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The Effect of Sewage on the Distribution of Seaweed at the  
Bats Cave East Bank Sewage Outfall in East London, South  
Africa

THEODORE CHARLES KLENK

Submitted in partial fulfilment of the requirements for  
degree of

Master of Science

in the department of Plant Sciences  
Rhodes University, Grahamstown.

January 1985

## PREFACE

The experimental work described in this thesis was carried out from November 1982 to November 1984 under the supervision of Professor S.C. Seagrief at Rhodes University.

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

## ACKNOWLEDGMENTS

It is a great pleasure to acknowledge the guidance, help and encouragement from Professor S.C. Seagrief, for making this project possible.

I would like to express my thanks to Mr D.L. Blasko who taught me how to use a computer and was able to help design the programmes used with the data. He also used his surveying skills to find levels throughout the outfall area.

My grateful thanks go to Mr C. Malherbe who offered his assistance throughout the two years of the project. His unselfish help throughout has enabled this project to finish this year.

I would like to express my thanks to my father-in-law, Mr B. Van Vuuren who was always behind me with help whether it be a beach buggy for collecting or a car or fuel.

To Mrs P. Hanssen for the use of the computer and the meals between pages, thank you.

I would like to record my thanks to Dr K. Tinley who convinced me that there was a need for this type of project and it was not impossible.

I would also like to thank Mr H. Forrest from the city engineer's department who supplied me with information about the East London Sewage Works.

I am extremely grateful to Professor M.J. Wynne for his very kind and rapid responses about identifications.

I would like to acknowledge the kind help with identifications from Dr W. Scott who provided blue-green algae identifications, and Professor M. Hommersand and Mr R. Simons

for assistance in seaweed identification.

To my wife Wendy and family, I offer my sincere gratitude for their patience and support.

## TABLE OF CONTENTS

Preface	ii
Acknowledgements	iii
Chapter 1 Introduction	1
1.1 Aims	6
Chapter 2 The Study Area	
2.1 The Study Area	8
2.2 Geography	10
Chapter 3 Distribution of Seaweeds at Bats Cave Rocks	
Introduction	17
3.1 Methods	18
3.2 Results and Discussion	20
Checklist of Species	33
Chapter 4 The Use of Seaweed Densities in Determining Ecological Effects on the Sewage Outfall Area	
Introduction	39
4.1 Methods and Materials	42
4.2 Results and Discussion	53
Chapter 5 Algal Successions in Polluted and Unpolluted Areas	
Introduction	68
5.1 Methods and Materials	70
5.2 Location and Geography of Areas	73
5.3 Results and Discussion	74
Chapter 6 Observations	103
6.1 Die Off	103
6.2 Seasonality	103
6.3 Corallines	104
6.4 Use of Infrared Film	104
6.5 Succession	106

Chapter 7	Discussion	108
Chapter 8	Summary	111
Appendix 1	Seaweed Species and Reference Numbers Used in Study	113
Appendix 2	The Development of the Computer Programme Used for Data Manipulation in this Study	116
Appendix 3	List of Herbarium Sheets Made During the Study	119
Appendix 4	Notes on Species Identifications	121
Appendix 5	List of Permanent Microscope Slides Made During the Study	122
	References	126
	Plates	139

DEDICATED TO MY FATHER,

CHARLES T. KLENK (1922-1984)

... And God said, Let the waters bring forth abundantly the moving creature that hath life ... and God created great whales, and every living creature that moveth, which the waters brought forth abundantly ...

Genesis 1:20, 21 (AV)

## Chapter 1

### INTRODUCTION

The effect raw sewage has on the distribution of seaweed along a section of the South African coastline is the topic of this study. Although the results follow previous findings about the effect sewage has on the distribution of seaweed species, this study area forms a unique situation where, for sixty-six years, raw, untreated sewage has been pumped directly into the sea within the city limits of East London. The location of the receiving waters is a small cove with a conspicuous 900mm diameter pipe (Plate 1.2) releasing its contents at the low water spring tide mark (Watling, 1983) to mix with the waves. Untreated sewage contains large amounts of organic matter and wastes with a high organic content are not easily dissolved and can be carried considerable distances from the point of discharge (Pearce, 1971) (O'Sullivan, 1971). The sewage is then able to mix along the shoreline but at a much lower dilution rate than would be the case with an underwater pipeline extending out under the sea.

The effect can be seen in the results of the study of the relationships of seaweed species in the immediate vicinity of the outfall and then working away towards a control established at 1000m southwest of the outfall. An extra control, 35km southwest of the outfall, was used to establish a checklist for comparison (See plates 1.3 and 1.4).

The use of attached seaweeds for this study is

significant because of their inability to move away from pollution. Because of this characteristic, seaweeds can be used as indicator organisms (Burrows, 1971).

The most recent pollution studies using seaweeds have presented these ever present organisms to an ecology-minded society and provided us with yet another organism which reacts to man's pollution of the Earth. The seaweed reacts to the substances introduced into the estuaries and oceans and can actually be utilized to show where man's pollution is spreading. Burrows (1971) proposed using this reaction as a possible indicator organism for pollution. The response of Ulva to the presence of sewage pollution was shown, and it was found that Ulva could make use of the nitrogen in the form of ammonium and that under polluted conditions, the plants had a high nitrogen and organic sulphur content compared with that under non-polluted conditions.

O'Sullivan (1971) found that the introduction of pollutants reduced seaweed diversity and short-circuited the energy flow. He stated that the addition of organic wastes provides energy in the form of chemical bonds and the natural ecosystem adapts from one fuelled by the energy of sunlight to one fuelled by the oxidation of organic wastes. This would eventually eliminate the normal fauna because of an excess of respiration over photosynthesis especially when the amount of waste matter is great. This causes a reduction of diversity and an increase in absolute numbers or density around the outfalls. He also pointed out that desirable species in nutrient-lean waters are replaced by possibly less desirable

species.

Borowitzka (1972) determined algal species diversity and found a decrease in species numbers in the outfall vicinity. This reduction was most evident in the brown and red algae. He found the instability of the environment in the outfall regions held the communities at primitive, pioneering stages and were characterised by a low algal species diversity.

Murray and Littler (1974) found the outfall area to have a lower species diversity and reduced numbers of larger species that were replaced by a more productive low turf. The critical ecological effect revealed by the study was the increased instability in the area of the outfall plume. The organisms present had simpler and shorter life histories and were characteristic of communities in early stages of succession.

Littler and Murray (1975) reported 49% fewer species of micro-organisms in the outfall area than in the nearby control areas. Species of Lithothamnium were conspicuously absent from the outfall area possibly because of their growth locations along crevices of rocks and the higher effluent concentrations which accumulate in these regions. They observed that ~~whereas~~ large brown algae were common in the control areas, they were absent in the outfall area. Blue-green algae were common on the higher shores of the outfall region and showed tolerance to the pure sewage diluted only at high tide by seawater. While species of Lithothamnium were missing from the outfall area, another coralline Corallina officinalis var. chilensis, became the dominant intertidal

coralline of the outfall region. They stated that a critical effect of the outfall could be decreased environmental stability, thereby favouring rapid colonizers and more sewage-tolerant organisms. The simpler and shorter life histories and smaller growth forms were characteristics the organisms in this polluted environment possessed.

Previous results were supported by Littler and Murray (1977) when they emphasized the rapid recovery of successional plots in the outfall area while the control plots had not fully recovered after one year. Another finding of theirs was that species comprising the intertidal turf, characteristic of sewage-disturbed areas, showed considerably greater productivity per unit of thallus area than most macrophytes measured and that outfall populations tended to have higher energy contents than populations in unpolluted areas. These energy rich components were entering the intertidal food web through omnivores and suspension feeders of the outfall community.

Another point Littler and Murray (1977) made was that the sewage tolerant species had low photosynthetic quotient values during exposure to effluent as compared with species of low tolerance which had a higher value. This was again brought out by Kindig and Littler (1980), when experiments were carried out with 10 Southern Californian macrophytes exposing them to untreated, secondary<sup>-reated</sup>, and secondary chlorinated sewage during long-term studies in the laboratory. While 3 species demonstrated enhanced growth in the presence of primary sewage, chlorination of the effluent had only short-term negative

effects. Experiments with Corallina officinalis var. chilensis as well as a few non-calcareous species which show considerable tolerance to sewage stress showed signs of physiological acclimation to sewage stress.

Murray and Littler (1978) compared the algal succession of a sewage polluted area with a non-polluted area on San Clemente Island, California. They reported the abundance of blue-green algae and diatoms in the early successional stages in both polluted and non-polluted areas. The outfall study plots showed a more rapid recovery following clearing and sterilization as compared with the control areas which had not completely recovered within 30 months. The species that were responsible for the rapid recolonization were referred to as pioneer or "opportunistic" species with rapid growth rates, high productivity and simple thallus forms with large surface to weight ratios (Murray and Littler, 1978).

Littler and Murray (1978) studied the use of opportunistic high energy algal forms (Ulva and the blue-greens) as food by certain organisms as compared with the use of articulated coralline algae in the unpolluted areas. The outfall grazer populations utilized these high energy sub-climax algae. The macro-invertebrates in the polluted habitat grazed greater populations of blue-green algae and bacteria. These macro-invertebrate populations contained higher energy contents than those in the unpolluted habitat.

Watling (1983) investigated the pollution status of the East London area and found that, with the introduction of untreated sewage into the sea, the currents make it possible

for the increase in its potential to impact the swimming beaches. Because of lack of evidence (although further studies were planned) he found no direct signs of contamination of marine life<sup>and</sup> could only assume at this stage that the lack of faunal diversity and numbers was due to the inhospitable coastline and not to pollution.

Gardner<sup>et al.</sup> (1983) reported high E. coli I/100ml counts indicative of moderate sewage contamination at Nahoon Beach, 1500m from the outfall.

### 1.1 Aim of Present Investigation

In order to determine which seaweeds were unable to survive in the stressed area and how far the effect of the effluent extended along the coast, various methods were applied and carried out over a two-year period between November 1982 and November 1984.

Three major long-term studies took place. The first study was to determine the presence or absence of the seaweeds throughout (1) the entire study area and then (2) in areas broken up into sections with known distances from the outfalls.

The second method involved statistical evaluations using point intersect methods and photography to produce information to determine species density, diversity, evenness, and to provide the information required to work with a number of ecological equations in the future.

The third method incorporated a long-term survey on

cleared plots in various sectors of the study area. The recolonization of the plots was recorded over a thirty-week period.

## Chapter 2

### 2.1 The Study Area

There are two outfalls within the study area (Plate 2.5) (Fig. 2.1). The northern one receives sewage from the northeast suburbs of East London. This 500mm diameter pipe (the Nahoon pipe) (plate 2.1) empties about 3.5 million litres of raw sewage per day into the sea. The main outfall receives the sewage from the rest of the city (except for two areas further inland) and releases 19 million litres per day into the ocean (Keppie, 1983) (Plates 2.2-2.5). The sewage is mainly domestic waste with the occasional addition of dyes from a local textile factory. The dye has been useful in following the currents which carries the sewage away from the outfalls (see Plates 2.7-2.9).

A sewage plume is usually visible extending out from the cove though the direction depends largely on the wind direction (Plate 2.6).

The sewage system at the time of this study is almost as it was when installed in 1922. The use of the outgoing tide to carry accumulated sewage away, soon became inefficient as the load grew with the population. At present two screening stations, using metal grids to screen out materials that may otherwise restrict the flow, are the only form of treatment applied to the raw sewage. One collects from the Nahoon side while the other collects from the city. These barminuter stations are manned by workers who clean the grids throughout

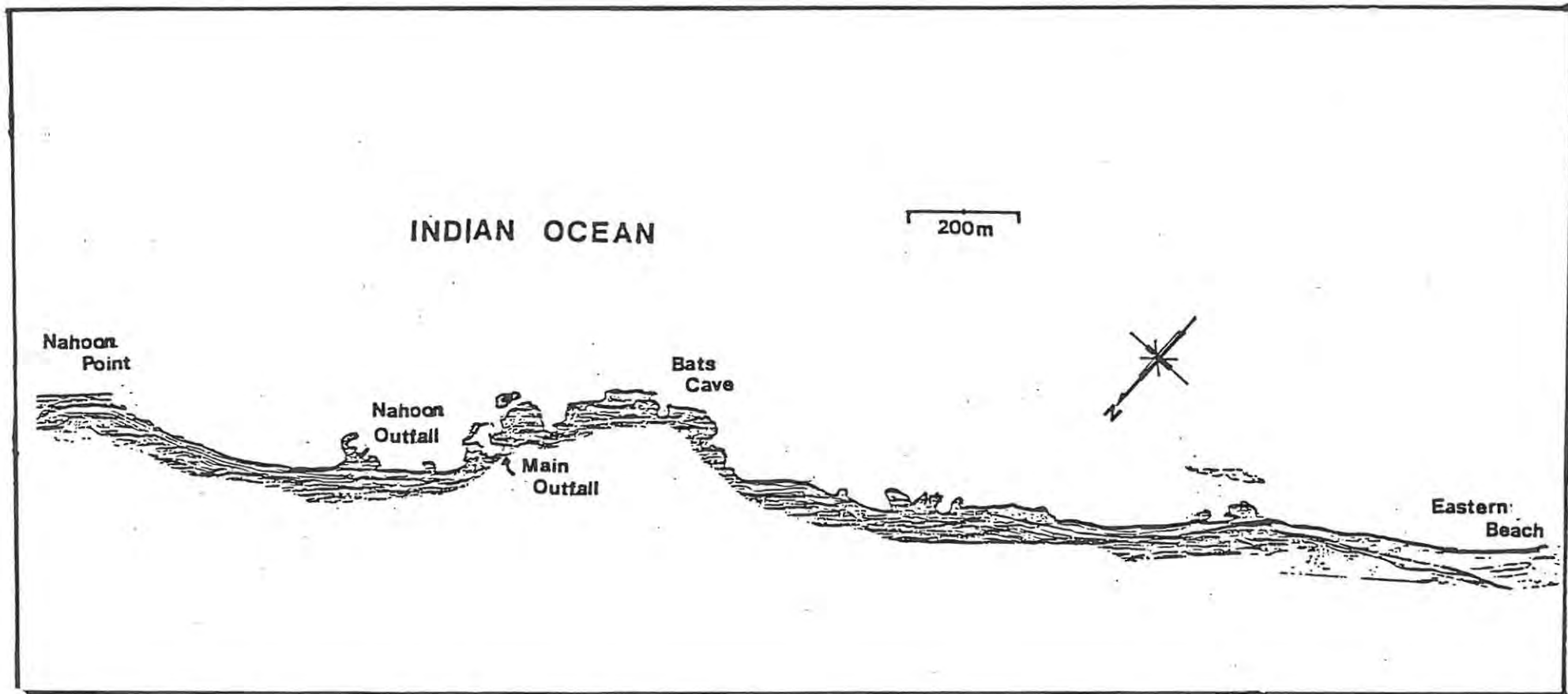


FIG. 2.1 LOCATION OF OUTFALLS

Modified from a City Engineers map

the day (See plates 2.10-2.12).

## 2.2 Geography

With the exception of a few small beaches with an average width of 25m, most of the study area consists of rock platforms that are from 5m to 20m wide, which rise steeply to cliffs ranging from 10m to 25m in height. This zone is still affected by splash and spray during high surf periods. The land quickly climbs and 100m from the sea, it averages 55m in height and is covered by dense bush and trees.

Dune Rock, (false-bedded calcareous sandstone) (Eyre, 1938), makes up the cliffs as well as the platforms and gives a consistent substrate throughout. Some of the south-east coast's highest forelands (30m-60m) are found along these dune rock cliffs (Heydorn and Tinley, 1980) (See plates 2.13 and 2.14).

Eyre<sup>et al</sup> (1938) surveyed the area mostly to the west of Bats Cave because of the "precipitous nature and inaccessibility of the eastward part ..." so the geographical descriptions listed in that study were, for the most part, 800 to 2000m west of the area in this study.

The location of the study area is 33°01'S and 27°57'E. The area lies on a point between two rivers, namely the Buffalo and Nahoon Rivers (Fig. 2.2). The annual runoff of each of these rivers is about 82 million cubic metres (Heydorn and Tinley, 1980). Two lesser streams straddle either side of the study area but their mouths are usually closed.

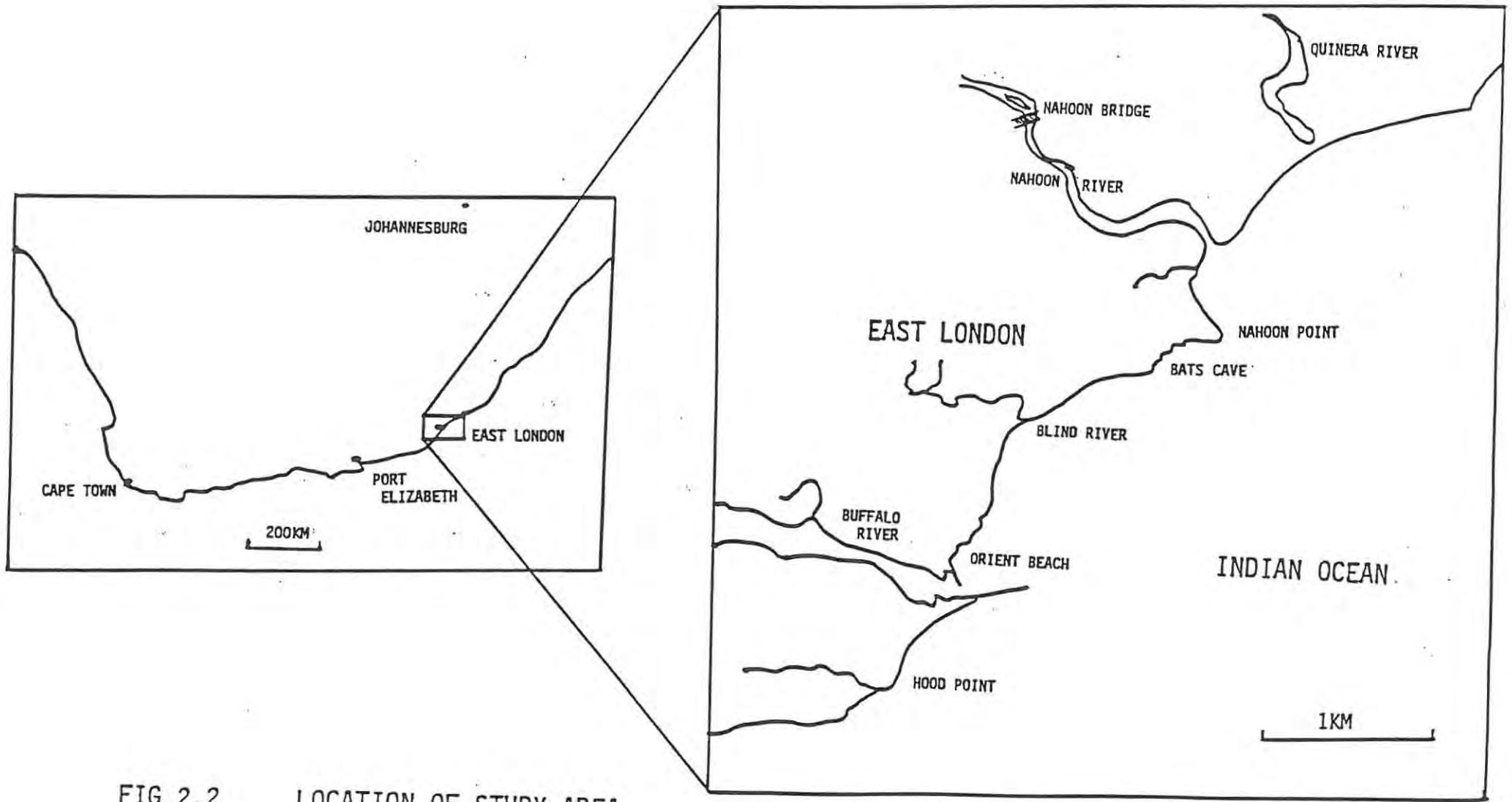


FIG 2.2 LOCATION OF STUDY AREA  
from Watling (1983)

The tides of the area are described by Heydorn and Tinley (1980) as mesotides which are typical for most of the African Continent's coastline. The mean level of the tide is 1,2m while the mean range is 1,6m (0,4 at MLWS to 2,0 at MHWS). This does not include extreme levels due to storms (Heydorn and Tinley, 1980). Low water during spring tides occurs from 9h00 to 10h30 and 21h00 to 23h00 and thus, from the point of view of desiccation, this is a favourable time for exposed seaweeds (Isaac, 1937).

The mean air temperature for East London is 18,7°C with an absolute maximum of 41,3°C and a minimum of 2,3°C. The humidity averages 72% at 8h00 and 65% at 14h00 (Heydorn and Tinley, 1980).

Isaac (1937) recorded the mean water temperature for East London as 17,6°C. The water temperature has a mean range of 15°C (from an extreme of 10°C to 25°C) but, with an average of 22°C in January and 16°C in July, an overlap of plants and animals from tropical areas and temperate seas is formed. Stephenson (1944) and Brown and Jarman (1978) regard this area as a subtropical province with definite tropical affinities but also possessing numerous common species with the warm temperate coast to the south.

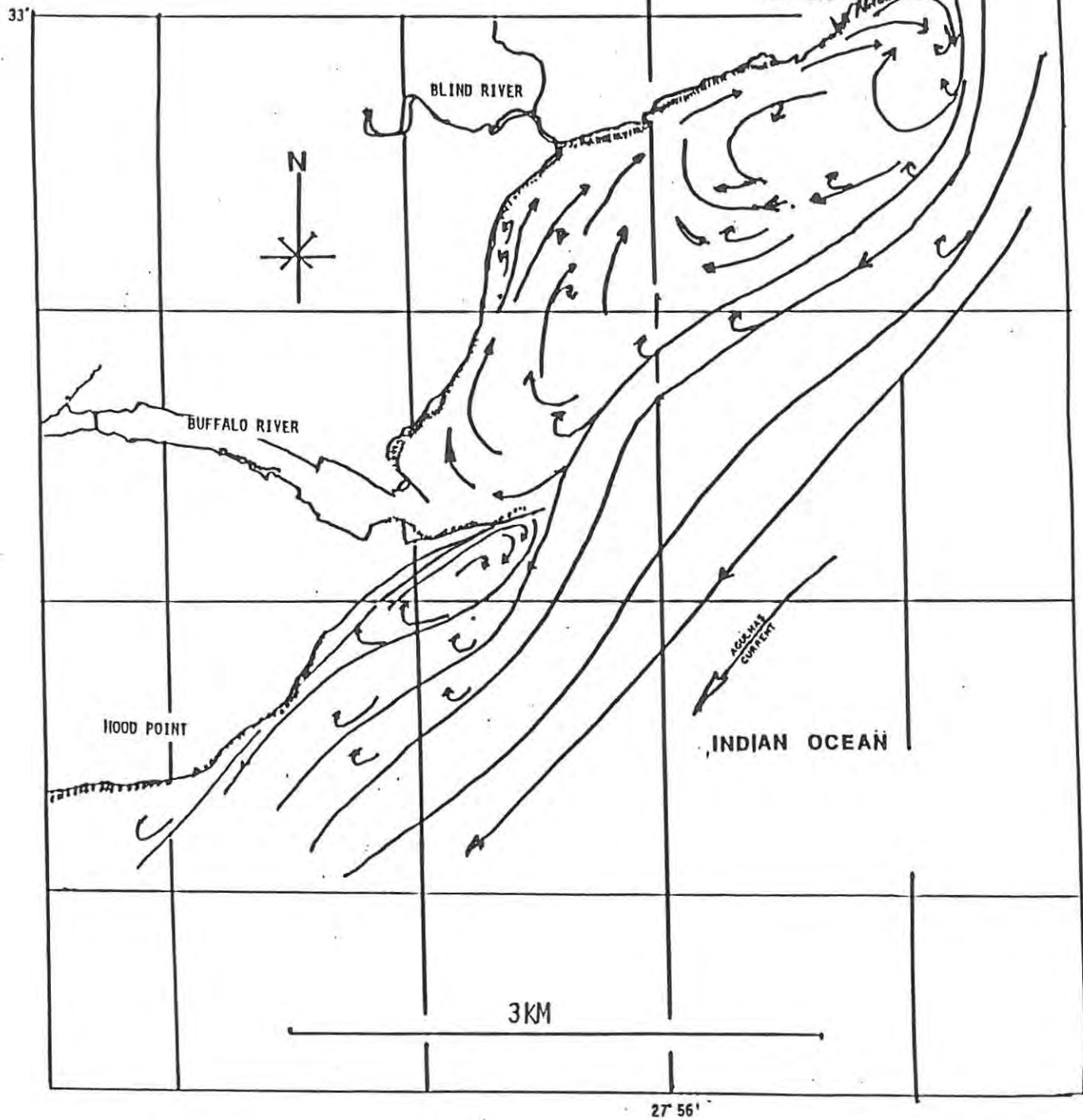
The inshore temperature can change (drop) dramatically within 12 hours during an easterly gale. On the other hand, westerly winds move surface waters of the Agulhas Current shorewards (to the left) causing downwelling and allowing fish of tropical seas to occur closer inshore (Heydorn and Tinley, 1980).

The Agulhas Current carries tropical water southwards past the east and southeast coasts. Whillier (1962) showed that cyclonic (clockwise) vortices occurred between the Buffalo River mouth and Nahoon Point which caused a northward drift close to the shore (Fig. 2.3). This current would travel past the outfall area carrying the sewage northwards. However, the sewage tends to hug the coast on either side of the discharge points and can be entrained for a considerable period in coastal gyres which develop in the immediate vicinity of the outfalls. It later rejoins the Agulhas Current and continues south (Watling, 1983). The outfall on the west bank of East London is not affected by this northward drift as sewage enters the southward current and moves away from the city.

The rocks of the main outfall cove are covered by a grey film extending upwards to an average height of 1.31m above mean low water (MLW) (Plate 2.2). This grey material is composed mainly of blue-green algae and takes on an appearance similar to the activator tunnels in the secondary stages of a sewage treatment plant. This grey film is also found around the Nahoon pipe but on a much smaller scale and extending only 0.13m in height above MLW.

Although the cove is usually awash even at low tide (Plate 2.2), the salinity remains below normal up to at least 30m from the outfall (Fig. 2.4). At this point, despite the much larger plume size, the wave action has mixed the waters enough to return them to normal salinity. Livingstone<sup>et alia</sup> (1968) found salinity returning to normal within 120m of an

FIG 2.3 INSHORE CURRENTS AT EAST LONDON



From Whillier, 1962

# Salinity (ppt) 8-10-83

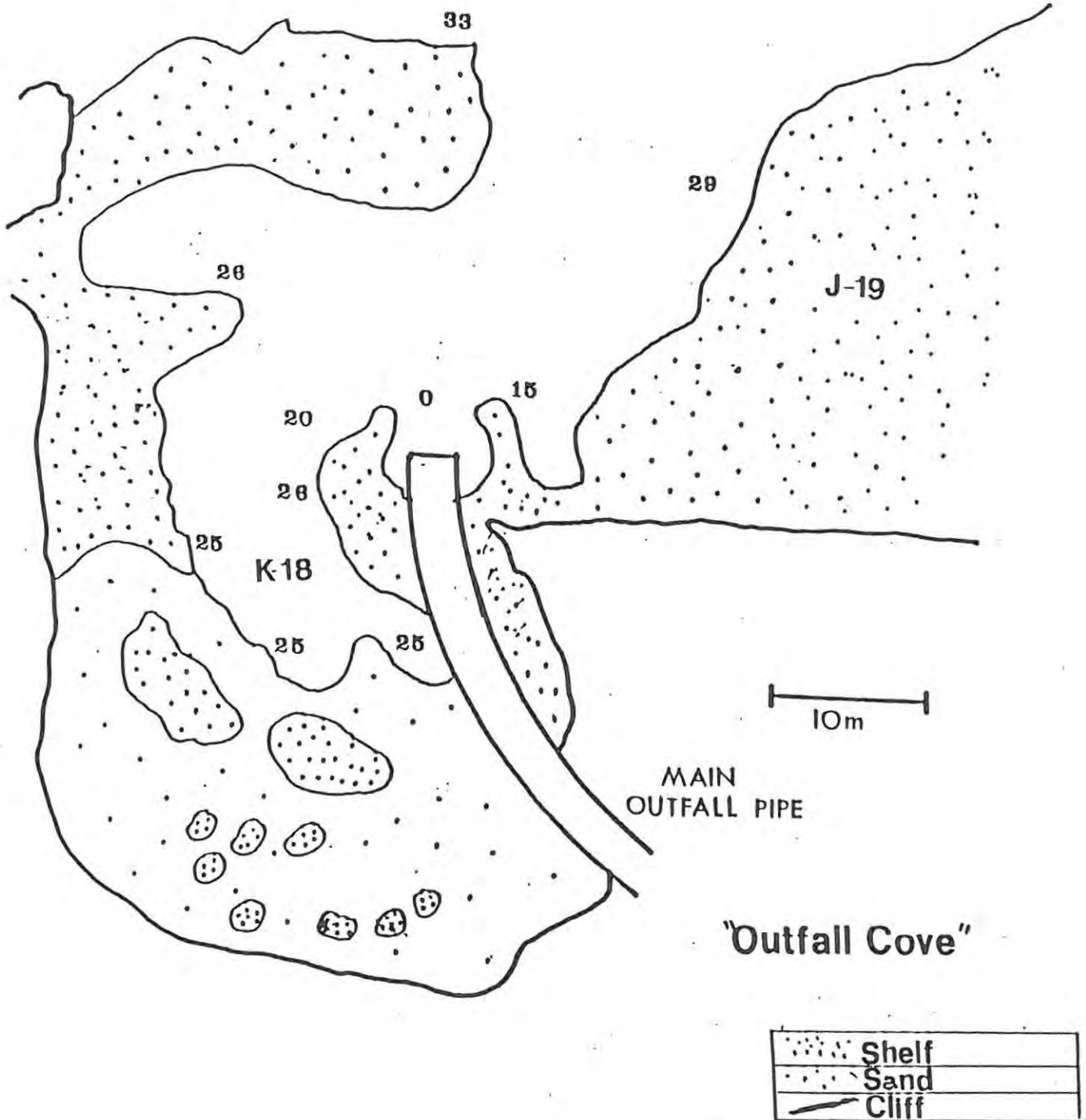


FIG 2.4 SALINITY(PPT) IN MAIN OUTFALL COVE

underwater outfall in Natal.

The East London Municipality carries out water tests along the coast once a week. Besides testing for bacteria and coliforms, checks are made of the nutrient and salinity levels at sample sites about 700m from the outfall and further away. The results, however interesting they might be, are confidential but will probably be released once a sewage treatment plant is installed. Watling (1983) recorded high E. Coli I counts along the East London coastline and found that the "Bats Cave sewage impacts the coastline between Quinera River mouth and the Nahoon River" including the Nahoon River estuary as far as the bridge (See fig.2.2). The E. coli I levels found in many areas of Watling's survey far exceeded the California Administrative code minimum standards for public water contact of 1000/100ml (Littler and Murray, 1975).

## Chapter 3

### DISTRIBUTION OF SEAWEEDS AT BATS CAVE ROCKS

#### INTRODUCTION

The distribution of seaweeds found along Bats Cave rocks is affected by the sewage which is released into the sea daily. Besides the effects untreated sewage has on the coastline, high bacterial and nutrient content and low oxygen and salinity levels tend to eliminate a great variety of species. The shock to the ecosystem can eliminate organisms already under stress in intertidal zones. Systems tend to favour micro-organisms which are adapted or can mutate and evolve rapidly to cope (O'Sullivan, 1971) (See plates 3.1-3.4). The seaweeds that do survive often increase their numbers because of lack of competition for space and nutrients (Seagrief, 1971). The almost total occupation of the rock's surface by these tolerant seaweeds is probably because sessile animals cannot live there (Katada and Satomi, 1975).

Katada and Satomi (1975) record that large seaweeds predominate over small seaweeds on unpolluted coastlines in Japan except where the violent shock of waves hinders their growth. In the latter case, smaller algae predominate with larger algae confined to pools in the rocks or to sheltered areas. Littler and Murray (1975) reported large brown algae which were common in the control area as being absent in the outfall area they were studying in California. The inhospitable

coastline at Bats Cave (Watling, 1983) may play a partial role in the seaweed distribution, but the smaller species found along these rocks may also be influenced by the outfalls, and within the outfall area, other factors must be considered.

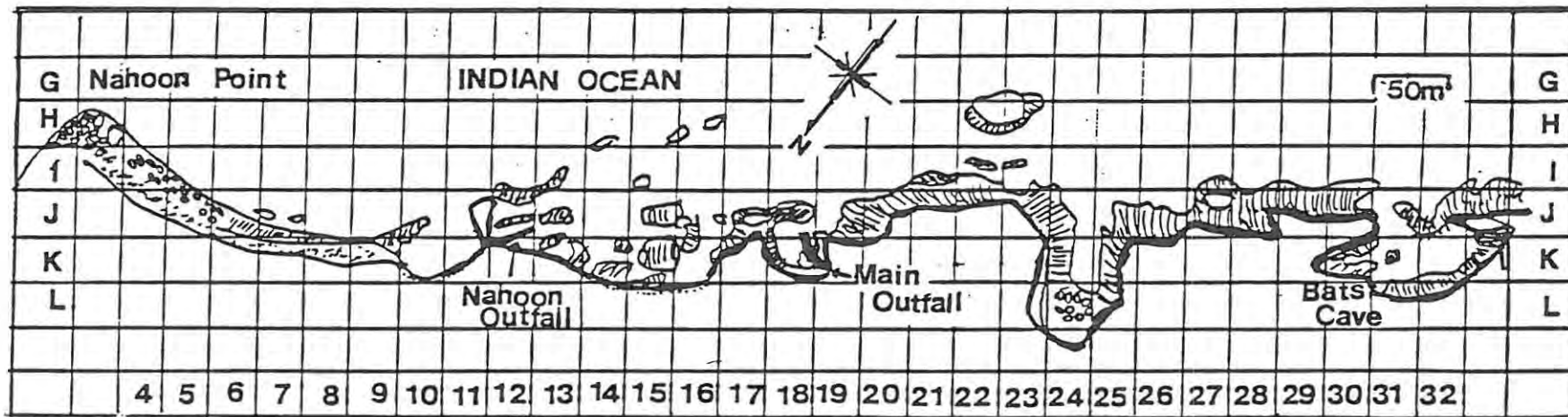
Very few surveys of seaweed species have been carried out for this particular area. Stephenson (1948) recorded 123 species from a 1938 survey (Eyre<sup>et alia</sup>, 1938). Brown and Jarman (1978) recorded 210 species for this area which they refer to as a sub-tropical overlap area. They recorded only 29 species as endemic to the area, but the total was the highest for Southern Africa. Seagrief (in press) has listed 285 species for the Eastern Cape. This comprises over half of the 547 species listed for South Africa (Seagrief, 1984). The species numbers from these studies were for large areas of coastline and not limited to the 2.5km of the study area.

### 3.1 Methods


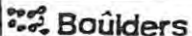
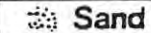

A collection of the intertidal seaweeds in the study area was carried out. Before this could be done, a map was drawn of the study area and broken up into sections of approximately 30 square metres. With this grid map, the areas could then be sampled separately (Fig. 3.1).

Samples were collected and preserved in jars containing 4% formalin in seawater. Field notes were made on common, abundant species and where there was any doubt involving identification, herbarium sheets were made or microscope slides using 25% Karo Corn Syrup in seawater. The slides

FIG. 3.1 GRID MAP OF STUDY AREA



Each grid approximately 30m x 30m

 Shelf	 Boulders
 Sand	 Cliff face

were later sealed with clear nail varnish and labelled for future reference.

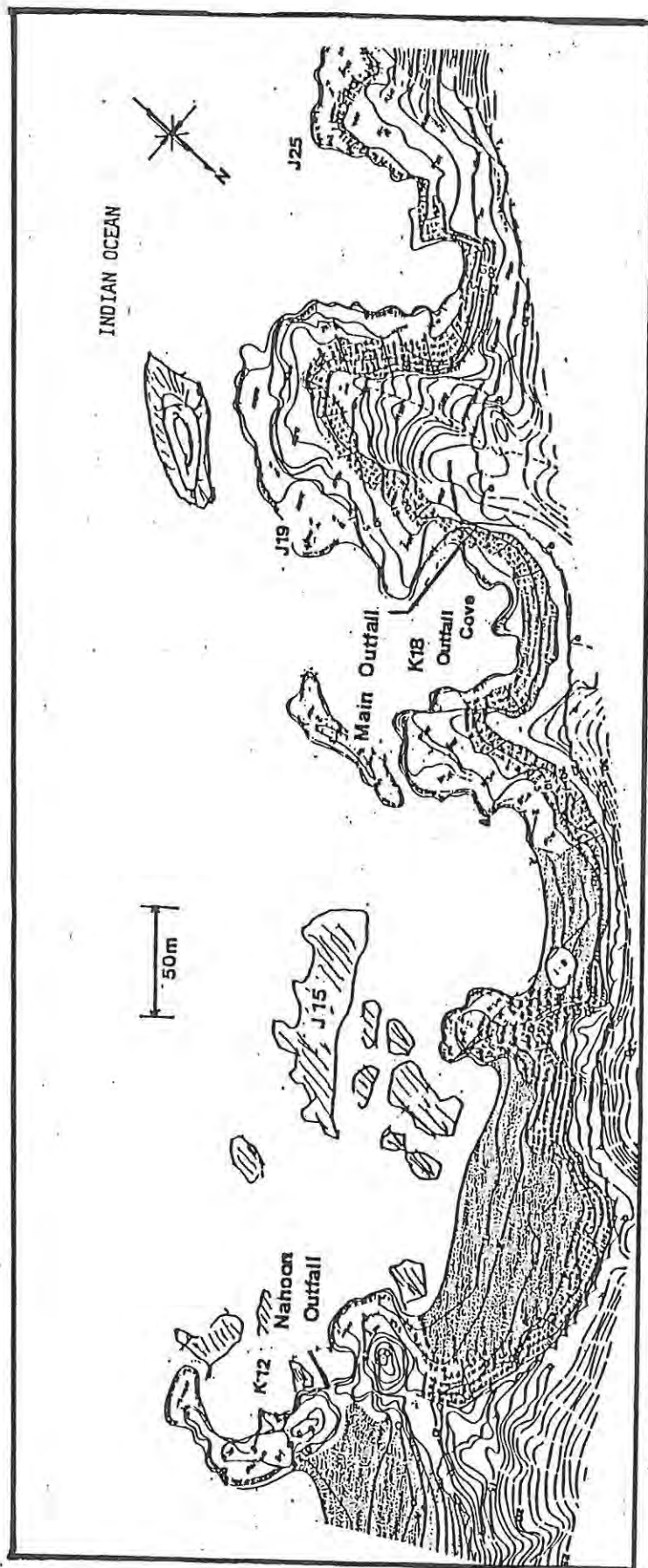
Identifications were carried out with the aid of a number of references to Southern Africa seaweed. Day (1969), Simons (1976), and Seagrief (1967, 1980, 1984, in press) were used with references made to De Toni (1889), Fritsch (1935, 1945) Kutzing (1977), Kylin (1938, 1956) and Bold and Wynne (1978). Microscopes used in the identification process were a Vickers M10A, Leitz-Wetzlar dissecting microscope and a Spencer microscope with an oil immersion lens.

