The Limnology of the Touw River Floodplain

B R Allanson and A K Whitfield

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A.K. WHITFIELD

The cover photograph is by courtesy of the Cape Department of Nature & Environmental Conservation.

Errata:

page 6 - line 3 - "Date" should read "Data".
page 13 - para. 2 - line 2 - "proection" should read "protection".
page 13 - para. 2 - line 4 - "minotor" should read "monitor".
page 25 - caption to Fig. 5 - line 1 - "waters" should read "waders".
page 31 - para. 2 - line 4 - "Wildnerness" should read "Wilderness".
page 31 - para. 5 - line 6 - "700" should read "100".
page 31 - para. 6 - line 2 - "Rondevlei" should read "Eilandvlei".
page 35 - first reference - line 2 - "Ujpublished" should read "Unpublished".

The Touw River Floodplain.
Part I: Ecological structure in relation to planning and management.

B R ALLANSON and A K WHITFIELD

A report prepared by the Institute for Freshwater Studies, Rhodes University, in collaboration with the Cooperative Scientific Programmes, Inland Water Ecosystems, of the Council for Scientific and Industrial Research.

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ABSTRACT

This report is the summary of a larger two-volumed work originally presented to the Coastal Lakes Working Group in 1981. The floodplain is in essence a series of small, shallow lakes, running in an east-west direction between the village of Sedgefield in the east and Wilderness in the west. They have been formed by segmentation of an earlier barrier lagoon associated with the Touw River. They have kept their connection with the Touw River estuary and so form part of its floodplain.

The physical and chemical structure of the lakes is dominated by tidal influence when the estuary mouth is open and by erratic flooding of the Touw River and the Duiwe River, the latter flowing into Eilandvlei and which during floods is responsible for marked but short-lived pulses of phosphate and nitrate derived from agricultural activity on the upland catchment.

Normally the lakes are pristine and constitute, together with their associated reed covered margins, an important wetland for a variety of animal forms, particularly birds. The aesthetic quality of this coastal region and the floodplain is under threat by the demands of human activity associated with urban development.

UITTREKSEL

Hierdie verslag is 'n opsomming van 'n groter werk van twee volumes wat oorspronklik in 1981 aan die Kusmerewerksgroep voorgelê is. Die vloedvlakte bestaan uit 'n reeks klein, vlak mere wat in 'n oos-wes rigting tussen Sedgefield in die ooste en Wildernis in die weste geleë is. Hulle is gevorm deur die segmentering van 'n vroeëre strandmeer geassosieer met die Touwrivier. Hulle het hul verbintenis met die Touwrivier se getymeer behou en vorm so deel van sy vloedvlakte.

Die fisiese en chemiese struktuur van die mere word oorheers deur die invloed van die gety wanneer die getymeer se monding oop is en deur ongereelde vloeding van die Touw- en Duiweriviere. Lg. vloei in Elandsvlei in en is gedurende vloede verantwoordelik vir merkbare maar kortstondige pulse fosfaat en nitraat afkomstig vanaf landboukundige aktiwiteit in die hoërliggende opvangsgebiede.

Die mere is normaalweg ongerep en saam met hulle geassosieerde rietbedekte oewers vorm hulle 'n belangrike habitat vir 'n verskeidenheid diersoorte, veral voëls. Die estetiese kwaliteit van hierdie kusstreek en vloedvlakte word bedreig deur die eise van menslike aktiwiteite geassosieer met stedelike ontwikkeling.

CONTENTS

1. INTRODUCTION

The floodplain of the Touw River has been the subject of a diverse array of hydrological and ecological field programmes. The primary objectives of these studies were to provide the Lake Areas Development Board (LADB), and more recently the National Parks Board, with an array of up-to-date environmental information. This has been achieved in large measure by the Touw River Floodplain Working Group set up by the Cooperative Scientific Programmes (CSP) division of the CSIR. Funds to carry out the investigations reported on in part II and III were provided from the budget of the Inland Waters Ecosystems National Programme of CSP, and much material assistance has been given by the Lakes Conservation Laboratory of the Cape Department of Nature and Environmental Conservation. This department has also provided a much needed research input into both limnological and ornithological investigations.

