Eighteen stations were established in the estuary, along the beach and approximately 100 m offshore on both sides of the mouth (Figure 13). Stations in the estuary ranged from the mouth to approximately 9 km upstream. These stations were occupied once during the high tide cycle and repeated during the low tide cycle. At each station samples of water and sediment were taken for the usual chemical parameters as well as meiofauna.

There is a strong tidal influence on the estuary, which is well illustrated by the nutrient and salinity measurements of the water. During the high tide cycle, the salinity as far upstream as Station 6 (3 km from the mouth) was greater than 33 ^{o}/oo. The salinity at Station 7 (near the main road bridge, 6 km from the mouth) was greater than 11 ^{o}/oo, showing considerable penetration of salt water as far upstream as this. Salinities at Stations 1 and 2, in the lagoon formed by the silting up of the original mouth, were low, which seem to indicate that the tidal currents sweep past this branch of the estuary and that there is a much smaller tidal interchange of water from this area. Salinities during the low tide cycle were much lower, eg at Station 3 it was below 26 ^{o}/oo. Salinities at Stations 1 and 2 increased at low tide, showing that more mixing occurs in this area while the flow is towards the sea. There is a marked tidal variation in silicate and nitrate levels, which clearly demonstrates the movement of water up and down the river. The organic content of sediments obtained from the estuary is extremely high, OA values of greater than 10 mg O_2/g dry weight of sediments having been recorded for some samples collected near the mouth.

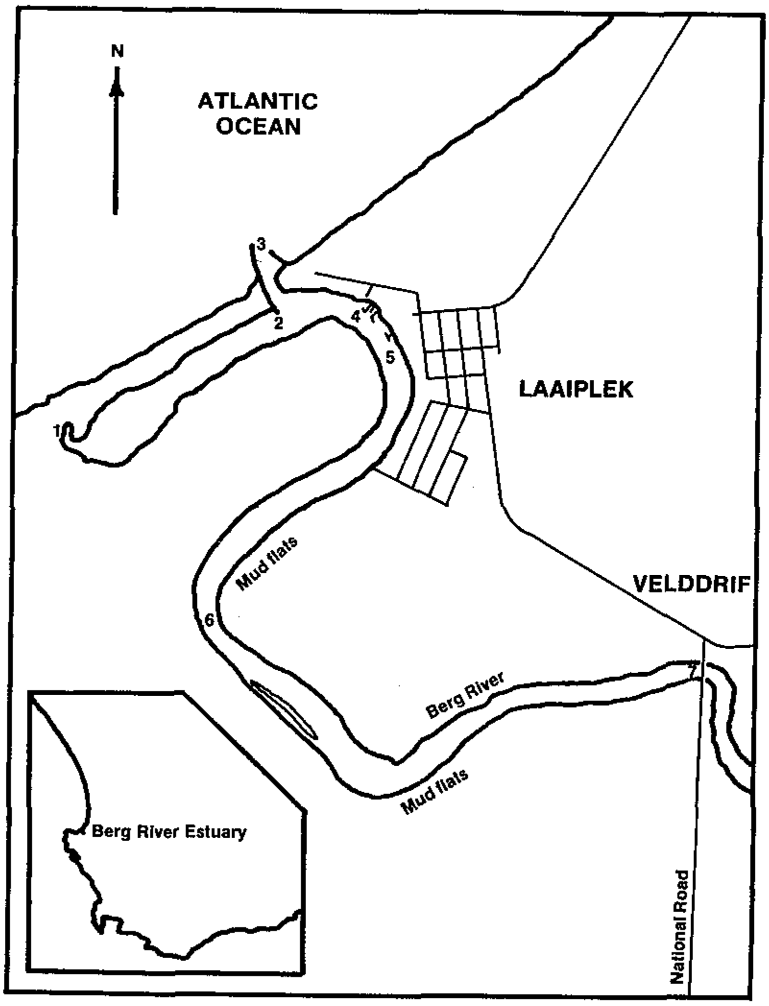

Figure 13. The Berg estuary.

A rough impression from the total numbers of animals collected seems to show an increase from Station 4 to Station 6, ie in the upriver direction. Further upstream towards Station 9 there is a decrease in numbers. Although the fish factory was not in operation, the low figures obtained near the factory outfall (Station 5) may be due to the excessive amounts of sludge on the river bottom. Environmental stress definitely exists here and the low oxygen values found may exclude many meiofaunal groups. The reduced salinity found on the bottom at Station 6 may be the cause of the drop in animal numbers. Five sediment cores taken to the north and south of the harbour entrance yielded high meiofaunal counts. An exception was a core taken immediately to the south of the harbour entrance, where excessively coarse shelly sediment showed low animal numbers. Such deposits are apparently unsuitable for meiofaunal colonisation. This site frequently receives very high wave energy input.

OCEAN REFERENCE TRANSECTS

East Coast transect

The chief aims of the east coast oceanic reference transect are to trace widely dispersed pollutants near the shore, and in deep water, off Durban and to determine background environmental conditions for pollution monitoring purposes. The coastal monitoring surveys are aimed at evaluating and monitoring conditions at specific localities off the Natal coast.

A total of fourteen cruises have been undertaken since May 1972, as summarised in Table 5. Six surveys of the east coast oceanic reference transect have been completed and numerous data have been collected at coastal monitoring stations between Kosi Bay in the north and Port Edward in the south. Figure 14 illustrates the location of the sampling lines.