The results were entered into an Apple II computer using a programme written to store and retrieve the information as needed (See Appendix 2). Common species were easily located as well as species uncommon to a particular area. The seaweeds were also entered as predetermined numbers to allow for rapid handling of the data.

### 3.2 Results and Discussion

The outfall areas became the focal point of the study and concentration was focused on the presence or absence of species in this area as compared with the presence and abundance of, or lack of the same species further away. The tolerance of certain species to the sewage could be seen in the intertidal zone. Study below this zone was almost impossible because of the nature of the area.

Chapman (1979) noted that "the leafy green thalli of the Chlorophyta are conspicuous on sewage polluted shores".



Modified from a City Engineers map

FIG. 3.2    OUTFALL AREA

Although a few red seaweeds did occur in the outfall area, they were difficult to recognize mainly because of the thick coverage of blue-green algae. Borowitzka (1971) found a "reduction in red and brown species" while Littler and Murray (1977) found 90% more taxa in samples in their control area than in the outfall area. Borgese (1975) wrote that "sewage pollution produces excessive growth of algae in coral reefs .. smothering coral polyps".

These 'Chlorophyta' may be less desirable species and, because of their rapid growth rate and the reduction of grazers (Borowitzka, 1971) to take advantage of the food supply to feed, can become a source of pollution when they die off (O'Sullivan, 1971).

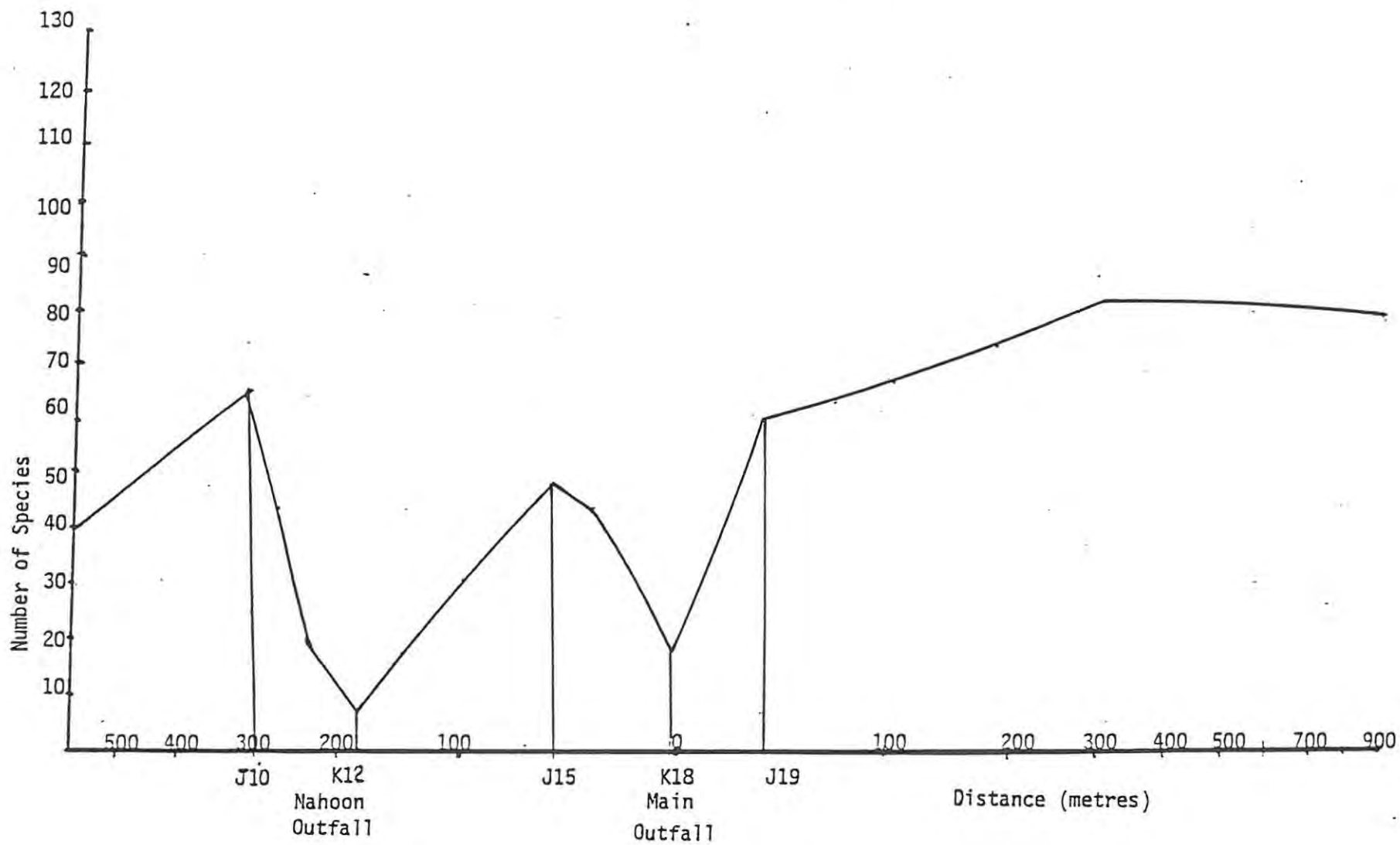
### 3.2.2.

During the two year period of the study, 131 different species of seaweed were collected in the study area. Concentrated study in the outfall area produced many more species than would have been expected. However, the totals were still lower than for the areas further away and a gradient of species numbers from the outfall towards the control was evident (Fig. 3.3)

The reduced number of species near the outfalls and the absence of certain species common to the control areas suggest that this area is experiencing a situation where the species present are able to withstand the extra stress exerted by the presence of sewage.

The J19 zone which lies within 30m of the main outfall,

Fig. 3.3 SPECIES NUMBERS IN RELATION TO DISTANCE FROM OUTFALL



had 60 species present. The main outfall released its contents in the K18 area (Fig. 3.4). Only 18 species, including those on the cliff face, were recorded here. These species, mainly the blue-greens, were very sparse throughout the rest of the study area. Likewise, the K12 area (Fig. 3.5) around the Nahoon outfall was limited to 8 species. The most affected area besides the outfall locations was the area between the two pipes. Altogether, 48 different species occurred between the two outfalls.

When the distance from the outfalls increased, the number of species increased (Fig. 3.3). From J20 to J24 (30-90m from the outfall), 67 species were found and this increased to 70 at J25 (100m from the outfall). The J30-40 areas (250m from the outfall) had 81 species and from J40 on, 79 species were found.

There was also an increase towards the north-east of the Nahoon Outfall, although the numbers dropped when the substrate changed from dune rock to boulders. The J10 region had 65 species. Only 45 species were found towards J6 and J7 where the substrate changed to boulders. Littler and Littler (1984) reported boulder fields in the Gulf of California as regions where stress from boulder movements resulted in fewer species of seaweed inhabiting these fields as compared with stable bedrock substrate.

A number of common species found throughout most of the study were missing in the outfall areas. Although J19 had 60 species, common species including Gelidium pristoides, Acrosorium maculatum, Griffithsia sp., Gigartina pistillata,

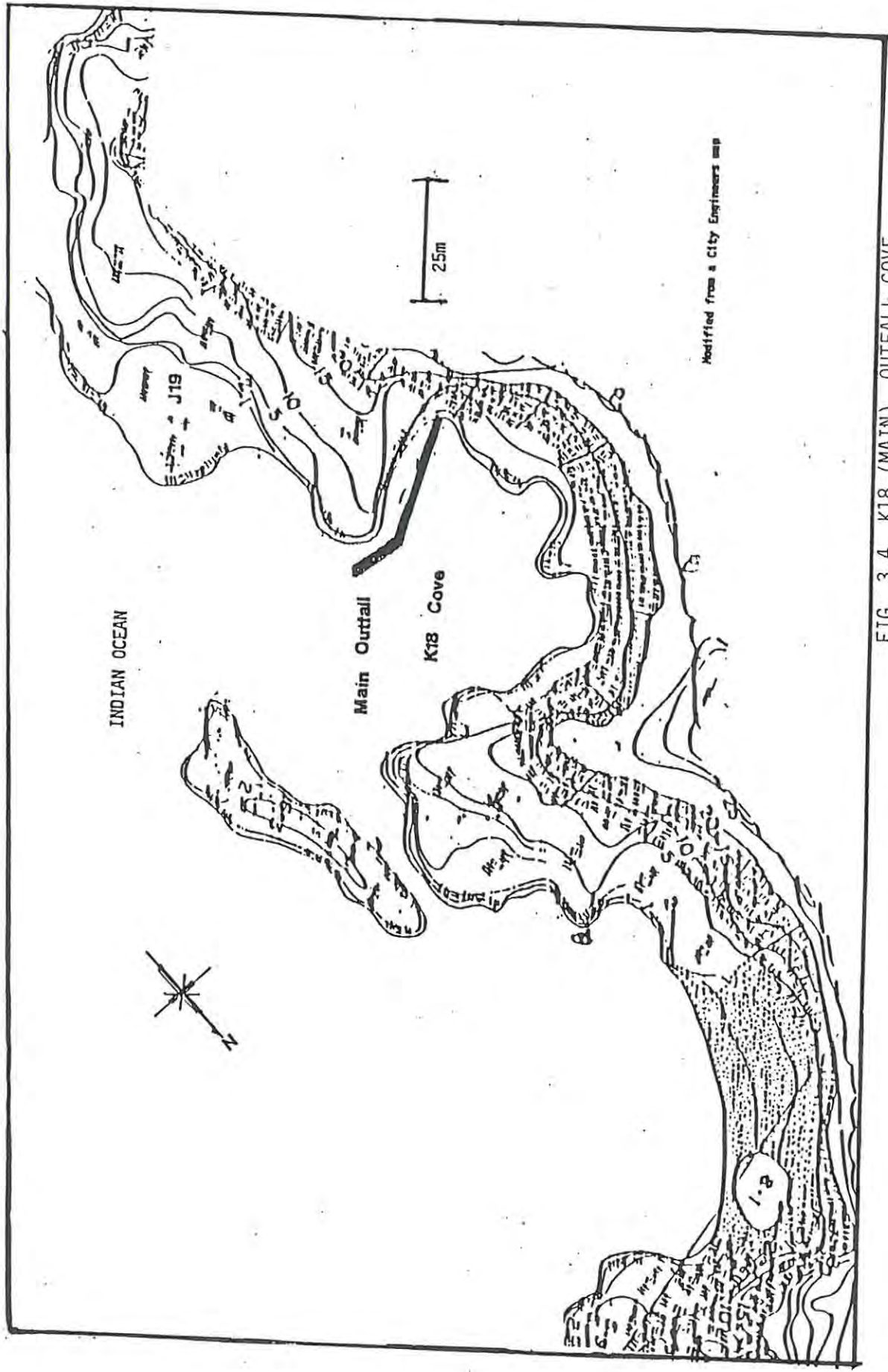


FIG. 3.4 K18 (MAIN) OUTFALL COVE

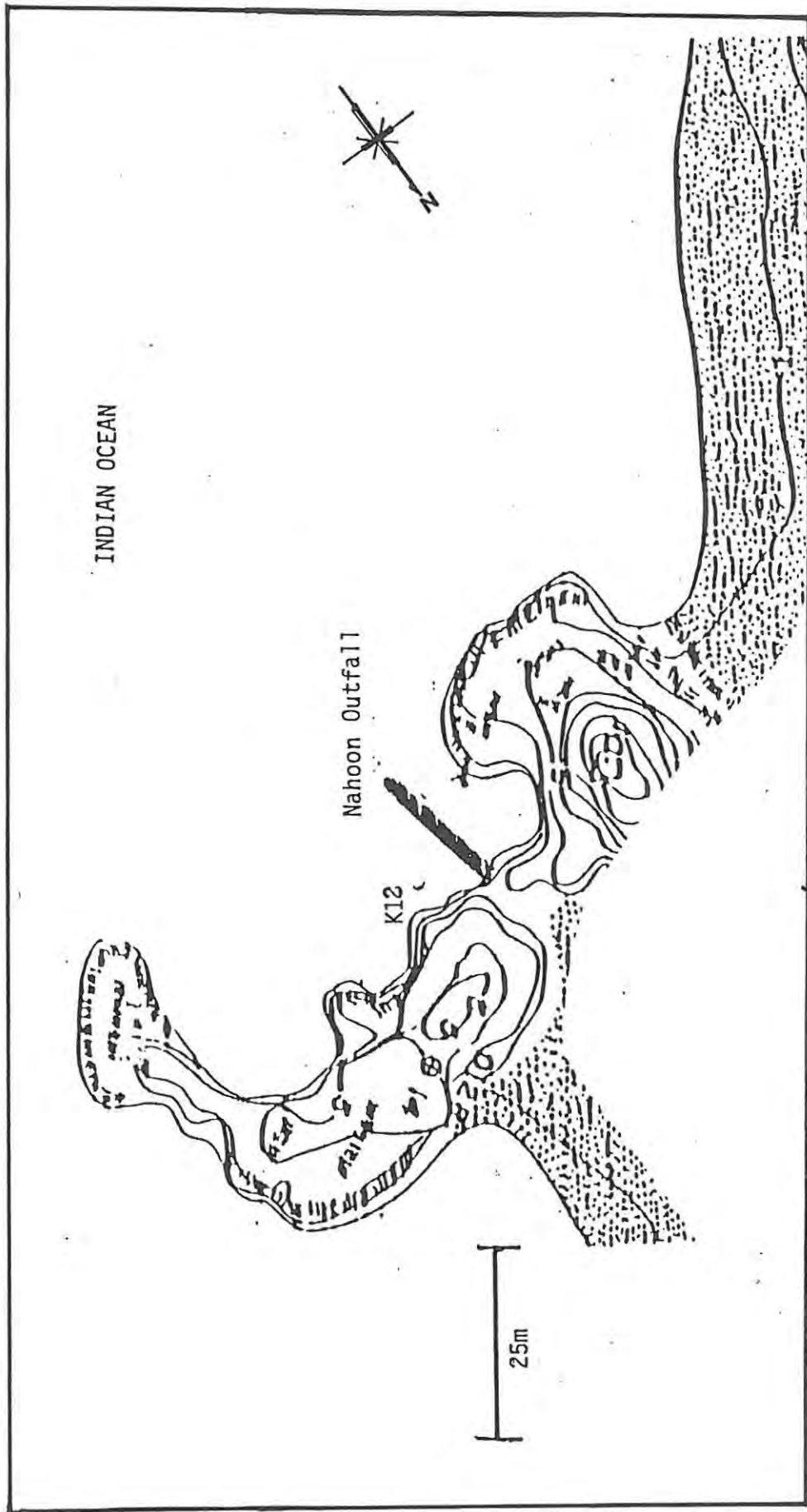


FIG. 3.5 K12 OUTFALL (NAHOON) COVE

and 4 species of Flocamium were absent. The Corallines were present but reduced in size and restricted to the section of the J19 area furthest from the outfall. Polyopes constrictus was only found from 100m, whereas Gelidium versicolor and Halimeda cuneata only occurred as close as 80m.

Most brown algae was also absent which supports Borowitzka's idea (1971). Species of Zonaria, Dictyota, Sargassum, Iyengaria and Dictyopteris only occurred from 100m from the outfall and Ecklonia biruncinata was only found in 2 rockpools, 250m and 500m from the outfall. From 1000m, the brown algae were more common.

A very small Porphyra capensis was found growing epiphytically on the green algae within 15m of the pipe in J19. This was the only record of P. capensis in the study area, while heavy growths were monitored 35km away throughout the two years.

Blue-green algae were mainly restricted to the outfall regions where heavy growth occurred. Although their presence was recorded for other areas including the controls, the heavy dominant growth found within 30m of the outfalls did not occur.

Species of Bryopsis, Cladophora, Enteromorpha and Chaetomorpha regularly occurred near the outfalls, and although they also occurred farther away, they occurred in greater numbers and were more consistently present in the outfall areas.

Common species to all areas were Ulva sp., Caulerpa filiformis, Hypnea spicifera, Cladophora rugulosa, Ceramium arenarium, Polysiphonia cf. incompta, Rhodymenia sp. and

Amphiroa cf. rigida. Whether the species common to all of the areas could be termed as the 'opportunistic'<sup>species</sup> (Murray and Littler, 1974) species, or if any of the species found (Table 3.1 and 3.2) in the outfall area could be termed opportunistic, tolerant species cannot be determined from just their presence or absence. Some smaller species recorded in the outfall zone were sometimes one time collections and were not found in the areas again. This may have resulted from favourable conditions for the particular species existing for a short time and then when the conditions returned to 'normal', the species disappeared. Heterosiphonia sp., Audouinella sp., Erythrotrichia welwitschii, Derbesia sp. and Laurencia natalensis were only found once in the outfall area and not recorded again. Prolonged spells of south-west wind tend to drive the outfall plume away from J19 and towards the North-east. The warm, cleaner water probably provides the conditions needed for less tolerant species to grow. This has also been observed near J15. Blue water flowed into the bay and the plume from the Nahoon outfall flowed along the J12 rocks and out to sea (Fig. 3.6).

The species found in the outfall areas of K18 and K12 (Table 3.1) represent a reduced species number under the direct influence of the outfalls. The species found within 50m of the outfall (Table 3.2) represent a higher number of species but still reduced. This could be considered a secondary influence. The appearance of a number of species from 50m supports this. The area 100m and more from the outfall could be said to be under a tertiary influence as

SPECIES FOUND IN THE OUTFALL SECTORSK18

Codium duthleae  
 Gelidium reptans  
 Hildenbrandtia sp.  
 Rhizoclonium sp.  
 Chroococcus minutus  
 Entophysalis sp.  
 Nostocoida limicola  
 Oscillatoria bonnemaisonii  
 Oscillatoria amoena  
 Sphaerotilus natans  
 Enteromorpha intestinalis  
 Gelidium arenarium  
 Ulva sp.  
 Chaetomorpha sp.  
 Polysiphonia incompta  
 Chaetomorpha antennina  
 Nostocoida limosa  
 Cyanophyta (blue-greens)

K12

Cladophora cf. capensis  
 Enteromorpha intestinalis  
 Gelidium arenarium  
 Gigartina minima  
 Chaetomorpha antennina  
 Ulva sp.  
 Sphaerotilus natans  
 Gelidium caespitosum

TABLE 3.2

SPECIES FOUND IN THE SECONDARY POLLUTED AREA WITHIN 50mOF THE OUTFALLS

Bostrychia mixta  
 Bryopsis caespitosa  
 Bryopsis flanaganii  
 Bryopsis sp.  
 Caulacanthus ustulatus  
 Ceramium arenarium  
 Ceramium centroceratiforme  
 Chaetomorpha sp.  
 Champia compressa  
 Cladophora cf. capensis  
 Enderachne binghamiae  
 Enteromorpha intestinalis  
 Gelidium arenarium  
 Gigartina minima  
 Gymnothamnion elegans  
 Herposiphonia sp.  
 Lithothamnium sp.  
 Platysiphonia miniata  
 Polysiphonia incompta  
 Porphyra capensis  
 Pterosiphonia clostophylla  
 Ralfsia expansa  
 Ulva sp.  
 Lomentaria sp. ff  
 Cyanophyta (Blue-greens)  
 Amphiroa cf. rigida  
 Chaetomorpha antennina  
 Enteromorpha cf. prolifera  
 Champia parvula  
 Licmophora sp.  
 Nitzschia sp.  
 Chroococcus minutus

Amphiroa ephedraea  
 Arthrocardia sp.  
 Caulerpa racemosa var. zeyheri  
 Corallina sp.  
 Hypnea spicifera  
 Lithophyllum sp.  
 Pleonosporium sp.  
 Sphaerotilus natans  
 Callithamnion stuposum  
 Centroceras clavulatum  
 Ceramium obsoletum  
 Colpomenia sinuosa  
 Gelidium pristoides  
 Gelidium caespitosum  
 Heterosiphonia sp.  
 Audouinella sp.  
 Oscillatoria bonnemaisonii  
 Caulerpa filiformis  
 Chaetomorpha robusta

Gigartina ptilillata  
 Chondrococcus tripinnatus  
 Bachelotia antillarum  
 Erythrotrichia welwitschii  
 Rhodymenia sp.  
 Corallina officinalis  
 Derbesia sp.  
 Enteromorpha sp.  
 Gelidium amansii  
 Gelidium reptans  
 Gigartina sp.  
 Gracilaria denticulata  
 Griffithsia confervoides  
 Hypnea rosea  
 Jania sp.  
 Laurencia glomerata  
 Laurencia natalensis  
 Laurencia sp.

Cheilosporum cultratum  
 Chondrococcus hornemanni  
 Cladophora rugulosa<sup>4</sup>  
 Codium duthleae  
 Codium lucasii  
 Codium stephensiae  
 Plocamium cornutum  
 Polyopes constrictus  
 Polysiphonia sp.  
 Rhodymenia natalensis  
 Plocamium sp.

SPECIES FOUND IN AREA J-19

Bostrychia mixta  
 Bryopsis caespitosa  
 Bryopsis flanaganii  
 Bryopsis sp.  
 Caulacanthus ustulatus  
 Ceramium arenarium  
 Ceramium centroceratiforme  
 Chaetomorpha sp.  
 Champia compressa  
 Cladophora cf. capensis  
 Enderachne binghamiae  
 Enteromorpha intestinalis  
 Gelidium arenarium  
 Gigartina minima  
 Gymnothamnion elegans  
 Herposiphonia sp.  
 Lithothamnium sp.  
 Platysiphonia miniata  
 Polysiphonia incompta  
 Porphyra capensis  
 Pterosiphonia cloiophylla  
 Ralfsia expansa  
 Ulva sp.  
 Cyanophyta (Blue-greens)  
 Amphiroa cf. rigida  
 Chaetomorpha antennina  
 Enteromorpha cf. prolifera  
 Champia parvula  
 Licmophora sp.  
 Nitzschia sp.  
 Chroococcus minutus  
 Sphaerotilus natans  
 Callithamnion stuposum  
 Centroceras clavulatum  
 Ceramium obsoletum  
 Colpomenia sinuosa  
 Amphiroa ephedraea  
 Arthrocardia sp.  
 Caulerpa racemosa var. zeyheri  
 Corallina sp.  
 Hypnea spicifera  
 Heterosiphonia sp.  
 Audouinella sp.  
 Oscillatoria bonnemaisonii  
 Caulerpa filiformis  
 Chaetomorpha robusta  
 Cladophora rugulosa  
 Corallina officinalis  
 Enteromorpha sp.  
 Gelidium amansii  
 Gelidium reptans  
 Gelidium caespitosum  
 Gigartina sp.  
 Jania sp.  
 Laurencis glomerata  
 Placophora binderi  
 Polysiphonia sp.  
 Chondrococcus tripinnatus  
 Bachelotia antillarum  
 Rhodymenia sp.

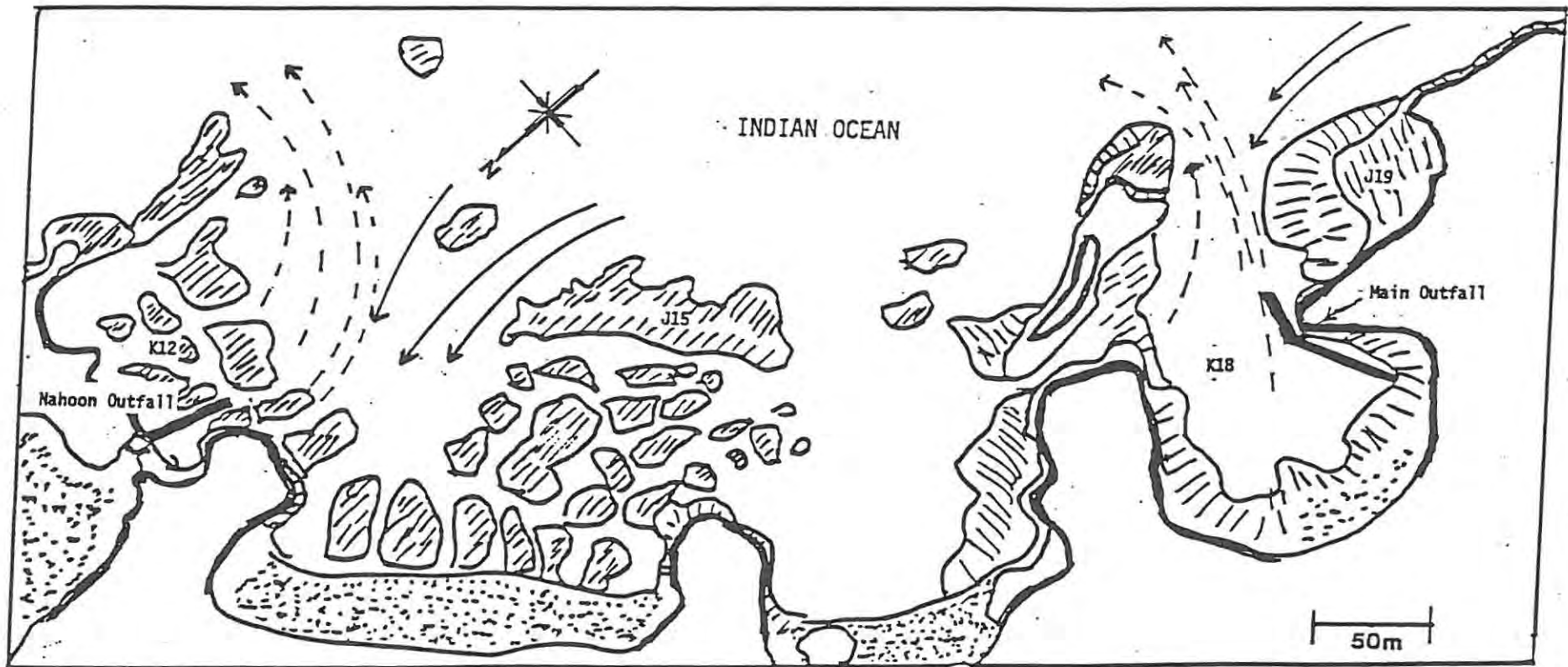


FIG. 3.6 INSHORE CURRENTS OBSERVED NEAR OUTFALLS DURING SOUTHERLY WINDS

Shelf	Boulders
Sand	Cliff Face
Clean Water	
Sewage	

there are still a number of species with reduced presence. From 250m towards the main control at 1000m, evidence of reduced species numbers fades and by 1000m, a normal flora, as compared with the area monitored 35km away, existed.

Borowitzka (1971) and Littler and Murray (1975) reported decreased species numbers in the outfall zone as a result of the influence of sewage. The results of the collections along the Bats Cave rocks show a species reduction of 87% within the outfall cove and 44% up to 50m from the outfalls. Using Borowitzka's (1971) and Littler and Murray's (1975) results as a guide, the effect on the seaweed by the sewage near the East Bank Outfalls is reducing the number of species that can exist in this region.

CHECKLIST OF SPECIES FOUND DURING THE STUDY FROM  
BATS CAVE ROCKS AND KIDDS BEACH ROCKS, 1982-84

(X=Kidds Beach only)

- Division: CHLOROPHYCOPHYTA (Green Algae)
- Order: ULVALES  
Family: ULVACEAE  
Enteromorpha compressa (Linnaeus) Greville X  
Enteromorpha intestinalis (Linnaeus) Link  
Enteromorpha prolifera (O.F. Mueller) J. Agardh  
Enteromorpha sp.  
Ulva insignis (Areschoug) Papenfuss  
Ulva rigida C. Agardh X  
Ulva sp.
- Order: CLADOPHORALES  
Family: CLADOPHORACEAE  
Chaetomorpha antennina (Bory) Kuetzing  
Chaetomorpha crassa (C. Agardh) Kuetzing X  
Chaetomorpha robusta (Areschoug) Papenfuss  
Chaetomorpha sp.  
Cladophora cf. capensis (C. Agardh) De Toni  
Cladophora rugulosa Martens  
Rhizoclonium sp.
- Order: CAULERPALES  
Family: CAULERPACEAE  
Caulerpa filiformis(Suhr) Hering  
Caulerpa holmesiana Murray X  
Caulerpa racemosa(Forsskål) J. Agardh var. zeyheri(Sonder et Kuetzing) Weber-van Bosse
- Family: CODIACEAE  
Codium duthieae Silva.  
Codium extricatum Silva  
Codium lucasii Setchell sub sp. capense Silva  
Codium platylobium Areschoug  
Codium stephensiae Dickinson
- Family: BRYOPSISIDACEAE  
Bryopsis flanagani Barton  
Bryopsis setacea Hering  
Bryopsis caespitosa Suhr ex Kuetzing  
Bryopsis sp.
- Family: DERBESIDACEAE  
Derbesia sp.
- Family: UDOTACEAE  
Halimeda cuneata Hering in Krauss

- Division: PHAEOPHYCOPHYTA (Brown algae)  
 Order: ECTOCARPALES  
 Family: ECTOCARPACEAE  
Bachelotia antillarum (Grunow) Gerloff  
Ectocarpus confervoides (Roth) Le Jolis  
Ectocarpus sp.
- Order: RALFSIALES  
 Family: RALFSIACEAE  
Ralfsia expansa(J. Agardh) J. Agardh
- Order: DICTYOTALES  
 Family: DICTYOTACEAE  
Dictyopteris longifolia Papenfuss  
Dictyota liturata J. Agardh  
Dictyota sp.  
Dictyota naevosa(Suhr) J. Agardh  
Zonaria subarticulata (Lamouroux) Papenfuss  
Zonaria tournefortii (Lamouroux) Montagne  
Zonaria sp.
- Family: STYPOCAULACEAE  
Phloiocaulon squamulosum (Suhr) Geyler X
- Order: CHORDARIALES  
 Family: CORYNOPHLAEACEAE  
Leathesia difformis(Linnaeus) Areschoug
- Family: SPLACHNIDIACEAE  
Splachnidium rugosum(Linnaeus) Greville X
- Order: DICTYOSIPHONALES (SCYTOSIPHONALES)  
Colpomenia sinuosa(Roth) Derbès et Solier  
Endarachne binghamiae J. Agardh  
Iyengaria stellata(Boergesen) Boergesen
- Order: LAMINARIALES  
 Family: ALARIACEAE  
Ecklonia biruncinata (Bory) Papenfuss
- Order: FUCALES  
Sargassum heterophyllum(Turner) C. Agardh  
Sargassum longifolium(Turner) C. Agardh  
Carpophyllum scalare Suhr X

Division: RHODOPHYCOPHYTA (Red algae)

35

Class: RHODOPHYCEAE  
Sub-Class: BANGIOPHYCIDAE  
Order: BANGIALES  
Family: BANGIACEAE  
Porphyra capensis Kuetzing

Family: ERYTHROPELTIDACEAE  
Erythrotrichia welwitschii (Ruprecht) Batters

Sub-Class: FLORIDIOPHYCIDAE  
Order: NEMALIONALES  
Family: ACROCHAETIACEAE  
Audouinella sp.

Family: CHAETANGIACEAE  
Galaxaura diesingiana Zanardini

Family: GELIDIACEAE  
Gelidium amansii (Lamouroux) Lamouroux  
Gelidium arenarium Kylin  
Gelidium caespitosum Kylin  
Gelidium micropterum Kuetzing  
Gelidium pristoides (Turner) Kuetzing  
Gelidium reptans (Suhr) Kylin  
Gelidium versicolor (S.G. Gmelin) Lamouroux

Order: CRYPTONEMIALES  
Family: CORALLINACEAE  
Amphiroa bowerbankii Harvey X  
Amphiroa ephedraea (Lamarck) Decaisne  
Amphiroa cf. rigida Lamouroux  
Arthrocardia sp.  
Arthrocardia carinata (Kuetzing) Johansen  
Cheilosporum cultratum (Harvey) Areschoug  
Cheilosporum proliferum (Lamouroux) De Toni  
Corallina officinalis Linnaeus  
Corallina sp.  
Jania crassa Lamouroux  
Jania sp.  
Lithophyllum sp.  
Lithothamnium sp.  
Polyporolithon patena (Hooker fil et Harvey) L.R. Maso

Family: CRYPTONEMIACEAE  
Polyopes constrictus (Turner) J. Agardh  
Prionitis nodifera (Hering) Barton

Family: RHIZOPHYLLIDACEAE  
Chondrococcus hornemanni (Lyngbye) Schmitz  
Chondrococcus tripinnatus (Hering) Delf & Michell

- Family: SQUAMARIACEAE  
Peyssonnetia capensis Montagne  
Hildenbrandtia sp. 36
- Order: GIGARTINALES  
Family: GRACILARIACEAE  
Gracilaria beckeri (J. Agardh) Papenfuss  
Gracilaria capensis Schmitz ex Mazza X  
Gracilaria denticulata Schmitz ex Mazza  
Gracilaria verrucosa (Hudson) Papenfuss  
Gracilaria sp.
- Family: PLOCAMIACEAE  
Plocamium beckeri Simons  
Plocamium corallorhiza (Turner) Harvey  
Plocamium cornutum (Turner) Harvey  
Plocamium suhrii Kuetzing  
Plocamium sp.
- Family: SPHAEROCOCCACEAE (CAULACANTHACEAE)  
Family: PHACELOCARPACEAE Caulacanthus ustulatus (Turner) Kuetzing  
Phacelocarpus oligacanthus Kuetzing x  
Phacelocarpus tortuosus Endlicher et Diesing X
- Family: HYPNEACEAE  
Hypnea rosea Papenfuss  
Hypnea spicifera (Suhr) Harvey
- Family: PHYLLOPHORACEAE  
Gymnogongrus glomeratus J. Agardh  
Gymnogongrus polycladus (Kuetzing) J. Agardh X
- Family: GIGARTINACEAE  
Gigartina insignis (Endlicher et Diesing) Schmitz in Barton  
Gigartina minima Kylin  
Gigartina paxillata Papenfuss  
Gigartina pistillata (S.G. Gmelin) Stackhouse  
Gigartina sp.
- Order: RHODYMENIALES  
Family: RHODYMENIACEAE  
Erythrymenia obovata Schmitz in Mazza  
Botryocladia madagascariensis G. Feldmann  
Rhodymenia natalensis Kylin  
Rhodymenia sp.  
Epymenia capensis (J. Agardh) Papenfuss  
Epymenia obtusa (Greville) Kuetzing
- Family: CHAMPIACEAE  
Champia compressa Harvey  
Champia parvula (C. Agardh) Harvey

Order:  
Family:

CERAMIALES  
CERAMIACEAE

37

CROUANIA GROUP

Antithamnionella verticillata (Suhr) Lyle

CERAMIUM GROUP

Centroceras clavulatum (C. Agardh in Kunth) Montagne

Ceramium arenarium Simons

Ceramium centroceratiforme Simons

Ceramium obsoletum C. Agardh

Ceramium sp.

Microcladia gelidii Simons

Spyridia cupressina (Harvey) Kuetzing

CALLITHAMNION GROUP

Callithamnion stuposum Suhr

Callithamnion sp.

COMPSOTHAMNION GROUP

Pleonosporium sp.

Pleonosporium harveyanum (J. Agardh) De Toni

GRIFFITHSIA GROUP

Griffithsia confervoides Suhr

Griffithsia secunda Harvey ex J. Agardh

DASYPHILA GROUP

Dasyphila cryptocarpa (Holmes) Schmitz X

PTILOTA GROUP

Gymnothamnion elegans (Schousboe ex C. Agardh) J. Agardh

Family:

DELESSERIACEAE

HYPOGLOSSUM GROUP

Bartoniella crenata Kylin X

SARCOMENIA GROUP

Platysiphonia miniata (C. Agardh) Boergesen

CRYPTOPLEURA GROUP

Acrosorium maculatum (Kuetzing) Papenfuss

Family:

DASYACEAE

Heterosiphonia sp.

Family:

RHODOMELACEAE

POLYSIPHONIA GROUP

Polysiphonia incompta Harvey

Polysiphonia urbana Harvey

Polysiphonia sp.

Rhodomelopsis africana Pocock

Tayloriella sp.

PACHYCHAETA GROUP

Pachychaeta brachyarthra (Kuetzing) Trevisan

## PTEROSIPHONIA GROUP

Pterosiphonia cloiophylla (C. Agardh) Falkenberg

## BOSTRYCHIA GROUP

Bostrychia mixta Hooker fil. et Harvey

## PLACOPHORA GROUP

Placophora binderi (J Agardh) J. Agardh

## HERPOSIPHONIA GROUP

Herposiphonia sp.

## POLYZONIA GROUP

Polyzonia elegans Suhr

## LAURENCIA GROUP

Laurencia flexuosa KuetzingLaurencia glomerata KuetzingLaurencia natalensis KylinLaurencia sp.

Division:

CHRYSOPHYCOPHYTA

Class:

BACILLARIOPHYCEAE

Biddulphia sp.Licmophora sp.Nitzschia sp.