The Touw River floodplain, some 900 ha in extent, is the most important wetland on the southern Cape coast. Its existence is threatened by direct competition with the burgeoning expansion of human demands upon the resources of the southern Cape coast from Knysna to George. The National Parks Board has the responsibility of restraining and controlling these demands effectively, and this summary of our findings and recommendations will provide a basis upon which to create a wise management policy.

Within the time available, and having regard to the immediately important issues upon which decisions have to be taken, the environmental investigations have been somewhat biased towards hydraulics and the application of observed data to the National Research Institute of Oceanology floodplain model with which it has been possible to simulate the hydraulic behaviour of the floodplain. This understood, the structure of the floodplain plant community, both emergent and submerged, is an equally vital pillar upon which to support sensible management policies. A number of important consequential issues are associated with these two principal components. They are *inter alia* the quality of the floodplain water, and the response of the faunal community to changes in the floodplain, as we are aware of the particular sensitivity of the fauna, both invertebrate and vertebrate, to both insidious and cataclysmic environmental change. Particularly sensitive to such change is the avifauna, for which a particular concern is shown by the Cape Department of Nature and Environmental Conservation.

It is also recognised by the Working Group that human activity remains one of the major ecological elements in the floodplain and its catchments. Sound environmental management should be able to link the reasonable demands of man to those of the other floodplain components. It is hoped that this report will contribute towards this coexistence.

2. THE GEOMORPHOLOGY AND CLIMATE OF THE FLOODPLAIN

In order to appreciate the environmental sensitivity of this coastal ecosystem, we need to go back some 45 000 years to its Pleistocene and to 5 000 years ago to its more recent Holocene history. At the start of the major cycles of glaciation in the northern hemisphere some 45 000 years ago, the sea totally covered the Wilderness embayment, the lakes and Swartvlei, and lapped the cliff face of the very much older landscape of the Tertiary uplands upon which much of the present agricultural development is taking place.

With the withdrawal of the sea due to the accumulation of water in the massive northern ice-cap, rejuvenation of the streams occurred and they cut deeper into the edge of the Tertiary uplands and began to form an erosive phase over the sandy shores exposed by the receding sea. As a consequence, the coastal streams broadened and increased in depth. This process continued until some 10 000 years ago when, with the end of the northern hemisphere glaciation, sea level began to rise and the sea transgressed once again over the coastal plain. With the increase in land temperatures, the temperature differential between sea and land would have been larger than it is today, resulting in strong predominantly south westerly winds which were the motive force which built the serried dunes so typical of this region of the south coast. Some have been permanently submerged as evidenced by the submerged sand-rock reefs in Wilderness Bay. This movement of sand blocked the estuary of the coastal rivers and their basins began to fill from river flows, and as their levels rose they were reconnected to the sea by new estuarine meanders. This tidal phase has lasted throughout the Holocene to present times. What we must recognise is that this process of infilling has taken some 5 000 years. We have increased this rate alarmingly by our total disregard of these time scales, superimposing our own and consequently threatening the ecological stability of these important wetland systems.

Study Area

As defined, for the purposes of this report, the area extends approximately from 33°59' to 34°00'S and 22°35' to 22°43'E. It is located on the southern coast of South Africa, between the towns of George and Knysna, and adjoins the Indian Ocean (Figure 1).

The western portion is the lagoon and floodplain of the Touw River, linked by a natural channel (the Serpentine) to the first of the three lakes (Eilandvlei) and thence by smaller channels to Langvlei and Rondevlei. Almost all the area defined falls within the 5 m contour a.m.s.l. It was under the management of the Lakes Area Development Board and the Cape Department of Nature and Environmental Conservation.

The area is about 911 hectares (Weisser, 1979).

Topography

On the northern boundary, steeply rising, formerly well-forested slopes represent the remains of old sea cliffs. To the south, high consolidated old sand dunes protect the system from on-shore (southerly) winds. The gradient from Rondevlei, the most easterly of the chain of lakes, to the Touw River lagoon, is very slight, over a straight-line distance of 13 km. Minor variations in water level can thus produce slow but wide-ranging effects throughout the system.

Martin (1962) estimates the system was formed in its present shape some 7 000 years ago but estuarine conditions have existed for only 4-5 000 years (Martin, 1956).