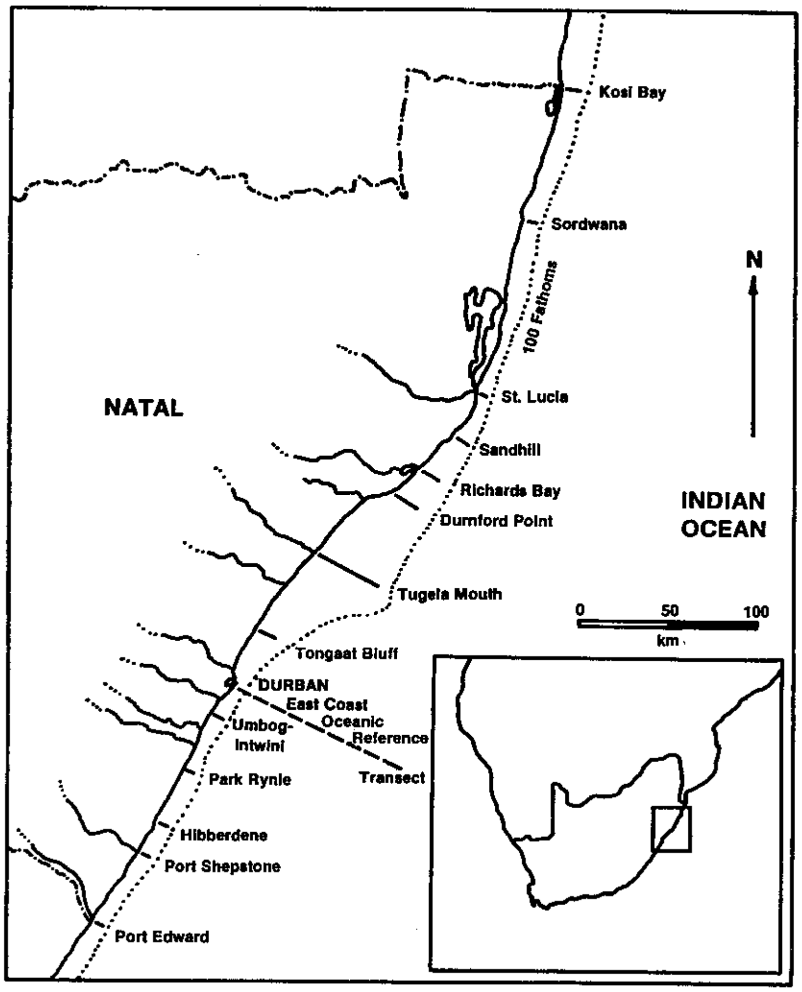

Figure 14. Location of oceanic reference and coastal monitoring sampling lines along the Natal coast.

The east coast oceanic reference transect is comprised of stations situated approximately 2, 4, 6, 8, 10, 25, 50 and 100 km offshore on a line bearing about 128^{o} T off Cooper Light (Durban), There has been some variation in the location of stations comprising the coastal monitoring grid. Prior to 1974 the stations on each sampling line were situated 1, 4 and 7 km offshore on a line running approximately at right angles to the coastline and, in addition to the sampling lines indicated in Figure 1, three further lines situated off Cooper Light (2), Umkomaas (N) and Margate (R) were

Table 5. Summary of cruises along the East Coast

CRUISE NO	DATE	PURPOSE
1. MN 72/13	15. 5.72	Coastal monitoring off Sandhill, Richards Bay, Port Durnford, Tugela Mouth, Tongaat Bluff, Umbogintwini, Park Rynie, Hibberdene and Port Shepstone
2. MN 72/19	19. 7.72	Coastal monitoring off Umbogintwini, Umkomaas, Park Rynie, Hibberdene, Port Shepstone, Margate, Port Edward
3. MN 72/28	11.12.72	Coastal monitoring off St Lucia, Sandhill, Richards Bay, Port Durnford, Tugela Mouth and Tongaat Bluff
4. MN 73/02	6. 2.73	Coastal monitoring off Umbogintwini, Umkomaas, Park Rynie, Hibberdene, Port Shepstone, Margate and Port Edward
5. MN 73/05	28. 2.73	Coastal monitoring off Cooper Light
6. MN 73/12	22. 5.73	Coastal monitoring off Cooper Light, Tongaat Bluff, Tugela Mouth, Port Durnford, Richards Bay, St Lucia, Park Rynie, Hibberdene, Port Shepstone, Margate, Port Edward, Umkomaas and Umbogintwini
7. TB Davie Cruise 290	20. 9.73	Sediment survey - Port Elizabeth to Richards Bay
8. MN 74/07	11. 3.74	East coast oceanic reference transect 1
9. MN 74/16	3. 6.74	East coast oceanic reference transect 2
10. MN 74/26	23. 9.74	East coast oceanic reference transect 3 and coastal monitoring off Tongaat Bluff
11. MN 74/34	3.12.74	East coast oceanic reference transect 4 and coastal monitoring off Richards Bay and Tugela Mouth
12. MN 75/07	17. 3.75	East coast oceanic reference transect 5 and coastal monitoring off Umbogintwini, Park Rynie, Hibberdene, Port Shepstone and Port Edward
13. MN 75/11	5. 5.75	East coast oceanic reference transect 6
14. MN 75/24	2. 9.75	Coastal monitoring off St Lucia, Sordwana Bay and Kosi Bay

included. Subsequent to September, 1974 it was decided to abandon sampling at Umkomaas and Margate, in view of the close proximity of neighbouring sampling lines, and to relocate the stations on a basis of water depth rather than distance offshore. This was to allow a more realistic comparison of data. The line of stations off Cooper Light was replaced by the east coast oceanic reference transect.

A large volume of data relating to the chemistry of the sediments off the east coast of South Africa was obtained during a sedimentological survey undertaken by the R V Thomas B Davie during September, 1973.

With the exception of the September, 1973 cruise of the R V Thomas B Davie, the R V Meiring Naude has been used exclusively in the collection of the samples.

A large volume of data relating to environmental conditions off the Natal coast has been amassed. These data will form the basis of a continuing pollution monitoring programme. In view of the large volume of the data, and the rapidity with which it has been accumulated, it has not been possible to assimilate it fully at this stage. A data storage and retrieval facility, which is in the process of being established, will allow a more detailed appraisal of the data in due course.

A brief summary of major findings follows.

Physical and chemical data includes salinity, water temperature, current speed and direction, nutrients (phosphorus, silica, nitrate, ammonia and nitrite), pH, total alkalinity, dissolved oxygen, oxygen absorbed from alkaline permanganate and Kjeldahl nitrogen. Some of these parameters are of direct value in pollution monitoring but the majority merely provide supportive information on environmental conditions in general. All these results confirm to an expected pattern and there is little that can be said, at this stage, concerning the significance of the values.

Considerable variations of easily oxidised and nitrogenous materials and particle size were evident from the sediment analyses. However, all the values fell within a range expected for Natal coastal sediments.

Generally, organic content tended to increase with depth and was high oft large river mouths. Furthermore, the sediments to the north of Durban were worse and poorer in organic materials than those to the south. Silty patches were encountered on occasions in the vicinity of river mouths.

Faunal composition and density evaluations revealed diverse populations typical to Natal nearshore coastal sediments. On no occasion was evidence of toxic or enriched conditions encountered in the benthic faunal analyses. There appeared to be a trend towards greater total numbers and number of species at the deeper stations of the coastal monitoring lines. Statistical analysis of some of the data indicated that duplicate samples were comparable in terms of total numbers, number of species and species recovered. There also appeared to be some regional affinity between samples. A similarity analysis indicated the existence of two distinct faunal communities, one existing off Natal's north coast and the other off Natal's south coast.

Samples of zooplankton which were collected during surveys of the east coast oceanic reference transect were intended primarily for pesticide residue and trace metal analysis. A species analysis of the zooplankton was necessary, however, to determine its composition and origin in terms of water mass. This information assisted in the appraisal of the pesticide and trace metal determinations with regard to origin of contamination.

Sediment and zooplankton samples from the east coast oceanic reference transects were analysed for pesticide residues. Dieldrin and DDT were found at low concentrations in some of the inshore zooplankton samples but absent from those taken further offshore. Very small concentrations of Dieldrin, DDT and DDE were found to be present in a few of the nearshore sediment samples.