Division:

CYANOPHYTA (CYANOCHLORONTA) (Blue-green algae)

Chroococcus minutusEntophysalis sp.Microcoelus sp.Nostocoida limicolaNostocoida limosaLyngbya sp.Oscillatoria bonnemaisoniiOscillatoria amoena

## BACTERIA

Beggiatoa sp.Sphaerotilus natans

## Chapter 4

### THE USE OF SEAWEED DENSITIES IN DETERMINING ECOLOGICAL EFFECTS ON THE SEWAGE OUTFALL AREA

#### INTRODUCTION

The photogrammetric method, developed by Littler (1971) and used by Murray and Littler (1974) and Littler and Murray (1975, 1977) was utilized with a few modifications to suit the study area. They used this as a fast and relatively simple method for collecting data in the limited time allowed in intertidal sampling. Murray and Littler (1974) and Littler and Murray (1975, 1977) used the data to work out mean cover, frequency comparisons and diversity of animal and macrophyte species in a sewage outfall area and a control area on San Clemente Island in California. Frequency values were plotted against tidal height for the most abundant species in the outfall and control areas. The diversity was determined using four different indices to "avoid difficulties inherent with the use of a single index based on a simple species count" (Littler and Murray, 1975). All comparisons in the control area revealed greater species diversity than the outfall. The evenness in abundance of individual species within each collection was also greater in the control areas. Blue-green

algae (treated as a single unit) were found to have the greatest cover in the outfall and control areas. Ulva californica had the second highest cover in the outfall area, whereas Corallina officinalis var. chilensis had the second highest cover in the control area.

Murray and Littler (1978) again used this method of collection to generate the numerical data employed in their analysis while studying algal succession in polluted and unpolluted areas.

Littler and Littler (1984) compared % cover, frequency, richness and diversity of macroalgal communities in a boulder vs. a stable bedrock intertidal zone. Productivity, predation, structure, toughness and calorific values were determined and compared. All parameters of the algal communities of the bedrock environment were found to exceed those in the boulder fields. New space was constantly being provided in the boulder fields because of the regular rock movement, abrasion and smothering and even movement to darker (underside) areas. The species dominant in this type of environment were the stress tolerant, opportunistic species. This results in a "dramatic reduction in slower recruiting biotically competent forms" (Littler and Littler, 1984).

Borowitzka (1971) determined algal species diversity by placing a grid (with intersecting nylon lines every 5cm) along a transect line and dropping a pin at the intersection of the lines. The species at the base of the algal thallus were then recorded.

The size of the quadrat is important when used to observe

relations between individuals and is capable of <sup>generating</sup> a variety of interpretations (Pielou, 1969). Pielou warned against quadrats being so small as to be unable to contain at least two individuals of the same species or too large so that one of the two species will occur in every quadrat.

Kitching (1937) used a quadrat of 25cm by 25cm, Borowitzka (1972) used a 50cm by 50cm quadrat, Littler and Murray (1975) used a 30cm by 50cm quadrat, Emerson and Zedler (1978) used a 10cm by 10cm quadrat and Littler and Littler (1984) and Littler and Kanker (1984) used a quadrat size of 20cm by 50cm.

There has been no set size of quadrats, but a side length of 50cm appears to be the maximum used for this type of study. Different sizes were experimented with to find a reasonable number of species within reasonable proportions.

The quadrat size used could not overlap into rock pools as this vegetation could not be considered in the same conditions and should be studied as a separate unit (Levyns, 1924; Isaac, 1949).

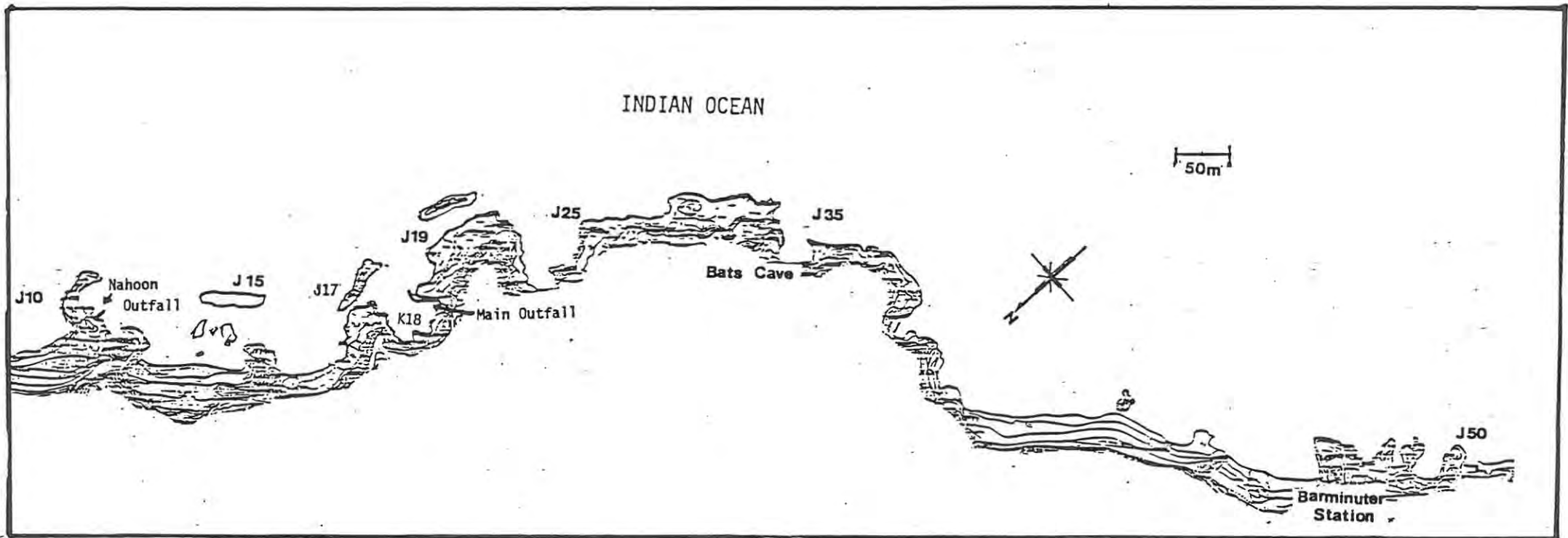
There was also the factor of being able realistically to set out the quadrat, record observations and determine densities and frequencies of the species present, and photograph them all within a given spring low tide cycle and possibly in between waves which sometimes accompany these tides. Another factor against a large quadrat was that it would be less likely that the smaller seaweeds might be overlooked.

#### 4.1 Methods and Materials

A quadrat size of 25cm by 25cm was found to be very efficient for the particular conditions of the study area. The quadrats were set out along transect lines chosen after a survey to ensure the similarity in the height above mean low water (MLW) (Fig. 4.1). This was done using a Wild NA1 Automatic Level with a Nova 5m extendable staff. A 50m Stylon tape was used to mark off the lines in either 1m or 2m sections. The benchmark was established from MLW by reciprocal levelling. All level loops were closed back to the starting point. MLW was determined by marking a calm section of water 30 minutes before and after and at the given time by the SA tide tables for MLW over a period of three days and finding the average mark. The information from this survey supplied levels for the transect lines to ensure they were geographically the same height above a certain point (called sea-level) as well as having the same type of exposure to the waves. The only varying factor was the distance from the outfall (See plates 4.1 to 4.9).

Two labelled quadrats were placed on either side of the line, diagonally across from each other. This allowed for a maximum number of species to be involved and restricted overlapping. Intervals of 2 to 3 metres between samples were used but there was always a sample at the beginning of the line (next to the cliff face) and the end of the line (usually a drop-off or splash zone).

Photographs were taken at right angles to the substrate



Modified from a City Engineers map

FIG. 4.1 LOCATION OF LINE TRANSECTS

and two photographs were taken of each quadrat (Littler and Murray, 1975). Two 35mm cameras were used, one using 100 or 200 ASA color slide film depending on light conditions and the other camera used Ektachrome Infrared film (2236) with a yellow No.12 filter to cut blue light. The infrared was used to increase accuracy in determinations of various species especially blue-green algae (Littler and Murray, 1977; Littler, 1984).

The point-intersect method (Murray and Littler, 1974) was used to determine cover from the photographs. Each quadrat was surveyed in the field, making notes of species present, their location, and their estimated cover by means of a tape recorder. Samples of any doubtful or unknown species were collected and labelled for later identification. With this field information, the slides were shown on a screen within a grid of 100 red dots dispersed symmetrically throughout the grid. Black dots were used for the infrared photos. Cover was recorded as 1% for each "hit" of a species on a dot and any species observed in the quadrats but not landing on a dot was recorded as 0.1% cover (Littler and Murray, 1975). In order to reduce error, each slide was evaluated twice, once rightside up and then turned upside down and counted again. All field work was completed before any evaluations took place to avoid any 'oversampling' in areas which might have influenced and 'padded' the results.

The overall cover for the algae was determined for each quadrat and then for each line.

The data for the quadrats in each line were also combined

with lines of similar distance from the outfall. The data for three sectors were grouped together for comparison. The sectors were (1) polluted (within 50m from the outfalls), (2) > 100m (between 100m and 150m from the outfalls, and (3) > 250m (260m and 1000m from the outfalls).

Murray and Littler (1974) determined the control area to be within 40 to 100m of the outfall on San Clemente Island but the outfall there only released  $0.5\%_{vel.}$  of what the East Bank outfall at Bats Cave releases per day. Therefore, the sectors for the control areas were set up at +100m and >250m (+250m) from the outfalls.

Once collected and correlated, the field data were entered into an Apple II computer and a "Basic" programme calculated the occurrence and total cover (cm) based on quadrat size and density. The % frequency was calculated from total occurrence of the species and cover dominance % from total species cover compared with total quadrat area. The frequency and cover dominance were added to determine the importance value of the species. This was calculated for each line and then for each sector. As the line transects were all of the same height above sealevel, % frequency did not incorporate tidal height as in Murray and Littler (1974).

Odum (1971) listed several useful indices of species structure in communities. An index of similarity, (S), between two samples was used to calculate an index (%) comparing the relationships between two lines. The number of species common to both lines were divided by the sum of the total species for each line to determine the similarity (See

Bray and Curtis, 1957).

$$S = 2C / A + B$$

where A = total species in sample A

B = total species in sample B

C = total species common to A and B

Borowitzka (1971), Murray and Littler (1974) and Littler and Murray (1975, 1977) used general diversity as a means to show differences between polluted and unpolluted environments. One of the principle effects of disturbance such as sewage pollution on the structure of marine communities is to decrease the diversity (Littler and Murray, 1975), and it is possible to measure this change some distance from the source of pollution. The method of evaluation was proposed by Shannon (See Shannon and Weaver, 1949).  $H'$  represents diversity and is calculated by the following formula;

$$H' = -\sum (n_i/N) \log(n_i/N)$$

or

$$-\sum P_i \log P_i$$

where  $n_i$  = importance value for each species

$N$  = total of importance values

$P_i$  = importance probability for each species

$$= n_i/N \quad (\text{Odum, 1971})$$

The data collected and listed in Table 3.1 easily fit into this formula. As natural logarithms are employed, the unit is called a "natural bel". Pielou (1969) writes however that in ecology, the unit to be used and the name given to it have yet to become standardized. Also, using the same formula,  $H' = -C \sum P_i \log P_i$ , where  $C$  is a constant, Pielou states that the size of the unit depends on the value given to  $C$  and on the base used for logarithms. This can cause variations in the results from one study to another. In Borowitzka (1971), the algal species diversity ranged from .14 to 2.17 while Murray and Littler (1974) ranged from 2.805 to 3.912 and in Littler and Murray (1977), 1.68 to 2.49 for macrophytes.

It is customary to make  $C=1$  but then  $\log_2$ ,  $\log_e$  or  $\log_{10}$  can be used (Pielou, 1969). Pielou (1969) set out 3 conditions for  $H'$ .

(1) That, for a population with a given number of species, the measure of diversity will be a maximum when all the species are present in equal proportions.

(2) That, given two populations in which the species are evenly represented, the population with the larger number of species will have the higher diversity.

(3) That, if when measuring the diversity of classification A, ( $H'(A)$ ), and measuring the diversity for classification B, ( $H'(B)$ ), if A and B are both used together for a single diversity, ( $H'(AB)$ ), then  $H'(AB) = H'(A) + H'(B)$ . Any number of classifications can be used (Pielou, 1969).

To use the formula, a classification of the population must be substituted for  $P_i$  or  $(n_i/N)$ . A proportion for the

classification for each set of data is calculated by  $(n_i/N)$ .

Diversity measure can be split into two or more specific components or classifications. These can be a representation of presence or absence (Borowitzka, 1971), % coverage, biomass or any combination of these or other factors. As there is no direct, set method, data sets from different studies may vary but the diversity,  $(H')$ , will still be measured as the largest number or value will have the greatest diversity.

As the importance value was calculated from % cover and % frequency, diversity,  $(H')$ , is based on 2 classifications in this study.

Pielou (1969) pointed out that merely stating a population has a certain diversity value is not very informative. Therefore a measure of evenness is calculated by taking the ratio of observed diversity of a collection to the maximum it could have, given the same number of species as a reference point. This maximum value is attained when individuals are divided among the species as evenly as possible. The populations' evenness ( $J'$ ) is determined by the formulae;

$$J' = H' / \log s$$

where  $H'$  = diversity

$s$  = number of species

Murray and Littler (1974) and Littler and Murray (1977) used  $J'$  when listing diversity. From their results,  $J'$  is usually highest where the diversity was highest.

TABLE 4.1

## DATA FOR QUADRATS IN EACH LINE TRANSECT

49

J23 line Diversity=3.01 Evenness=1.30

SPECIES	DENSITY PER QUADRAT									
	1	2	3	4	5	6	7	8	9	10
Lithophyllum sp.	46	24	52	1	11	0	0	0	0	0
Ceramium arenarium	4	2	2	0	9	15	35	13	20	3
Ulva sp.	0	0	4	13	9	45	0	4	3	2
Gelidium arenarium	0	0	7	15	0	0	0	0	0	0
Bryopsis caespitosa	0	0	0	0	1	7	4	0	0	0
Chaetomorpha antennina	0	0	0	10	12	6	4	4	0	0
Caulacanthus ustulatus	0	0	0	0	6	0	0	0	0	4
Cladophora rugulosa	0	0	0	0	0	1	0	0	0	0
Hildenbrandtia sp.	0	0	0	0	0	0	0	0	0	4

J25 line Diversity=3.54 Evenness=1.22

SPECIES	DENSITY PER QUADRAT										
	1	2	3	4	5	6	7	8	9	10	11
Ceramium arenarium	3	0	19	8	0	2	8	0	16	14	11
Lithothamnium sp.	19	10	6	0	16	10	12	30	8	15	.1
Lithophyllum sp.	25	15	0	0	0	0	0	13	0	0	.1
Corallina officinalis	18	20	35	74	25	7	20	0	15	15	0
Hildenbrandtia sp.	.1	0	0	0	0	0	0	0	0	0	0
Polysiphonia incompta	.1	0	0	0	0	0	0	0	0	0	0
Herposiphonia sp.	.1	.1	0	0	0	0	0	0	0	0	0
Griffithsia secunda	.1	.1	0	0	0	0	0	0	0	0	0
Chaetomorpha antennina	0	0	8	0	8	0	0	0	14	0	0
Ulva sp.	0	0	3	7	0	0	5	1	8	27	6
Hypnea spicifera	0	0	2	0	4	2	0	4	5	2	0
Caulacanthus ustulatus	0	0	0	11	25	12	24	9	8	4	0
Endarachne binghamiae	0	0	0	0	0	0	0	0	0	4	30
Champia paryula	0	0	0	0	0	0	0	0	0	.1	0
Jania sp.	0	.1	0	0	0	0	0	0	0	0	0
Acrosorium maculatum	0	.1	0	0	0	0	0	0	0	0	0
Laurencia glomerata	0	0	0	0	0	0	0	0	0	16	0
Blue-green algae	0	0	0	0	0	12	0	0	0	0	0

J15 line Diversity= 2.95 Evenness=1.34

SPECIES	DENSITY PER QUADRAT							
	1	2	3	4	5	6	7	8
<i>Bostrychia mixta</i>	8	0	0	0	0	0	0	0
<i>Ulva</i> sp.	10	50	0	0	4	0	60	64
<i>Chaetomorpha antennina</i>	40	50	0	0	40	46	30	45
<i>Ceramium arenarium</i>	40	20	0	0	40	46	4	4
<i>Caulerpa filiformis</i>	0	0	85	83	0	0	0	0
<i>Champia parvula</i>	0	0	0	0	12	8	0	0
<i>Caulacanthus ustulatus</i>	0	0	0	0	0	0	40	64
<i>Endarachne binghamiae</i>	0	0	0	0	0	0	4	0
<i>Bryopsis caespitosa</i>	0	0	0	0	0	0	12	4

J10 line Diversity= 3.39 Evenness=1.36

SPECIES	DENSITY PER QUADRAT							
	1	2	3	4	5	6	7	8
<i>Gelidium pristoides</i>	35	36	7	24	0	0	0	0
<i>Ulva</i> sp.	1	3	0	4	8	23	40	22
<i>Lithophyllum</i> sp.	37	32	55	21	0	5	0	5
<i>Lithothamnium</i> sp.	0	8	.1	16	10	8	10	5
Blue-green algae	0	28	21	17	0	0	0	0
<i>Polysiphonia incompta</i>	0	0	2	0	18	0	0	50
<i>Caulacanthus ustulatus</i>	0	0	0	0	33	85	29	56
<i>Amphiroa rigida</i>	0	0	0	0	3	10	0	0
<i>Chaetomorpha antennina</i>	0	0	0	0	4	4	70	40
<i>Endarachne binghamiae</i>	0	0	0	0	.1	5	0	4
<i>Ceramium arenarium</i>	0	0	0	0	0	17	42	0

J35 line Diversity=3.60 Evenness=1.29

SPECIES	DENSITY PER QUADRAT					
	1	2	3	4	5	6
<i>Ulva</i> sp.	10	0	7	0	2	19
<i>Lithothamnium</i> sp.	20	0	10	0	3	0
<i>Polysiphonia incompta</i>	34	30	0	0	0	0
<i>Amphiroa rigida</i>	2	0	0	0	0	0
<i>Arthrocardia</i> sp.	11	0	10	0	0	0
<i>Platysiphonia miniata</i>	7	0	0	0	0	0
<i>Callithamnion stuposum</i>	.1	0	0	0	0	0
<i>Cladophora</i> cf. <i>capensis</i>	.1	0	0	0	0	0

J19 +30m line

Diversity= 3.44

Evenness= 1.24

SPECIES	DENSITY PER QUADRAT							
	1	2	3	4	5	6	7	8
Ulva sp.	3	4	0	0	4	.1	1	4
Ceramium arenarium	30	31	72	26	10	8	35	13
Chaetomorpha antennina	22	26	25	62	45	19	10	35
Polysiphonia incompta	30	31	.1	26	10	0	.1	12
Herposiphonia sp.	.1	.1	0	0	0	0	0	0
Amphiroa rigida	3	0	0	4	3	7	0	0
Gelidium caespitosum	5	0	0	0	0	0	0	0
Cladophora cf. capensis	.1	.1	.1	0	.1	.1	.1	.1
Bryopsis caespitosa	0	4	0	0	17	16	4	10
Platysiphonia miniata	0	0	0	0	.1	0	0	0
Laurencia glomerata	0	0	0	0	0	0	5	0
Jania sp.	0	0	0	0	0	0	30	5
Arthrocardia sp.	0	0	0	0	0	0	46	24
Corallina officinalis	0	0	0	0	0	0	10	0
Champia parvula	0	0	0	0	0	0	0	.1
Blue-green algae	0	0	0	0	0	0	0	10

J19 +10m line

Diversity= 3.07

Evenness=1.33

SPECIES	DENSITY PER QUADRAT							
	1	2	3	4	5	6	7	8
Chaetomorpha antennina	35	17	68	34	90	90	0	50
Blue-green algae	30	18	0	0	15	15	19	80
Ralfsia expansa	0	0	1	0	0	0	0	0
Ulva sp.	0	0	0	0	15	15	0	0
Cladophora capensis	0	0	0	0	6	6	5	0
Bryopsis caespitosa	0	0	0	0	20	20	0	40
Porphyra capensis	0	0	0	0	9	9	16	10
Enteromorpha intestinalis	0	0	0	0	15	15	44	0
Bachelotia antillarum	0	0	0	0	24	24	0	0
Caulerpa filiformis	0	0	0	0	0	0	44	0

J17 line

Diversity= 3.08

Evenness= 1.33

SPECIES	DENSITY PER QUADRAT							
	1	2	3	4	5	6	7	8
Ceramium arenarium	28	2	20	19	33	25	18	24
Ulva sp.	40	60	44	40	.1	18	0	1
Chaetomorpha antennina	90	80	44	28	.1	.1	40	50
Amphiroa rigida	2	0	0	0	10	2	0	0
Caulacanthus ustulatus	6	0	12	0	0	26	0	0
Bryopsis caespitosa	0	0	10	9	10	6	16	7
Colpomenia sinuosa	0	0	1	0	1	.1	0	0
Champia parvula	0	0	0	0	35	7	0	0
Platysiphonia miniata	0	0	0	0	4	0	0	0
Enderachne binghamiae	0	0	0	0	4	1	0	.1

J50 line

Diversity= 3.42

Evenness=1.29

52

SPECIES	DENSITY PER QUADRAT											
	1	2	3	4	5	6	7	8	9	10	11	12
<i>Gelidium pristoides</i>	20	9	30	32	11	18	52	47	0	0	0	0
Turf	64	68	0	0	61	51	0	0	15	18	0	0
<i>Ulva</i> sp.	.1	7	0	.1	5	4	2	0	0	.1	15	26
<i>Lithophyllum</i> sp.	.1	0	18	0	0	5	10	10	5	11	0	0
<i>Bostrychia mixta</i>	.1	0	0	0	0	0	0	0	0	0	0	0
<i>Lithothamnium</i> sp.	0	0	18	15	5	23	7	5	5	0	0	0
<i>Caulacanthus ustulatus</i>	0	0	0	3	0	6	8	2	26	8	7	17
<i>Ceramium arenarium</i>	0	0	0	0	0	0	0	0	33	26	0	0
<i>Corallina officinalis</i>	0	0	0	0	0	0	0	0	8	10	10	10
<i>Colpomenia sinuosa</i>	0	0	0	0	0	0	0	0	0	0	13	10
<i>Arthrocardia</i> sp.	0	0	0	0	0	0	0	0	0	0	5	15
<i>Polysiphonia incompta</i>	0	0	0	0	0	0	0	0	0	0	10	35
<i>Jania</i> sp.	0	0	0	0	0	0	0	0	0	0	10	10
<i>Pterosiphonia cloiophylla</i>	0	0	0	0	0	0	0	0	0	0	5	5

K18 line

Diversity= 1

Evenness=0

SPECIES	DENSITY PER QUADRAT				
	1	2	3	4	5
Blue-green algae	100	100	100	100	100

The data for each quadrat appears in Table 4.1. The basic data of species density per quadrat is listed. Indices for similarity, evenness and diversity were calculated from this data.

#### 4.2 Results and Discussion

The location of the line transects are located on the map (Fig. 4.1) and the average height above mean low water of these lines was 1.52m. 80 quadrats were analysed from the 9 transect lines. 38 different species of seaweed were identified from these quadrats (Table 4.9). The 9 lines were grouped into 3 sectors; 4 near the outfalls (within 50m), 3 lines 100m from the outfalls and the last two lines were 250m and 1000m from the outfalls, respectively. A tenth line, located directly behind the main outfall (See plate 2.2), was totally covered in a mat of blue-green algae and the identification of individual species in the field or with photographs was not practical. Previous work has dealt with blue-greens in the intertidal zone as a single unit (ie. blue-green algae) (Murray and Littler, 1974) (Littler and Murray, 1975, 1977). As only a listing for blue-green algae could be assumed and because of the totally different covering to the rest of the areas, these data were not combined with the polluted sector data.

Individual line transect information (Table 4.1) and combined information from the 3 sectors (Table 4.2) regarding

TABLE 4.2

## DATA FOR THE THREE SECTORS

Polluted (within 100m) Sector Diversity=3.60 Evenness=1.11

OCC	COVER	FREQ %	COVER DOM %	IV/200	SPECIES
20	2732.5	62	13	75	ULVA SP
29	7570	98	37	127	CHAETOMORPHA ANTENNINA
25	3725	78	19	97	CERAMIMUM ARENARIUM
3	1325	9	6	15	CAULERPA FILIFORMIS
5	398.1	15	1	16	CHAMPPIA PARVULA
5	890	15	3	18	CAULACANTHUS USTULATUS
13	781	40	3	43	BRYOPSIS CAESPITOSA
1	6.25	3	0	3	BOSTRYCHIA MIXTA
4	56.8	12	0	12	ENDARACHNE BINGHAMIAE
7	1168	21	5	26	CYANOPHYTA (BLUE-GREEN)
3	462.5	9	2	11	ENTEROMORPHA INTESTINALIS
10	110.6	31	0	31	CLADOPHORA CF. CAPENSIS
4	275	12	1	13	PORPHYRA CAPENSIS
1	6.25	3	0	3	RALFSIA EXPANSA
2	300	6	1	7	BACHELOTIA ANTILLARUM
1	31.25	3	0	3	LAURENCIA GLOMERATA
2	210.75	6	1	7	JANIA SP
1	62.5	3	0	3	ARTHROCARDIA SP.
2	25.6	6	0	6	PLATYSIPHONIA MINIATA
7	193.75	21	0	21	AMPHIROA CF. RIGIDA
2	1.25	6	0	6	HERPOSIPHONIA SP
1	31.25	3	0	3	GELIDIUM CAESPITOSUM
7	682.5	21	3	24	POLYSIPHONIA INCOMPTA
3	13.1	9	0	9	COLPOMENIA SINUOSA
1	62.5	3	0	3	CORALLINA OFFICINALIS

+100m Sector Diversity=3.76 Evenness=1.14

OCC	COVER	FREQ %	COVER DOM %	IV/200	SPECIES
2	1.25	6	0	6	ACROSORIUM MACULATUM
7	131	23	0	25	HYPNEA SPICIFERA
16	1082	53	5	58	LITHOTHAMNIUM SP.
22	1488	73	7	80	ULVA SP
12	1150	40	6	46	CHAETOMORPHA ANTENNINA
20	1631	66	8	74	CERAMIMUM ARENARIUM
1	.625	3	0	3	CHAMPPIA PARVULA
13	1943	43	10	53	CAULACANTHUS USTULATUS
3	75	10	0	10	BRYOPSIS CAESPITOSA
6	313	20	1	21	ENDARACHNE BINGHAMIAE
4	487	13	2	15	CYANOPHYTA (BLUE-GREEN)
2	100	6	0	6	RALFSIA EXPANSA
1	100	3	0	3	LAURENCIA GLOMERATA
1	.625	3	0	3	JANIA SP
1	412	3	2	5	ARTHROCARDIA SP.
1	37.5	3	0	3	CHEILOSPORUM CULTRATUM
2	81.25	6	0	6	AMPHIROA CF. RIGIDA
2	1.25	6	0	6	HERPOSIPHONIA SP
2	1.25	6	0	6	GRIFFITHSIA SECUNDA
4	438	13	2	15	POLYSIPHONIA INCOMPTA
1	25	3	0	3	COLPOMENIA SINUOSA
9	1431	30	7	37	CORALLINA OFFICINALIS
15	2130	50	11	61	LITHOPHYLLUM SP
2	137	6	0	6	GELIDIUM ARENARIUM
5	693	16	3	19	GELIDIUM PRISTOIDES
1	6.25	3	0	3	CLADOPHORA RUGULOSA
2	25	6	0	6	HILDENBRANDTIA SP

+250m Sector

Diversity=3.75 Evenness=1.21

DCC	COVER	FREQ %	COVER DOM %	IV/200	SPECIES
8	1368	44	12	56	GELIDIUM PRISTOIDES
6	1731	33	15	48	TURF(22/110/94/14/9)
13	608	72	5	77	ULVA SP
7	369	38	3	41	LITHOPHYLLUM SP
1	.625	5	0	5	BOSTRYCHIA MIXTA
10	693	55	6	61	LITHOTHAMNIUM SP.
12	1381	66	12	78	CAULACANTHUS USTULATUS
6	1268	33	11	44	CERAMIIUM ARENARIUM
7	519	38	4	42	CORALLINA OFFICINALIS
2	143	11	1	12	COLPOMENIA SINUOSA
4	256	22	2	24	ARTHROCARDIA SP.
4	681	22	6	28	POLYSIPHONIA INCOMPTA
3	175	16	1	17	JANIA SP
2	62.5	11	0	11	PTEROSIPHONIA CLOIOPHYLLA
1	12.5	5	0	5	AMPHIROA CF. RIGIDA
1	43	5	0	5	PLATYSIPHONIA MINIATA
1	.625	5	0	5	CALLITHAMNION STUPOSUM
1	.625	5	0	5	CLADOPHORA CF. CAPENSIS
3	300	16	2	18	GIGARTINA PISTILLATA
2	44	11	0	11	ENDARACHNE BINGHAMIAE
2	93	11	0	11	CHAMPYA PARVULA
1	68	5	0	5	LAURENCIA GLOMERATA

the species found in the line, their occurrences, total coverage (cm), overall frequency and cover (%) and the importance value/200, compare all factors being calculated. The diversity ( $H'$ ) and evenness ( $J'$ ) are listed along with the distance or average distance of the line from the outfalls.

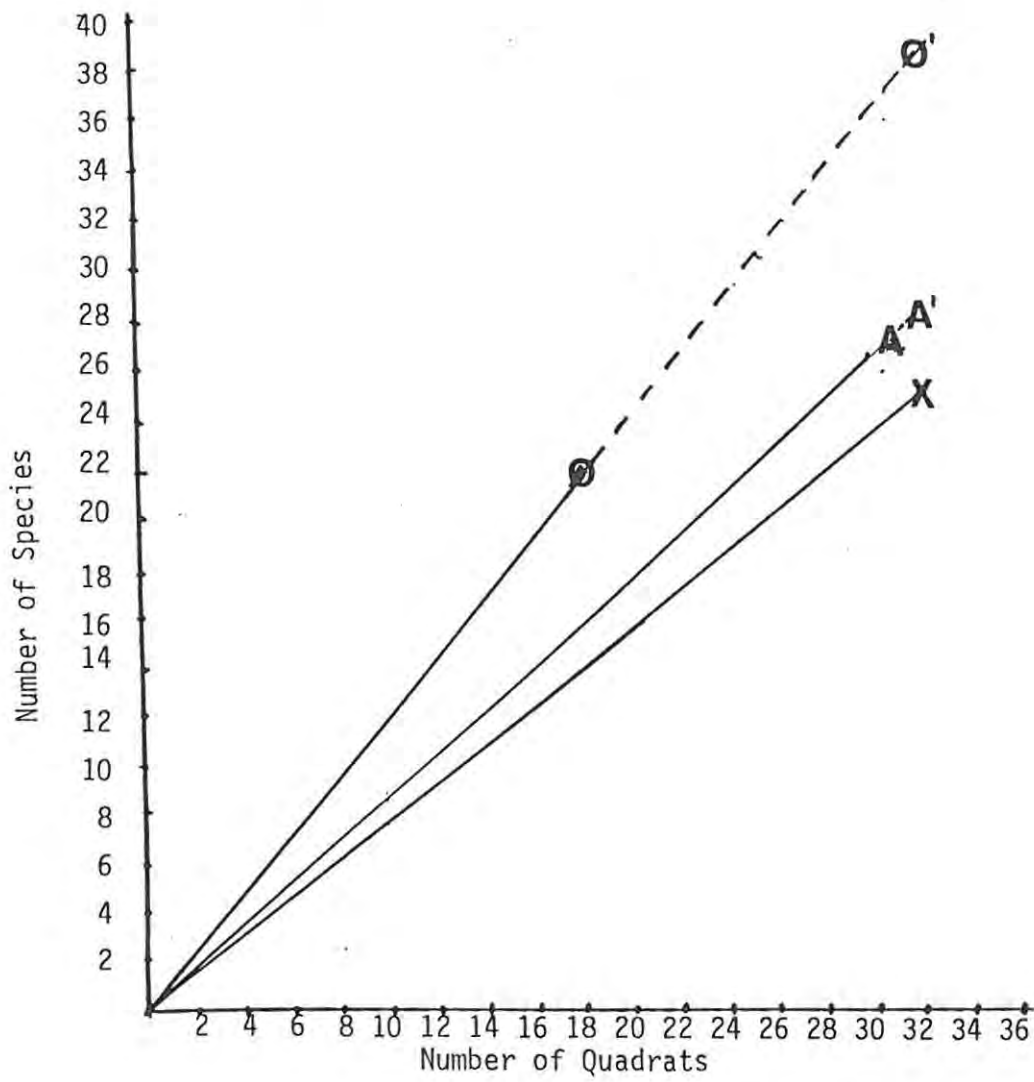
To determine the area affected by the pollution, more line transects were located within 100m of the outfalls. This accounts for the fact that the polluted sector had more transect lines and therefore quadrats than the +100m and +250m sectors. The data for the polluted sector were based on 32 quadrats while the +100, and +250 sector data was based on 31 and 18 quadrats, respectively. Table 4.3 lists the three sectors with quadrat and species numbers.

TABLE 4.3

COMPARISON OF QUADRAT AND SPECIES NUMBERS IN OUTFALL AND CONTROL AREAS

	Polluted	+100m	+250m
Quadrats	32	31	18
Species	25	27	22

Comparing the number of species in the 3 sectors, the control area appears to have fewer species than the polluted but when the numbers are taken in proportion (no. of species/ no. of quadrats x no. of species) (Fig. 4.2) to the



Ø	+250m
Ø'	+250 projected
A	+100m
A'	+100m projected
X	Polluted
----	Projected

FIG. 4.2 PROPORTIONAL SPECIES NUMBERS

actual number of quadrats used to collect the data, then a new result (Table 4.4) occurs with the control area having the largest proportional number of species per sector.

TABLE 4.4

COMPARISON OF QUADRAT AND PROPORTIONAL SPECIES NUMBERS IN THE OUTFALL AND CONTROL AREAS

	Polluted	+100m	+250m
Quadrats	32	31	18
Prop. species	19.5	23.4	26.4

The diversity of the 3 sectors supported Borowitzka (1971), Murray and Littler (1974), and Littler and Murray (1977). The sector with the lowest density and diversity (3.60) was the closest to the outfall. The +100m sector recorded a diversity of 3.76 and the +250m sector diversity was 3.75. Evenness was also maintained with the polluted sector having the lowest value (Table 4.5).

TABLE 4.5

PATTERNS OF SPECIES DIVERSITY FOR CONTROL AND OUTFALL AREAS BASED UPON IMPORTANCE VALUE

Sector	No. Species	H'	J'
Polluted	25	3.60	1.119
+100m	27	3.76	1.141
+250m	22	3.75	1.215

Although the diversity of the polluted sector was lowest, the geography of the transects and certain quadrat placings may have played a role in the diversity difference being only 4% less (0.15). Of the different lines contained in the polluted sector, each line, as characteristic of all lines in the study, extended towards the edge of the ledge. The J15 line represents the line within the polluted sector which was furthest from either outfall. Although most quadrats fell on an area containing very few species, the outermost quadrats occurred within a splash zone which, depending on wind and surf conditions, came into contact with much cleaner water than the rest of the lines included in this sector. The species in this splash zone were very similar to those found in the +100m and +250m sectors. This zone also fell outside the coralline line (See 6.3, Observations). 4 of the 9 species occurring in this line occurred in the last 4 quadrats in the splash zone.

The +250m sector contained 2 line transects, J35 and J50 which were located 260m and 1000m from the outfall, respectively. There was only 53% similarity between the two; so, had there been more lines set out between these two areas, the probability of more species being included would have been high. To do this would 'pad' the results which already show reduction in diversity and evenness in the polluted sector. The J50 line of the +250m sector also had a <sup>category</sup> species listed as "turf", which included 4 or 5 species intermingled through a mat surface which was the main cover for many of the quadrats in this area. When these species occurred individually, they

were scored but the score (density/quadrat) did not include their density in the turf.

The K18 line, which is not included in the polluted sector results, consisted of 5 quadrats which were totally covered with blue-green algae (100%). The diversity in this case works out to 1.00 using the blue-green algae as a single unit. When included with the polluted sector results, the diversity drops from 3.60 to 3.42.

In comparing the similarity (max. 100%) for the 3 sectors, each sector maintained around a 60% similarity index with respect to the other sectors (See Table 4.6).