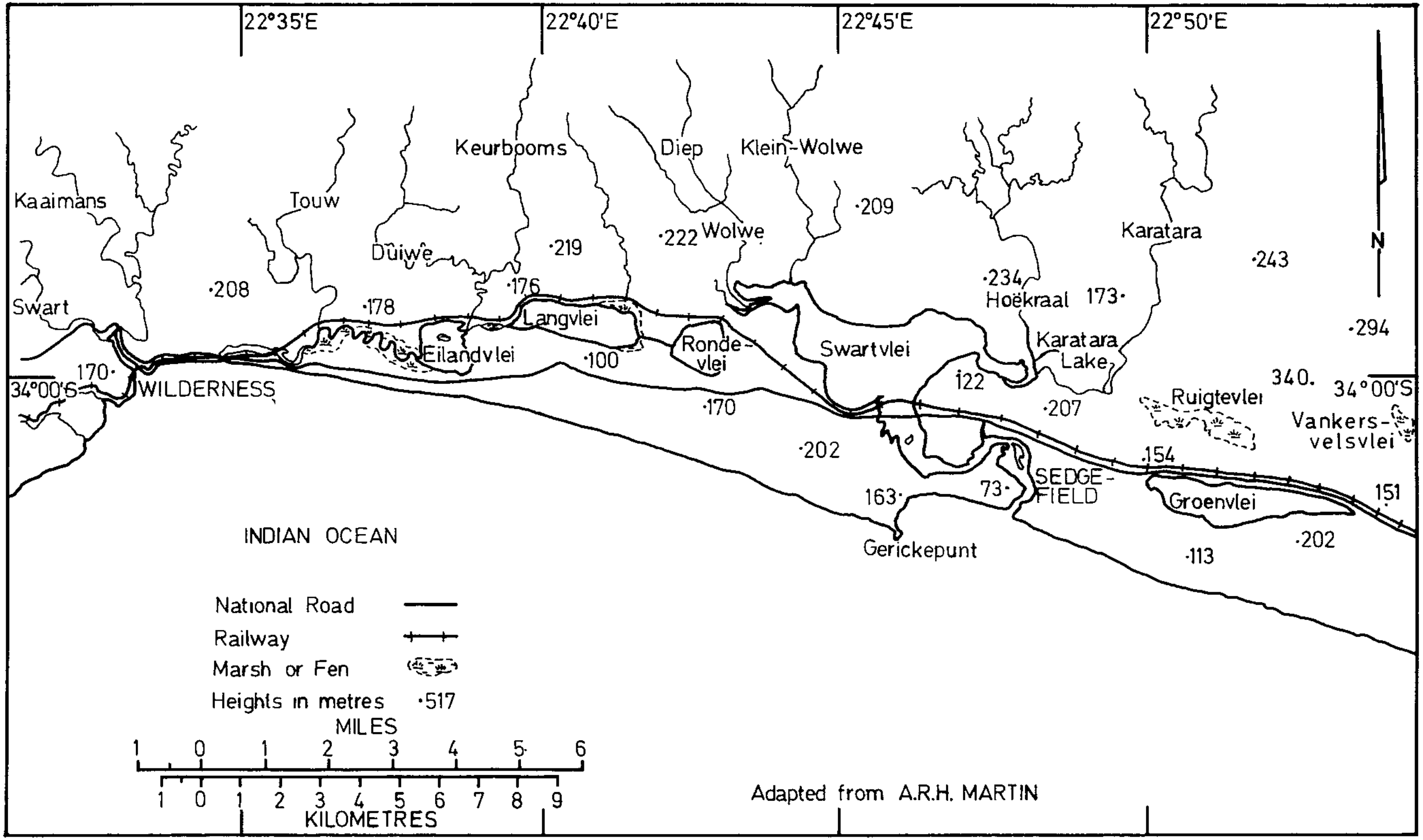

Figure 1. The Wilderness embayment and associated coastal lakes.

Soils

The soils are derived from Pleistocene and Recent Coastal Sands rock but most of the floodplain is covered with a dark alluvium, rich in organic matter. The higher-lying parts have a loose sandy soil low in humus content.