Trace metal analyses was carried out on seawater, sediment and zooplankton samples from both the east coast oceanic reference transect and some of the coastal monitoring lines. Most of these results agreed reasonably well and were self consistent. Odd high values which appeared from time to time were attributed to sample contamination. The levels of the various metallic elements were, on the whole, comparable with those reported by other workers in the field. Statistical analysis of the data indicated that in most cases there were no significant differences between stations or cruises with regard to the trace metal concentrations in sea water. The elements tested varied widely in concentration and distribution and no definite pattern could be detected. However, there was an indication that levels of mercury, copper and zinc tended to be generally lower away from the Durban area.

South and West Coast transects

It was decided that ocean reference cruises should be undertaken quarterly in order to collect data and to observe any marked seasonal variations which may occur. Four cruises were carried out on the University of Cape Town vessel Thomas B Davie during February, April, July and October 1975 (Fricke *et al* 1975). On all of these cruises the south and west coast transects were sampled. Stations were approximately 3, 8, 40 70 and 100 km offshore on both transects, plus one in the Breede River estuary and two in Saldanha Bay, making a total of 13 on each cruise (see Figure 15). In addition, two stations in St Helena Bay and 30 stations in Saldanha Bay (sediment samples only) were occupied during the February and July cruises respectively.

At all stations water samples for temperature, oxygen, salinity, nutrient and trace metals were collected from the international depths. Standard methods of analysis were used. Samples of tar balls were collected by means of a neuston net at all stations, conditions permitting. The XBT became operational for the first time during the July cruise and was used with success at all stations with a depth of greater than 75 m. Unfortunately, due to an electrical malfunction, BT drops could not be made during the October cruise, but this has been rectified and it is hoped that the apparatus will be operational on future cruises. The plankton net was used for the first time during the October cruise. Plankton hauls were made and the apparatus tested in order to find optimal operating conditions. In future plankton for trace element analyses will be collected at all stations.

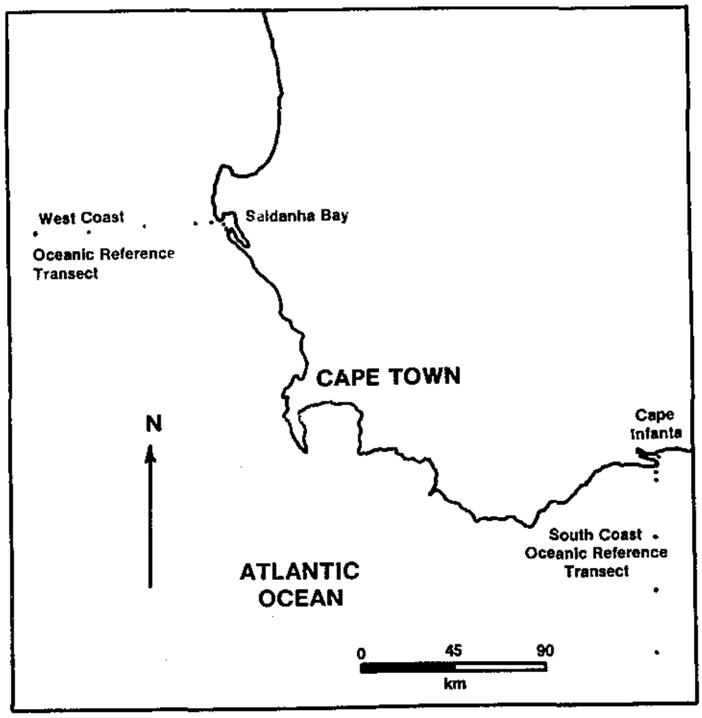

Figure 15. Location of the South and West Coast oceanic reference transects.

Sediment samples were obtained where possible by means of a Van Veen grab. This has met with mixed success and it has not been possible to obtain sediment samples where the sea bed is rocky or in rough conditions due to premature closing of the grab. Thus it is hoped to obtain samples by means of a corer in future where these conditions prevail.

In all, the following samples were collected during the four cruises; 281 for temperature, oxygen, salinity, nutrients, 140 for trace metals, 26 tar balls, 42 sediments and 7 BT.

The data obtained on all cruises undertaken so far will be combined with data to be obtained on cruises during 1976. This will then be subjected to detailed study. Thus only a few general comments can be made at this stage.

Surface temperatures tend to be slightly lower inshore. This is especially evident on the west coast during summer. Variations in the surface temperatures appear to be more marked during summer, the west coast being appreciably cooler than the south coast. Surface temperatures varied only slightly during winter. Thermoclines appear to be better defined in the Agulhas Bank water than in the Benguela Current. The depths at which they occur are variable but appear to be greater in winter.

The salinities generally showed a decrease with depth. Mean surface salinities range from $34,7^{o}/oo$ to $35,5^{o}/oo$ with a mean of approximately $35,1^{o}/oo$.

Dissolved oxygen content appears to be a maximum in the region of thermocline, decreasing rapidly below this. Nutrient concentrations increase with depth.

Trace element analysis of sea water is at present limited to lead and cadmium, but it is hoped to include a much larger number of elements in the near future. Values so far obtained for lead range from 20 to 370 ng/l and for cadmium from 2 to 25 ng/l.

The quantities of floating tar obtained show considerable variability as is characteristic of this type of study. The neuston net (width 40 cm) was towed at 3 knots for 1 nautical mile (1 853 m) giving a sample area of 740 m^2. Tar balls were found in about 70% of the hauls and amounts of tar obtained varied from zero to 31,6 mg/m^2. The value of 31,6 mg/m^2 is far higher than any others obtained (the second highest being 7,7) and the mean value, neglecting this abnormally high figure, is 0,93 mg/m^2.

GENERAL POLLUTION STUDIES

Investigations which were not formally part of the National Marine Pollution Survey but which are nevertheless of considerable importance to the field of marine pollution can be classified in two categories: general pollution studies and studies of coastal waters dynamics.

Pollution of the sea by fish factories (Shannon 1975).

Much of the pollution of the sea by factories processing pelagic fish (e g pilchard, anchovy), emanates from the use of wet offloading systems for transferring fish from the boats to the factories. In such a system the fish are pumped ashore in a seawater medium, and the water is subsequently returned to the sea. When fish in poor condition are offloaded in this manner, serious organic pollution of the sea is caused. The effluent can have COD's in excess of 100 000 mg/l and as the volumes are considerable, the effluent has an adverse impact on the marine environment. Nutrient enrichment occurs, the sea water becomes depleted (totally depleted at times) of oxygen and settling of scales and other particulate material takes place. In addition, oil from the fish that may be present in the flume water can contaminate boats, harbours, beaches and sea birds in much the same manner as mineral oil.