TABLE 4.6

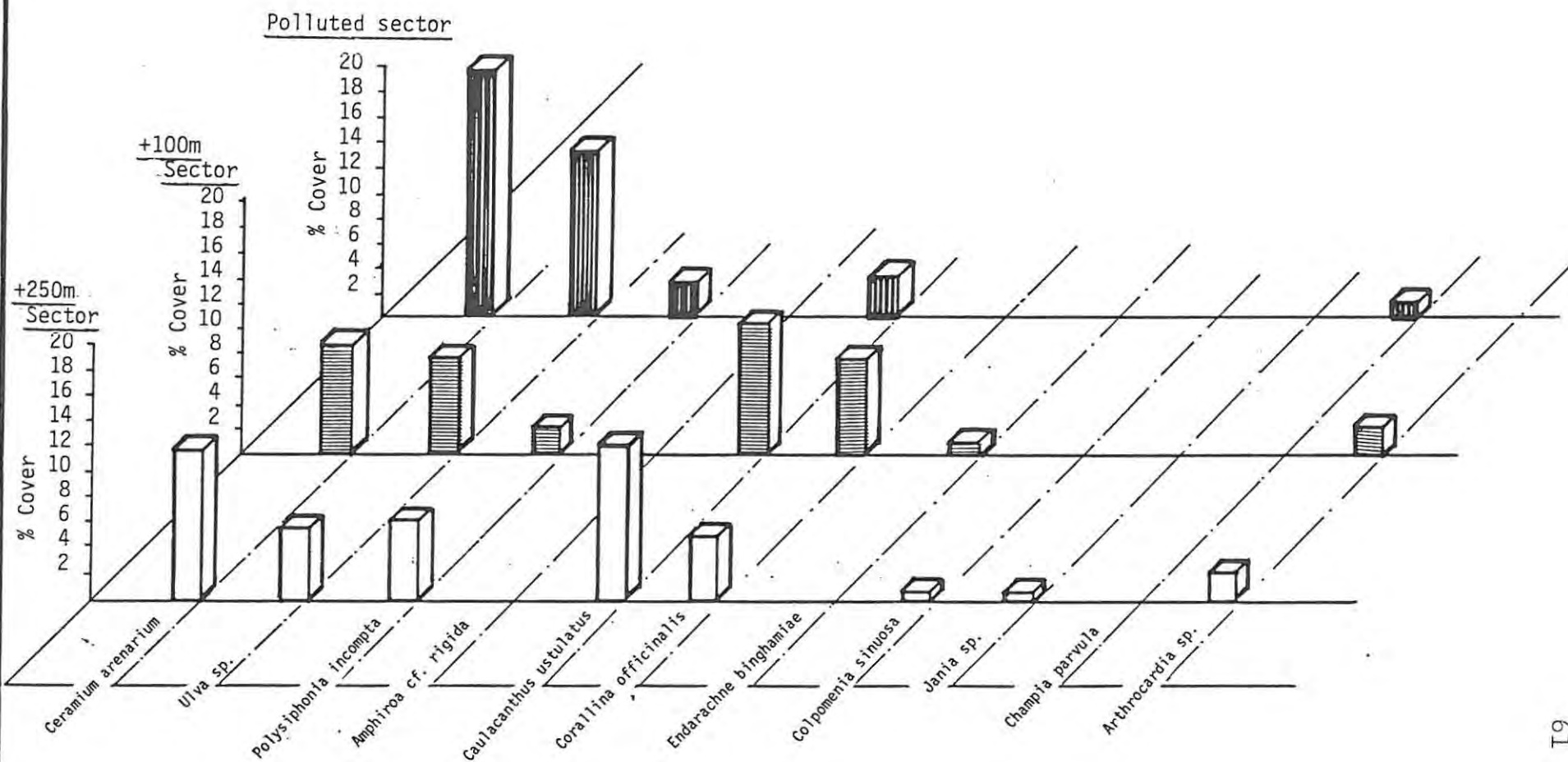
COMPARISONS OF SIMILARITY (%) FOR THE OUTFALL AND THE CONTROL SECTORS

	Polluted	+100m	+250m
Polluted	-	65%	63%
+100m	65%	-	61.2%

Eleven species were common to all 3 sectors. The similarity index for the three was 28%. The total cover of the 11 species in each area is represented in Fig. 4.3

The 11 species common to the 3 sectors ranged in importance values (I.V.) from 3/200 to 97/200. The highest average I.V. for the 3 sectors was Ulva sp. with a 77/200

FIG. 4.3 TOTAL COVER (%) OF THE 11 SPECIES COMMON TO THE 3 SECTORS



average value. As the I.V. represents the % cover and % frequency of the species, the most common species found in the quadrats would be the species with the highest I.V. Although Ulva sp. is well known for its presence around outfall areas, it is not necessarily restricted to these areas (Burrows, 1971). Chapman (1979) listed ranges of salinity tolerated by certain seaweeds from intertidal locations. Ceramium sp. and Polysiphonia sp. (2nd and 5th highest I.V. average; (See Table 4.7) were listed as two tolerant species with ranges of 0.4 to 2.2 and 0.3 to 2, respectively, (using 1.0 for normal, 35ppt, seawater). This may help explain their large occurrence and coverage in the polluted areas where the salinity is lower than normal.

The K18 line transect had only blue-green algae and its I.V. was 200/200. The I.V. for blue-green algae in the polluted sector was 26/200 and the +100m sector was 15/200. When K18 is included in the polluted sector, its I.V. moves up to 90/200 which then becomes the highest I.V. for the sector. Littler and Murray (1977) recorded blue-green algae to be the most abundant.

While only the larger species prevailed in the results, a list from samples collected of the smaller species in each quadrat was drawn up and if no definite 'hit' was recorded during the analysis of the photographs, a value of 0.1 was assigned to the species listed.

Although the results may not give a true reflection of the species "value", it is still recorded under occurrence and still receives an I.V.



LIST OF SEAWEEDS WHICH OCCURRED IN THE QUADRATS ALONG THE LINE TRANSECTS

Bryopsis caespitosa  
Acrosorium maculatum  
Ralfsia expansa  
Ulva sp.  
Cyanophyta (blue-green algae)  
Gigartina pistillata  
Amphiroa cf. rigida  
Chaetomorpha antennina  
Champia parvula  
Bachelotia antillarum  
Griffithsia secunda  
Callithamnion stuposum  
Caulacanthus ustulatus  
Caulerpa filiformis  
Ceramium arenarium  
Cladophora cf. capensis  
Cladophora rugulosa  
Colpomenia sinuosa  
Corallina officinalis  
Endarachne binghamiae  
Enteromorpha intestinalis  
Gelidium pristoides  
Gelidium arenarium  
Gelidium caespitosum  
Herposiphonia sp.  
Hildenbrandtia sp.  
Hypnea spicifera  
Jania sp.  
Laurencia glomerata  
Lithophyllum sp.  
Lithothamnium sp.  
Platysiphonia miniata  
Polysiphonia incompta  
Porphyra capensis  
Pterosiphonia cloiophylla  
Turf (22/110/94/14/9) (refers to seaweed number in turf)  
Arthrocardia sp.  
Bostrychia mixta

The results show the polluted sector to have less species per quadrat compared with the control areas. The polluted area displayed greater overall cover (95% vs 64% and 80%; (See fig.4.4). This, along with its reduced diversity (3.60) and evenness, reflects the fact that in harsh environments, the opportunistic species with the short life histories will dominate the area (Borowitzka, 1971), (Murray and Littler, 1974) (Littler and Murray, 1975, 1977). Also with less competition for space from macro-invertebrates and fewer grazers, the cover was generally full.

The difference between the diversity of the 2 control areas, 3.76 vs 3.75 would indicate an accepted value between two similar areas.

As a result of a factor causing a stress situation in the outfall environment (sewage), there is a reduction in species numbers, diversity and evenness, and a greater cover from the fewer species present.

Past studies have shown that when a stress situation occurs, whether man-made or natural, the species that can adapt either through its ability to resist the stress situation or through its reproductive methods will be the species that will emerge out of the status quo and become dominant.

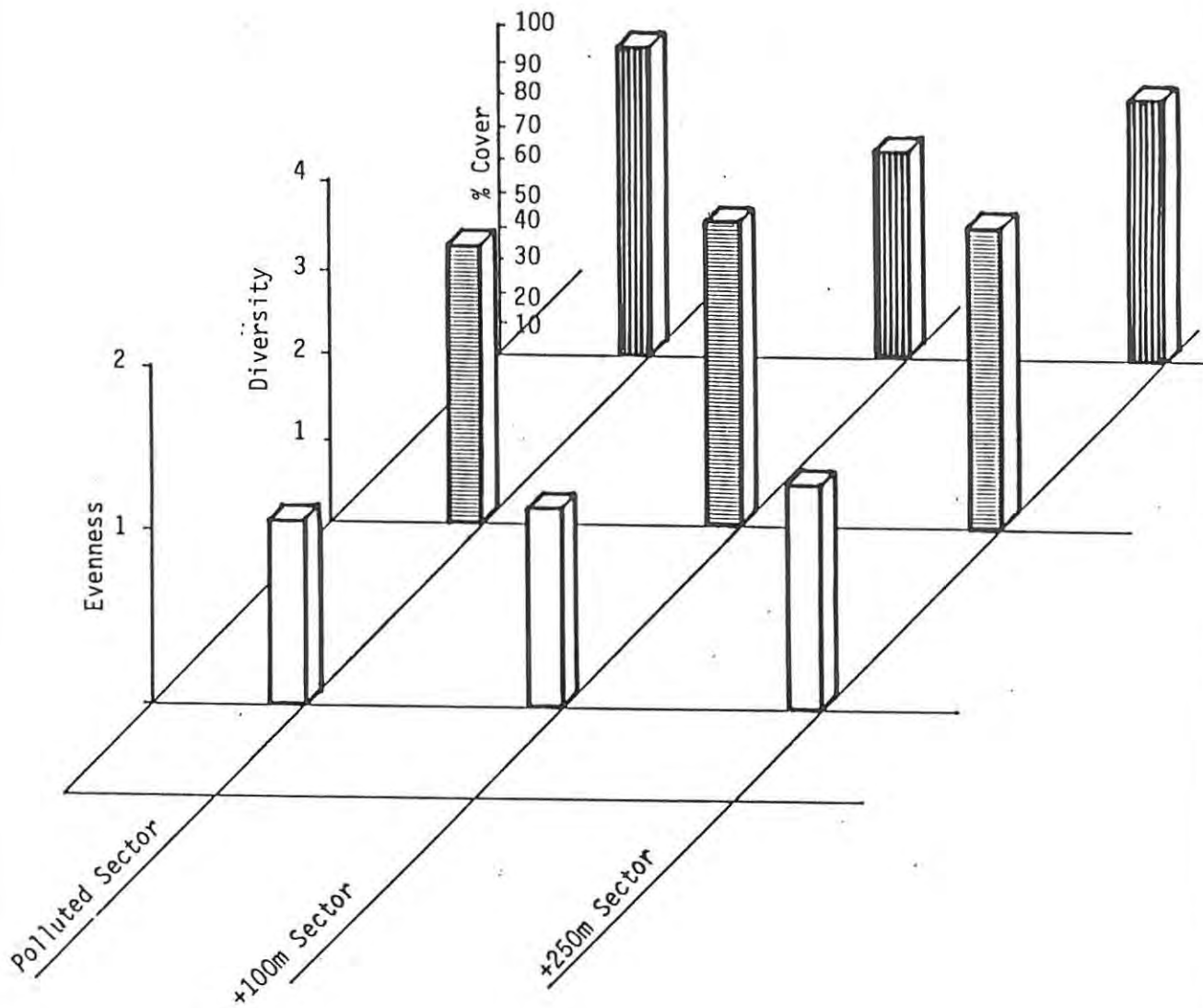


FIG. 4.4 COMPARISON OF % COVER, DIVERSITY, AND EVENNESS OF THE THREE SECTORS

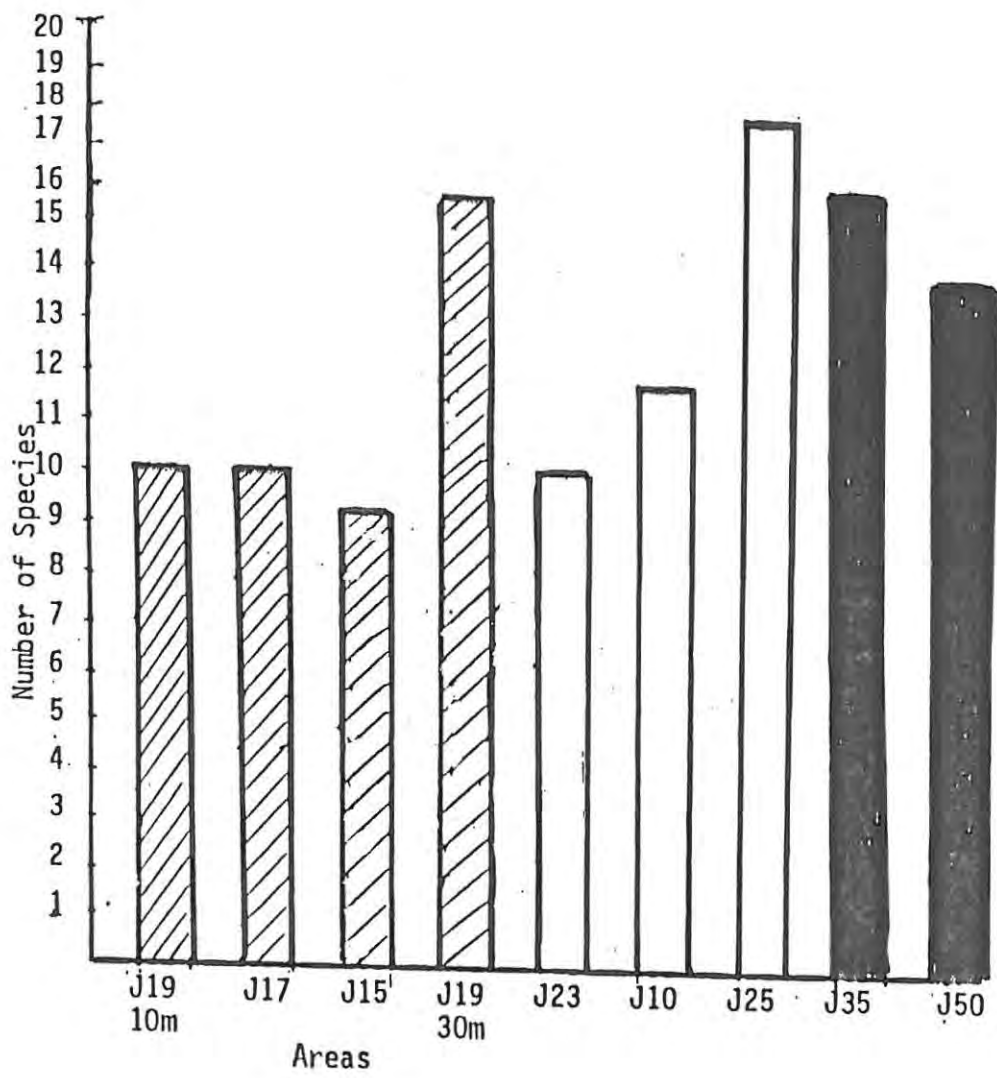


FIG. 4.5 SPECIES NUMBERS FOR EACH LINE TRANSECT.

Key to Sectors	
■	+250m
□	+100m
▨	Polluted

## Chapter 5

## ALGAL SUCCESSIONS IN POLLUTED AND UNPOLLUTED AREAS

## INTRODUCTION

In order to determine which species of algae would be able to be termed as an 'opportunistic' species, the recovery of the marine algae on fully denuded rock surfaces in polluted and control areas was monitored over a 30-week period from April to November 1984. This period was chosen after a similar experiment, carried out one year previously, provided information on the time needed for plots to recover in this particular environment.

Recolonization studies in the past (Kitching, 1937; Bokenham, 1938; Fahey and Doty, 1949; Emerson and Zedler, 1980) have shown that pioneer or opportunistic short life cycle species recolonize shortly after clearing and the longer life cycle species move in over a period of time. Katada and Satomi (1975) describe four groups involved in the succession of bare rock surface. The first group, microbes (benthic diatoms and others), becomes dominant within half a month after the clearing of the surface. The second group, erect forms of ephemerae (annuals) and eclipses (algae which pass the unfavourable season in the form of a minute body) appears between a half to three months later. The third group, lumpish and crustaceous forms of ephemerae and true annuals and eclipses, appears between several months to one and a half

years later. The fourth group, various perennials, root, stem, frond, and rhizome survivors, becomes nearly dominant at the earliest after one year and usually need several years to reach a climax (Katada and Satomi, 1975).

Murray and Littler (1978) showed that in outfall study plots rapid-recovery occurred following an experimental disturbance. The quick recovery of the blue-greens, Ulva, diatoms and others resulted from "vegetative, sexual or asexual reproduction mediated through suspended cells. These algae clearly have the capacity for rapid recruitment even under the influence of sewage effluent" (Murray and Littler, 1978). These rapid recovery seaweeds dominating the disturbed shoreline appear to show considerable mortality due to exposure to sewage toxicants yet can still maintain a relatively constant population because of their potential for rapid recruitment (Murray and Littler, 1978). Within 1 month, 100% overall cover had been reached. The unpolluted area took 3.0 months before reaching 100% cover. These plots were dominated during this time by similar algae to those of the outfall area. Blue-green algae, filamentous Ectocarpaceae and colonial diatoms were abundant components of the early successional stages for polluted and unpolluted areas. However, the rapid recovery rates of the outfall area suggested a pattern for harsh environments whereas a more complex pattern of development over a greater period of time was evident in the control areas.

In his results from regrowth experiments near a sewage outfall in Australia, Borowitzka (1971) found the low diversity

communities behind the outfall unstable and, due to the presence of the outfall, the algal communities were held at a primitive, pioneering stage. The algal communities leading away from the outfalls represented a gradient of communities from pioneer to relatively mature stages and were held at their respective stages of maturity by the outfalls.

### 5.1 METHODS AND MATERIALS

Metal quadrats 25cm by 25cm square (.0625 square metres) were placed in areas selected by their similarity in height above mean low water (MLW), which was determined earlier (See chapter 3), and its exposure to the waves. The actual placing of the quadrat in the area was done at random. The area was marked out with four steel nails in the corners, and Fratleys Putty was placed around the base of the nails to secure them.

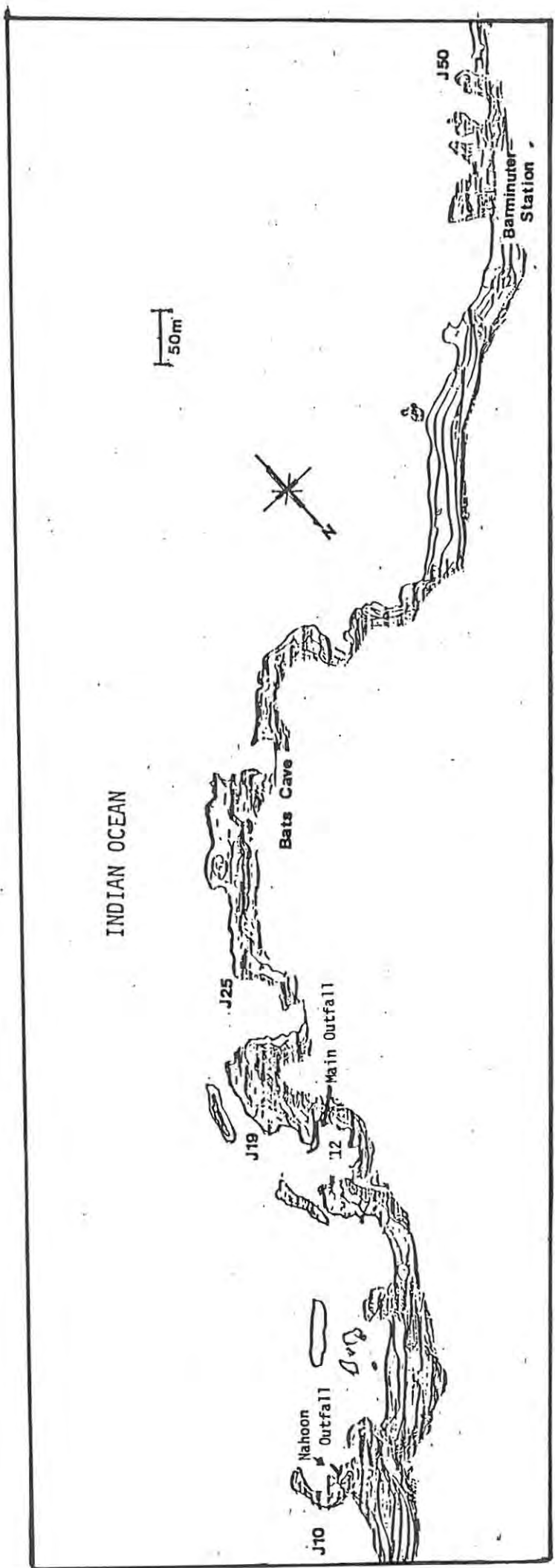
Each quadrat was photographed on colour slide film, and a visual survey of the macroscopic seaweeds was done before the plot was scraped clean. All material within the quadrat was collected and preserved in 4% formalin and seawater for identification. After scraping and wirebrushing to remove even the encrusting corallines, petrol was poured over the area, set alight and allowed to burn. After the first burn, more scraping was done and the petrol added again. As a final effort to sterilize the plot, 95% ethanol was poured over the plot which remained until the incoming tide washed it away. To allow for easy relocation, the outer perimeter was also cleared and painted. This proved unnecessary as the plots

stood out long after the paint had disappeared.

The cleared plot was photographed again and a continuing series of observations, collections and photography was carried out during spring tides (every two weeks when possible) for 30 weeks. Identification of the algae was done visually in the field and recorded by means of a small Panasonic tape recorder with a remote control microphone. A seal tab plastic bag kept any water splashing off the recorder. All species present were collected (disturbing the plot as little as possible and taking from the outer boundary when a positive identification could be made between the algae in the plot and that on the boundary). These species were preserved as before, and Karo slides were made of the smaller species and labelled. Two extra clearings were done, one at the beginning of winter and one at the beginning of spring, to check if the seasons had had any effect on the recovery of the plots. The Bray and Curtis (1957) index of similarity was employed to measure the degree of recovery (%) (Murray and Littler, 1978) of each plot to its preclearing stage.

Similarity was measured between the 6, 12, 18 and 30 week recovery intervals of the polluted and unpolluted areas. Results for 24 and 26 weeks were not obtained because of equinox high surf conditions

The areas selected for the clearings were given codes referring to the grid map (Fig. 3.1). The actual location of the plots is shown in Fig. 5.1.



Modified from a City Engineers map

FIG. 5.1 LOCATION OF PLOTS IN THE SUCCESSION STUDY

## 5.2 Location and Geography of Areas.

The six plots cleared are located in J10, K18, J191, J1911, J25, and J50. The extra clearings were done in J19 and J10 (See Fig. 5.1)

The J10 plot was located 280m northeast of the main outfall pipe and 85m northeast of the Nahoon outfall (See plate 4.10). It was located on the edge of a flat rock and is 1.15m above MLW. It is exposed to full wave action at high tide.

The K18 plot was located 15m behind the outfall within the cove on a rock angled down into the wash and was .9m above MLW (Plate 2.2).

The first J19 plot, J191, was located 25m south of the outfall on a rock shelf subjected to southerly and easterly wave action and back wash from the cove during high tide. This plot was 1.23m above MLW.

The second J19 plot, J1911, was located 10m further out towards the edge of the rock shelf and about 20m from the outfall. It was lower (.85m above MLW) than J191 and subjected to more wave action (See plate 4.1).

The J25 plot was located 95m southwest of the outfall and .5m from the drop off of the ledge (See plate 4.5). It was 1.25m above MLW and subjected to full wave action at higher tides.

The J50 plot was used as a control plot for the clearings as it followed the pattern of the Kidds Beach control plots done the previous year. This area also exhibited an algal flora similar to areas along this coast not affected by sewage

(See plates 1.3 and 1.4). The plot was 1000m southwest of the outfall on a rock shelf above a tidal pool, 0.9m above MLW, and subjected to the full force of the waves during higher tides.

### 5.3 Results and Discussion

The results of the plot clearings reflected the results of Borowitzka (1971) and Murray and Littler (1978). Rapid recovery in the polluted areas occurred while the control plots recovered at a much slower rate. The total cover (%) of the plots over a 30-week period (Tab. 5.2) shows a rapid recovery in the outfall plots (4 to 8 weeks) whereas the control plots took much longer to achieve full coverage (12 to 18 weeks).

One exception was the J10 plot which, while 100m away from the Nahoon outfall, is the closest control plot to the outfalls. 97% cover was achieved in 4 weeks. Six species of algae were present (Fig. 5.2) which was the maximum any plot had at 4 weeks. Coverage in the polluted areas tended to rise rapidly and then slowly decrease due to grazing by limpets observed in the plots after full cover had been achieved.

The control areas, J25 and J50, followed a similar pattern for the control areas mentioned in Murray and Littler, (1978) where the more complex pattern of development took a greater period of time.

Fifty eight different species were found, including those found prior to clearing the plots (Table 5.1). These included 6

LIST OF SEaweEDS WHICH WERE FOUND IN THE PLOTS DURING THE SUCCESSION STUDY

Bostrychia mixta  
 Bryopsis caespitosa  
 Bryopsis flanaganii  
 Bryopsis sp.  
 Caulacanthus ustulatus  
 Ceramium arenarium  
 Ceramium centroceratiforme  
 Chaetomorpha sp.  
 Champia compressa  
 Cladophora cf. capensis  
 Enderachne binghamiae  
 Enteromorpha intestinalis  
 Gelidium arenarium  
 Gigartina minima  
 Gymnothamnion elegans  
 Herposiphonia sp.  
 Lithothamnium sp.  
 Platysiphonia miniata  
 Polysiphonia incompta  
 Porphyra capensis  
 Pterosiphonia cloiophylla  
 Ralfsia expansa  
 Ulva sp.  
 Lomentaria sp. ff  
 Cyanophyta (Blue-greens)  
 Amphiroa cf. rigida  
 Chaetomorpha antennina  
 Enteromorpha cf. prolifera  
 Champia parvula  
 Licmophora sp.  
 Nitzschia sp.  
 Chroococcus minutus  
 Entophysalis sp.  
 Nostocoida limicola  
 Oscillatoria bonnemaisoni  
 Oscillatoria amoena  
 Sphaerotilus natans  
 Callithamnion stuposum  
 Centroceras clavulatum  
 Ceramium obsoletum  
 Colpomenia sinuosa  
 Gelidium pristoides  
 Gelidium caespitosum  
 Heterosiphonia sp.  
 Audouinella sp.  
 Lyngbya sp.  
 Griffithsia secunda  
 Nostocoida limosa  
 Amphiroa ephedraea  
 Arthrocardia sp.  
 Caulerpa racemosa var. zeyheri  
 Corallina sp.  
 Hypnea spicifera  
 Lithophyllum sp.  
 Pleonosporium sp.  
 Cheilosporium proliferum  
 Biddulphia sp.  
 Cladophora (unknown) sp.

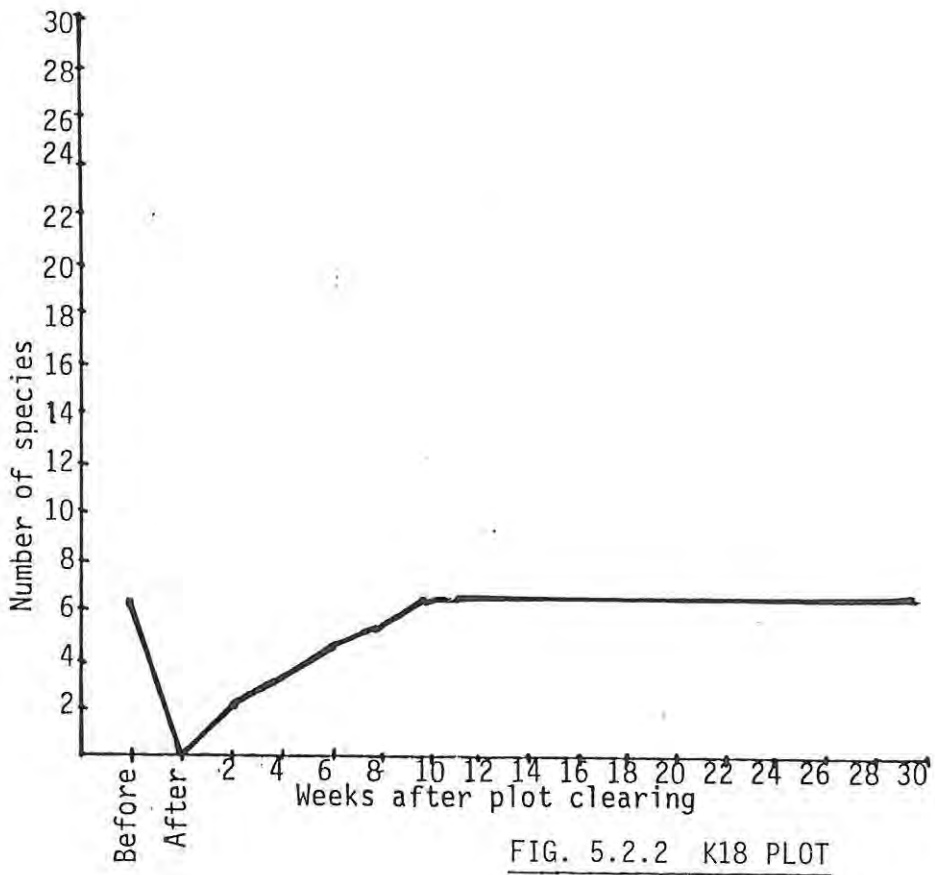
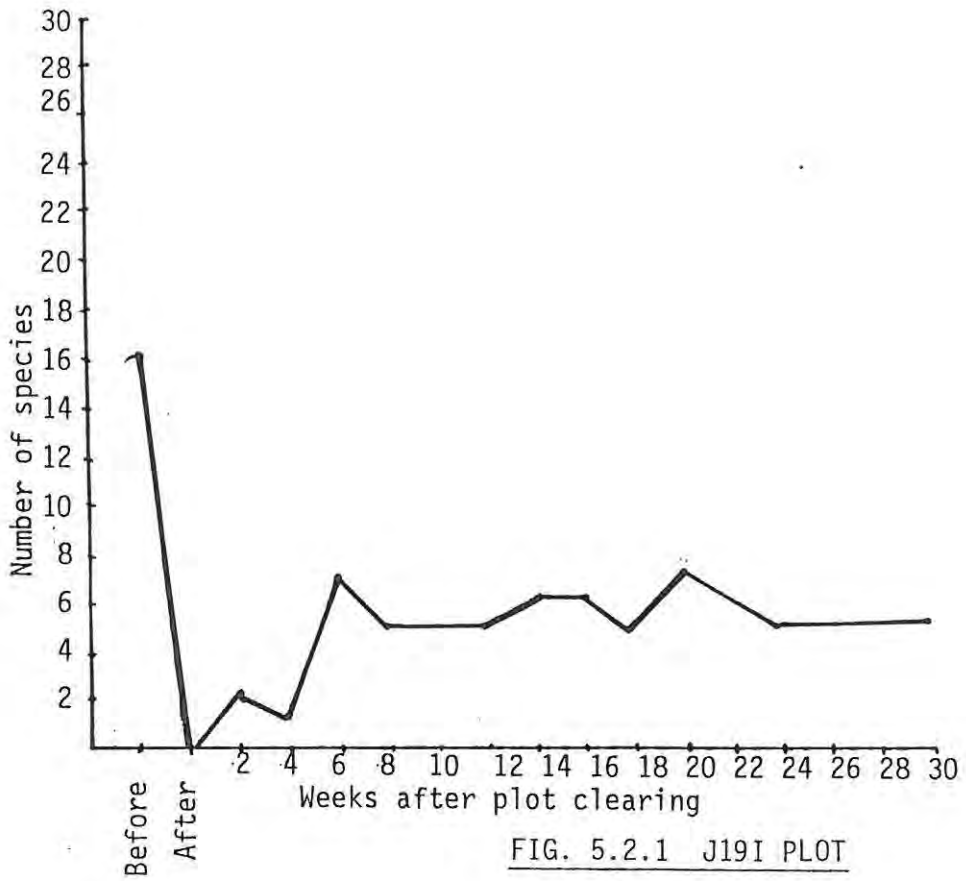
ff see Appendix 4

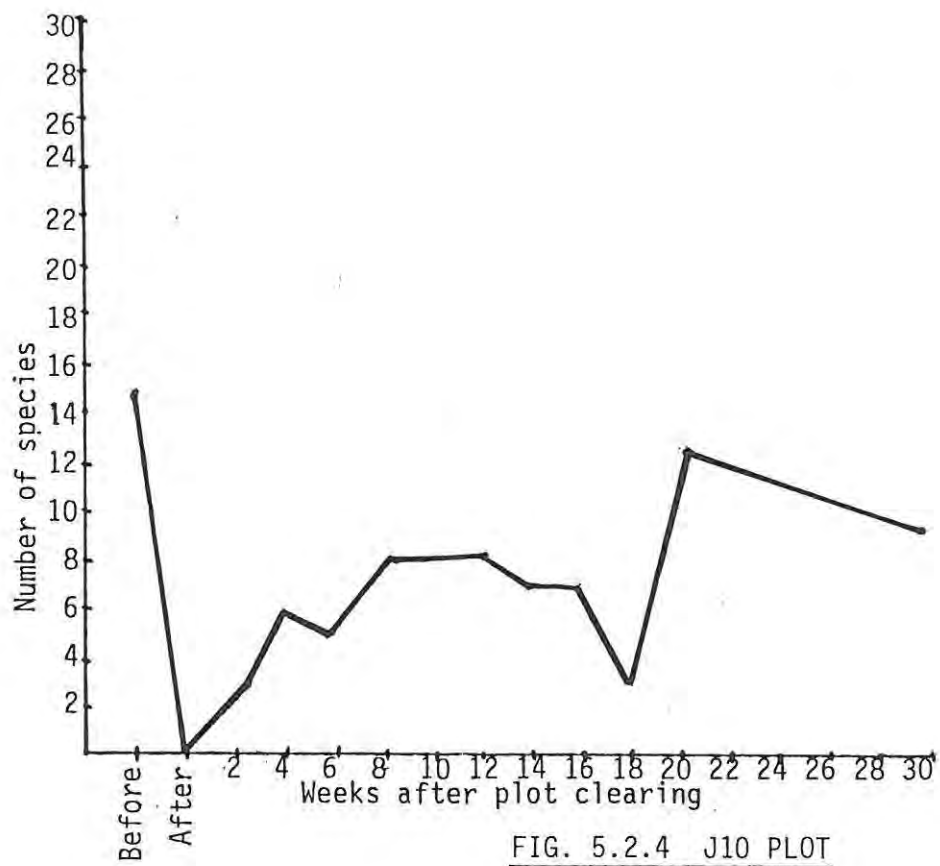
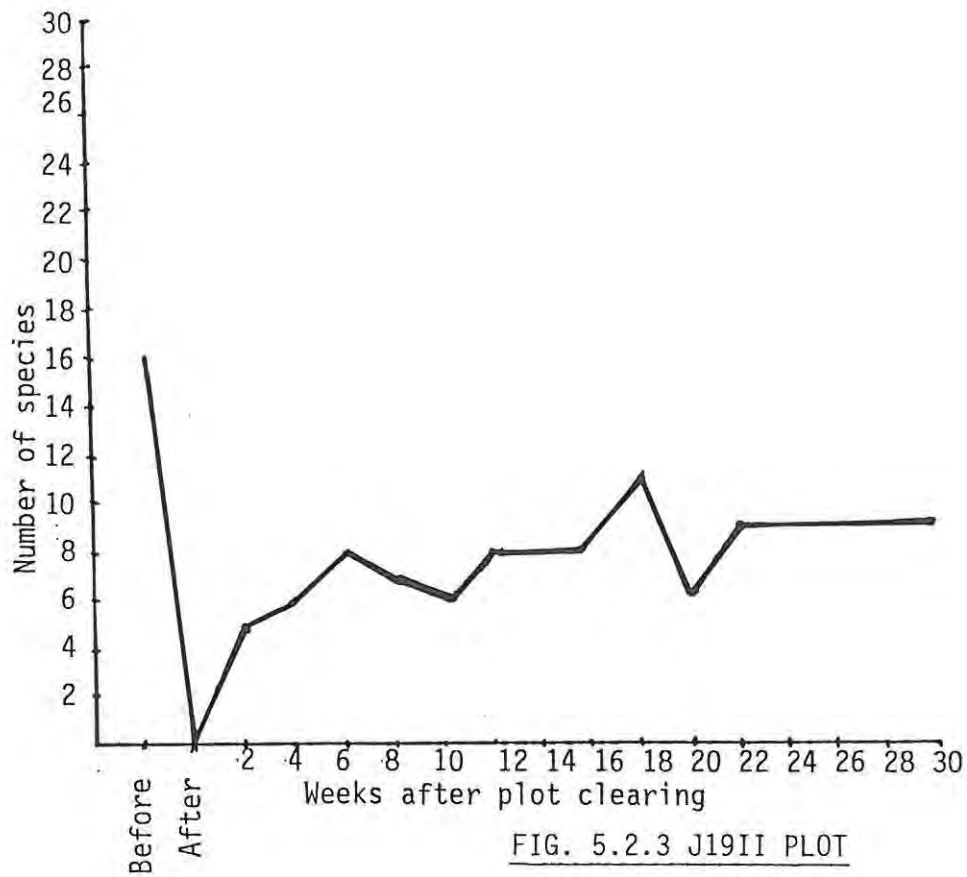
TABLE 5.2

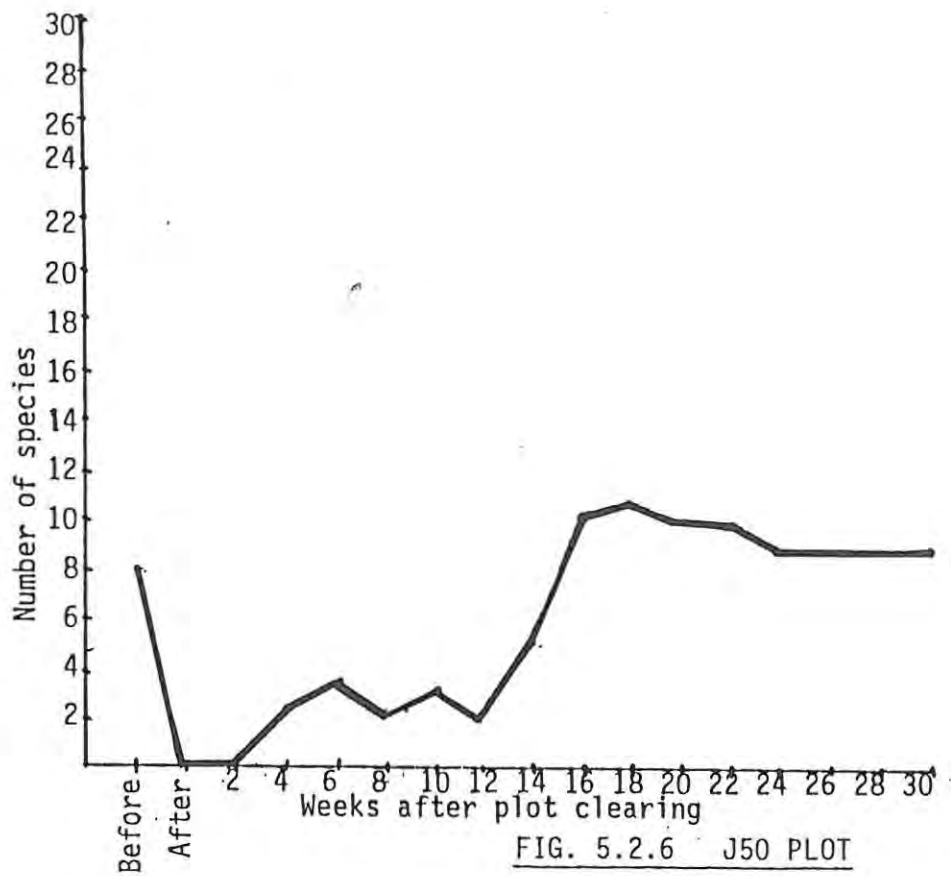
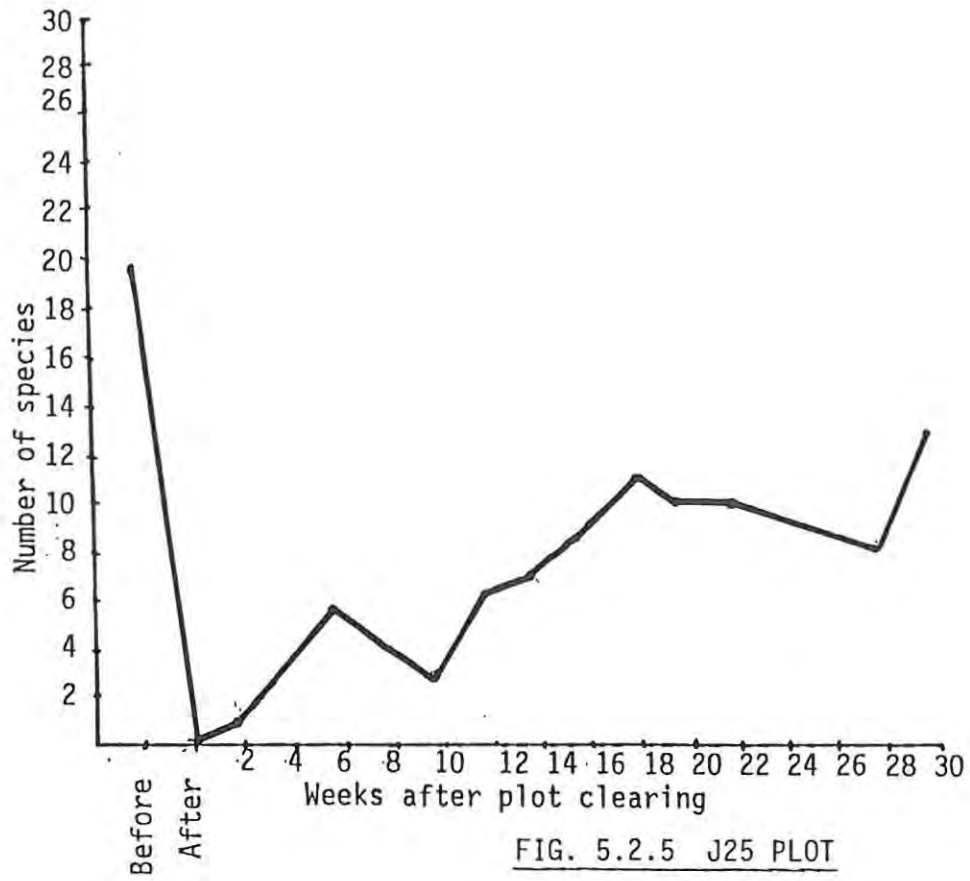
OCCURRENCE OF SPECIES IN PLOTS

<u>SPECIES</u>	<u>% OCCURRENCE</u>
Ulva sp.	66%
Enteromorpha intestinalis	54%
Cladophora cf. capensis	54%
Polysiphonia incompta	48%
Chaetomorpha antennina	48%
Ceramium arenarium	41%
Bryopsis caespitosa	29%
Cyanophyta (blue-green algae)	18%
Lomentaria sp. ff	17%
Herposiphonia sp.	16%
Endarachne binghamiae	14%
Champia parvula	14%
Caulacanthus ustulatus	13.9%
Chroococcus minutus	13%
Entophysalis sp.	12%
Lithothamnium sp.	12%
Arthrocardia sp.	12%
Oscillatoria bonnemaisoni	11%
Amphiroa cf. rigida	10%
Licmophora sp.	10%
Sphaerotilus natans	10%
Colpomenia sinuosa	9%
Nitzschia sp.	7%
Champia compressa	7%
Centroceras clavulatum	5%

The number of occurrences in a total of 93 samples is represented by the % occurrence.