Climate

The climate is mild and temperate, without frost and with little variation in means. Maximum mean daily temperature (February) is 19.8°C and minimum mean daily temperature (July) 13.0°C. Precipitation occurs at all seasons and is generally light within the area. Heavier precipitation occurs in the catchments of the two major feeder streams, the Touw and Duiwe Rivers. Rainfall is probably less than 900 mm per annum and close to 860 mm (figure given for George by Tyson (1971)). The catchments of the feeder streams receive the following amounts (Görgens & Hughes, 1981):- Touw River - 915 mm: Duiwe River - 910 mm: Langvlei streams - 900 mm.

Cloudy conditions are common. Prevailing winds are south-easterly and south-westerly so that the higher land south of the floodplain provides a certain amount of protection for the chain of water bodies lying in an east-west depression.

3. HYDROLOGY AND HYDRAULICS

A separate report entitled 'Hydrological investigations in the southern Cape Coastal Lakes region' has been published by Hughes & Görgens (1981). This will be tabled at the next meeting of the Working Group. This publication may be viewed as essential background to the more detailed hydrograph simulation studies of a number of catchments within the George-Knysna region which are still being undertaken at the present time. It includes information on the general physical setting of the area, as well as a more detailed examination of the available instrumentation and historical data base.

The major limitation to hydrological research within this area of the Southern Cape is associated with the quality of the available records of rainfall, runoff and evaporation. Table 1 summarises the state of the hydrological data base.

Notwithstanding the imperfect nature of the hydrological record, it has been possible to give predictions of flood levels in the Wilderness lagoon for 5 to 100 year floods. These data are given below and are derived by the National Research Institute of Oceanology from the hydrological work of Görgens & Hughes (1982).

HEIGHT ABOVE NORMAL WATER LEVEL, i.e. 1,4 m.a.m.s.l., Wilderness lagoon mouth

Years	5	10	20	50	100
Touw River	1,7 m	2,1 m	2,35 m	2,5 m	3,15 m
Eilandvlei	1,2 m	1,45 m	1,6 m	1,7 m	1,85 m
Lang- and Rondevlei	0,5 m	0,85 m	0,95 m	1,1 m	1,35 m

Table 1. The hydrological data base for the Touw River floodplain and associated catchments.

Data type	Number of gauging sites	Period available	Distribution	Quality of data
Daily flows	9	9-20 yrs.	1. All major streams.	1. Many high flow periods unrecorded because weir capacities inadequate. 2. Recent years' records not worked up yet by DWAFEC. 3. Outdated rating tables.
Hourly flows	9	9-20 yrs.	1. All major streams.	ditto
Daily rainfalls	26	20-60 yrs.	1. Very few in high rainfall headwater areas. 2. Very few in gauged portions of catchments.	1. Many missing record periods. 2. Adjacent gauges anomalous.
Hourly rainfalls (Autographic)	7	1. 2-10 yrs. 2. Six of these closed down since 1977.	1. Very poor.	1. High % of charts show no recognizable trace. 2. Anomalies between adjacent autographic and adjacent daily gauges. 3. Many charts unreadable.
Daily pan evaporations	4	2-6 yrs.	1. None inside gauged catchments. 2. All sites near the coast.	1. Many missing record periods.

This is an example of a model simulation for a water level of +1,4 m; results with various initial levels are contained in C/SEA 8113. Date of the floods of December 1980 and May 1981 are now available for further model calibration. The present results are the best estimates available and future results are not expected to vary significantly.

The hydraulics of the floodplain are described in detail in the CSIR Report C/SEA 8113 and C/SEA 8255. These studies are of exceptional importance as they refer to management practices vital to the ecology of the plant and animal communities in the floodplain. The principal conclusions which may be drawn from these investigations are:-

1. Flood control - The flood level in the Wilderness estuary is dependent solely upon the level of the sand sill at the mouth of the estuary, and the rapid increase to peak discharge of the Touw River (6-8 hrs) which allows the flood to 'short circuit' (Anderson, 1983) via the estuary. The field investigations and model studies which Mr K. Russell and his colleagues of NRIO have carried out, show that if the sand sill is maintained at +2.1-2.4 m MSL a 1:50 year flood with a peak flow of 120 cumecs will result in water levels in the Wilderness lagoon being maintained below +2.6 m MSL, above which level flooding of property will occur. The object of keeping the sill at this level is to provide the correct hydraulic conditions at the mouth to allow rapid scour of sand out of the mouth during floods of this magnitude.