The pelagic fishing industry in the Republic is based largely on the anchovy and is geared towards the production of fishmeal and oil rather than canning. As such, the industry lends itself to the use of vacuum equipment for transferring the fish from the boats to the factory. This vacuum removal, or dry offloading as it is termed, damages the fish to a greater degree than wet offloading, but produces only minimal pollution by comparison. Dry offloading does however give better yield than wet offloading and is considered by the industry as an economical process. During the 1973 fishing season only one factory in the Republic used dry offloading, but by January 1975 all operating pelagic fishing factories had installed, or were in the process of installing, dry offloading systems, involving an expenditure of the order of R2 million. Improvements in the house-keeping of certain factories and changes in the quota system for pelagic fish have also helped to minimise pollution during 1975.

The improvement in the water quality around those factories that have been successfully using the dry offloading system has been dramatic. Levels of dissolved oxygen have increased from virtually zero to 4 - 5 ml/l (i e only approximately a 20% depletion of the seawater average), nutrient levels have returned to near normal condition, and the incidences of fish oil pollution have been few in number. The aesthetic qualities of the sea have shown as dramatic an improvement. In the case of fish factory effluence the treatment not only resulted in the minimising of pollution, but the reduction ratio of raw fish to fish meal showed an improvement of approximately 5%.

The Cape fur seal as an indicator of marine pollution (Henry 1975).

There is a large body of evidence which demonstrates that pesticide residues can be transferred along a food chain, the concentrations becoming progressively higher in the higher trophic levels of the food chain. At the low concentrations of pesticide residues detected in plankton and fish taken from the South Atlantic, the identification and quantification of the residues is always difficult and sometimes ambiguous. To ensure the validity of these analyses, the Cape fur seal (*Arctocephalus pusillus*) was selected as an indicator species in an investigation of organo-chlorine pesticide contamination of ocean waters around the coast of the Republic.

Occupying a position at the top of the food chain, the diet of the Cape fur seal consists of fish, cephalopods and crustaceans. The geographical range of the Cape fur seal extends from Cape Cross on the South West Africa coast to Algoa Bay on the Cape south coast, a distance of some 2 500 km. The seals are widely scattered throughout the inshore waters but seldom venture further than 150 km from land. Thus the Cape fur seal, having a distribution covering a large part of South Africa's Atlantic coast line and with a relatively large proportion of its body mass as blubber, has all the atributes of a useful indicator species for pesticide pollution of the oceans.

Blubber samples were collected by members of the Sea Fisheries Branch's Marine Mammal Unit during an investigation on the South African seal population. The samples from Wolf and Atlas rocks, which are situated near to Luderitz Bay, were obtained during the 1974 seal harvest. Those from the Cape Peninsula were taken in 1975 during a survey which extended eastwards to Algoa Bay.

Table 6 summarises the results of analyses in two areas (1) Wolf Rock/ Atlas rock (ii) Cape Peninsula.

The differences in concentration levels between the samples from the West Coast and the Peninsula are difficult to explain in terms of the geographical positions of the sampling sites. The main sources of both pesticide and PCB contamination are North America and Western Europe and the atmosphere the most important pathway by which they reach the oceans. There is a well established reduction in concentration in wild life samples as one moves away from these main sources but the differences seen in these two sets of samples is too great to be explained in these terms.

Table 6. Residues in seal blubber, conc in ppm. (ND = Not Detected)

Area	No of samples	mean conc in blubber ppm				
		ppDDE	Dieldrin	ppTDE	ppDDT	PCB as AROCLOR 1254
Wolf/Atlas	15	1,74	ND	0,12	0,11	0,84
Cape Peninsula	14	2,13	0,03	0,34	1,03	4,85

A more acceptable explanation for the differences observed lies in the nature of the samples themselves. Those from the west coast contained a high proportion of blubber from seal pups which had not yet been weaned while those from the Peninsula were mainly from adults. It has been found that seal pups from Arctic Canada contain only one fourth of the concentrations found in adult seals from the same area.

The 'Total DDT' and PCB levels found in South African seals are similar to those found in Arctic Canada and Arctic Norway but very much lower than the levels in the North Sea, Baltic Sea and from the North American coastline.

Toxicity of heavy metals to marine fauna (Brown 1975)

The effects of cadmium pollution on the marine whelk *Bullia digitalis* were investigated by exposure of the animals to different concentrations of cadmium in sea water for a period of 24 days. Concentrations of 0,5 ppm and above of cadmium have a demonstrably adverse and potentially lethal effect on *Bullia*. It is, however, to be expected that much lower concentrations may affect reproduction or embryonic development and may also have other adverse effects on the adults. The animals used in the toxicity tests were analysed for cadmium content to discover whether *Bullia* accumulates cadmium from the surrounding sea water. Results were positive, *Bullia* accumulating cadmium particular in the viscera.

The toxicity of zinc to *Bullia digitalis* was assessed under similar conditions. Concentrations above 1 ppm zinc proved fatal to the animals, stress being aparent after 12 hours and most of the animals being paralysed within 32 hours. More than half the animals were dead by the fourth day.

Work on the effects of pollutants on the macrofauna of sandy beaches indicates that the permanent infauna (such as *Callianassa* and *Arenicola*) is far more tolerant of pollution than is the highly mobile epifauna (*Isopoda*, *Gastrosaccus*, etc). The latter usually react to pollutants by reversing their normal thigmotaxic behaviour thus tending to be carried away from polluted areas of the beach.

The effect of ammonium nitrate effluent on the fauna of Table Bay

During 1973 the firm of Fedmis (Pty) Ltd initiated an investigation into the possible effects of their effluent, consisting of an aqueous solution of ammonium nitrate, on the fauna of Table Bay (Brown 1974a).

An effluent pipe, 150 mm, was established in August, 1969. The effluent emerges some 530 metres from high-water mark on Milnerton Beach. The effluent flow is virtually continuous but varies considerably in volume (daily average 699 m^3). Up to the end of 1973, more than 4 million kg of ammonium nitrate had been discharged into Table Bay. The residence time of the effluent in the Bay varies between 24 and 95 hours. In calm conditions the dilution of the effluent 100 metres from the mouth of the pipe was consistently of the order of 1 000 times.

There is little indication of damage to the benthic fauna at the effluent site. The sandy-beach macro fauna was sampled quantitatively down a series of inter-tidal transects near the effluent site. The data obtained from the various transects were compared not only with one another, but also with data collected by Brown (in press, in prep) some 15 years earlier (ie before the Fedmis factory was established). No change had taken place in the macro fauna over this period despite increasing pollution from a number of sources.

The tolerance of a variety of biological materials to ammonium nitrate pollution was tested (Brown 1974b, Brown and Currie 1973, Currie *et al* 1974, Greenwood and Brown 1974). The animals tested show a remarkably wide range of tolerance, the development of some larvae being retarded by concentrations of ammonium nitrate as low as 0,5 ppm, while some adult animals appear to tolerate concentrations up to 1 000 ppm without displaying any observable abnormalities in behaviour.