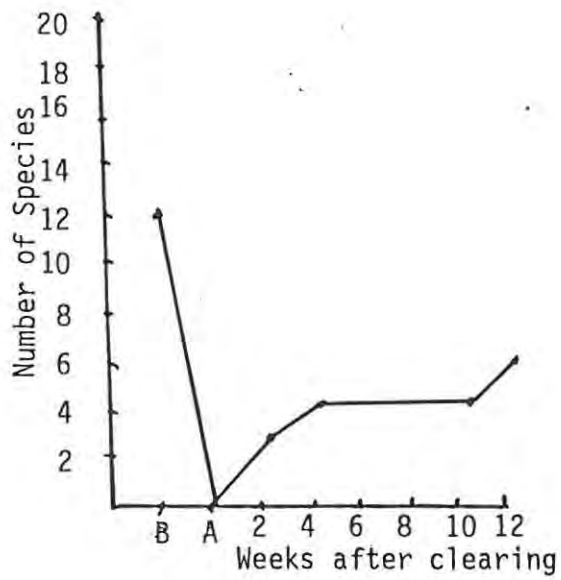


FIG. 5.2.7 J19 Spring Clearing

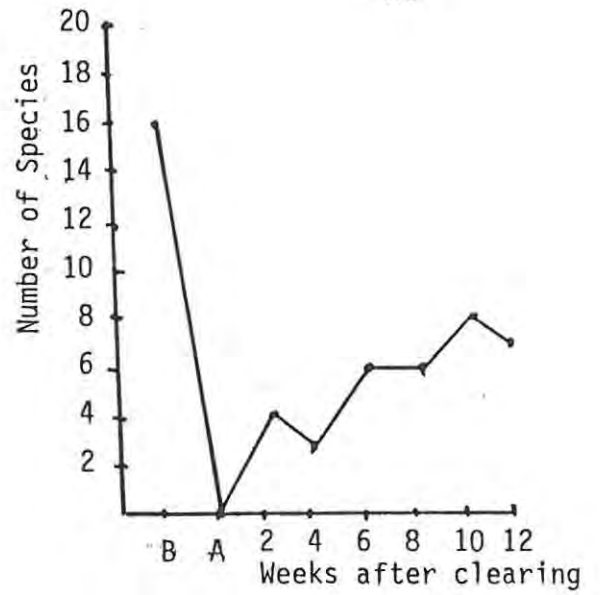


FIG. 5.2.8 J19 2nd clearing

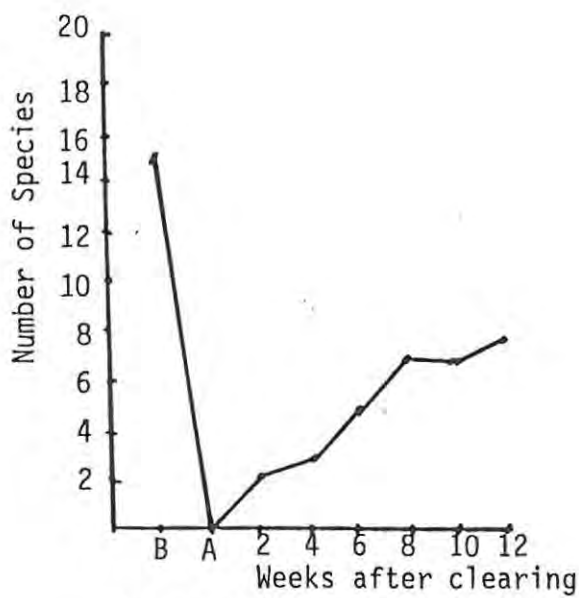


FIG. 5.2.9 J10 2nd clearing

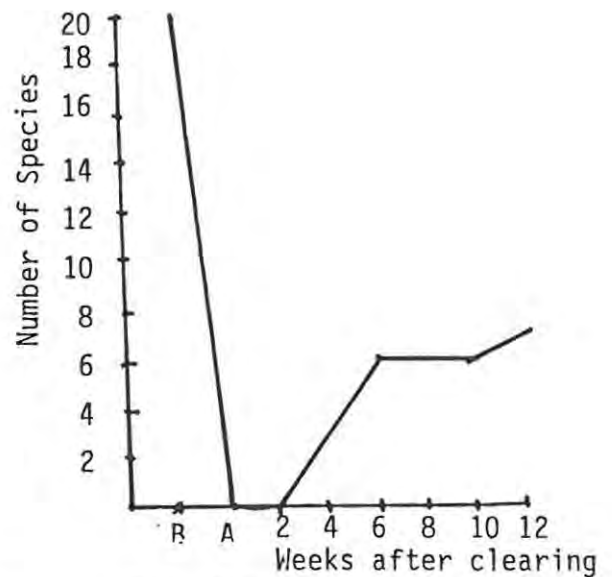
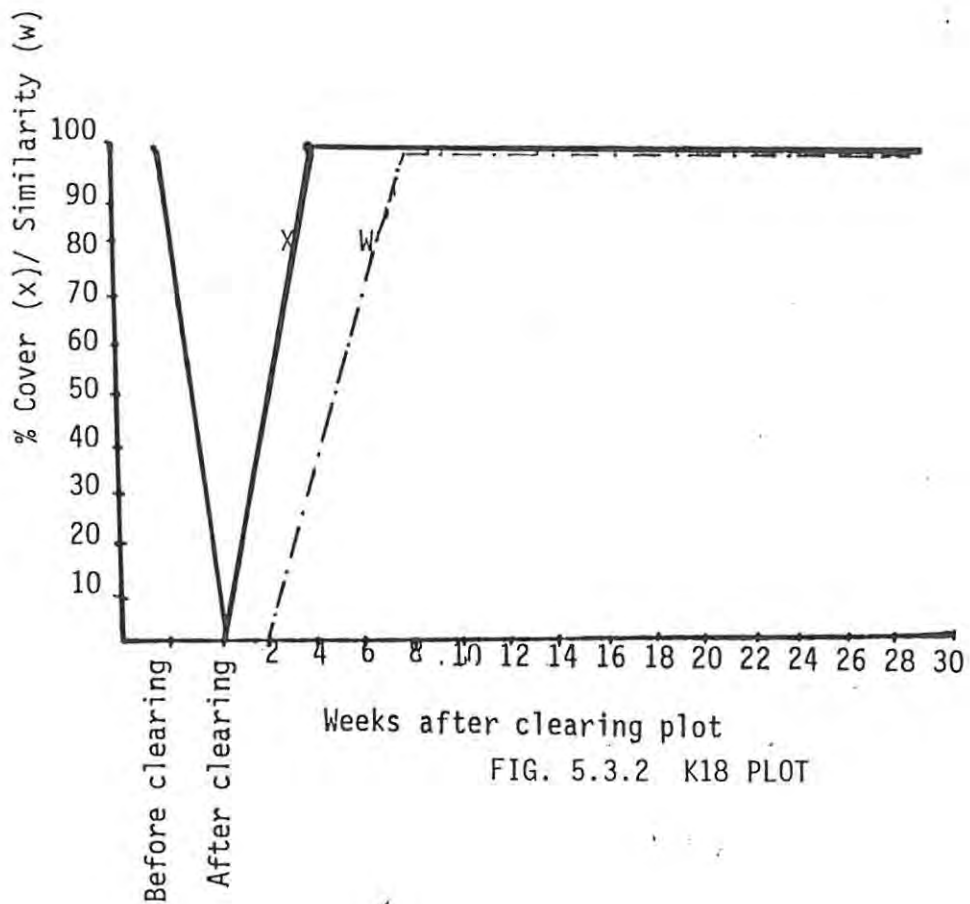
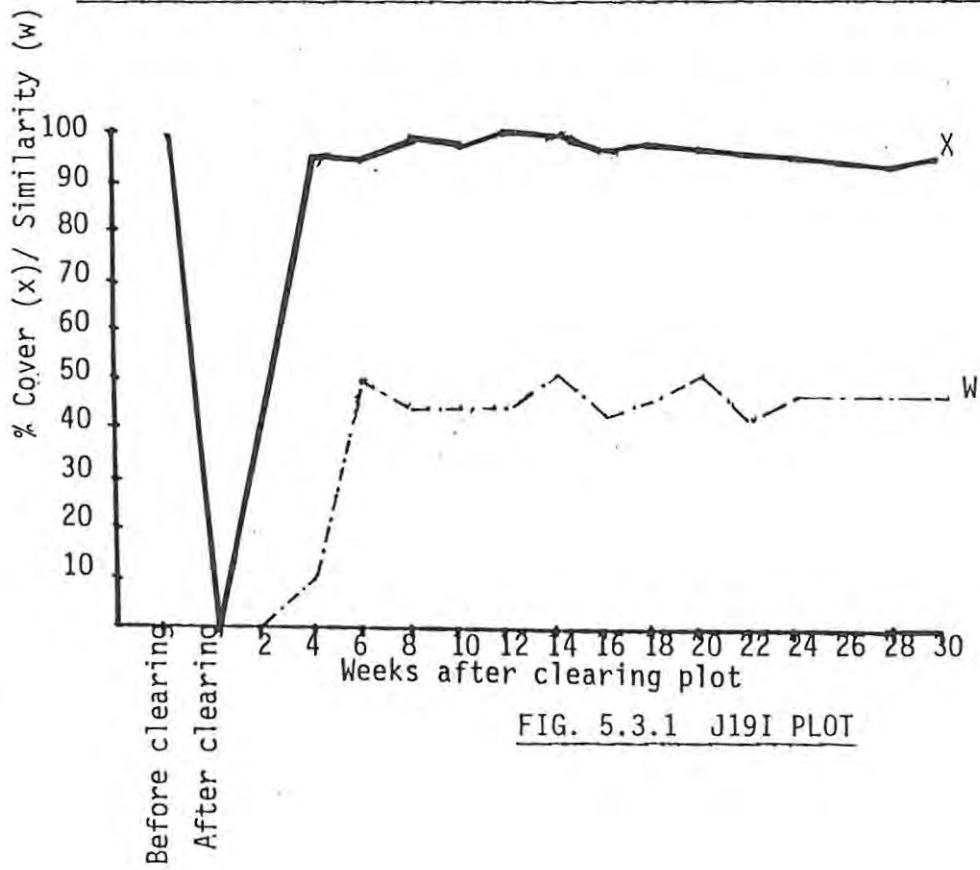


FIG. 5.2.10 Kids Beach

FIG. 5.3 % COVER AND % SIMILARITY FOR PLOTS IN THE SUCCESSION STUDY



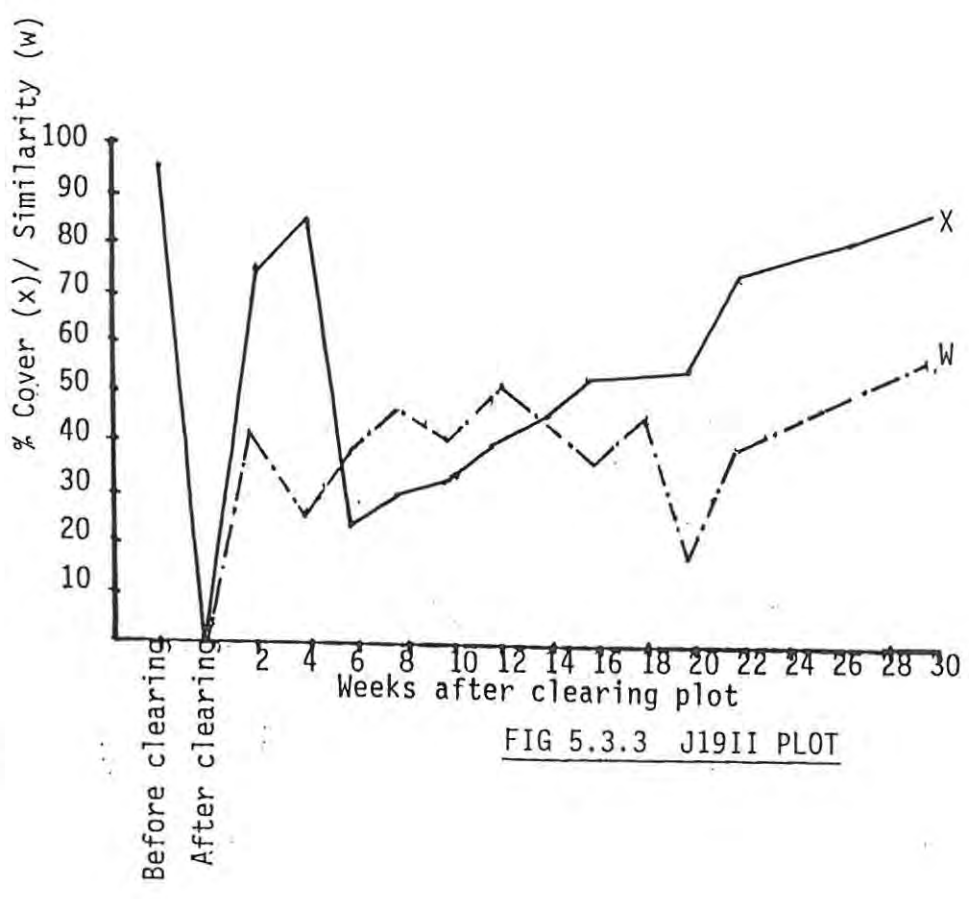


FIG 5.3.3 J19II PLOT

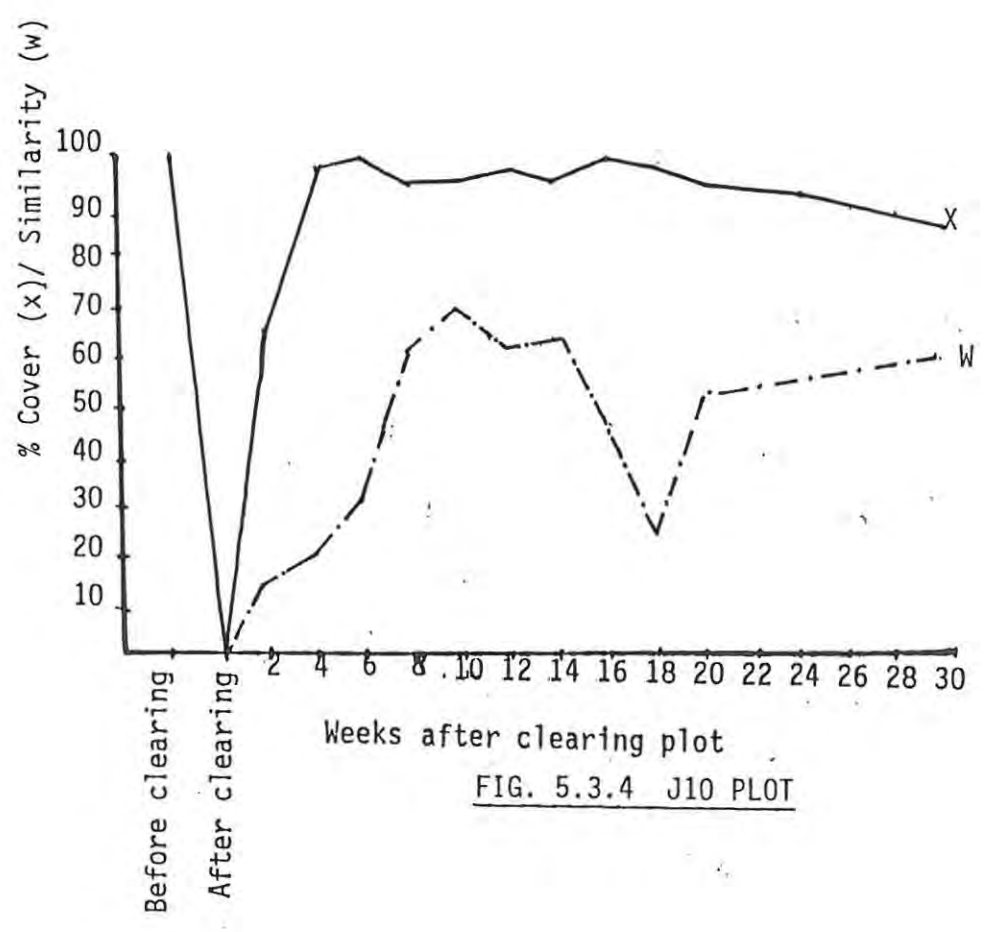


FIG. 5.3.4 J10 PLOT

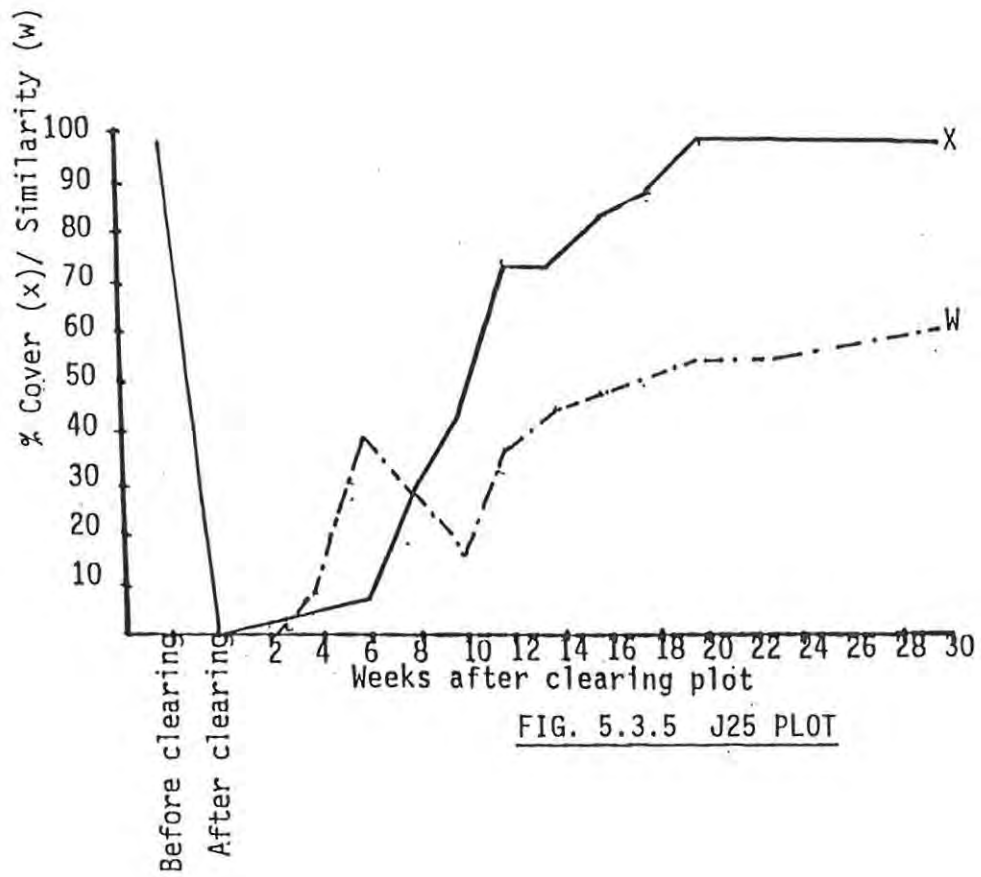


FIG. 5.3.5 J25 PLOT

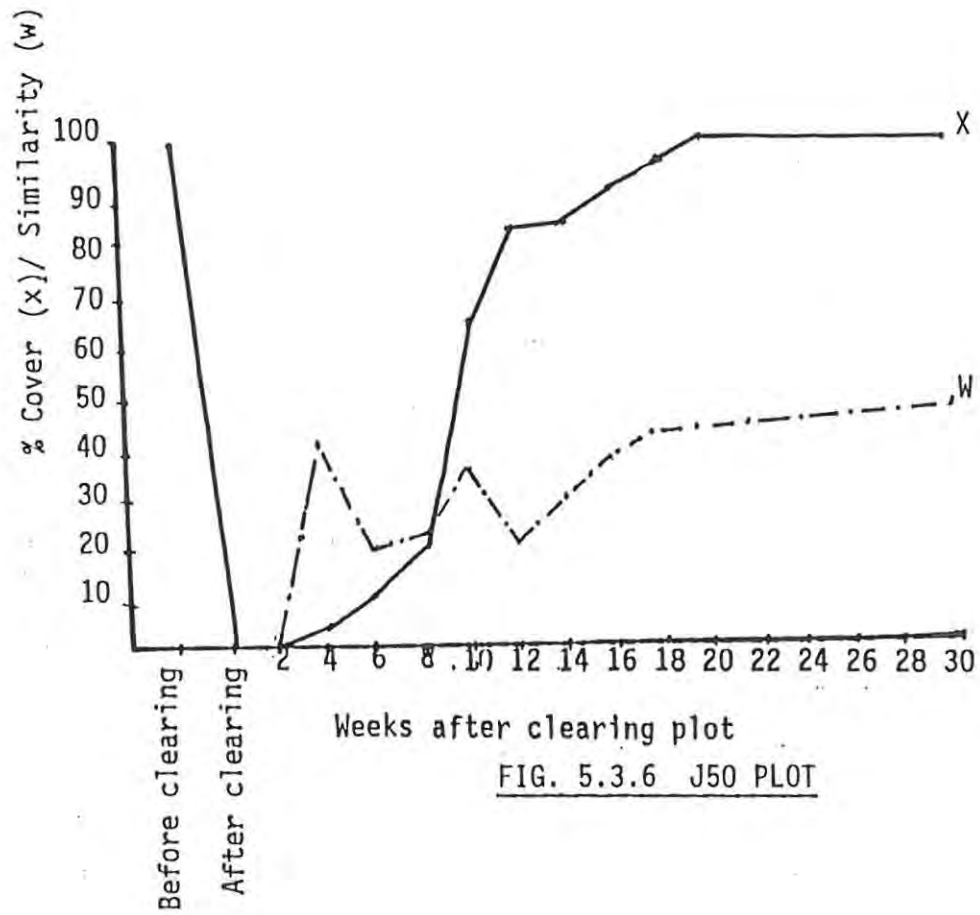


FIG. 5.3.6 J50 PLOT

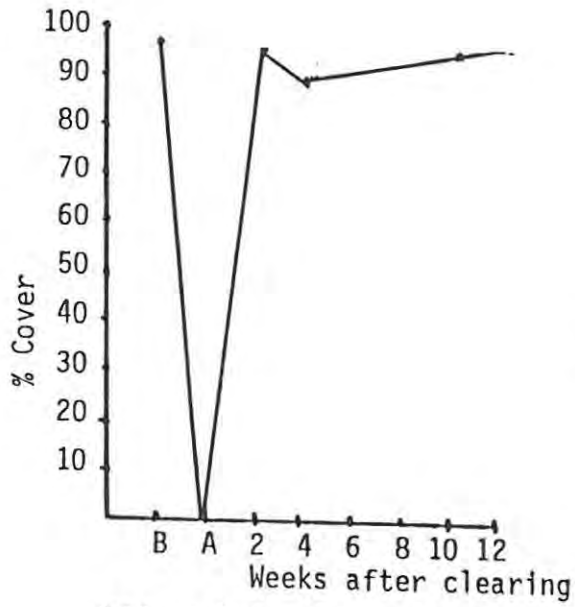


FIG. 5.3.7 J19 Spring Clearing

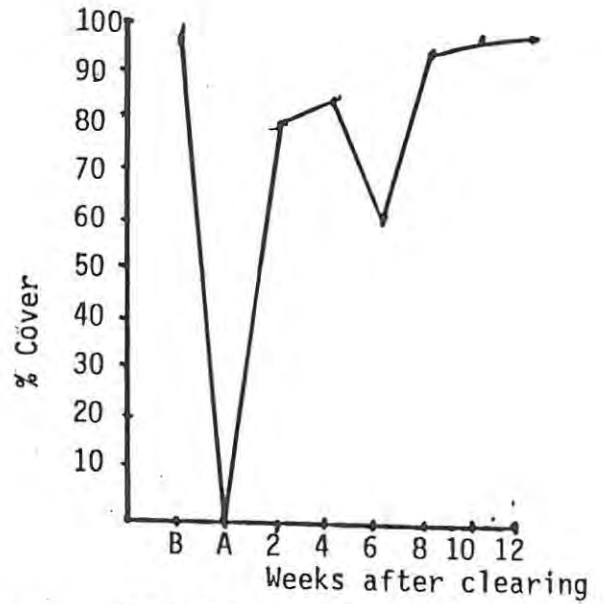


FIG. 5.3.8 J19 second clearing

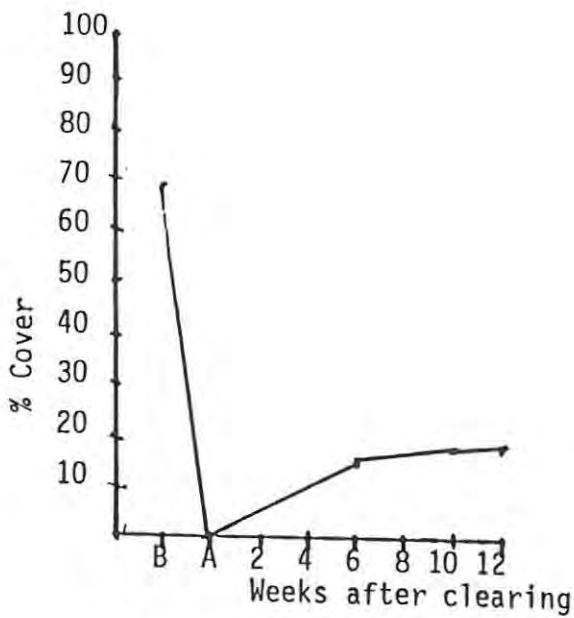


FIG. 5.3.9 Kidds Beach

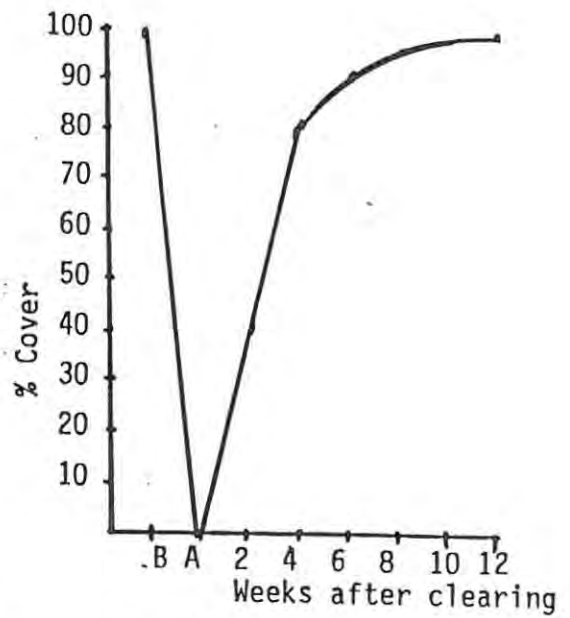


FIG. 5.3.10 J10 second clearing

individual blue-green algae species that were consistently identified from samples and 1 species of bacteria (Sphaerotilus) common in the outfall area. The blue-greens that could not be identified were included under the heading Cyanophyta.

A noticeable pattern of regrowth occurred within the first four weeks. Borowitzka (1971) recorded slight growth of mainly Enteromorpha and some diatoms within the first few weeks near an Australian sewage outfall.

Two weeks after clearing, the plots at locations J191 and J10 were completely covered by a brown slime consisting of the diatoms Nitzschia sp. and Licmophora sp. (See plate 5.1). Two weeks later, the locations were covered in a carpet-like layer of Enteromorpha intestinalis (Plate 5.2). This became less prominent after 6 weeks when other species began to colonize the plots.

Secondary clearings carried out 2 months after the primary clearings revealed the same pattern and a clearing done 4.5 months after the primary clearings recorded the same result.

As in Murray and Littler's study, ~~Murray and Littler~~ (1978), the control areas (J25 and J50) took longer to recover but also continued their recovery to a more complex developmental pattern with increasing species numbers. The outfall locations, while recovering quickly, maintained the opportunistic species acquired in the early recovery stages and were held in this pioneering state throughout the study.

Most plots by the end of the 30 weeks resembled the surrounding areas. The exceptions were the control areas.

J25 was thickly covered in Ulva sp. which was interspersed with other species. This was contrary to the rest of the area in which Ulva sp. was very sparsely dispersed. The J50 plot was noticeable because of its depressed state compared with the thickly matted surrounding surfaces. The surrounding surface was mainly corallines, and they had only just started to reappear on the J50 plot.

The K18 plot located in the outfall cove behind the pipe recovered within 6 weeks. At that point it was not distinguishable from the rest of the surrounding surface. A mat of blue-green algae had quickly colonized this denuded rock surface, and there was little change in coverage or appearance after 8 weeks.

The predominant species occurring overall in the plots was Ulva sp., which occurred in 66% of the plots. Enteromorpha intestinalis and Cladophora cf. capensis occurred in 54% of the plots and Chaetomorpha sp., Polysiphonia cf. incompta and Ceramium arenarium occurred in 48%, 47% and 41% of the plots, respectively (Table 5.2).

Many of the species <sup>however</sup> though, were only found<sup>d</sup> in a few of the plots. Ulva sp., Chaetomorpha sp. and Enteromorpha intestinalis occurred in each plot for at least a few weeks during the study. The blue-green algae and Cladophora cf. capensis were prominent in the outfall areas. Herposiphonia sp. was found in most plots before clearing took place, but it only reappeared in plots more than 100m from the outfall. The encrusting corallines, Lithothamnium sp. and Lithophyllum sp. and the articulated corallines, Arthrocardia sp. and

Cheilosporum proliferum, only appeared on the J25 and J50 plots after 14 to 16 weeks. Colpomenia sinuosa only appeared at J50 whereas Endarachne binghamiae recolonized J19II and J25, both of which were subjected to heavy surf conditions.

Ceramium arenarium was prominent in the outfall area and extended fully to J10 and J25. It only appeared on the J50 plot at 30 weeks.

A common seaweed found throughout the shelf area, Caulacanthus ustulatus, did not occur in the outfall area but appeared in J10 and J25.

The economically valuable Gelidium pristoides occurred in the J10 plot prior to clearing but had not grown in any plot during the 30-week period.

Bryopsis caespitosa was prominent in the J19I and J19II plots from 6 weeks. Blue-green algae were mainly restricted to the K18 plot, but samples were collected from plots J19, J10 and J25.

Polysiphonia cf. incompta colonized all plots quickly except the 1000m control, J50. It only appeared on that plot after 22 weeks. The monitoring of this seaweed provided proof that it was a rapid colonizer. Samples taken from an 8-week old plot were fertile. These plants were probably no more than 4-weeks old.

The length of time a species occurred on a plot (See table 5.2) is an indication of the environment the species would be suited to. Many species could establish themselves in the polluted area during a period when conditions might favour the development of species less tolerant to sewage. This might

only last for a few weeks and then, when conditions change, the particular species would die.

The distribution of the species at the end of the 30 weeks enabled 3 groups of species to emerge.

1. Tolerant of the pollution.
2. Unable to recolonize in the polluted area.
3. Thrives in polluted area and less prominent away from the outfall (See Fig. 5.4).

Species tolerant of the polluted area which took advantage of the lower species diversity (See chapter 4) in the outfall area were Ulva sp., Chaetomorpha sp., Bryopsis caespitosa, Ceramium arenarium and Polysiphonia cf. incompta.

Species which had not appeared in the polluted area within the 30 week study period but which occurred in the control plots were the corallines, Arthrocardia sp., Amphiroa cf. rigida, Lithothamnium sp. and Cheilosporum proliferum and the brown alga, Colpomenia sinuosa.

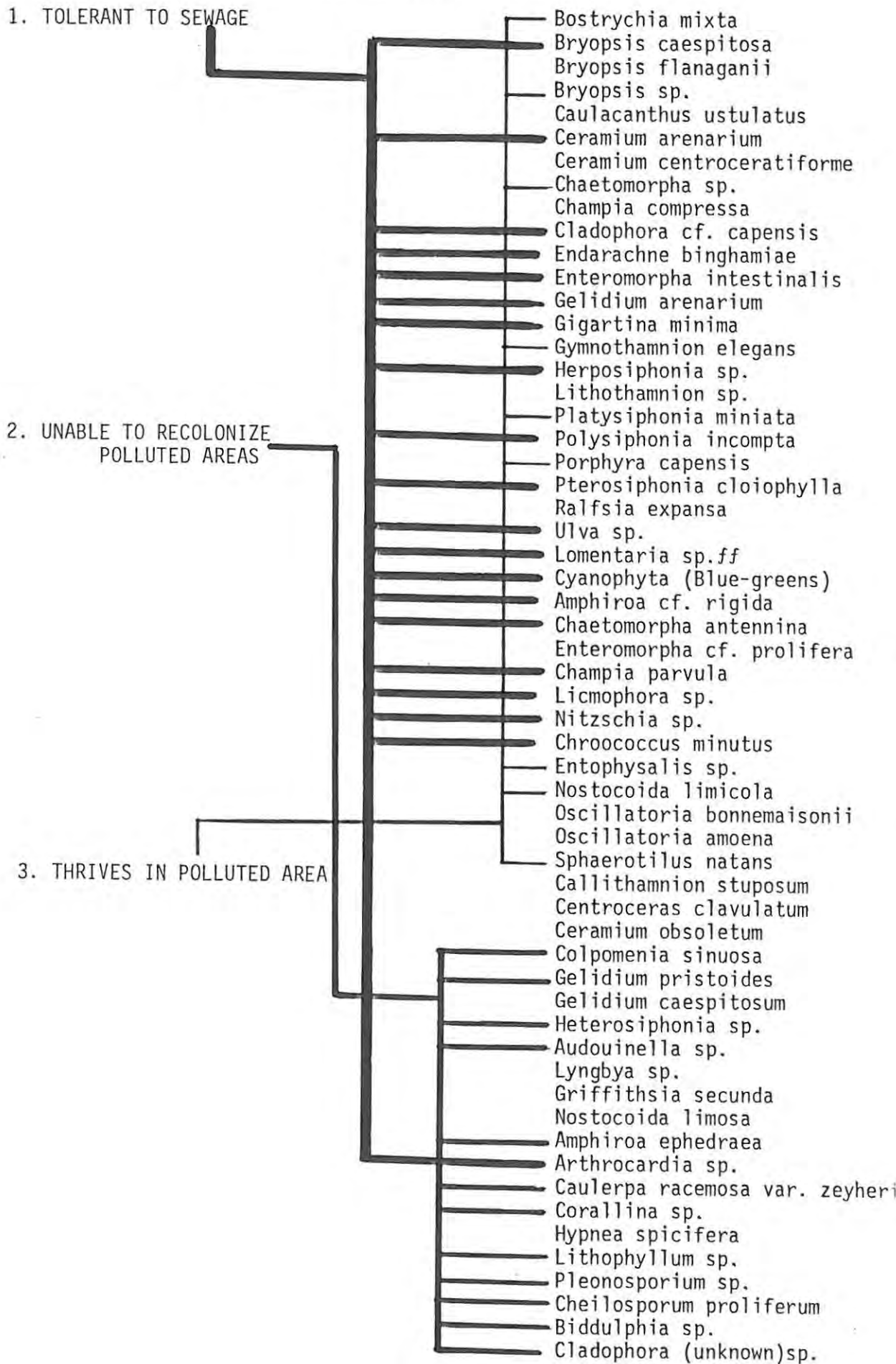
Species which thrive in the polluted areas but were not able to recolonize control plots were the blue-green algae and Gladophora cf. capensis.