The model has established that the initial water level in the lakes influences only slightly peak levels in the estuary, but contributes to maximum levels in the upper lakes. It has also shown that by maintaining the sill within this range, minor floods are accommodated by reverse flow into the lake system. The effectiveness of this reverse flow storage can be improved by a wise policy of dredging.

2. Dredging - At all stages of investigation the need to dredge areas of the estuary and floodplain was established. Removal of sand by dredging seaward of the Touw River railbridge is central to improvement in both the flow regime and recreational use of the estuary. No hydraulic advantage will be served by dredging the Serpentine between Eilandvlei and Touw River estuary. However, a distinct advantage will accrue to flood water storage if the channel between Eilandvlei and Langvlei is deepened. At present it is severely overgrown by *Phragmites australis* and *Potamogeton pectinatus*. The consequent siltation of the channel has created an effective block to lake interflow when levels fall below +1.2 m MSL.

An important consequence of this analysis is the need to manipulate the storage capacity of the lakes and their associated wetlands. This can only be done by means of a sluice gate which can be opened or closed depending upon the hydraulic requirements of the lake complex and estuary. These findings dictate that the sluice gate would be open during normal non-flood regimes, but would allow retention of water in the lakes compartment during those periods when the mouth had been opened and scoured by floods. The period during which the mouth remains open is very variable depending largely upon the transport of sand in the longshore current and the complex web of events which control the transport of sand along the coastline and into estuaries. Once the mouth has closed, the sluice would be opened and the lakes and floodplain will drain into the lagoon, so raising its water level and improving both its aesthetic and recreational appeal.

4. PHYSICAL AND CHEMICAL PROPERTIES OF THE LAKES AND ESTUARY

It is essential to record at the outset that during the three year period of the investigation (1979-1981), the Southern Cape coastal belt has been subject to two major rainfall patterns: 1979 was considerably wetter than the first nine months of 1980. As a consequence, water levels on the floodplain were maintained by flow from the Touw River until August 1979 when the bar was breached and levels fell in the Wilderness lagoon to 1 m above mean sea level. The mouth was not open for very long as the Touw River floods were not maintained in October and November 1979. The ensuing summer was dry and in the autumn and winter of 1980 only 278 mm of rain was measured at the Lakes Conservation gauge as compared with 392 for the same period in 1979.

The effect of this reduction in rainfall and therefore river flows, was a fall in water levels in the lakes and vleis of the system. It could be argued that this was reasonably fortuitous as it provided an opportunity during 1980 to examine the effect of drought upon a number of important physico-chemical properties of the wetland system. Of particular note would be the influence of man's activities on the floodplain. The summer and autumn of 1980/81 was noteworthy for high rainfall along the southern coast, which provided an opportunity to assess the influence of major flooding of the principal rivers upon the floodplain.

Conventional limnological gear and techniques were used at nine stations in the floodplain. The location of these stations is given in Figure 2.