The effect of the effluent is most likely to be felt by planktonic organisms, including developing larvae, and in this respect a danger area may be said to exist at and near the surface of the sea, in the form of a narrow ellipse extending between 200 and 300 metres north and south of the effluent pipe. It must be borne in mind, however, that the effluent enters a bay which suffers pollution - including nitrogen enrichment - from a number of sources, only a few of which have been investigated (Marine Effluent Research Unit 1970, Banks 1971, van Ieperen 1971).

The biological effects of oil and dispersant pollution on the Struisbaai/ Arniston Coastline

On the 22nd July, 1974 the 98 326 ton Oriental Pioneer went aground on rocks near Cape Agulhas lighthouse. The wreck was lying less than 2 km offshore and was carrying approximately 2 000 tons of bunker oil. The wreck finally broke up a month later, and by the end of August a considerable portion of the Struisbaai shore had been polluted by the oil spill. During this period large quantities of dispersant was pumped into the fuel tanks as well as sprayed onto the slick itself.

The intertidal zone at Struisbaai was investigated on the 2nd September, 1974 (Brown 1975). The sandy beach was found to have a fairly rich and varied infauna which did not appear to have been unduly disturbed by the oil pollution. Even though the area was polluted some years before when the Wafra was wrecked (Day *et al* 1971), the fauna was richer than that found on many relatively unpolluted Cape Peninsula beaches (Brown in prep). No direct comparisons were possible, however, as the species are different, the polychaet worms *Onuphis, Lumbrinereis* and *Goniadopsis* not being found in any numbers on the beaches of the Cape Peninsula, while apparently constituting the bulk of the fauna of the lower part of the intertidal slope at Struisbaai. The impression given by the richness of the infauna is offset by the absence of *Talorchestia* from the drift line and the complete absence of active swimmers on the lower part of the beach.

A week after the sampling trip, large numbers of apparently dead sea urchins *Parechinus angulosus* were washed up onto the beaches. No traces of oil were apparent on them, neither could any abnormality of the internal organs be found. It is thus not possible to state whether they had been killed by oil pollution, dispersant pollution or a combination of the two.

By the middle of September some thousands of penguins had died on Dyer Island. Many of these were not, however, contaminated by oil, and two individuals examined showed no traces of oil either on their feathers or in their gut. The possibility of death following dispersant pollution therefore cannot be ruled out altogether in this case as well.

COASTAL WATERS DYNAMICS

There are good practical reasons for wanting information about the movement of waters in coastal regions. Such information is used in planning the disposal of industrial, municipal and nuclear power station wastes, in predicting the movements of oil spills and sediments, and in guiding the search for disabled craft.

In general the currents in coastal regions are of two kinds; those nearshore (within a distance of several surf widths from the shore) which are set in motion by the action of waves, and those further off-shore where the wind action and the influence of major ocean currents are the motivating forces. In combination these form a current system of considerable complexity.

Coastal and nearshore currents have been intensively studied along the Natal coast and considerable progress has been made in their understanding. In Cape waters, however, little concentrated attention has been given to them though the information which has come from the study of upwelling from the standpoint of fisheries constitutes a useful background. In an attempt to make good this deficiency some investigations are being undertaken on the coastline to the north of Cape Town, initially at Matroos Bay and at Duynefontein.

Matroos Bay (Gunn 1975, Harris and Gunn 1975)

Matroos Bay (Figure 16) is situated approximately 40 km north of Cape Town and is almost semi-elliptical in shape with an area of about 9 x $10^5 m^2$. The mouth of the bay faces south-west.

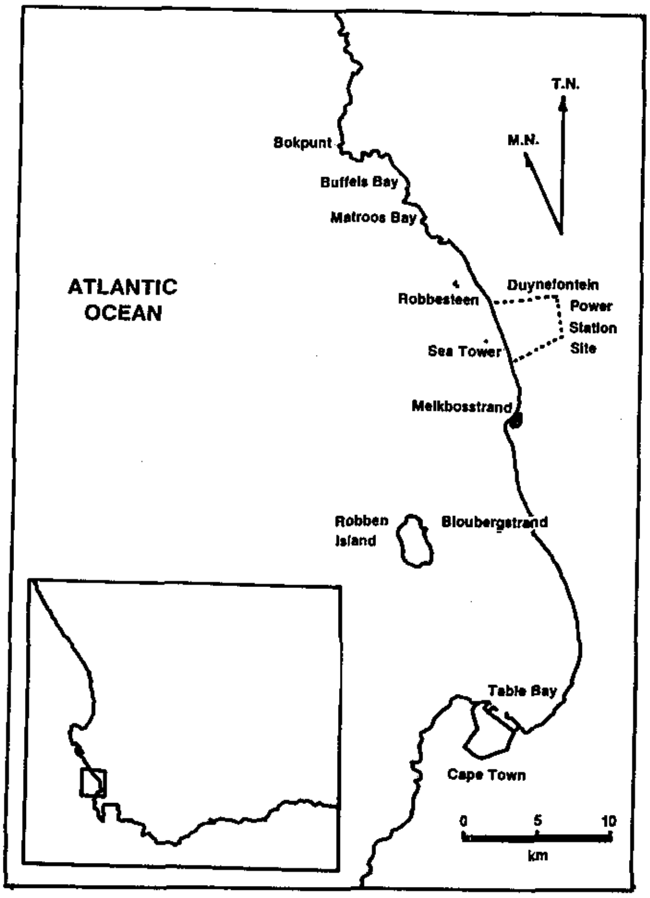

Figure 16. Location of Matroos Bay and the Duynefontein nuclear power station.

A shallow reef exists at a distance of 400 m WNW of the southern headland. Other than this the bottom topography is faily regular except near the sandy beach where wave action may change the profile. The maximum depth at the mouth of the bay is approximately 12,5 m.

No very satisfactory means of measuring coastal currents exists, and recourse has had to be made to the tracking of floats with drogues or dye patches either from the shore or from an aircraft. Aerial photographs of water discoloured by plankton, kelp detritus or silt has been another source of information. On a larger scale radiation thermometry has also been shown to offer possibilities because of the relatively steep temperature gradients set up by wind-induced upwelling. Electronic methods of float tracking are under development.

The evidence gathered from the field work suggests that the circulation is greatly influenced by the wind. The contrasting circulations during conditions of onshore and offshore winds are consistent with this conclusion. Furthermore, the closer coupling of the circulation in the bay with the coastal current during the condition of south-going winds is in accord with the concepts of Ekman, which *inter alia* predict a tendency for wind drift currents to be deflected to the left in the Southern Hemisphere. It is noted that when the coastal current was north-going, the coupling with the bay was considerably less - though no north-going wind was blowing at the time.