Callithamnion stuposum, Audouinella sp. and Gelidium pristoides did not reappear on any of the plots within the 30 week study period (See plates 5.4 to 5.22 for plot successions).

### 5.3.1. Similarity

Similarity between the recovered plots and their original plot before clearing, was determined (See Bray and Curtis,

DISTRIBUTION OF SPECIES



*ff* see Appendix 4

1957) (Fig. 5.3). The average similarity for the control plots was 39% compared with 55% for the polluted plots. The most rapid recovery occurred in K18 with an 86% similarity average over 30 weeks. This reflects a totally polluted environment with only a few species able to survive and therefore fewer species to recolonize the plot. The lowest similarity was recorded at J50 (34%).

The control plots took a longer period to recover but, having a higher species diversity (See Chapter 4), more species appeared.

With fewer species able to withstand the stress environment afforded by the outfall, the species which occurred there would be the tolerant, opportunistic species of this particular outfall.

The competition that the species tolerant to the pollution face in the control areas would seem to keep their numbers constant. Once introduced to the polluted environment, however, the lack of competition allows these species to thrive.

The use by the tolerant species of the excess nutrients present from the sewage for growth is another factor which was investigated by Burrows (1971). This could also play a role in the rapid recolonization due to excess growth. Throughout the study, Ulva sp. collected from the plots consistently varied in size. The Ulva which was predominant in J19 was always much larger in size than the Ulva in J10 and J50. The J10 and J50 Ulva was consistently shorter than the J19 Ulva. Its consistency ruled out grazing by invertebrates. The J19 Ulva, although resembling the other Ulva during the

young stages, was much longer and leafier. Burrows (1971) suggested that species of Ulva near sewage outfalls in Britain made use of nutrients released and this may affect their size. It was also proposed that Ulva could be used as indicators of pollution.

A definite pattern occurred in the successional study carried out along the Bats Cave rocks. A gradient from the outfall plots towards the control plots was apparent. Recovery in the polluted plots occurred rapidly through the presence of opportunistic species which were able to colonize the denuded rock surface with possibly the help of diatoms (See Observations, Chapter 6) which prepared the surface for attachment. Rapid growth of some of these species may have been brought about by increased levels of nutrients from the untreated sewage. Only sewage-tolerant species were able to establish themselves for any length of time. The farther from the outfall the plots were located, however, the longer recolonization took. The longer period allowed for a greater variety of species to be established.



















TABLE 5.3.2

## COMPARISON OF SPECIES OCCURRENCE THROUGHOUT THE STUDY AREA PLOTS

Areas								
K18	J19I	J19II	J19SP	J10	J25	J50	KB	
								<i>Bostrychia mixta</i>
								<i>Bryopsis caespitosa</i>
								<i>Bryopsis flanaganii</i>
								<i>Bryopsis</i> sp.
								<i>Caulacanthus ustulatus</i>
								<i>Ceramium arenarium</i>
								<i>Ceramium centroceratiforme</i>
								<i>Chaetomorpha</i> sp.
								<i>Champia compressa</i>
								<i>Cladophora</i> cf. <i>capensis</i>
								<i>Endarachne binghamiae</i>
								<i>Enteromorpha intestinalis</i>
								<i>Gelidium arenarium</i>
								<i>Gigartina minima</i>
								<i>Gymnothamnion elegans</i>
								<i>Heterosiphonia</i> sp.
								<i>Lithothamnium</i> sp.
								<i>Platysiphonia miniata</i>
								<i>Polysiphonia incompta</i>
								<i>Porphyra capensis</i>
								<i>Pterosiphonia clotophylla</i>
								<i>Ralfsia expansa</i>
								<i>Ulva</i> sp.
								<i>Lomentaria</i> sp. ff
								Cyanophyta (Blue-greens)
								<i>Amphiroa</i> cf. <i>rigida</i>
								<i>Chaetomorpha antennina</i>
								<i>Enteromorpha</i> cf. <i>prolifera</i>
								<i>Champia parvula</i>
								<i>Licmophora</i> sp.
								<i>Nitzschia</i> sp.
								<i>Chroococcus minutus</i>
								<i>Entophysalis</i> sp.
								<i>Nostocoida limicola</i>
								<i>Oscillatoria bonnemaisonii</i>
								<i>Oscillatoria amoena</i>
								<i>Sphaerotilus natans</i>
								<i>Callithamnion stiposum</i>
								<i>Centroceras clavulatum</i>
								<i>Ceramium obsoletum</i>
								<i>Colpomenia sinuosa</i>
								<i>Gelidium pristoides</i>
								<i>Gelidium caespitosum</i>
								<i>Heterosiphonia</i> sp.
								<i>Audouinella</i> sp.
								<i>Lyngbya</i> sp.
								<i>Griffithsia secunda</i>
								<i>Nostocoida limosa</i>
								<i>Amphiroa ephedraea</i>
								<i>Artbrocardia</i> sp.
								<i>Caulerpa racemosa</i> var. <i>zeyheri</i>
								<i>Corallina</i> sp.
								<i>Ilypnea spicifera</i>
								<i>Lithophyllum</i> sp.
								<i>Pleonosporium</i> sp.
								<i>Cheilosporium proliferum</i>
								<i>Biddulphia</i> sp.
								<i>Cladophora</i> (unknown) sp.

ff see Appendix 4

TABLE 5.3.3

COMPARISON OF SPECIES OCCURRENCE IN THE SECTORS WITH  
VARYING DISTANCES FROM THE OUTFALL

Sectors				
Polluted	+100m	+1000m	Kidds Beach	
				<i>Bostrychia mixta</i>
				<i>Bryopsis caespitosa</i>
				<i>Bryopsis flanaganii</i>
				<i>Bryopsis</i> sp.
				<i>Caulacanthus ustulatus</i>
				<i>Ceramium arenarium</i>
				<i>Ceramium centroceratiforme</i>
				<i>Chaetomorpha</i> sp.
				<i>Champia compressa</i>
				<i>Cladophora</i> cf. <i>capensis</i>
				<i>Endarachne binghamiae</i>
				<i>Enteromorpha intestinalis</i>
				<i>Gelidium arenarium</i>
				<i>Gigartina minima</i>
				<i>Gymnothamnion elegans</i>
				<i>Herposiphonia</i> sp.
				<i>Lithothamnium</i> sp.
				<i>Platysiphonia miniata</i>
				<i>Polysiphonia incompta</i>
				<i>Porphyra capensis</i>
				<i>Pterosiphonia cloiophylla</i>
				<i>Ralfsia expansa</i>
				<i>Ulva</i> sp.
				<i>Lomentaria</i> sp. <i>ff</i>
				Cyanophyta (Blue-greens)
				<i>Amphiroa</i> cf. <i>rigida</i>
				<i>Chaetomorpha antennina</i>
				<i>Enteromorpha</i> cf. <i>prolifera</i>
				<i>Champia parvula</i>
				<i>Lichophora</i> sp.
				<i>Nitzschia</i> sp.
				<i>Chroococcus minutus</i>
				<i>Entophysalis</i> sp.
				<i>Nostocoida limicola</i>
				<i>Oscillatoria bonnemaisoni</i>
				<i>Oscillatoria amoena</i>
				<i>Sphaerotilus natans</i>
				<i>Callithamnion stupeosum</i>
				<i>Centroceras clavulatum</i>
				<i>Ceramium obsoletum</i>
				<i>Colpomenia sibouosa</i>
				<i>Gelidium pristoides</i>
				<i>Gelidium caespitosum</i>
				<i>Heterosiphonia</i> sp.
				<i>Audouinella</i> sp.
				<i>Lyngbya</i> sp.
				<i>Griffithsia secunda</i>
				<i>Nostocoida limosa</i>
				<i>Amphiroa ephedraea</i>
				<i>Artbrocardia</i> sp.
				<i>Caulerpa racemosa</i> var. <i>zeyheri</i>
				<i>Corallina</i> sp.
				<i>Hypnea spicifera</i>
				<i>Lithophyllum</i> sp.
				<i>Pleonosporium</i> sp.
				<i>Cheliosporium proliferum</i>
				<i>Biddulphia</i> sp.
				<i>Cladophora</i> (unknown) sp.

*ff* see Appendix 4

## Chapter 6

### OBSERVATIONS

A number of observations were made during the two-year period of study around the sewage outfalls.

#### 6.1 Die-off

Emmerson and Zedler (1978) mentioned a die-off period and this occurred in the Bats Cave Rocks area toward the end of the winter (August). The density of the seaweeds along the rocks thinned out and the plot clearings, which were still rich in cover, stood out on the rocks. (Plate 5.3)

#### 6.2 Seasonality

Very little seasonality was shown in the study area during the study period. Two species found at Kidds Beach (35km control site) did exhibit a tendency to grow during the summer (Caulerpa holmesiana and Porphyra capensis). The first was not found at all in the study area whereas the second occurred in a very minute form near the outfall but was not found anywhere else within the area.

Plots cleared in April and then in August recovered with similar and almost identical patterns. Collections carried out over different dates all had a tendency to contain more or less the same species. The water temperature during the

study period when collections took place was within a 6°C range.

### 6.3 Corallines

An area existed in the J12 to J19 area where the corallines did not grow. While Littler and Murray (1975) and Kindig and Littler (1980) reported tolerance of Corallina officinalis var. chilensis to sewage, this was not the case in the Bats Cave rocks area. An imaginary line extending from about 5m in from the edge of the rocks (the splash zone) (Fig. 6.1), across the area between the two outfalls and about 25 to 30m out on the J19 rocks from the main outfall was almost void of coralline seaweeds. An area about 100m away with almost identical geography, contained most of the coralline species listed in the study area. Only Amphiroa cf. rigida (also found in the J19 outfall area) was found growing in a few small areas. The encrusting corallines were absent.

### 6.4 The Use of Infrared Film

The use of Infrared film in seaweed studies has been encouraged by the work of Littler and Murray (1975, 77, 78). While evaluating the photographs taken of the quadrats, it became apparent that normal color film was not able to distinguish between all of the species found in the quadrats. The encrusting species of corallines are difficult enough to

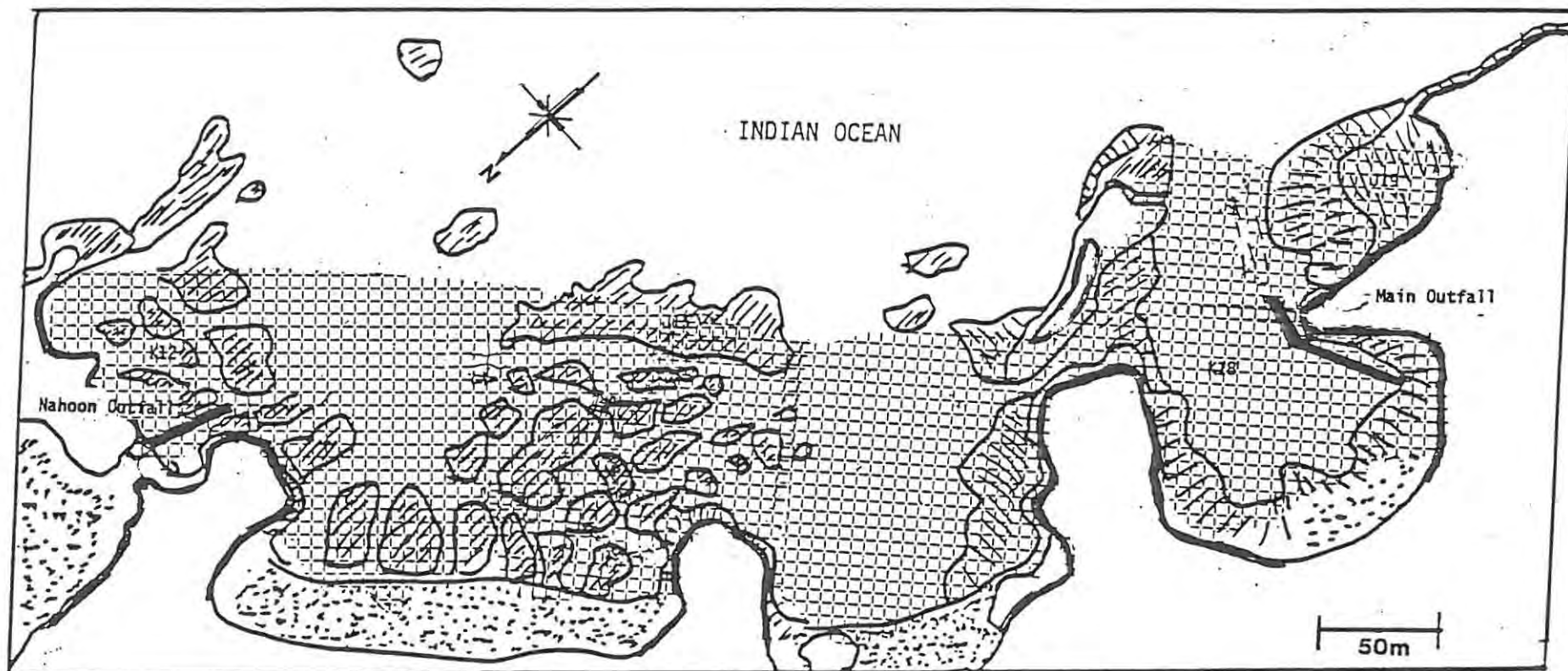
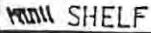

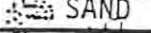

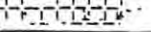


FIG 6.1

POLLUTED SECTOR SHOWING REGIONS WHERE CORALLINE ALGAE GROWTH IS ABSENT

 SHELF	 BOULDERS
 SAND	 CLIFF FACE
 ABSENT	

distinguish ~~between~~ during an intertidal survey, but infrared film reveals two distinct shades representing Lithothamnium sp. and Lithophyllum sp. (See plates 6.1 and 6.2).

### 6.5 Succession

It became clear through microscopic examination of samples from the plots in this particular area that diatoms provided an attachment medium for the other species, which enabled rapid recovery of the plots. This is contrary to Kitching (1937) who found "little evidence of one organism assisting in the establishment of another". Emerson and Zedler (1978), found diatoms to be the earliest colonizers on disturbed rocks but also found little evidence of any species requiring the presence of another for establishment (Plate 5.1).

Where these diatoms did not occur or were reduced in numbers, recovery took a longer period of time. The control plots followed this pattern. Kitching (1937) and Emerson and Zedler (1978) were not studying the effect of sewage on recolonization and it is probably because the rapid colonizing species can utilize the excess diatoms in the outfall area for attachment that these areas show such rapid recovery rates.

The % cover for the plots (See Fig. 5.3) clearly shows that in plots characterized by the diatom presence in the early stages (J19I, J19II, J10. J19SP, J19-2, J10-2) maximum cover occurred within 6 weeks. Where the diatoms did not colonize the rocks (J25 and J50), recovery occurred, but took a longer period of time. Although a longer period of time

was needed in the control plots, as soon as a small amount of cover occurred on the rock, rapid growth followed and full cover was achieved soon after.

One characteristic observed during the clearing of the plots was that they were 1-2cm thick with a mat of older algae and sand. This occurred at all plot locations. The polluted region was able to regain the mat-like surface within 4-8 weeks. This was possible because of the rapid development of the diatoms and the ensuing Enteromorpha coverage which allowed sand to accumulate around their base. Not only did this provide a better surface for attachment of other species, but it also provided a moist, sponge-like surface to reduce desiccation during low tide.

The J50 plot experienced almost the same phenomenon but occurred over a much longer period of time. At 30 weeks the accumulated mat surface on the plot was still not level with the surrounding surface. However, once the mat had finally made its appearance, the recovery of the plot and species numbers found on the plot increased.

## Chapter 7

## DISCUSSION

Watling (1983) concluded that the nature of the coastline and seabed along the East London coast makes the construction of a deepwater outfall impossible. A solution would be to treat the 23 million litres discharged at the low water mark daily. Primary treatment would not suffice if the waste were still to be discharged into the surf, so secondary or tertiary treatment would be necessary to enable the reduced diversity of seaweed species to return to normal.

Referring to pollution, Seagrief (1971) wrote that, "(where) there were many kinds of plants on which many animals could feed, there are now a few kinds of plants whose use as a source of food is restricted to the animals that eat it".

The reduction of the number of species of seaweed of 87% in the outfall areas and 44% up to 50m from the outfalls was found in the collections. Most brown algae was absent in the outfall areas. Ecklonia biruncinata, a common species along the immediate coast, was only found from 250m.

Using the photogrammetric method (Littler and Murray, 1975, 1977), species density, diversity, evenness and similarity were determined from quadrats set out along line transects. Cover was found to be greater in the polluted sectors, but species diversity was reduced. Diversities of 3.76 and 3.75 were recorded for the combined line transects at 100m and 250-1000m, respectively. The diversity for the

combined polluted sector was 3.42 including the line behind the outfall pipe. Eleven species of seaweed were found to be common to all three sectors. Of these, Ulva sp. emerged with the highest average importance value (I.V.) (based on coverage and occurrence) of 77/200. When the line behind the outfall is included in the polluted sector, the blue-green algae I.V. goes to 90/200 surpassing Ulva sp.

Similarity between the polluted sector and the controls remained about 60%. This meant that there was a 40% difference between the species in the control and polluted sectors.

During the successional study, denuded rock surfaces closest to the outfall exhibited rapid recovery, reaching 100% cover within 6 to 8 weeks. The species involved in the rapid recolonization were species with short life histories and these plots did not develop much further than this opportunistic species state (Murray and Littler, 1978). The control plots recovered at a slower rate but more species were able to colonize these plots.

The opportunistic species which were able rapidly to colonize the denuded rock surfaces were common species found in the polluted area during the collections. They also emerged with high importance values during the diversity study. They were characterized by the fact that they occurred throughout the study area, and their dominance of the polluted areas decreased as the distance from the outfall increased.

The major effects the sewage has on the seaweed in the

intertidal zone along the East Bank Sewage Outfall is

- (1) reducing the number of species,
- (2) eliminating certain species of seaweed from the outfall area,
- (3) nourishing opportunistic, short life species and
- (4) reducing species diversity especially within 30m of the outfalls.

## Chapter 7

## SUMMARY

The 23 million litres of raw sewage released daily along the Bats Cave rocks from the East Bank sewage outfall in East London, has been found to reduce the number of species of seaweed found along the intertidal zone up to 100m in either direction of each outfall pipe. This adds up<sup>to</sup> a 450m section of reduced species numbers and reduced species diversity in seaweed.

The primary effect occurs within 30m of the outfall pipes where up to 87% fewer species were found. The secondary effect occurred within 50m where 44% fewer species were found.

Although species numbers returned to 'normal' from 100m there was still an absence of larger brown seaweed until 250m from the outfall.

The high nutrient content present in raw sewage seemed to encourage rapid recolonization of denuded surfaces near the outfall by opportunistic, 'pioneer' species of seaweed which may not necessarily be the food source of the organisms living off this lowest trophic level. These species appeared in other surfaces during the early successional stages but soon gave way to other species. The other species did not appear in the polluted areas and the opportunistic species remained.

The recovery rate of the denuded surfaces was also greater in the polluted area and 100% coverage was attained after

4 to 6 weeks compared with 12 to 18 weeks in the controls. The excess diatom layer found on the denuded surface after two weeks could provide attachment for seaweed species encouraging rapid colonization.

LIST OF SEAWEED SPECIES AND THEIR REFERENCE NUMBERS USED IN THE STUDY

REFERENCE NO.	SPECIES
1	ACROSORIUM MACULATUM (KUETZING) PAPERFUSS
128	AEODES ULVOIDEA SCHMIDZ
2	AMPHIROA BOWERBANKII HARVEY
131	AMPHIROA CF. RIGIDA LAPOUROUX
4	AMPHIROA EPHEDEA (LAMARCK) DECAISIE
119	ANTITHAMNICHELLA VERTICILLATA (SUHR) LYLE
4	ARTHROCARDIA CARIATA (KUETZING) JOHNSON
5	ARTHROCARDIA SP.
136	AUDOUINELLA SP
142	BACHELOTIA ANTILLARUM (GRUNOW) BERLOFF
6	BARTONIELLA CREMATA KYLIN
148	BIDDULPHIA SP
7	BOSTRYCHIA MIXTA HOOKER FIL. ET HARVEY
8	BOTRYCLADIA MADAGASCARIENSIS B. FELDMANN
9	BRYOPSIS CAESPITOSA - SUHR EX KUETZING
10	BRYOPSIS FLAVIGANII BARTON
11	BRYOPSIS SETACEA HERING
12	BRYOPSIS SP
141	CALLITHAMNICON SP.
13	CALLITHAMNICON STUPOSUM SUHR
18	CARPOPHYLLUM SCALARE SUHR
14	CAULACANTHUS USTULATUS (TURNER) KEUTZING
15	CAULERPA FILIFORMIS (SUHR) HERING
16	CAULERPA HOLMESIANA MURRAY
17	CAULERPA RACEMOSA (FORSKAL) J. AGARDH VAR. ZEYHERII.
19	CENTRO CERAS CLAVULATUM (C. AGARDH IN KUNTH) MONTAGNE
22	CERAMIIUM ARETARIUM SIMONS
23	CERAMIIUM CENTRO CERATIFORME SIMONS
21	CERAMIIUM OBSOLETUM C. AGARDH
20	CERAMIIUM OBSOLETUM C. AGARDH ?
132	CHLOROPHYTES ANTEPILINA (BORY) KUETZING
24	CHLOROPHYTES CRASSA (C. AGARDH) KEUTZING
25	CHLOROPHYTES ROBUSTA (ARESCHOUB) PAPERFUSS
26	CHLOROPHYTES SP
27	CHLOROPHYTES COMPRESSA HARVEY
135	CHLOROPHYTES PARVULA (C. AGARDH) HARVEY
28	CHEILOSPORUM CULTRATUM (HARVEY) ARESCHOUB
143	CHEILOSPORUM PROLIFERUM (LAPOUROUX) DE TONI
29	CHONDROCOCCUS HORNEMANNII (LYNDBYE) SCHMITZ
134	CHONDROCOCCUS TRIPINATUS (HERING) DELF ET MICHELL
151	CHONDROCOCCUS MINUTUS
140	CLADOPHORA (UNKNOWN) SP.
31	CLADOPHORA CF. CAPENSIS (C. AGARDH) DE TONI
33	CLADOPHORA RUGULOSA HARTENS
34	CODIUM DUTHIEAE SILVA
144	CODIUM EXTRICATUM SILVA
35	CODIUM LUCASII SETCHELL SUB. SP. CAPENSE SILVA
36	CODIUM PLATYLOBIUM ARESCHOUB
37	CODIUM STEPHENSIAE DICKINSON
38	COLPORENIA SINUOSA (ROTH) DERBES ET SOLIER
39	CORALLINA OFFICINALIS LINNAEUS
40	CORALLINA SP
121	CYANOPHYTES (BLUE-GREEN ALGAE)
124	DASYPHILIA CRYPTOCARPA (HOLMES) SCHMITZ
41	DERBESIA SP
42	DICTYOPTERIS LONGIFOLIA PAPERFUSS
161	DICTYOTA LITURATA J. AGARDH
43	DICTYOTA MAEVOSA (SUHR) J. AGARDH
44	DICTYOTA SP

REFERENCE NO.	SPECIES
45	ECKLOHIA BIRUCINATA (BORY) PAPERFUSS
46	ECTOCARPUS CONFEROIDES (ROTH) LE JOLIS
47	ECTOCARPUS SP
48	EIDAPACHIE BIRUCINATAE J. AGARDH
133	ENTEROMORPHA CF. PROLIFERA (O F HUELLER) J. AGARDH
52	ENTEROMORPHA COMPRESSA (LINNAEUS) GREVILLE
53	ENTEROMORPHA INTESTINALIS (LINNAEUS) LINK
54	ENTEROMORPHA SP.
152	ENTOPHYSALIS SP
49	EPHÉMIA CAPEENSIS (J. AGARDH) PAPERFUSS
50	EPHÉMIA OBTUSA (GREV.) KUTZ
145	ERYTHROTRICHIA WELWITSCHII (RUPRECHT) BATTERS
51	ERYTHREHIA OBOVATA SCHITZ IN MAZZA
55	GALAXAURA DIESSINGIANA ZAKARDINI
56	GELIDIUM ALEXISII (LAMOUREUX)
60	GELIDIUM AREMARIUM KYLIN
61	GELIDIUM CAESPITOSUM KYLIN
160	GELIDIUM MICROPTERUM KUETZING
57	GELIDIUM PRISTOIDES (TURRIER) KUETZING
58	GELIDIUM REPTANS (SUHR) KYLIN
59	GELIDIUM VERSICOLOR (S & GRIELIN) LAMOUREUX
163	GIGARTINA INSIENSIS (EIDLICHER ET DIESSING) SCHITZ IN BARTON
62	GIGARTINA HINIKI KYLIN
63	GIGARTINA PAXILLATA PAPERFUSS
122	GIGARTINA PISTILLATA (S & GRIELIN) STACKHOUSE
127	GRACILARIA BECKERI (J. AGARDH) PAPERFUSS
65	GRACILARIA CAPEENSIS SCHITZ EX MAZZA
66	GRACILARIA DENTICULATA SCHITZ EX MAZZA
67	GRACILARIA VERRUCOSA (HUDSON) PAPERFUSS
68	GRIFFITHSIA CONFEROIDES SUHR
146	GRIFFITHSIA SECUNDA HARVEY EX J. AGARDH
115	GRIFFITHSIA OLIGERATA J. AGARDH
129	GRIFFITHSIA POLYCLADUS (KUETZING) J. AGARDH
69	GRIFFITHSIA ELEGANS (SCHOUSBOE EX C. AGARDH) J. AGARDH
70	HALIMEDA CURVEATA HERING IN KRAUSS
71	HERPOSIPHONIA SP
72	HETEROSIPHONIA SP
73	HILDEBRANDTIA SP
74	HYPNEA ROSEA PAPERFUSS
75	HYPNEA SPECIFERA (SUHR) HARVEY
76	HYMENARIA STELLATA (BOERGESSEN)
150	JANIA CRASSA LAMOUREUX
77	JANIA SP
78	LAURENCIA FLEXUOSA KUETZING
79	LAURENCIA OLIGERATA KUETZING
80	LAURENCIA NATALENSIS KYLIN
81	LAURENCIA SP
82	LEATHESIA DIFFORMIS (LINNAEUS) ARESCHOU
137	LICHOPHORA SP
83	LITHOPHYLLUM SP
84	LITHOTHAMNION SP
139	LYNGBYA SP
126	MICROCLADIA GELIDII SINENSIS
153	MICROCOELUS SP
138	MITZSCHIA SP
154	NOSTOCOIDA LITHICOLA
155	NOSTOCOIDA LIHOSA
157	OSCILLATORIA MIOBIA
156	OSCILLATORIA BOERHAVISCHII

125	PACHYCHAETA BRACHYARTHRA (KUETZING) TREVISAN
86	PEYSSONNELIA CAPENSIS MONTAGIE
123	PHACELOCARPUS OLIGACANTHUS KUETZING
118	PHACELOCARPUS TORTUOSUS ENDLICHER ET DIESSING
130	PHLOIOCAULON SQUAMULOSUM (SUHR) BEYLER
87	PLACOPHORA BINDERI (J AGARDH)
88	PLATYSIPHONIA MINIATA (C AGARDH) BOERBESEN
89	PLEONIOSPORIUM HARVEYANUM (J AGARDH) DE TONI
120	PLEONIOSPORIUM SP
162	PLOCANIUM BECKERI SIMONS
90	PLOCANIUM CORALLORHIZA (TURNER) HARVEY
91	PLOCANIUM CORIUTUM (TURNER) HARVEY
114	PLOCANIUM SP.
92	PLOCANIUM SUHRII KUETZING
93	POLYDIPES CONSTRICTUS (TURNER) J AGARDH
85	POLYPOROLITHON PATEWA (HOOKER F ET HARVEY) L R MASON
94	POLYSIPHONIA INCOMPTA HARVEY
96	POLYSIPHONIA SP
95	POLYSIPHONIA URBANA HARVEY
97	POLYZONIA ELEGANS SUHR
98	PORPHYRA CAPENSIS KUETZING
117	PRIONITIS MODIFERA (HERING) BARTON
99	PTEROSIPHONIA CLOTOPHYLLA (C AGARDH) FALKENBERG
100	RALESIA EXPANSA (J AGARDH) J AGARDH
102	RHIZOCLONIUM SP
103	RHODOCHORTON SP
116	RHODOMELOPSIS AFRICANA POCCOCK
104	RHODYMENIA NATALENSIS KYLIN
149	RHODYMENIA SP
105	SARGASSUM HETEROPHYLLUM (TURNER) C AGARDH
106	SARGASSUM LONGIFOLIUM (TURNER) C AGARDH
158	SPHAEROTILUS NATANS
107	SPLACHNIDIUM RUGOSUM (LINNAEUS) GREVILLE
108	SPYRIDIA CUPRESSINA (HARVEY) KUETZING
165	TAYLORIELLA SP.
147	ULVA INSIGIIS (ARESCHOUD) PAPENFUSS
109	ULVA RIBIDA C AGARDH
110	ULVA SP
113	ZOARIA SP
111	ZOARIA SUBARTICULATA (LAHOUROUX) PAPENFUSS
112	ZOARIA TOURNEFORTII (LAHOUROUX) MONTAGIE

## Appendix 2

### The Development of the Computer Programme used for Data Manipulation in this study

The data collected was entered into an Apple II computer and saved on disk by a programme designed for this purpose.

Faced with the long names of the seaweeds and the possibility of error when entering the names each time, a programme was designed that provided a one-time entry of the seaweed name and author which could be changed if needed. Upon entry, the seaweed was given a number by which it was then referred to for the rest of the study. The number also referenced the data file locations which allowed quicker handling, and also took up less space in the memory of the computer.

Each collection was labelled with an area according to a grid map and the date of collection. This information, along with the water temperature for the day and the seaweeds collected, was entered into the programme and stored in two files (Titles and Poa) on a disk. The Titles file held the area, date, water temperature, and the starting and ending file numbers for the Poa file containing the relevant seaweed numbers. The name of the seaweed was only used when a print-out was required. In the case of an entry being incorrect because of mistaken identity or entry, a repair programme for each file was used.

With all of the data in the files, methods of organizing the information quickly and efficiently were developed.

Two sets of files using a common names file were used. Data for plot clearings were kept in one set and the East London collections were kept on another.

In order to retrieve and use the data, a separate programme loaded all data files into memory where it was then possible to organize the information very quickly. The following information could be retrieved using the menu (See Fig. A.2);

1. seaweed (x) found in areas ie. 1, 3, 6, 8 etc.
2. area (x) has seaweeds ie. 13, 15, 17, 44 etc.
3. all seaweeds found in study area.
4. list of each area and total species found (names or total ie. 6 species).

The mathematics involved in determining the importance values, diversity, evenness and similarity were done with special programmes which calculated the different relationships and then sent final values to the printer for hard-copy output.

All programmes were designed such that they could be used independently of each other or combined into one large menu controlled programme providing all functions when required.

TABLE A.2

MENU OF COMPUTER PROGRAMMES USED FOR DATA MANIPULATION

## MENU FOR SEAWEED FILE PROGRAMME

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SELECT REQUIRED PROGRAMME

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1. RETRIEVE SEAWEED NAMES
2. ADD/CHANGE SEAWEED NAMES
3. INPUT AREA DATA
4. RETRIEVE AREA DATA
5. RETRIEVE AREA/DATE/TOTAL SPECIES
6. COMPARE AREA DATA
7. END PROGRAMME

\*\*\*\*\*

ENTER A NUMBER AND PRESS RETURN

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## APPENDIX 3

## HERBARIUM SHEETS MADE DURING THE STUDY FROM 1982 to 1984

Species	No.	Location	Date Collected
BARTONIELLA CRENATA	9	KB	31/3/83
CHONDROCOCCUS HORNEMANNII	15	BC	30/3/84
RHODYMENIA SP	11	BC	30/3/83
DICTYOTA NAEVOSA	14	KB	31/3/83
BARTONIELLA CRENATA	15	KB	31/3/83
CARPOPHYLLUM SCALARE	16	OBD	23/4/83
POLYOPES CONSTRICTUS	17	BC	23/4/83
CENTROCERAS CLAVULATUM	19	BC	23/4/83
GALAXAURA DIESTINGIANA	20	KB	2/1/83
ENDARACHNE BINGHAMIAE	21	BC	28/5/83
ULVA SP	22	BC	28/5/83
LAURENCIA FLEXUOSA	23	OBD	30/5/83
LAURENCIA FLEXUOSA	24	OBD	30/5/83
HYPNEA ROSEA PAFENFUSS	25	KB	30/5/83
PTEROSIPHONIA CLOIOPHYLLA	26	KB	31/3/83
ARTHROCARDIA SP.	27	KB	3/3/83
CHAETOMORPHA CRASSA	28	KB	31/3/83
BARTONIELLA CRENATA	29	KB	31/3/83
PLOSMIUM CORALLORHIZA	30	OBD	30/5/83
ENTEROMORPHA INTESTINALIS	32	J17	1/7/83
LAURENCIA NATALENSIS	33	J17	1/7/83
RHODOMELOPSIS AFRICANA	36	J11	1/7/83
CAULERPA FILIFORMIS	37	J17	1/7/83
CAULERPA FILIFORMIS	39	J17	1/7/83
CERAMIUM OBSOLETUM	40	OBD	11/9/83
CALLITHAMNION STUPOSUM	41	KB	11/9/83
ZONARIA SP	42	KB	11/9/83
SPYRIDIA CUPRESSINA	44	OBD	11/9/83
BARTONIELLA CRENATA	45	OBD	11/9/83
GELIDIUM VERSICOLOR	47	OBD	11/9/83
CHONDROCOCCUS TRIPINNATUS	48	OBD	11/9/83
CLADOPHORA RUGULOSA	49	OBD	11/9/83
DICTYOTA NAEVOSA	50	KB	9/10/83
CHAMPIA COMPRESSA	51	KB	9/10/83
ECKLONIA BIRUNCINATA	52	KB	9/10/83
AEGDES ULVOIDEA	55	KB	10/10/83
GIGARTINA PISTILLATA	56	I23	29/9/83
GRACILARIA DENTICULATA	57	OBD	29/10/83
HYPNEA ROSEA	58	OBD	29/10/83
POLYZONIA ELEGANS	61	OBD	6/11/83
PHACELOCARPUS OLIGACANTHUS	62	OBD	5/11/83
PHACELOCARPUS OLIGACANTHUS	63	OBD	5/11/83
PHACELOCARPUS OLIGACANTHUS	64	OBD	5/11/83
GELIDIUM VERSICOLOR	65	K80 ASSORTED	3/1/84
CALLITHAMNION STUPOSUM	75	K25	27/9/84
GYMNOTHAMNION ELEGANS	75	K25	27/9/84
AMPHIROA CF. RIGIDA	76	K25	27/9/84
PLATYSIPHONIA MINIATA	77	J1911	8/9/84
POLYSIPHONIA INCOMPTA	78	J1911	8/9/84
GELIDIUM ARENARIUM	91	J23	13/10/84
LAURENCIA GLOMERATA	92	J25	13/10/84
POLYSIPHONIA INCOMPTA	93	J19SP	13/10/84
POLYSIPHONIA INCOMPTA	94	J19CL	13/10/84
DICTYOPTERIS LONGIFOLIA	95	J50	24/10/84
DICTYOPTERIS LONGIFOLIA	96	J50	24/10/84

Species	No.	Location	Date Collected
ZONARIA SUBARTICULATA	97	J58	24/10/84
ZONARIA SUBARTICULATA	98	J58	24/10/84
RHODYMENIA SP	99	J15	24/10/84
RHODYMENIA SP	100	J15	24/10/84
CORALLINA SP	101	J15	24/10/84
GRIFFITHSIA SECUNDA	102	J25CL	1/4/84
GRACILARIA VERRUCOSA	103	BC	28/5/83
GIGARTINA PAXILLATA	104	BC SLUTE	28/10/84
GIGARTINA PISTILLATA	105	BC SLUTE	28/10/84
GRACILARIA DENTICULATA	106	J7	10/11/84
ZONARIA TOURNEFORTII	107	K30	28/5/83
ULVA INSIGNIS	108	H22	30/3/83
PEYSSONNELIA CAPENSIS	109	J30-39	15/4/84
GIGARTINA PAXILLATA	110	BC SLUTE	15/4/84
ARTHROCARDIA SP.	111	BC	15/4/84
GIGARTINA PAXILLATA	112	J35-40	4/12/82
GELIDIUM AMANSII	113	BC	4/12/82
CERAMIUM OBSOLETUM	114	BC	4/12/82
SARGASSUM LONGIFOLIUM	115	KB	10/11/84

## APPENDIX 4

## NOTES ON CERTAIN SPECIES IDENTIFICATIONS FROM THE STUDY AREA

On a few occasions the identification of a particular species was not able to be confirmed and there are a few species which were identified by sources which may have combined or broken up similar species.