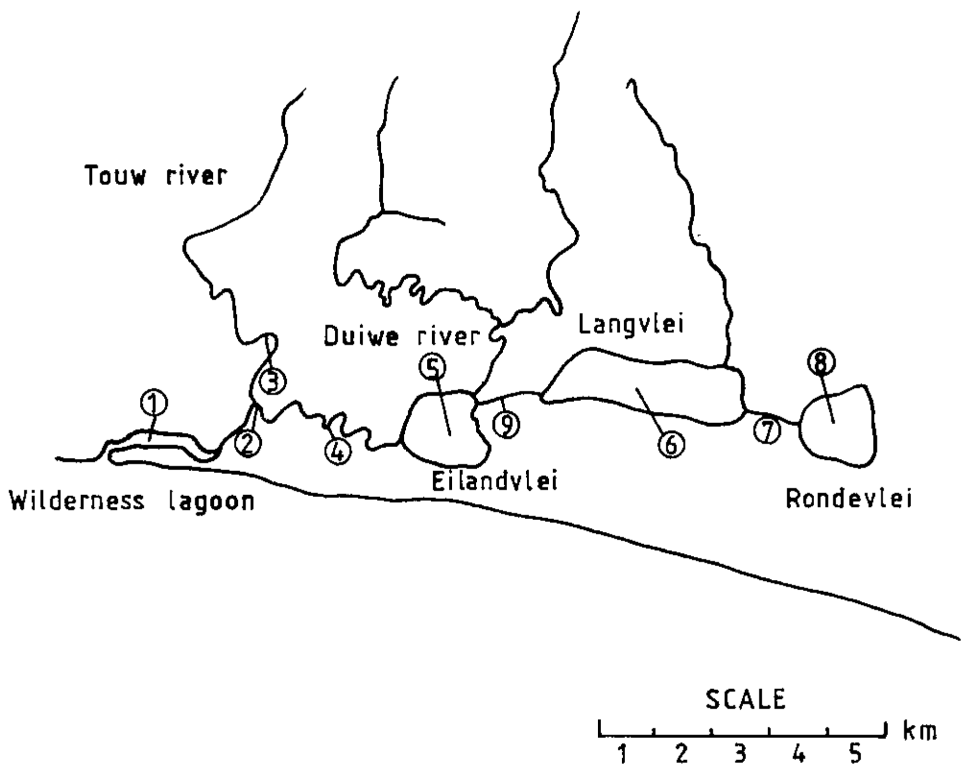

Figure 2. Position of sampling stations used during both drought and flood conditions on the floodplain.

Table 2a, b summarises the physico-chemical characteristics of the floodplain during low flow or drought conditions and three periods of major flooding which the region experienced during the summer of 1980/81 and late in the autumn of 1981. These data will serve as a base line against which to judge the magnitude and severity of future change as the environment and catchment of the floodplain is subject to increasing use by man.

The data from which this table was formed are discussed in more detail in the following sections.

Drought conditions

Salinity: All sampling stations showed an overall increase in salinity during 1979 and 1980. This was particularly marked in the Wilderness lagoon in which salinity changed from 2°/₀₀ in July 1979 to 13°/₀₀ in October following the invasion of seawater when the bar was breached. The reduction of river flow during the summer of 1979/80 and the following winter maintained salinity levels as shown below.

	Wilderness Lagoon	Eilandvlei	Langvlei	Rondevlei
Salinity °/₀₀	14-25	6-10	10-13	12-16

Dissolved oxygen: Notwithstanding these increases in salinity which were presumably largely due to evaporation and reduced freshwater inflow during 1980, dissolved oxygen showed no remarkable changes from saturation in the water columns at each sampling locality. There were isolated areas in the Serpentine which exhibited reducing conditions at the mud-water interface, but this is to be expected in vleis of this structure.

The broader significance of this result is that contrary to what might be expected, the impact of septic tank discharges upon the wetland as a whole is not sufficiently large in magnitude to affect this important quality of lake and river water. This view is supported by data as given below on the concentrations of nitrate (N) and phosphate (P) in the waters of the floodplain.

Nitrate (N) and Phosphate (P): The most striking increase in PO_4(P) in Wilderness lagoon was found immediately following the breaching of the bar when total phosphate (PO_4-P) rose from 9 μgℓ to 17 μgℓ, between August and September 1979. Thereafter total phosphate fell to 1 $\mu g \ell^{-1}$ (at the limit of detection) in July 1980. In August and September of 1980 there was an increase to 11 $\mu g \ell^{-1}$ due probably to the increase in flow in the catchment of the floodplain. None of these concentrations is, however, approaching what might be construed as levels at which eutrophication could occur. It will be appreciated that because of these low total phosphate (TP) values, the more conventional measure, soluble reactive phosphorus (SRP) will be low as well. This is indeed the case with SRP varying between 1-2 $\mu \ell^{-1}$!

The increase in TP following incursion of the sea is exactly what we might expect from an earlier study of the phosphorus dynamics in the estuary of Swartvlei, which showed that the allochthonous phosphate resources of the estuary were of marine origin! Nitrate (N) was