Several features of the wave driven circulation have been observed. The most striking is a rip current heading diagonally towards the middle of the bay and having its origin at the base of the northern headland. On many occasions this rip dominated the cirulation in the northern half of the bay. The strength of the rip appears to be related to the wave amplitude, and hence energy, of the waves moving into the bay. It is fed by a strong longshore current flowing north close to the shore (Figure 16). Diving in this vicinity has shown that the rip has scoured a channel 4 to 5 m deep in the sand bottom. The channel is quite localised with a steep rise to an area only one metre deep about 50 m from shore.

There are generally two breaker lines in the bay. The first a spilling breaker over an offshore sand bar, with waves reforming over a deeper channel to form surging or plunging breakers on the shore. It is in this deeper channel that strong longshore currents have been observed feeding the rip currents. The number of rips observed varies with wave energy, fewer rips occurring in days of high energy input.

Duynefontein (Bain 1975, Bain and Harris 1976)

The project aims to establish the dominant features underlying mechanisms of the water circulation in the nearshore and coastal region, in order that predictions can be made of the dispersion and dilution of radioactive wastes and nuclear power station coolants, discharged over the shallow sloping beaches in embayments of the Cape coast. Initial attention has been focused on the site of the Koeberg Nuclear Power Station off Melkbosstrand (Figure 16). Although the site has a long straight coast line, it is bounded by curved headlands 1,5 km in extent approximately 6,5 km and 5,0 km north and south respectively from the power station position. The bounds of the present study extends between these headlands and several kilometres offshore.

The temperature gradients in the first few kilometres from the shore during the upwelling months are quite sufficient for the main features of the surface temperature distribution to be resolved by airborne radiation thermometry (ART). Interpretation of the surface temperature distribution in terms of water movements is considerably facilitated by a time series of measurements. However, the upwelling process is such that the time scale of measurable change is 12 hours rather than 24. The local nature of upwelling leads to quite small sources of cold water which can act as very useful tracers of coastal water movements in this time dependent region of the sea. Despite early misgivings, the use of a light aircraft has proved satisfactory.

The method of photogrammetry of dye marked floats, has gone some way to solve the problem of determining reasonably synoptic current vectors over a fairly large expanse of water which is not very stationary. No great accuracy is claimed for it but in the absence of any other practical method it will serve for measuring near-surface currents. The measurement of low velocity deep currents in the presence of high winds still presents problems.

The technique has been used successfully under wind velocities ranging from calms to 40 km/hr.

The radar tracked float technique remains the best for long term current measurements with light airs.

Broadly the purpose of this study of coastal water movements in its first phase is to try to gain some understanding of the coastal current and temperature regimes, between Cape Town and Bok Point. In the pursuit of this larger scale objective the regime in Duynefontein Bay has been kept clearly in mind. It will be appreciated that such conclusions as can be drawn are not based on as much data as would be desired. Most of the field measurements have been made in the upwelling season and reflect strongly the effect of winds with a strong southerly component which dominates the summer months; a time of active water movements and strong temperature contrasts. The more quiescent conditions will be sampled in the coming quarter.

The interpretation of the currents from temperature distribution has shown (with the reservations mentioned above) that the gross circulation at the season of upwelling in the region of interest is strongly influenced by the changing orientation of the coast between Cape Point and Bok Point, in relation to the direction of the upwelling wind. Tentative conclusions are that a jet, generated along the coast just north of Cape Point leaves the coast in a direction of 340° - 350° and passes to the west of Robben Island. Water on the Robben Island side of this jet is entrained in it. Another current is generated by southerly winds between Cape Town and Blaauwberg Strand. This is affected by the entrainment, and in the vicinity of Melkbosstrand, tends to be deflected seaward towards the north of Robben Island. This deflection probably occurs only after the Peninsula Jet is established - perhaps a day or so after the commencement of the southerly winds. It has important consequences on the pattern of surface isotherms off Duynefontein Bay.

On a smaller scale the currents under the influence of southerly winds, in and off Duynefontein Bay seem (with our present state of knowledge) to behave as follows:

When the winds are strong the whole current system is north-going. There is no evidence as yet that the coastal currents sweep into the bay. On the contrary, it seems that the water supplying the surface currents in the bay arises locally. If this is true, continuity demands a sub-surface supply at the southern end - local upwelling. This is substantiated by a local cold spot. An interesting conclusion which is fairly well established is that north-going currents in the bay are deflected offshore before reaching Robbesteen Island. The reason for this is not clear but the topography, strong local rip currents or the grosser circulation, suggest themselves as influential features.

If the nuclear power station coolant can be discharged so that it can be confluent with this cold current which deflects offshore, dispersal would be facilitated.

With the light winds the evidence from the cruise data, the dye floats and the moored-buoy current measuring system indicate that a lee eddy can sometimes arise in the southern end of the bay - currents within the bay being sluggish or even counter to those without.

After the wind ceases there may be some residual north-going current. Its decay characteristics are not yet known but the moored-buoy current measuring system should throw some light on this. When the north-going current has decayed the movement of water off the bay shows a tendency to flow shorewards. Currents within the bay are (as evidenced by radar tracked floats) of small velocity and variable in direction - perhaps dominated by the wave driven currents of the nearshore circulation depending on wave heights. Again, studies in the quiescent months may thow more light on this. There seems little doubt that residence times are relatively large under these conditions. The radar tracked floats have shown that residence time in a square mile may be as long as 17 hours, and is on the average about half of this. It is obvious from these results and from the fact that days with little or no wind occur very frequently in Cape waters in the autumn and winter months, that this condition is a very important one for nuclear power station coolant problems.

The synoptic ART surveys have produced a number of results of considerable interest.

With upwelling winds there are three positions along the coast under study where the upwelling (as interpreted from ART temperatures) is initially most active. These are the southern sector of Table Bay, Duynefontein Bay (especially the southern end) and Buffels Bay. It cannot therefore be expected that isotherms will run parallel to the coast, though with sustained winds the cold upwelled patches do elongate mainly alongshore. However, there are other factors causing nonhomogeneity of temperature distribution. Along the margins of the coast (approximately the surf zone) there is a discrete band of warm water which may persist continuously from Duynefontein to Table Bay. A further factor is the deflection offshore of the Table Bay Current in the vicinity of Duynefontein Bay, causing a bulge of cold water seaward. This deflection may be the reason why there has been no evidence to date of the Table Bay Current sweeping into Duynefontein Bay though there may be some continuity in the flow of the warm nearshore band. The evidence on the contrary is that within the bay under southerly winds the wind drift current is supplied by local upwelling. (It may be well to confirm the reasonableness of this assumption by continuity studies).

The presence of the warm littoral band of warmer water argues a degree of isolation of that region of the sea from that offshore of it. In nine observations the temperature differential across it was 1,5 - 2 ^{o}C on three occasions and 0,5 ^{o}C on three occasions, and on the remaining three days, under downwelling conditions, it could not be identified. The band is about 500 m wide as estimated from ART flight lines normal to the shore at

2 - 4 km spacing. This feature could prove to be a useful analytical tool in estimating heat exchange between the nearshore region and that offshore of it, and therefore relevant to the coolant disposal problem.