Although listed <sup>separately</sup> in the checklist, there exists a possibility that the species listed under *Epymania* (*E. capensis* and *E. obtusa*) may belong to the Genus *Rhodymenia*.

A species which occurred in a number of plot clearings has not yet been identified. Although earlier listed as *Gymnogongrus glomeratus*, this species may possibly belong to the genus *Lomentaria* (Wynne, personal communication, 1984).

## APPENDIX 5

PERMANENT MICROSCOPE SLIDES MADE DURING THE STUDY FROM 1982-1984

Species	No.	Location	Date Collected
<i>Gymnothermion elegans</i>	1	BC	21/4/83
<i>Pleonosporium harveyanum</i>	2	BC	21/4/83
<i>Halimeda cuneata</i>	3	BC	21/4/83
<i>Pleonosporium harveyanum</i>	4	BC	21/4/83
<i>Griffithsia confervoides</i>	5	BC	21/4/83
<i>Plocamium suhrrii</i>	6	BC	21/4/83
<i>Gelidium caespitosum</i>	7	BC	21/4/83
<i>Pleonosporium harveyanum</i>	8	BC	21/4/83
<i>Platysiphonia miniata</i>	9	BC	21/4/83
<i>Platysiphonia miniata</i>	10	BC	21/4/83
<i>Polysiphonia incompta</i>	11	KB 35-49	29/11/82
<i>Chaetomorpha</i> sp.	12	KB35-40	29/11/82
<i>Ceramium obsoletum</i>	13	KB	29/11/82
<i>Acrosorium maculatum</i>	14	KB	29/11/82
<i>Hypnea rosea</i>	15	KB-13	29/11/82
<i>Pterosiphonia cloiophylla</i>	16	KB	29/11/82
<i>Caulacanthus ustulatus</i>	17	KB	29/11/82
<i>Champia compressa</i>	18	KB	29/11/82
<i>Partoniella crenata</i>	19	KB	29/11/82
<i>Plocamium suhrrii</i>	21	KB	29/11/82
<i>Heterosiphonia</i> sp.	22	KB	2/1/83
<i>Enteromorpha intestinalis</i>	23	BC	1/7/83
<i>Chaetomorpha</i> sp.	24	BC	1/7/83
<i>Laurencia natalensis</i>	25	BC	1/7/83
<i>Audouinella</i> sp.	26	BC	1/7/83
<i>Bostrychia mixta</i>	27	J11	1/7/83
<i>Audouinella</i> sp.	27	J11	1/7/83
<i>Gelidium caespitosum</i>	28	J11	1/7/83
<i>Rhodomeopsis africana</i>	29	J11	1/7/83
<i>Gelidium pristoides</i>	30	BC	1/7/83
<i>Rhodomeopsis africana</i>	61	J11	1/7/83
<i>Audouinella</i> sp.	60	J11	1/7/83
<i>Cladophora</i> cf. <i>capensis</i>	31	J11	1/7/83
<i>Bryopsis setacea</i>	33	J17	1/7/83
<i>Gigartina</i> sp.	35	J17	1/7/83
<i>Caulerpa filiformis</i>	36	J17	1/7/83
<i>Sphaerotilus natans</i>	36	J17	1/7/83
<i>Erythrotrichia welwitschii</i>	36	J17	1/7/83
<i>Caulacanthus ustulatus</i>	37	J17	1/7/83
<i>Polysiphonia incompta</i>	38	J17	1/7/83
<i>Polysiphonia incompta</i>	39	J17	1/7/83
<i>Polysiphonia incompta</i>	40	J17	1/7/83
<i>Ceramium arenarium</i>	40	J17	1/7/83
<i>Gelidium caespitosum</i>	41	J17	1/7/83
<i>Centroceras clavulatum</i>	42	J17	1/7/83
<i>Laurencia natalensis</i>	43	J17	1/7/83
<i>Cladophora</i> cf. <i>capensis</i>	47	J17	1/7/83
<i>Cladophora</i> cf. <i>capensis</i>	48	J17	1/7/83
<i>Cladophora</i> cf. <i>capensis</i>	48	J17	1/7/83
<i>Cladophora</i> cf. <i>capensis</i>	52	J17	1/7/83
<i>Gelidium caespitosum</i>	53	J17	1/7/83
<i>Gymnogongrus glomeratus</i>	55	J17	1/7/83
<i>Callithamnion stuposum</i>	56	KB	2/1/83
<i>Gelidium pristoides</i>	63	J11	1/7/83
<i>Heterosiphonia</i> sp.	64	J11	1/7/83
<i>Gelidium caespitosum</i>	65	J11	1/7/83
<i>Gelidium caespitosum</i>	66	J40	28/5/83

Species	No.	Location	Date Collected
BOSTRYCHIA MIXTA	67	J40	28/5/83
GYMNOTHAMNION ELEGANS	67	J40	28/5/83
ANTITHAMNIONELLA VERTICILLATA	68	J40	28/5/83
PLEONOSPORIUM SP	70	J40	28/5/83
BOSTRYCHIA MIXTA	72	J40	28/5/83
HETEROSIPHONIA SP	73	BC	23/4/83
ACROSORIUM MACULATUM	74	AQUR. ROCKS	12/8/83
POLYZONIA ELEGANS	75	AQUR ROCKS	12/8/83
CENTROCERAS CLAVULATUM	76	BC	28/5/83
CALLITHAMNION STUPOSUM	77	K40	16/8/83
PLATYSIPHONIA MINIATA	78	J19	27/8/83
PORPHYRA CAPENSIS	80	J19	27/8/83
NITZSCHIA SP	81	K25	27/8/83
CAULACANTHUS USTULATUS	82	K25	27/8/83
BOSTRYCHIA MIXTA	84	L23/24	27/8/83
CENTROCERAS CLAVULATUM	85	L23/24	27/8/83
ENTEROMORPHA INTESTINALIS	86	J25	27/8/83
CERAMIUM CENTRO CERATIFORME	87	J25	27/8/83
CAULACANTHUS USTULATUS	88	J25	27/8/83
CHONDROCOCCUS TRIPINNATUS	88	J25	27/8/83
FLOCCAMUM SUHRII	89	OB DRIFT	11/9/83
PHAELOCARPUS OLIGACANTHUS	90	OB DRIFT	11/9/83
BRYOPSIS CAESPITOSA	91	K40	28/9/83
CERAMIUM ARENARIUM	92	IJK28/23	23/4/83
AUDOUINELLA SP	93	IJK28/23	23/4/83
PLATYSIPHONIA MINIATA	84	IJK 28/23	23/4/83
ENDARACHNE BINGHAMIAE	95	BC	5/11/83
CAULERPA HOLMESTIANA	96	OB DRIFT	6/11/83
PACHYCHAETA BRACHYARTHRA	97	OB DRIFT	6/11/83
GYMNOGONGRUS POLYCLADUS	98	OB DRIFT	6/11/83
ULVA SP	99	J50+8	2/6/84
ARTHROCARDIA SP.	100	J50+14	14/7/84
CLADOPHORA CF. CAPENSIS	100	J50+14	14/7/84
CERAMIUM ARENARIUM	105	J19	1/4/84
CYANOPHYTA (BLUE-GREEN ALGAE)	106	K18+2	14/4/84
CYANOPHYTA (BLUE-GREEN ALGAE)	106	K18	14/4/84
NITZSCHIA SP	107	J19	19/5/84
CLADOPHORA CF. CAPENSIS	108	J19	1/4/84
CERAMIUM ARENARIUM	108	J10	1/4/84
ENTEROMORPHA INTESTINALIS	109	J10	1/4/84
POLYSIPHONIA INCOMPTA	110	J10	1/4/84
POLYSIPHONIA INCOMPTA	111	J10	1/4/84
HERPOSIPHONIA SP	112	J10	1/4/84
GYMNOTHAMNION ELEGANS	113	K18	28/4/84
LICHOPHORA SP	114	J19	19/5/84
CERAMIUM ARENARIUM	114	J19	19/5/84
ENTEROMORPHA INTESTINALIS	114	J19	19/5/84
CLADOPHORA CF. CAPENSIS	114	J19	19/5/84
BRYOPSIS CAESPITOSA	114	J19	19/5/84
CLADOPHORA CF. CAPENSIS	115	J50	28/4/84
ULVA SP	115	J50	28/4/84
GELIDIUM VERSICOLOR	115	J50	28/4/84
POLYSIPHONIA INCOMPTA	116	J25	28/4/84
NITZSCHIA SP	116	J25	28/4/84
ENTEROMORPHA INTESTINALIS	117	J10	28/4/84
NITZSCHIA SP	117	J10	28/4/84

Species	No.	Location	Date Collected
POLYSIPHONIA INCOMPTA	118	J50	2/4/84
CHAMPJA PARVULA	119	J19	14/4/84
ENTEROMORPHA INTESTINALIS	120	J18	28/4/84
GELIDIUM REPTANS	121	J18	28/4/84
ENTEROMORPHA INTESTINALIS	122	J19	14/4/84
LICHOPHORA SP	122	J19	14/4/84
CLADOPHORA CF. CAPENSIS	123	J19	14/4/84
LICHOPHORA SP	123	J19	14/4/84
ENTEROMORPHA INTESTINALIS	124	J19	28/4/84
GYMNOGONGRUS GLOMERATUS	124	J19	28/4/84
ENTOPHYSALIS SP	125	K18	28/4/84
GYMNOGONGRUS GLOMERATUS	126	J19	14/4/84
ENTEROMORPHA INTESTINALIS	126	J19	14/4/84
CHROOCOCCUS MINUTUS	126	J19	14/4/84
SPHAEROTILUS NATANS	126	J19	14/4/84
CLADOPHORA CF. CAPENSIS	127	J19	14/4/84
CAULACANTHUS USTULATUS	128	J18	1/4/84
GYMNOGONGRUS GLOMERATUS	129	J50	2/4/84
LICHOPHORA SP	130	J18	15/4/84
LICHOPHORA SP	131	J18	14/4/84
CLADOPHORA CF. CAPENSIS	131	J18	14/4/84
CERAMIUM ARENARIUM	132	J19	28/7/84
PLATYSIPHONIA MINIATA	133	J19	28/7/84
CERAMIUM ARENARIUM	134	J19	19/5/84
CERAMIUM CENTRO CERATIFORME	134	J19	19/5/84
POLYSIPHONIA INCOMPTA	135	J19	2/6/84
POLYSIPHONIA INCOMPTA	136	J19	28/7/84
HERPOSIPHONIA SP	139	J25	28/7/84
ENDOPACHIE BINGHAMIAE	140	J25	28/7/84
CYANOPHYTA (BLUE-GREEN ALGAE)	141	K18	28/7/84
CHAMPJA PARVULA	142	J25	28/7/84
HYDREA SPICIFERA	143	J25	28/7/84
HETEROSIPHONIA SP	144	J50	28/7/84
CLADOPHORA CF. CAPENSIS	145	J50	11/8/84
CAULACANTHUS USTULATUS	146	J25	28/7/84
CLADOPHORA (UNKNOWN) SP.	147	J50	11/8/84
PTEROSIPHONIA CLOIOPHYLLA	149	J25	11/8/84
BRYOPSIS CAESPITOSA	150	J19	11/8/84
BRYOPSIS CAESPITOSA	151	J19	28/7/84
CLADOPHORA CF. CAPENSIS	152	J19	28/7/84
POLYSIPHONIA INCOMPTA	153	J19	28/7/84
CHAETOMORPHA ANTENNINA	154	J19	28/7/84
PORPHYRA CAPENSIS	155	K8	19/8/84
ENTEROMORPHA INTESTINALIS	156	J19	26/8/84
LICHOPHORA SP	156	J19	26/8/84
NITZSCHIA SP	156	J19	26/8/84
POLYSIPHONIA INCOMPTA	157	J18	25/8/84
HERPOSIPHONIA SP	158	J18	26/8/84
CYANOPHYTA (BLUE-GREEN ALGAE)	159	J18	26/8/84
CHAETOMORPHA ANTENNINA	160	J25	26/8/84
AMPHIROA CF. RIGIDA	161	J19	1/4/84
CHAETOMORPHA ANTENNINA	162	J25	26/8/84
POLYSIPHONIA INCOMPTA	163	J19	1/4/84
BOSTRICHIA MIXTA	164	J19	1/4/84
PORPHYRA CAPENSIS	165	J19	1/4/84
HERPOSIPHONIA SP	166	J19	1/4/84

Species	No.	Location	Date Collected
POLYSIPHONIA INCOMPTA	167	J19	1/4/84
ARTHROCARDIA SP.	168	J19	1/4/84
BRYOPSIS CAESPITOSA	169	J19	1/4/84
PLATYSIPHONIA MINIATA	170	J19	1/4/84
CERAMIUM ARENARIUM	171	J25	1/4/84
CHAETOMORPHA ANTENNINA	172	J19	8/9/84
ENTEROMORPHA INTESTINALIS	173	J19	8/9/84
LICHOPHORA SP	174	J19SP	8/9/84
ENTEROMORPHA INTESTINALIS	174	J19SP	8/9/84
CERAMIUM ARENARIUM	174	J19SP	8/9/84
ENTEROMORPHA INTESTINALIS	175	J19	8/9/84
CERAMIUM ARENARIUM	176	K25	27/9/84
CERAMIUM ARENARIUM	178	K25	27/9/84
GYMNOTHAMNIUM ELEGANS	178	K25	27/9/84
CERAMIUM ARENARIUM	177	K25	27/9/84
GYMNOTHAMNIUM ELEGANS	177	K25	27/9/84
PLEODOSPORIUM SP	179	KB+6	30/9/84
POLYSIPHONIA INCOMPTA	180	KB+6	30/9/84
HERPOSIPHONIA SP	181	J25	8/9/84
ARTHROCARDIA SP.	182	J25	8/9/84
AMPHIROA CF. RIGIDA	182	J25	8/9/84
CAULACANTHUS USTULATUS	183	J25	8/9/84
PLATYSIPHONIA MINIATA	185	J19II	8/9/84
POLYSIPHONIA INCOMPTA	185	J19II	8/9/84
CYANOPHYTA (BLUE-GREEN ALGAE)	186	K18	11/8/84
RALFSIA EXPANSA	187	J19II	11/8/84
CHAMPIA PARVULA	188	J25	11/8/84
LITHOPHYLLUM SP	189	J25	11/8/84
LITHOTHAMNIUM SP.	189	J25	11/8/84
CAULACANTHUS USTULATUS	190	J25	11/8/84
FORPHYRA CAPENSIS	191	J10	19/5/84
ENTEROMORPHA INTESTINALIS	192	J10-19	29/4-2/6
CLADOPHORA CF. CAPENSIS	193	J10	19/5/84
LICHOPHORA SP	193	J10	19/5/84
HERPOSIPHONIA SP	194	J10	30/6/84
CAULACANTHUS USTULATUS	196	J10	14/7/84
HERPOSIPHONIA SP	197	J10	16/6/84
HERPOSIPHONIA SP	198	J10	21/5/84
CAULACANTHUS USTULATUS	198	J10	21/5/84
CENTROCERAS CLAVULATUM	198	J10	21/5/84
GELIDIUM CAESPITOSUM	199	J10	21/5/84
COLPOMENIA SINUOSA	200	J50	19/5/84
ENTEROMORPHA INTESTINALIS	200	J50	19/5/84
ULVA SP	200	J50	19/5/84
GELIDIUM ARENARIUM	201	J23	13/10/84
GRIFFITHSIA SECUNDA	202	J25	13/10/84
CAULACANTHUS USTULATUS	203	J25	13/10/84
LICHOPHORA SP	204	J19	13/10/84
NITZSCHIA SP	204	J19	13/10/84
SPHAEROTILUS NATANS	204	J19	13/10/84
BRYOPSIS CAESPITOSA	204	J19	13/10/84
POLYSIPHONIA INCOMPTA	206	J19	2/10/84
POLYSIPHONIA INCOMPTA	207	J19	13/10/84
ARTHROCARDIA SP.	208	J19	13/10/84
BOSTRYCHIA MIXTA	209	J50	14/10/84
CORALLINA OFFICINALIS	210	J50	14/10/84
JANIA SP	211	J50	14/10/84
ARTHROCARDIA SP.	212	J50	14/10/84
CERAMIUM ARENARIUM	213	J25	19/5/84
CERAMIUM ARENARIUM	214	J25	1/7/84
GYMNOGONGRUS GLOMERATUS	215	J25	14/7/84

Species	No.	Location	Date Collected
ENTEROMORPHA INTESTINALIS	216	J1911	19/5/84
BIDDULPHIA SP	217	KBCL	19/8/84
CALLITHAMNION STUPOSUM	218	KBCL	19/8/84
CALLITHAMNION STUPOSUM	219	KBCL	19/8/84
CHEILOSPORUM PROLIFERUM	220	J50	24/10/84
POLYSIPHONIA SP	221	J50	24/10/84
MICROCOELUS SP	222	J50	24/10/84
ARTHROCARDIA SP.	223	J15	25/10/84
PLATYSIPHONIA MINIATA	223	J15	25/10/84
BACHELOTIA ANTILLARUM	224	J12	25/10/84
PLATYSIPHONIA MINIATA	225	J1911	25/10/84
GRIFFITHSIA SECUNDA	226	J25	25/10/84
HYPNEA SPICIFERA	227	J25	25/10/84
CALLITHAMNION STUPOSUM	228	J35	28/10/84
CERAMIIUM ARENARIUM	229	J25	1/4/84
CAULACANTHUS USTULATUS	230	J25	1/4/84
OSCILLATORIA BONNEMAISONII	232	K18	2/6/84
CHROOCOCCUS MINUTUS	232	K18	2/6/84
CYANOPHYTA (BLUE-GREEN ALGAE)	233	K18	2/6/84
CYANOPHYTA (BLUE-GREEN ALGAE)	231	K18	2/6/84
PTEROSIPHONIA CLOIOPHYLLA	234	J25	7/4/84
CORALLINA SP	235	J25	7/4/84
BIDDULPHIA SP	238	K40	23/4/83
GELIDIUM CAESPITOSUM	236	J19SP	11/8/84
BOSTRYCHIA MIXTA	237	J19	28/5/84
TAYLOPIELLA SP.	239	J26	25/10/84
PLOCAIUM CORNUTUM	240	J26	25/10/84
GRIFFITHSIA SECUNDA	241	J26	25/10/84
CENTROCERAS CLAVULATUM	242	J26	25/10/84
AUDOUINELLA SP	244	J39	28/9/83
AUDOUINELLA SP	245	J39	28/9/83
GELIDIUM REPTANS	246	JK39	28/5/83
NITZSCHIA SP	247	JK39	28/5/83
CERAMIIUM OBSOLETUM	248	JK39	28/5/83
GRIFFITHSIA SECUNDA	249	J30-33	23/4/83
PLEONOSPORIUM SP	250	J30-33	23/4/83
GRIFFITHSIA SECUNDA	251	J32-35	5/11/83
GELIDIUM REPTANS	252	BC	23/4/83
CYANOPHYTA (BLUE-GREEN ALGAE)	253	BC	23/4/83
GRACILARIA VERRUCOSA	254	BC	23/4/83
GELIDIUM MICROPTERUM	255	J9	10/11/84
BOSTRYCHIA MIXTA	256	BC	23/4/83
CORALLINA OFFICINALIS	257	BC	23/4/83
HETEROSIPHONIA SP	258	BC	23/4/83
GELIDIUM ARENARIUM	259	BC	23/4/83
PLATYSIPHONIA MINIATA	260	BC	23/4/83
CALLITHAMNION STUPOSUM	260	BC	23/4/83
PLATYSIPHONIA MINIATA	261	K32	28/10/84
DICTYOTA LITURATA	262	N-BCH	22/4/83
OSCILLATORIA BONNEMAISONII	263	J20	23/4/83

Species	No.	Location	Date Collected
BOSTRYCHIA MIXTA	264	K12	8/10/84
HERPOSIPHONIA SP	265	I12	23/10/84
BOSTRYCHIA MIXTA	266	I12	23/10/84
CERAMIIUM OBSOLETUM	267	H21	30/3/83
CHEILOSPORUM CULTRATUM	268	H20	31/3/83
PEYSSONNELIA CAPENSIS	269	BC	15/4/84
PTEROSIPHONIA CLOIOPHYLLA	270	J26-30	31/3/84
HYPNEA ROSEA	271	K15	10/11/84
GELIDIUM REPTANS	272	J12	8/10/83
CERAMIIUM OBSOLETUM	273	I31	22/4/83
CALLITHAMNION STUPOSUM	274	J12	31/10/82
OSCILLATORIA BONNEMAISONII	275	J19	20/8/84
AUDOUINELLA SP	276	J19	20/5/84
CHONDROCOCCUS TRIPINNATUS	277	J19	5/11/83
PEYSSONNELIA CAPENSIS	278	BC	26/5/83
LITHOTHAMNIUM SP.	279	J19	31/3/83
LITHOTHAMNIUM SP.	279	J20	10/10/83
CALLITHAMNION STUPOSUM	280	BC	26/5/83
NITZSCHIA SP	281	J25RP	30/3/83
UNKNOWN	282	J25	30/3/83
CLADOPHORA RUGULOSA	283	J25	30/3/83
TAYLORIELLA SP.	284	J25	30/3/83
AUDOUINELLA SP	285	J50	17/1/83
PORPHYRA CAPENSIS	286	J35-9	4/12/82
CERAMIIUM OBSOLETUM	287	BC	4/12/82
CAULACANTHUS USTULATUS	288	J39	4/12/82

## REFERENCE LIST

- Bokenham, N.A.H. 1938. The colonisation of denuded rock surfaces in the intertidal region of the Cape Peninsula. Ann. Natal. Mus. 9: 47-81.
- Bold, H.C. & Wynne, M.J. 1978. Introduction to the Algae. Prentice-Hall Inc., N.J. xiv + 706 pp.
- Borgese, E.M. 1975. The death of the oceans; Ch. 11, pp. 207-226. The Drama of the Oceans. Abrams Inc., N.Y.
- Borowitzka, M.A. 1972. Intertidal algal species diversity and the effect of pollution. Aust. J. Mar. Freshwater Res. 23: 73-84.
- Bray, J.R. & Curtis, J.T. 1957. An ordination of the upland forest communities of Southern Wisconsin. Ecol. Monogr. 27: 325-349.
- Brown, A.C. & Jarman, N. 1978. Coastal marine habitats. In: Werger, M.J.A. (Ed.) Biogeography and Ecology of Southern Africa. Ch. 38, pp. 1245-1277.
- Burrows, E. 1971. Assessment of pollution effects by the use of algae. Proc. Roy. Soc. Lond. (B) 177: 295-306.
- Chapman, A.R.O. 1979. Biology of Seaweeds. University Park Press, Baltimore, 134 pp.
- Day, J.H. 1969. A Guide to Marine Life on South African Shores. Balkema, Cape Town, iii + 300 pp.
- De Toni, J.B. 1889. Sylloge Algarum ... Vol. 1. Padua. 12 + cxxxix + 1315 pp.
- Emerson, S.E. & Zedler, J.B. 1978. Recolonization of intertidal algae: an experimental study. Mar. Biol. 44: 315-324.
- Eyre, J., Broekhuysen, G.J., Crichton, N. 1938. The South African intertidal zone and its relation to ocean currents. VI. The East London District. Ann. Natal. Mus. 9: 83-111.

- Fahey, E.M. & Doty, M.S. 1949. Pioneer colonization of intertidal transects. Biol. Bull. 97: 238-239.
- Fritsch, F.E. 1935. Structure and Reproduction of the Algae. Vol. 1. Cambridge University Press. xvii + 791 pp.
- Fritsch, F.E. 1945. The Structure and Reproduction of the Algae. Vol.2. Cambridge University Press. xiv + 939 pp.
- Gardner, B.D., Connell, A.D., Eagle, G.A., Moldan, A.G.S., Oliff, W.D., Orren, M.J. and Watling, R.J. 1983. Marine Pollution Survey Report 1976-1979. Sancor, Pretoria. 105 pp.
- Heydorn, A.E.F. & Tinley, K.L. 1980. Estuaries of the Cape. Part I. Synopsis of the Cape Coast - natural features, dynamics and utilization. CSIR/NRIO Report 380: 1-97.
- Isaac, W.E. 1938. Geographical distribution of seaweed vegetation in relation to temperature and other factors with special reference to South Africa. C. R. Congr. Int. Géogr. 1938, 2(7): 12-18.
- Isaac, W.E. 1949. Rock pool vegetation. Trans. R. Soc. S. Afr. 32(2): 1143.
- Katada, M. & Satomi, M. 1975. Ecology of marine algae. Ch. 6. Adv. Phycol. Jap. Tokida and Hirose, Jena.
- Keppie, G.B. 1983. Personal correspondence about East Bank sewage outfalls in East London, 4th February, 1983.
- Kindig, A.D. & Littler, M.M. 1980. Growth and primary productivity of marine macrophytes exposed to domestic sewage effluents. Mar. Environ. Res. 3: 81-100.
- Kitching, J.A. 1938. Studies in sublittoral Ecology II. J. Ecol. 25: 482-495.
- Kützing, F.T. 1854-1869. Tabulae Phycologicae. Vol. 1-19. Nordhausen. Reprinted J. Cramer, Vaduz, 1977.

- Kylin, H. 1938. Verzeichnis einiger Rhodophyceen von Sudafrica. Lunds Univ. Årsskr., N.F., Adv. 2, 34(8): 1-26.
- Kylin, H. 1956. Die Gattungen der Rhodophyceen. CWK Gleerups, Lund. xv + 673 pp.
- Levyns, M.R. 1924. Distribution of the seaweeds of the Cape Peninsula. S. Afr. J. Sci. 21: 265.
- Littler, M.M. 1984. Personal communication, 9th July, 1984.
- Littler, M.M. & Kanker, B.J. 1984. Heterotrichy and survival strategies of the red alga Corallina officinalis L. Botanica mar. 27: 37-44.
- Littler, M.M. & Littler, D.S. 1984. Relationships between macroalgal functional form groups and substrata stability in a tropical rocky intertidal system. J. Exp. Mar. Biol. Ecol. 74: 13-34.
- Littler, M.M. & Murray, S.N. 1975. Impact of sewage on the distribution abundance and community structure of rocky intertidal macro-organisms. Mar. Biol. 30: 277-291.
- Littler, M.M. & Murray, S.N. 1977. Influence of domestic wastes on the structure and energetics of intertidal communities near Wilson Cove, San Clemente Island, Calif. California Water Resources Centre Contribution No. 164. viii + 88 pp.
- Littler, M.M. & Murray, S.N. 1978. Influence of domestic wastes on energetic pathways in rocky intertidal communities. J. Appl. Ecol. 15: 583-595.
- Livingstone, D.J., De Goede, J.W. and Warren-Hansen, B.A. 1968. Distribution and occurrence of coliforms and pathogenic indicators of pollution within the surf zone and nearshore waters along a section of Natal Coast. CSIR/NIWR Report 278: 100.
- Murray, S.N. & Littler, M.M. 1974. Biological features of intertidal communities near the U.S. Navy sewage outfall, Wilson Cove, San Clemente Island, California. Naval Undersea Centre, San Diego, California. 85 pp.

- Murray, S.N. & Littler, M.M. 1978. Patterns of algal succession in a perturbed marine intertidal community. J. Phycol. 14: 506-512.
- O'Sullivan, A.J. 1971. Ecological effects of sewage discharge in the marine environment. Proc. Roy. Soc. Lond. B (177): 331-351.
- Odum, E.P. 1971. Fundamentals of Ecology. 3rd Ed. W.B. Sanders Co. Philadelphia. 574 pp.
- Pearce, J.B. 1971. Indicators of solid waste pollution. Mar. Poll. Bull. 2(1): 11.
- Pielou, E.C. 1969. An Introduction to Mathematical Ecology. Wiley-Interscience, N.Y. 286 pp.
- Seagrief, S.C. 1967. Seaweeds of the Tsitsikama Coastal National Park. National Parks Board Publication. Dagbreek H & G (Jhb). 164 pp.
- Seagrief, S.C. 1971. Seaweeds. Eastern Cape Naturalist. 44: 9-15.
- Seagrief, S.C. 1980. Seaweeds of Maputaland. In: Bruton, M.N. & Cooper, K.H. (Eds.). Studies on the Ecology of Maputaland. Rhodes University and Natal Branch of Wildlife Society of Southern Africa. pp. 18-41.
- Seagrief, S.C. 1984. A Catalogue of South African Green, Brown and Red Marine Algae. Memoirs of the Botanical Survey of South Africa No. 47. Botanical Research Institute, Dept. of Agriculture, Republic of South Africa. vi + 72 pp.
- Seagrief, S.C. (In press). "Marine Algae". In: Lubke, R.A., Bruton, M.N. and Gess, F.E. (Eds.). Field Guide to the Eastern Cape Coast.
- Shannon, C.E. & Weaver, W. 1949. The Mathematical Theory of Communication. University of Illinois Press, Urbana. 117 pp.
- Simons, R.H. 1976. Seaweeds of Southern Africa: Guide lines for their study and identification. Fisheries Bulletin of South Africa. 7: 1-117.

- Stephenson, T.A. 1944. The constitution of the intertidal fauna and flora of South Africa. II. Ann. Natal Mus. 10(3): 261-358.
- Stephenson, T.A. 1948. The constitution of the intertidal fauna and flora of South Africa. III. Ann. Natal Mus. 11(2): 207-324.
- Watling, R.J. 1983. Investigation into the pollution status of the East London area. Part 1. Report No. 27. University of Port Elizabeth Zoology Dept. Report Series. 82 pp.
- Whillier, A. 1962. Ocean currents at East London. Transactions of the S.A. Institute of Civil Engineers. 4: 1-7.
- Wynne, M.J. 1984. Personal communication, 31 Oct. 1984.

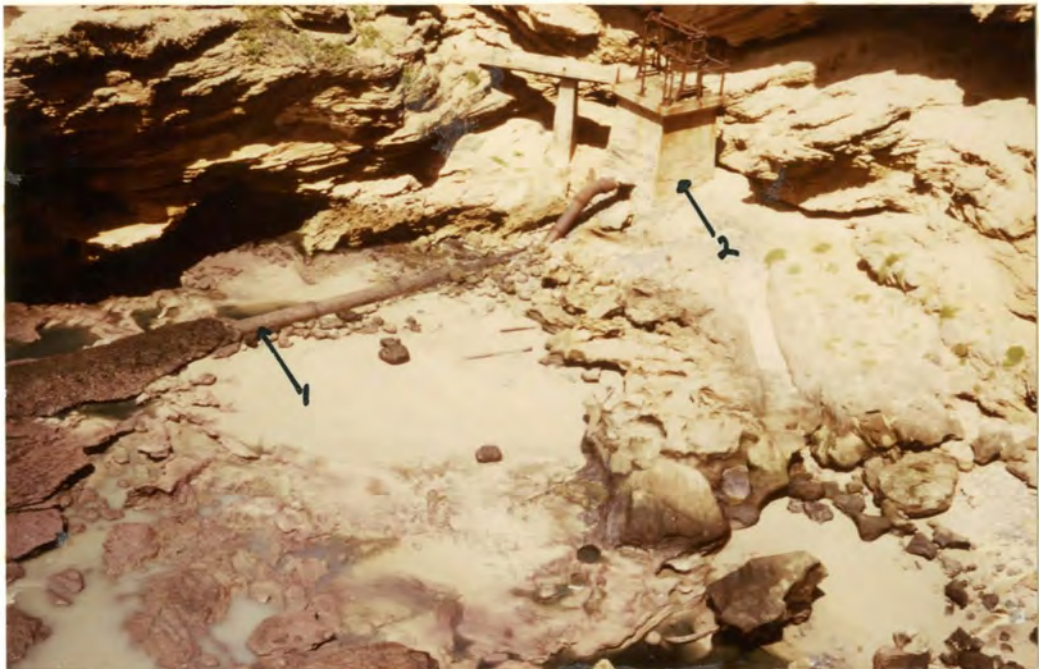
N.B. Pages 133 - 138 omitted in re-typing of References.

Plate 1.1 Bats Cave which is cut into dune rock cliffs and from where this area gets its name.

Plate 1.2 The main outfall pipe (1) leading to the sea. The cement structure (2) was used to control the sewage flow with a valve until the demand was increased. The K18 area is located in this cove.



1.1



1.2

Plate 1.3 Zonation found at the Kidds Beach rocks showing Caulerpa filiformis (light green), Hypnea spicifera (dark green), Ecklonia biruncinata (brown), and assorted corallines. This area was 35km south-west of the outfall and was used as a control for the collections.

Plate 1.4 The control area 1000m from the outfall contained assorted Codium <sup>spp.</sup> and corallines. This is the J50 area.

142



1,3



1,4

Plate 2.1 The Nahoon Outfall pipe (1) located 200m north-east of the main outfall pipe. The area is K12 on the grid map (Fig. 3.1).

Plate 2.2 The Main Outfall pipe (1) in the K18 cove. The grey film on the rocks is caused by the blue-green algae. This extends upwards to 1.2m above mean low water.

Plate 2.3 The K18 cove at high tide.



2.1



2.2



2.3

Plate 2.4 The outfall pipe (1) as it releases the sewage into the sea. The infrared film picks up the scarlet tinge of the blue-green algae on the rocks (2).

Plate 2.5 A view from the J19 area towards Nahoon Point. The K18 cove with the Main Outfall (1), the Nahoon Outfall (2) and Nahoon Point (3) are shown.

Plate 2.6 When the effluent meets the sea, it mixes with the clean water.

146



2.4



2.5



2.6

Plate 2.7 Dye released from a textile factory flows away in the nearshore currents. The breakwall for the harbour (1) can be seen; giving some indication on the distance to the city.

Plate 2.8 The dye mixing near the J23 area.

Plate 2.9 The K18 outfall cove.



2.7



2.8



2.9

Plate 2.10 The barminuter Station which is located 1000m south-west of the Main Outfall.

Plate 2.11 The metal grids which screen large objects. This is the only form of treatment the sewage receives before entering the sea. Another station is located near Nahoon Point for the Nahoon Outfall.

Plate 2.12 Objects caught by the grids are removed by a rake and deposited into bins for later removal.



2,10



2,11



2,12

Plate 2.13 The high dune rock cliffs of the study area with the dunes covered in vegetation behind. The location of the outfall area is labelled (1).

Plate 2.14 A view of the study area from the East London beachfront. Eastern Beach lies to the left.

152



2.13



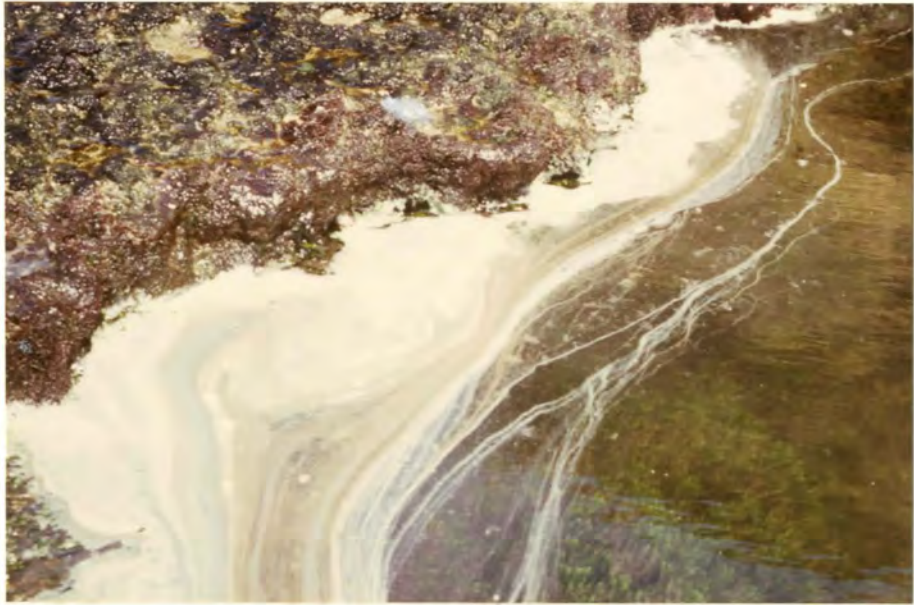
2.14

Plate 3.1 Slime in a tidal pool near J19 with Caulerpa filiformis visible below the surface.

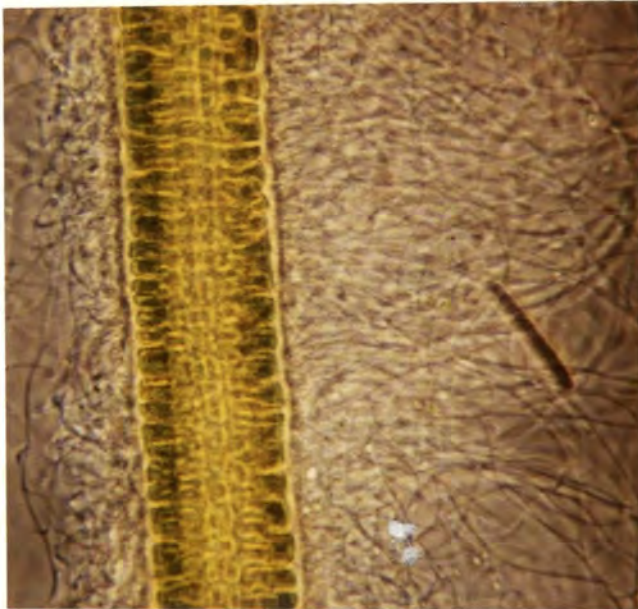
Plate 3.2 Enteromorpha with a bacterium Sphaerotilus natans attached. (Photo by Dr W. Scott)

Plate 3.3 Caulerpa filiformis with S. natans attached.