The above refer to winds with a strong southerly component. When these cease and the currents become slow onshore drifts, the temperature of the water advected shorewards depends upon the isotherm distribution caused by the previous southerly winds. One can anticipate that the water at the shore will first cool and then warm as the warmer water from offshore comes in.

It is clear that the currents and surface temperatures along and within Duynefontein Bay are spatially diversified and highly time dependent.

REFERENCES

Allanson B R and J D van Wyk 1969. An introduction to the physics and chemistry of some lakes in northern Zululand. *Trans R Soc S Afr* 38, 217-240.

Archibald C G M 1971. Aspects of the limnology of the Ifafa River estuary in relation to its possible eutrophication. In (National Institute for Water Research) Natal Rivers Research Report 37. 3 pp. Typescript.

Bain C A R 1975. Coastal water movement study. Progress report No 1 for period ending June 1975. Report to the Atomic Energy Board. 30 pp. Typescript.

Bain C A R and T F W Harris 1976. Coastal water movements study. Progress report No 2 covering the period July 1975 to January 1976. Report to the Atomic Energy Board. 88 pp. Typescript.

Banks D G 1971. Pollution survey of the Black River complex. Unpublished student project, Zoology Department, University of Cape Town. Typescript.

Brand P A J, P H Kemp, S J Pretorius and H J Schoonbee 1967. Water quality and abatement of pollution in Natal rivers. Part 1. Objectives of river surveys, description of methods used and discussion of water quality criteria. *Natal Town and Regional Planning Report* 13(1), 101 pp.

Breen C M and B J Hill 1969. A mass mortality of mangroves in the Kosi estuary. *Trans R Soc S Afr* 38, 285-303.

Broekhuysen G J and H Taylor 1959. The ecology of South African estuaries. Part 8. Kosi Bay estuary system. *Ann S Afr Mus* 44, 279-296.

Brown A C 1974a. Report on the effects of the effluent discharged into Table Bay by Fedmis (Pty) Ltd. Unpublished report, Zoology Department, University of Cape Town. 82 pp. Typescript.

Brown A C 1974b. Observations on the effect of ammonium nitrate solutions on some common marine animals from Table Bay. *Trans R Soc S Afr* 41, 217-223.

Brown A C 1975. Report on the biological effects of oil and dispersant pollution on the Struisbaai/Arniston coastline. Appendix 2 in Orren 1975.

Brown A C (in press). The ecology of the sandy beaches of the Cape Peninsula, South Africa. Part 5. A list of the fauna, with distribution records. *Trans R Soc S Afr* 42.

Brown A C (in preparation). The ecology of the sandy beaches of the Cape Peninsula, South Africa. Part 6. The spatial distribution of the fauna. *Trans R Soc S Afr*.

Brown A C and A B Currie 1973. Tolerance of *Bullia digitalis* (Prosobranchiata) to solutions of ammonium nitrate in natural sea waters. *S Afr J Sci* 69, 219-229.

Campbell G D and B R Allanson 1952. The fishes of the 1947, 1948 and 1949 scientific investigations of the Kosi area. *Bull Natal Soc Preserv wild Life nat Resour* 1(4), 1-8.

Christie N D and J C Allen 1972. A self-contained diver-operated quantitative sampler for investigating the macrofauna of soft substrata. *Trans R Soc S Afr* 40, 299-307.

Connell A D and J R Grindley 1974. Two new species of *Acartia* (Copepoda, Calanoida) from South African estuaries. *Ann S Afr Mus* 65, 89.

Connell A D, W D Turner, B D Gardner, T P McClurg, D J Livingstone, J E Carter and W J N Gertenbach 1975. National marine pollution monitoring programme (East Coast Section) progress report 2 (March 1974 to March 1975). Report to the National Programme for Environmental Sciences. 118 pp. Typescript.

Currie A B, A C Brown and G R Bennett 1974. The effect of ammonium nitrate solutions on some aspects of the biology of the black mussel, *Choromytilus meridionalis*. *Trans R Soc S Afr* 41, 209-215.

Darracott D A and C E Cloete 1976. Bibliography on marine pollution in South Africa. *South African National Scientific Programmes Report* 5, 131 pp.

Day J H, P A Cook, P Zoutendyk and R Simons 1971. The effect of oil pollution from the tanker *Wafra* on the Marine fauna of the Cape Agulhas area. *Zool Afr* 6, 209-219.

Fourie H O 1976. Metals in organisms from Saldanha Bay and Langebaan Lagoon prior to industrialization. *S Afr J Sci* 72, 110-113.

Fricke A H, P J Greenwood and G A Eagle 1975. National Marine Pollution Monitoring Programme (West Coast Section) progress report 1975. Report to the National Programme for Environmental Sciences. 50 pp. Typescript.

Greenwood P J and A C Brown 1974. The effect of ammonium nitrate solutions on fertilization and early development of the sea urchin *Parechinus angulosus*. *Zool Afr* 9, 205-209.

Gunn B 1975. Dynamics of Cape Coastal Waters. Report to the National Programme for Environmental Sciences. 5 pp. Typescript.

Harris T F W and B Gunn 1975. Dynamics of Cape Coastal Waters. Report to the National Programme for Environmental Sciences. 15 pp. Typescript.

Hemens J, D E Simpson and T P McClurg 1970. Detailed survey of Richards Bay. In National Institute for Water Research. Marine Disposal of Effluents Progress Report 20, 34 pp. Typescript.

Hemens J, T P McClurg, D E Simpson and R J Warwick 1971a. Detailed Survey of Richards Bay. In National Institute for Water Research. Marine Disposal of Effluents Progress Report 21, 37 pp. Typescript.

Hemens J, H Metz and S M H Cox 1971b. The Ifafa Estuary. In National Institute for Water Research. Natal Rivers Research Report 36, 20 pp. Typescript.

Hemens J, H Metz, D E Simpson and O J Coetzee 1971c. The Mlalazi Estuary. In National Institute for Water Research. Natal Rivers Research Report 37, 26 pp. Typescript.

Hemens J, H Metz, W D Oliff and D E Simpson 1972a. Natal coast estuaries : environmental surveys. Survey 3 - The Kosi Bay estuarine lakes. In National Institute for Water Research. Marine Disposal of Effluents Progress Report 23, 34 pp. Typescript.

Hemens J, H Metz, D E Simpson and R J Warwick 1972b. Natal coast estuaries : environmental surveys. Survey 4 - The Amatikulu Estuary. In National Institute for Water Research. Marine Disposal of Effluents Progress Report 24, 22 pp. Typescript.

Hemens J, H Metz, D E Simpson and R J Warwick 1973. Natal coast estuaries : environmental surveys. Survey 6. The Umtamvuna Estuary. In National Institute for Water Research. Marine Disposal of Effluents Progress Report 25, 24 pp. Typescript.