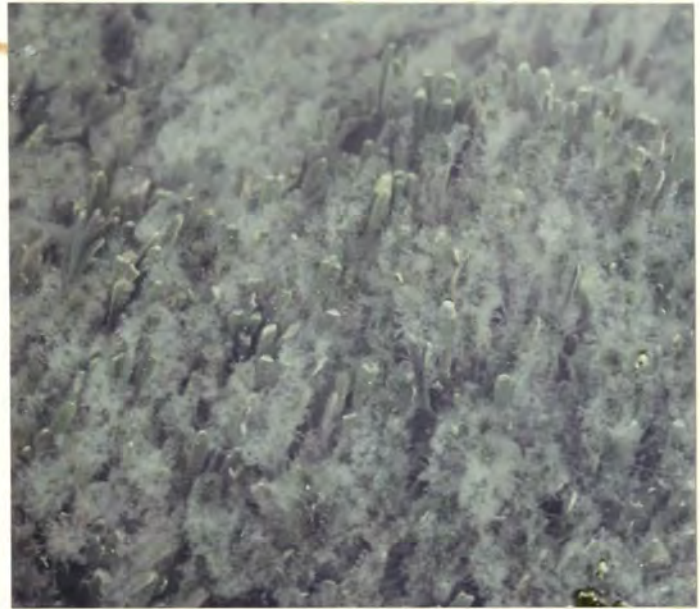
Plate 3.4 S. natans and other blue-greens with Chaetomorpha antennina near the Main Outfall.



3.1



3.2



3.3

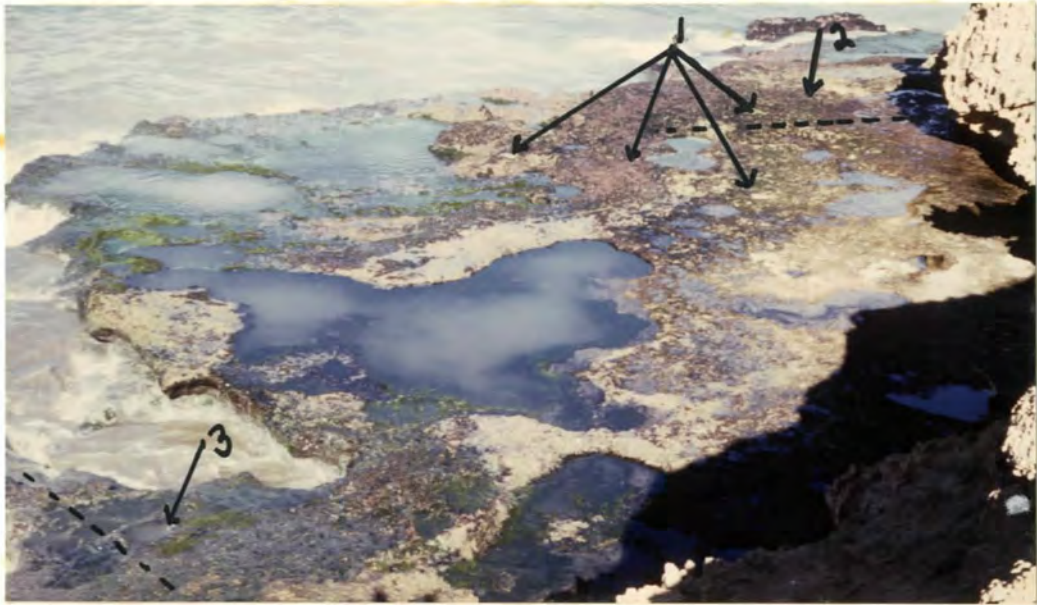


3.4

Plate 4.1 A view of the J19 study area at low tide. Plot clearings (1) and line transects (2) and (3) were carried out in this area.

Plate 4.2 The J19 study area at high tide.

Plate 4.3 An infrared view of the J19 study area with the Main Outfall pipe (1) in the foreground. The scarlet tinge in the foreground is blue-green algae while the bright red in the J19 area consists of Caulerpa filiformis and Corallines



4.1



4.2



4.3

Plate 4.4 The outfall (1), the J19 10m line (2) and the J19 30m line (3).

Plate 4.5 The J25 cove showing the J23 line (1) and the J25 line (2).

Plate 4.6 The J25 cove at high tide



44



45



46

Plate 4.7 The J15 area (1) at low tide.

Plate 4.8 The J50 control area at high tide. The location of the line (1) and plot (2) are indicated.



4.7



4.8

Plate 4.9 The J15 line (1), the J17 line (2), the Nahoon Outfall (3) and the Main Outfall (4).

Plate 4.10 The J10 line (1) and location of the J10 clearing (2). The Nahoon Outfall (3) is indicated.



4.9



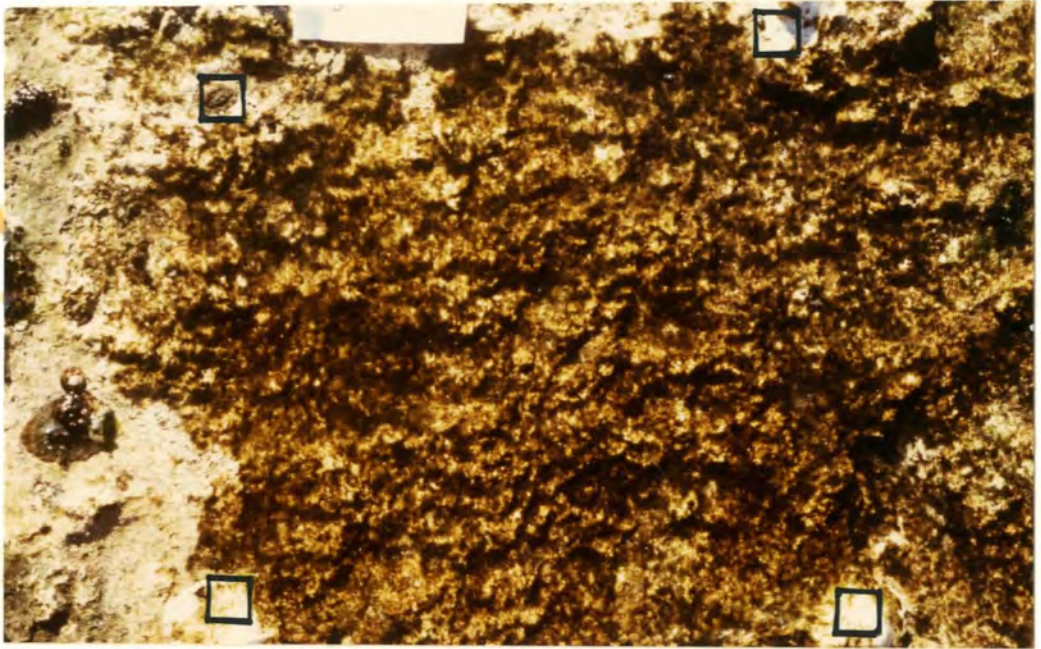
4.10

Plate 5.1 Cover of a cleared plot after two weeks of recovery by the diatom Nitzschia sp. in the J19 area near the outfall.

Plate 5.2 Cover of the plot in Plate 5.1 after 4 weeks recovery by Enteromorpha intestinalis.

Plate 5.3 The plot clearings, J191 (1), J19-2 (2), J19 Spring clearing (3) contrasting the rest of the rock surface. The Main Outfall (4) is indicated.

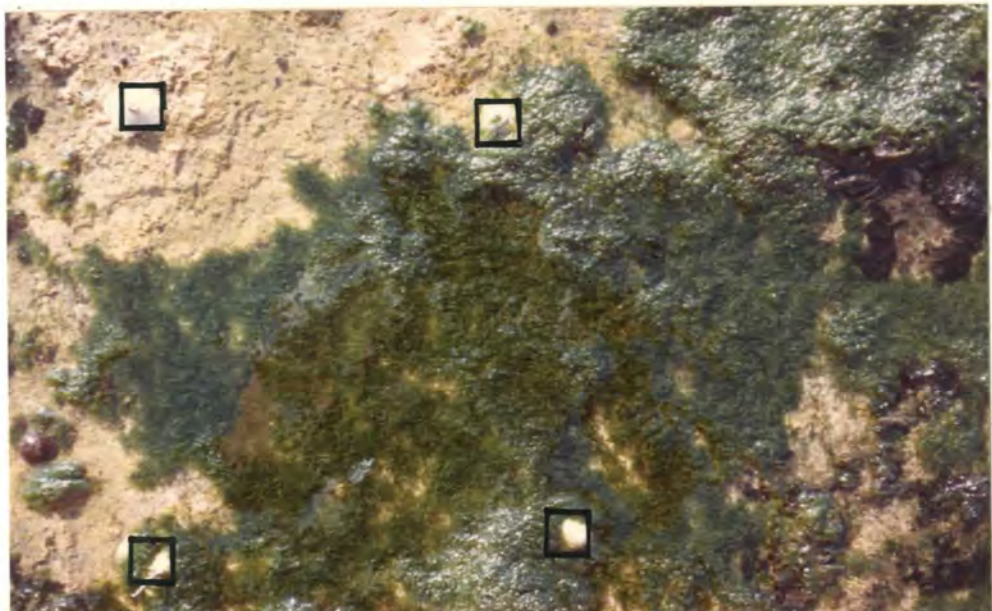
164



S.1

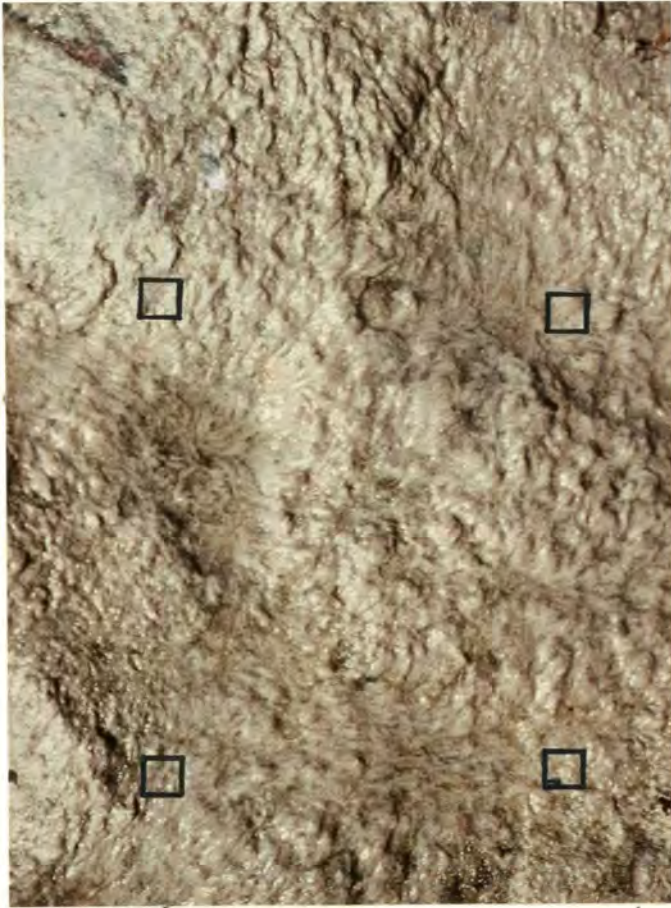


S.3



S.2

Plates 5.4 - 5.7 represent four plots, K18, J19, J25 and J50 respectively before the clearing process occurred. The outline of the plot is indicated.



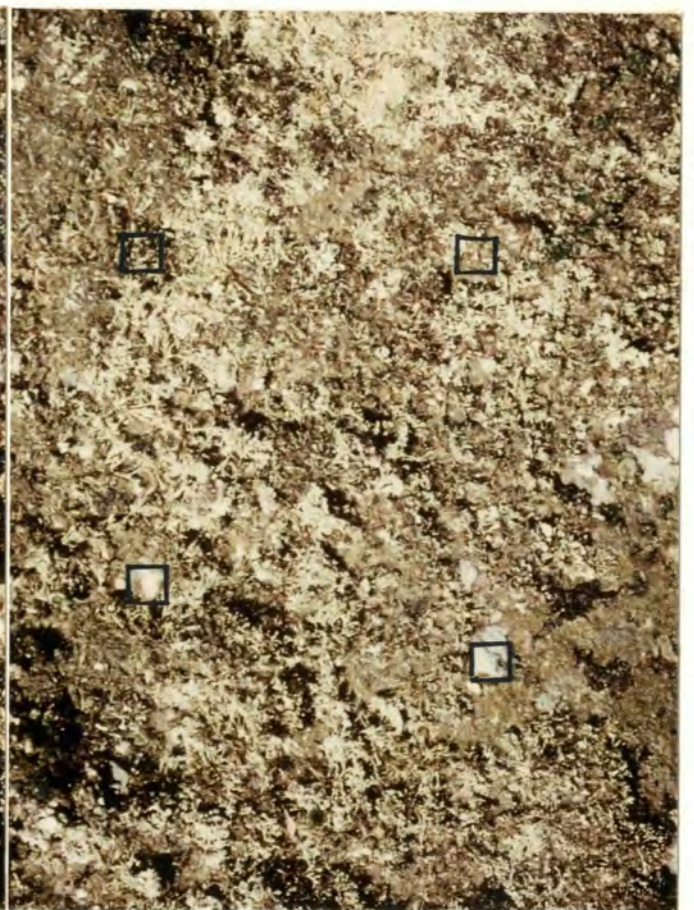
S14



S15



S16



S17

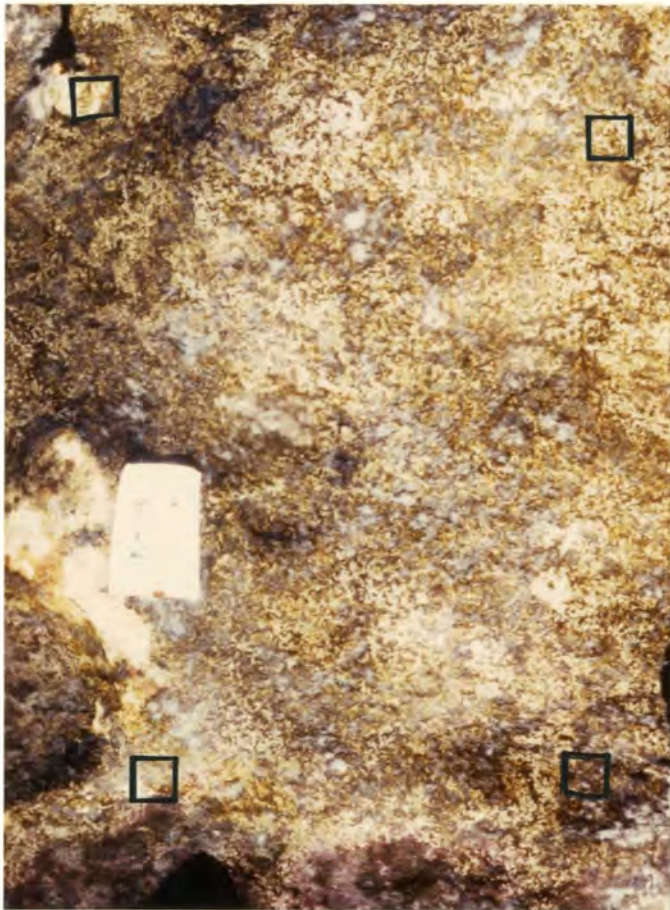
Plates 5.8 - 5.11 represent the 4 plots, K18, J19, J25 and J50 after 6 weeks recovery. The outline of the plot is indicated.

Plate 5.8 The K18 + 6 week plot has shown rapid recovery.

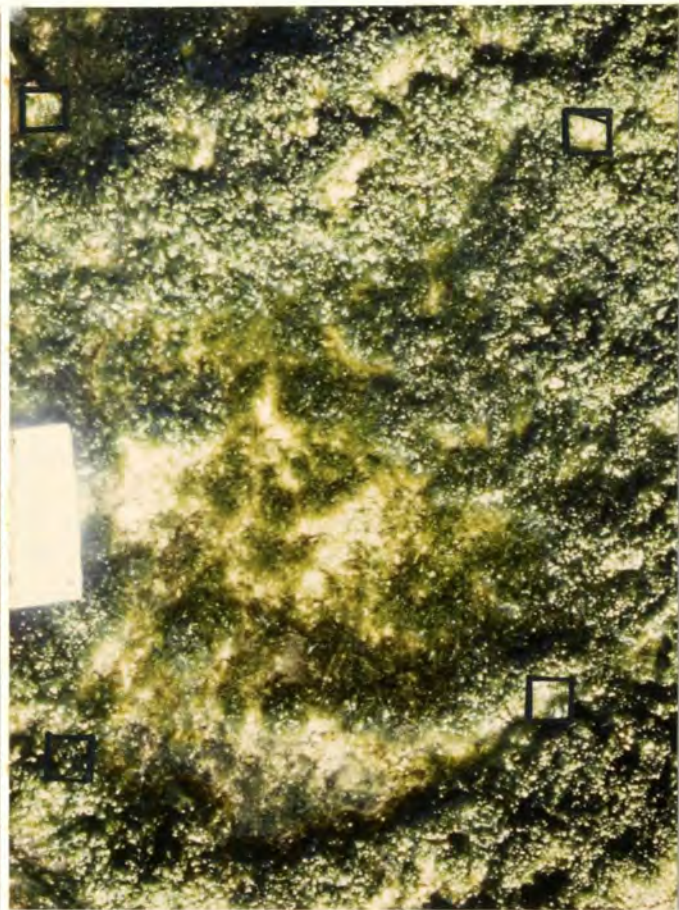
Plate 5.9 The J19I +6 week plot showed almost 100% cover at this point. The diatom and Enteromorpha stages have given way for Ulva sp.

Plate 5.10 The J25 +6 week plot showed a slight covering of diatoms with a few other species attached in the holes.

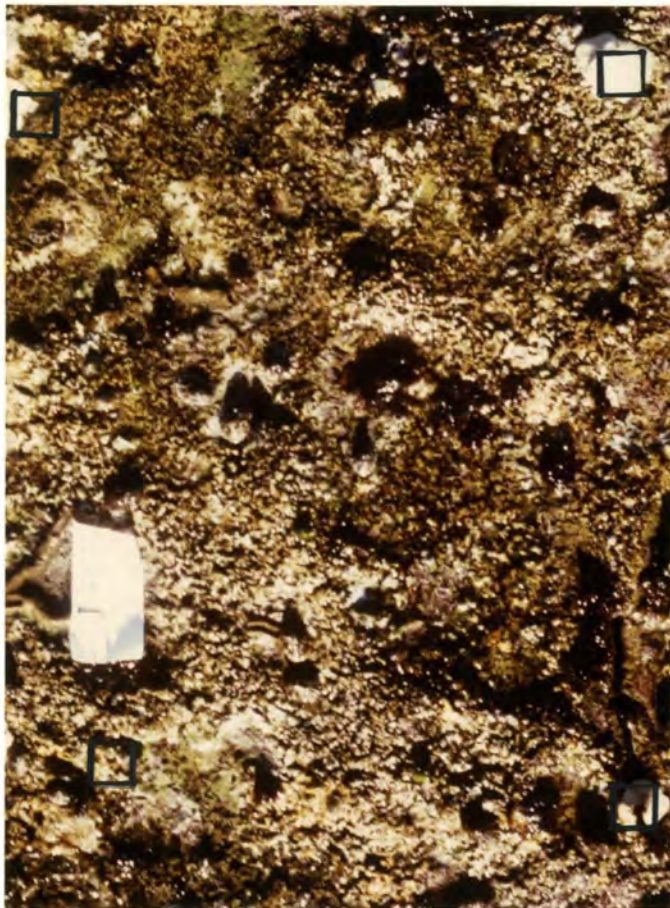
Plate 5.11 The J50 +6 week plot was covered slightly by Ulva sp.



S18



S19



S110



S111

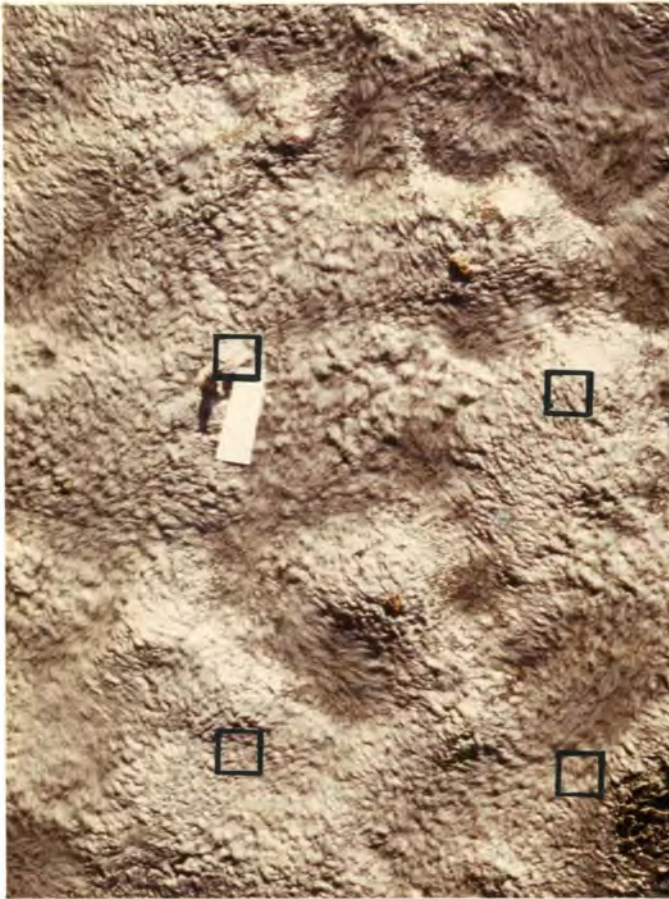
Plate 5.12 - 5.15 These plates represent the plots after 12 weeks recovery. The outline of the plot is indicated.

Plate 5.12 The K18 +12 week plot was fully recovered and could not be distinguished from the surrounding surface.

Plate 5.13 The J19I +12 week plot was covered completely. Cover consisted mainly of Ulva sp.

Plate 5.14 The J25 +12 week plot was not completely covered.

Plate 5.15 The J50 +12 week plot showed more cover but was still noticeable because of its depressed state compared with the surrounding surface.



S112



S113



S114



S115

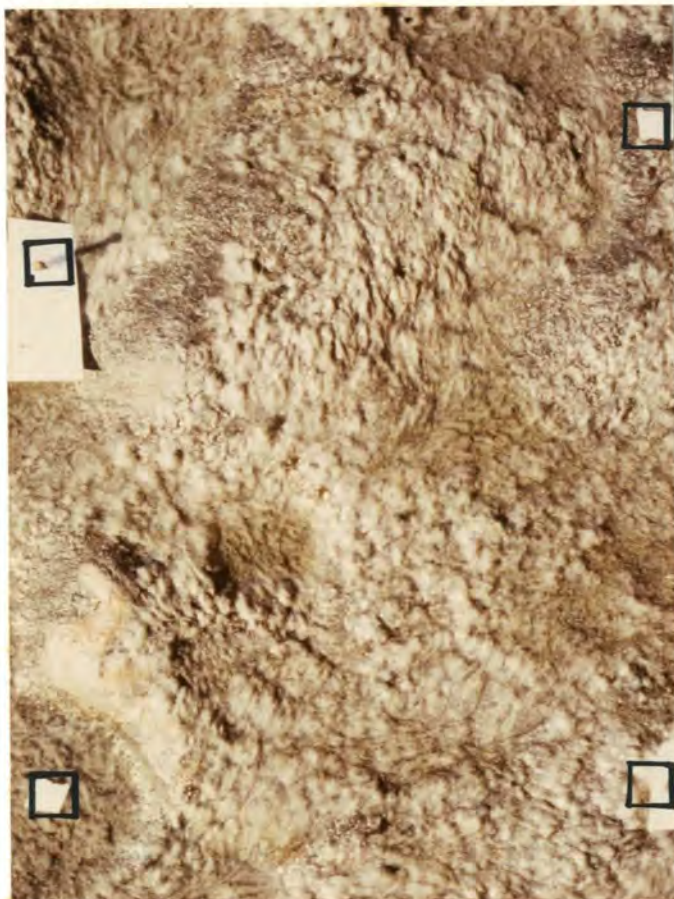
Plates 5.16 - 5.19 represent the plots after 18 weeks recovery. The outline of the plot is indicated.

Plate 5.16 The K18 +18 week plot showed little change.

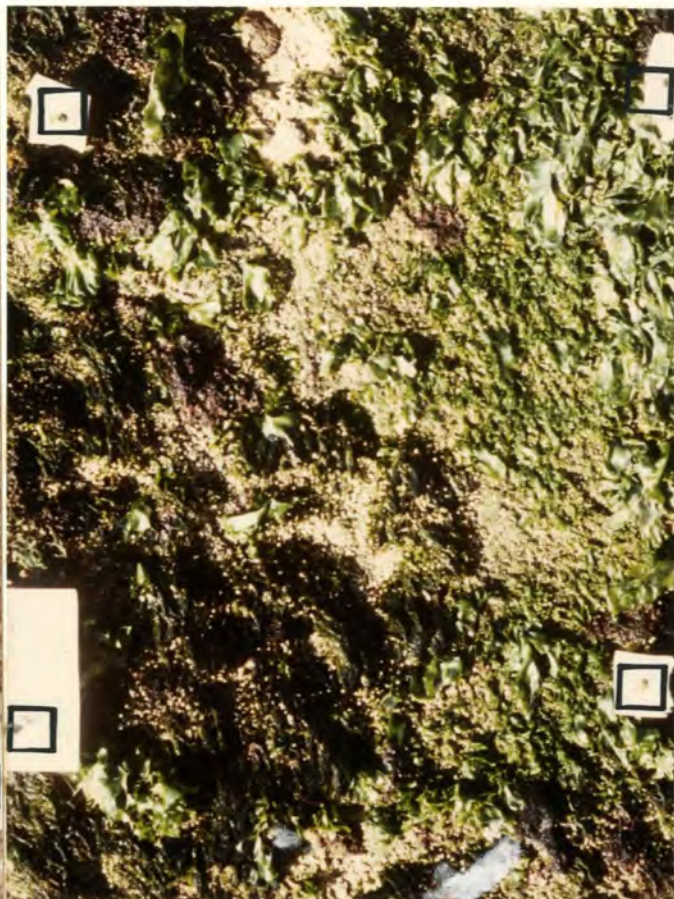
Plate 5.17 The J19I +18 week plot was well established with Bryopsis, Ceramium and Ulva.

Plate 5.18 The J25 +18 week plot was covered and Ulva sp. was the main seaweed present.

Plate 5.19 The J50 +18 week plot was 95% covered.



S.16



S.17



S.18



S.19

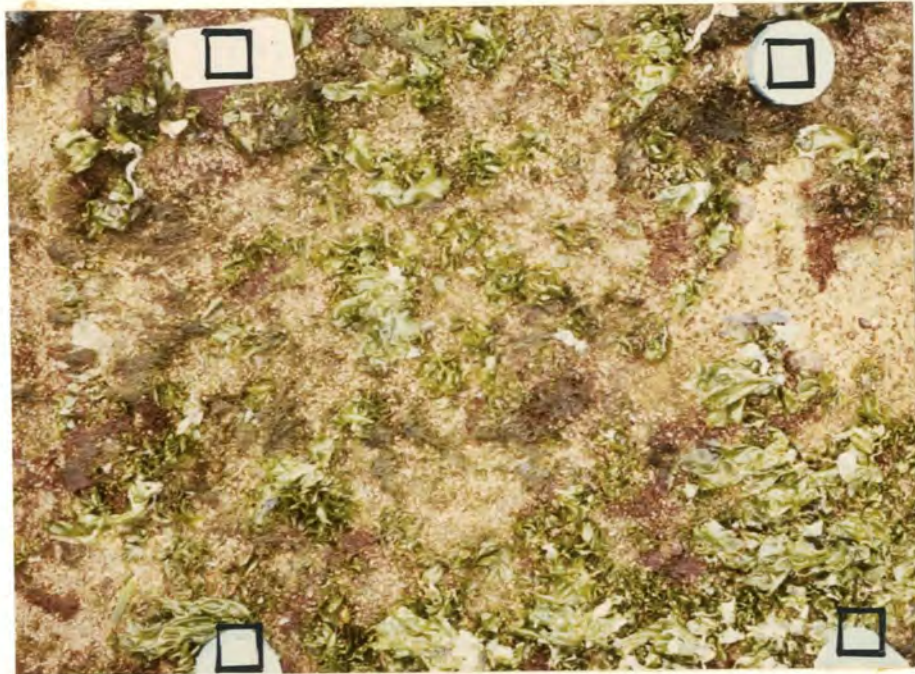
Plates 5.20 - 5.22 represent three of the plots after 30 weeks recovery. As there was no change in the K18 plot, refer to photo 5.16. The outline of the plot is indicated.

Plate 5.20 The J19I +30 week plot was still covered but had started to die back resembling the rest of the surface.

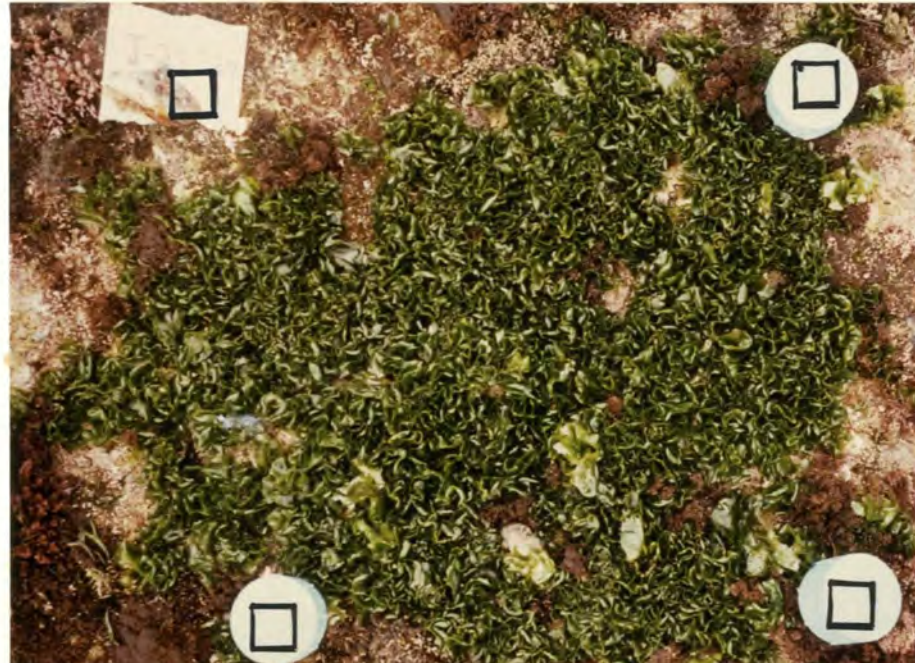
Plate 5.21 The J25 +30 week plot was completely covered in Ulva sp. with other species mixed in between the Ulva. The plot stood out from the surrounding surface.

Plate 5.22 The J50 +30 week plot was still not recovered like the surrounding surface but a number of species were found.

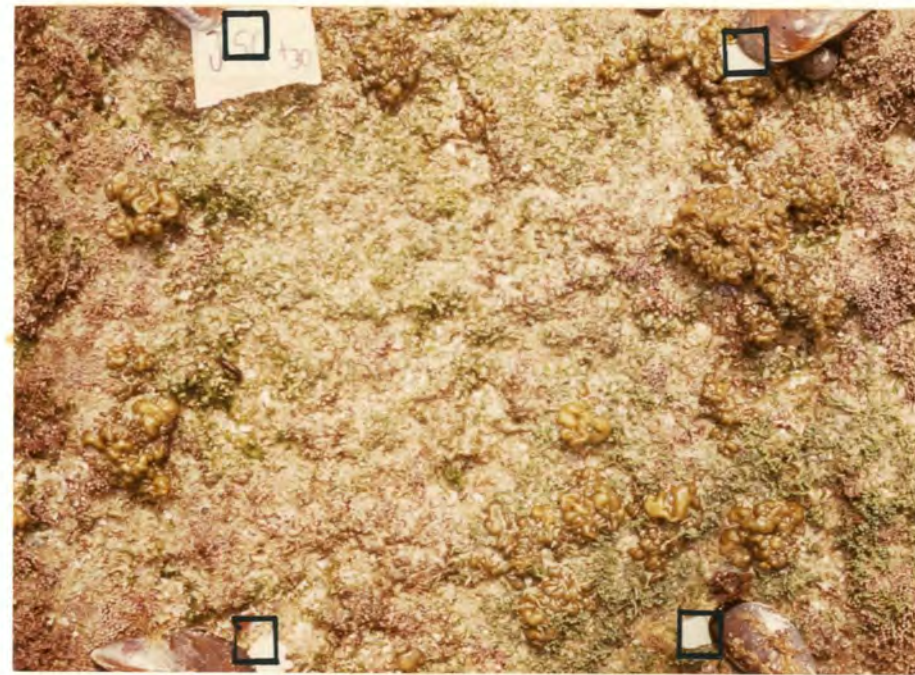
174



S.20



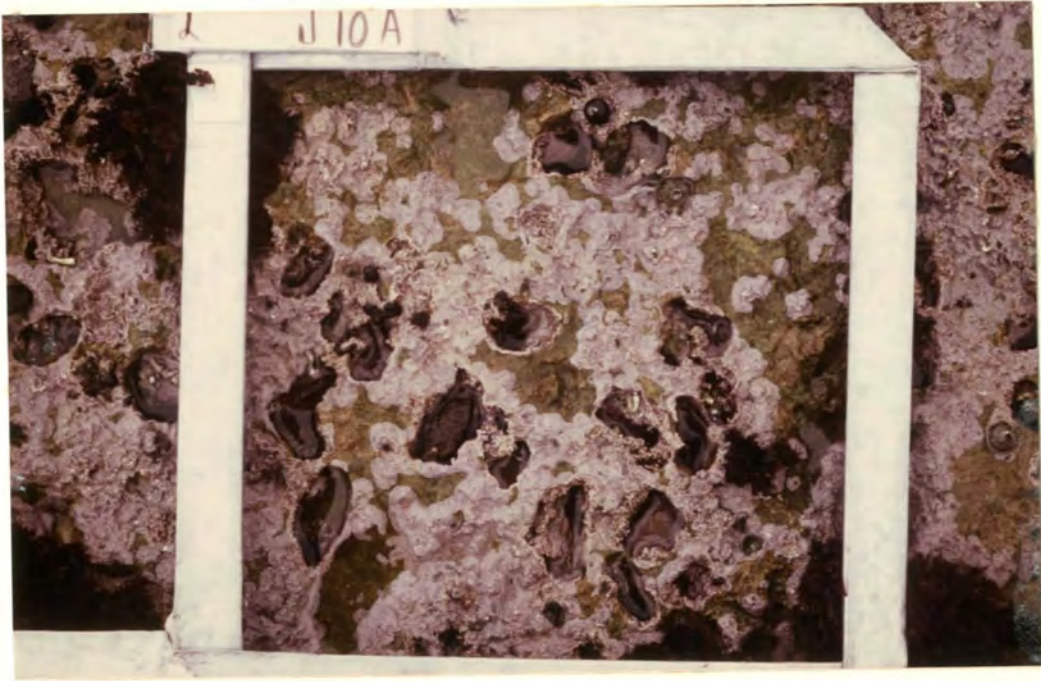
S.21



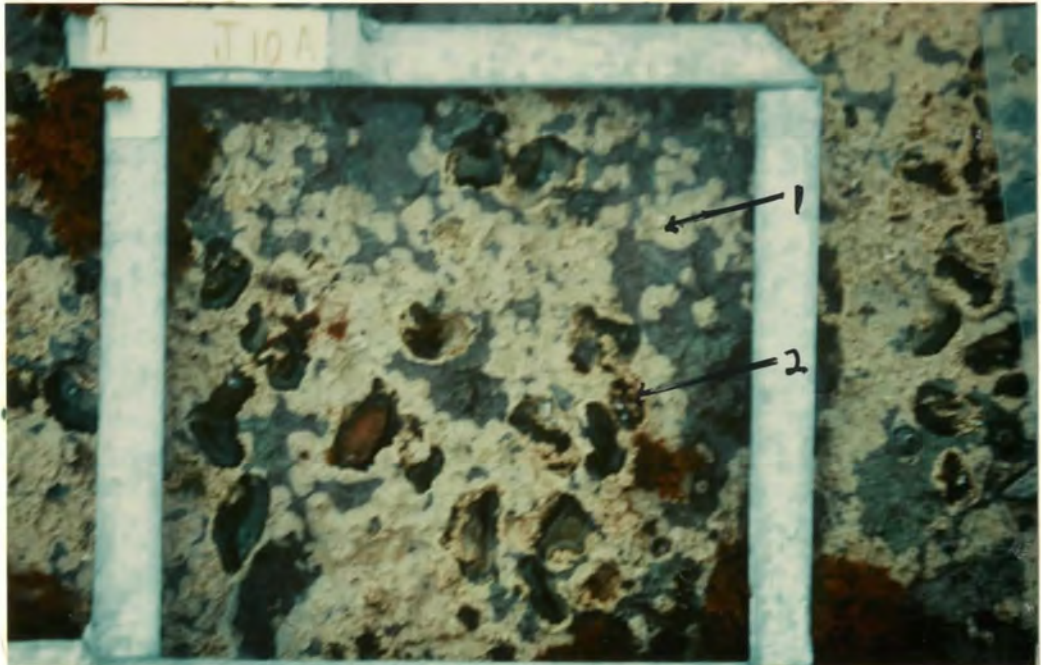
S.22

Plate 6.1 A quadrat at J23 with *Lithothamnium* sp. and *Lithophyllum* sp.

Plate 6.2 The same quadrat as in plate 6.1 but using infrared film. Two distinct species of encrusting corallines can be seen (1) and (2).



6.1



6.2