Hemens J and A D Connell 1975. Natal coast estuaries : environmental surveys. Richards Bay : southern ecological conservation area. In National Institute for Water Research. Marine Disposal of Effluents Progress Report 29, 22 pp. Typescript.

Henry J L 1975. The Cape fur seal, an indicator of marine pollution. Report to the National Programme for Environmental Sciences. 4 pp. Typescript.

Henry J L, S A Mostert and N Christie 1976. Phytoplankton production in Langebaan Lagoon and Saldanha Bay. Paper presented at the Symposium on Research in the Natural Sciences at Saldanha, Saldanha Bay, February 1976.

Hill B J 1969. The bathymetry and possible origin of Lakes Sibayi, Nhlange and Sifungwe in Zululand (Natal). *Trans R Soc S Afr* 38, 205-216.

Livingstone D J 1969. An appraisal of sewage pollution along a section of the Natal coast. *J Hyg, Camb* 67, 209.

Livingstone D J (1976, in press). An appraisal of sewage pollution along a section of the Natal coast after the introduction of submarine outfalls. *J Hyg, Camb*.

Livingstone D J, W J de Goede and Barbara A Warren-Hansen 1968. The distribution and occurrence of coliforms and pathogenic indicators of pollution within the surf-zone and near-shore waters along a section of the Natal coast. *CSIR Research Report* 278, 85 pp.

Marine Effluent Research Unit, University of Cape Town. 1970. Green Point outfall investigation. Final report. Typescript.

Millard N A H and G J Broekhuysen 1970. The ecology of South African estuaries. Part 10. St Lucia, a second report. *Zool Afr* 5, 277-307.

National Institute for Water Research 1968a. A survey of the bacteriology, chemistry and biology of the sea and beaches in the vicinity of Durban. Conditions prior to the use of submarine outfalls. Period 1964-1968. *CSIR Contract Report* C Wat 19, 185 pp.

National Institute for Water Research 1968b. Natal Rivers Research Report 31, 79 pp. Typescript.

National Institute for Water Research 1972a. Surveys monitoring the sea and beaches in the vicinity of Durban. Part 2. Conditions following the use of submarine outfalls. *CSIR Contract Report* C Wat 26, 31 pp & appendices, tables & diag.

National Institute for Water Research 1972b. Marine Disposal of Effluents Progress Report 24, 103 pp. Typescript.

National Institute for Water Research 1974. Surveys monitoring the sea and beaches in the vicinity of Durban. Part 3. Surveys between 1972-1974. *CSIR Contract Report* C Wat 30, 62 pp.

National Institute for Water Research 1975a. Surveys monitoring the sea and beaches in the vicinity of Durban. Part 4. Surveys between 1974-1975. *CSIR Contract Report* C Wat 31, 10 pp.

National Institute for Water Research 1975b. Marine Disposal of Effluents Progress Report 29, 59 pp. Typescript.

Oliff W D, C D Berrisford, W D Turner, J A Ballard and D C McWilliam 1967a. The ecology and chemistry of sandy beaches and nearshore submarine sediments of Natal. I. Pollution criteria for sandy beaches in Natal. *Wat Res* 1, 115-129.

Oliff W D, D C Berrisford, W D Turner, J A Ballard and D C McWilliam 1967b. The ecology and chemistry of sandy beaches and nearshore submarine sediments of Natal. II. Pollution criteria for nearshore sediments of the Natal coast. *Wat Res* 1, 131-146.

Oliff W D, W D Turner, B D Gardner and J B Sharp 1970. Sediment analysis as a means of characterising conditions in estuaries. In National Institute for Water Research. Marine Disposal of Effluents Progress Report 20, 15 pp. Typescript.

Orren M J 1975. National Marine Pollution Monitoring Programme (Cape Group) annual report for the period January to December 1974. Report to the National Programme for Environmental Sciences. 21 pp. Typescript.

Scarfe A D 1972. Honours Project, Zoology Department, University of Cape Town.

Schuster W H 1952. Fish culture in brackish water ponds of Java. *Spec Publs Indo-Pacif Fish Coun* 1.

Shannon L V 1975. Pollution of the sea by fish factories. Report to the National Programme for Environmental Sciences. 4 pp. Typescript.

Shannon L V and G H Stander 1976. The physical and chemical characteristics of the water in Saldanha Bay. Paper presented at the Symposium on Research in the Natural Sciences at Saldanha, Saldanha Bay, February 1976.

Simpson D E, H Metz, D J Livingstone and M Calder 1972. Natal coast estuaries : environmental surveys. Survey 5 - The estuary and lower reaches of the Umgeni River. In National Institute for Water Research. Marine Disposal of Effluents Progress Report 24, 25 pp. Typescript.

Stander G J, W D Oliff and D J Livingstone 1967. Problems in using the sea as part of a waste disposal system. Conference Paper 3, Annual Conference of the Institute of Water Pollution Control. 9 pp. Typescript.

Turner W D 1974. National Marine Pollution Monitoring Programme (East Coast impact area surveys) progress report no 1. Report to the National Programme for Environmental Sciences. 3 pp. Typescript.

Turner W D and D J Livingstone 1974. National Marine Pollution Monitoring Programme (East Coast impact area surveys) progress Report no 2. Report to the National Programme for Environmental Sciences. 10 pp. Typescript.

Turvey L G S 1960. Report on the lower Umhlatuzi River. Report H O File 3088 of the Department of Water Affairs. Typescript.

Van Ieperen M P 1971. Hydrology of Table Bay. Report, Department of Oceanography, University of Cape Town. 48 pp & 4 appendices.

Watling R J and H R Watling 1974. Environmental studies in Saldanha Bay and Langebaan Lagoon. I. Trace metal concentrations in selected molluscs and algae. *FIS Special Report* 70, 77 pp.

Watling H R and R J Watling 1975. Preliminary preparation of molluscs for trace-metal analysis. *FIS Special Report* 76, 9 pp.

APPENDIX A

COMMITTEE FOR MARINE POLLUTION 1974-1975

Dr E S W Simpson (chairman)	National Research Institute for Oceanology P O Box 320 STELLENBOSCH 7600
Dr J K Basson	Atomic Energy Board Private Bag X256 PRETORIA 0001
Prof A C Brown	Department of Zoology University of Cape Town Private Bag RONDEBOSCH 7700
Dr L R P Butler	National Physical Research Laboratory CSIR P O Box 395 PRETORIA 0001
Mr W D Oliff	NIWR Natal Regional Laboratory P O Box 17001 CONGELLA 4013
Dr L V Shannon	Sea Fisheries Branch Private Bag SEA POINT 8060
Mr G A Visser	Department of Planning and the Environment Private Bag X213 PRETORIA 0001
Mr M vd S Dreyer	Department of Transport Private Bag X193 PRETORIA 0001
Dr C E Cloete (coordinator from July 1975)	National Programme for Environmental Sciences CSIR P O Box 395 PRETORIA 0001