	Rondevlei (Station 8)	Langvlei (Station 6)	Channel E & L (Station 9)	Eilandvlei (Station 5)	Touw (Station 3)	Wilderness (Station 1)
Temperature (°C) $\bar{x} \pm 2$ s.e.	20.1 ± 0.6	20.0 ± 0.7	-	19.4 ± 0.6	18.9 ± 1.0	19.3 ± 1.0
range	13 - 27	13 - 27.5	-	12.5 - 25.5	10 - 26.5	12 - 24.5
Salinity (°/₀₀) $\bar{x} \pm 2$ s.e.	13.9 ± 0.6	10.6 ± 0.6	-	6.2 ± 0.2	4.6 ± 1.1	7.8 ± 1.0
range	12 - 16	8 - 13	-	4 - 10	0 - 18	0 - 25
Oxygen (mg ℓ^{-1}) $\bar{x} \pm 2$ s.e.	7.1 ± 0.5	7.0 ± 0.4	-	7.5 ± 0.3	6.5 ± 0.4	7.3 ± 0.3
range	0.2 - 14.4	0.6 - 11.2	-	0.3 - 11.7	2.9 - 10.0	1.4 - 9.6
pH $\bar{x}$ 2 s.e.	8.7 ± 0.1	8.1 ± 0.1	7.8 ± 0.2	8.1 ± 0.1	7.2 ± 0.3	8.0 ± 0.2
range	8.3 - 9.7	7.2 - 9.2	7.1 - 8.6	7.5 - 9.2	5.2 - 8.6	7.2 - 9.0
Secchi disc (cm) $\bar{x} \pm 2$ s.e.	62 ± 7	142 ± 20	-	179 ± 20	Clear to	135 ± 49
range	30 - 140	50 - 250	-	90 - 320	bottom	100 - 170
SRP (µg ℓ^{-1}) $\bar{x} \pm 2$ s.e.	4.1 ± 3.2	3.6 ± 2.6	0.7 ± 0.2	1.4 ± 0.9	0.6 ± 0.2	0.8 ± 0.3
range	1 - 20	1 - 18	1 - 1.5	0 - 9	0 - 1.8	0 - 2.2
TP (µg ℓ^{-1}) $\bar{x} \pm 2$ s.e.	65.4 ± 15.6	36.2 ± 9.6	30.0 ± 9.9	22.3 ± 4.5	8.0 ± 2.7	7.8 ± 2.5
range	10 - 117	5 - 66	3 - 48	3 - 59	1 - 16	1 - 17
NO_3 (µg ℓ^{-1}) $\bar{x} \pm 2$ s.e.	30.0 ± 4.9	159.4 ± 117	16.6 ± 11.4	8.3 ± 3.5	21.9 ± 7.8	29.0 ± 10.2
range	12 - 44	1 - 569	3 - 72	0 - 39	3 - 52	7 - 60
Chlorophyll α (µg ℓ^{-1}) $\bar{x} \pm 2$ s.e.	13.1 ± 2.1	11.0 ± 2.6	-	8.2 ± 2.5	-	1.8 ± 0.9
range	3 - 37	0.4 - 36	-	1 - 19	-	0.4 - 7

Table 2. Physico-chemical analyses of the Wilderness lakes for the period January 1979 - June 1981.

(a) Non-flood conditions

Table 2 (continued). (b) Flood conditions.

	Rondevlei (Station 8)	Langvlei (Station 6)	Channel E & L (Station 9)	Eilandvlei (Station 5)	Touw (Station 3)	Wilderness (Station 1)
Temperature ($^{\circ}$C) $\bar{x} \pm 2$ s.e.	18.5 ± 1.2	17.8 ± 1.5	-	18.3 ± 0.8	16.1 ± 1.1	16.6 ± 1.3
range	13 - 23	12.5 - 23	-	15 - 22	13 - 19	13.5 - 20
Salinity (°/₀₀) $\bar{x} \pm 2$ s.e.	11.6 ± 0.5	6.2 ± 0.6	-	3.2 ± 0.3	0.3 ± 0.4	2.0 ± 0.9
range	9 - 13	4 - 8	-	2 - 4	0 - 2	0 - 4
Oxygen (mg ℓ^{-1}) $\bar{x} \pm 2$ s.e.	7.3 ± 0.8	7.0 ± 1.1	-	7.1 ± 0.3	7.0 ± 1.1	7.2 ± 0.6
range	2.4 - 9.5	1.2 - 9.6	-	4.3 - 8.9	4.1 - 9.5	6.1 - 8.5
pH $\bar{x} \pm 2$ s.e.	8.6 ± 0.1	8.1 ± 0.2	7.0 ± 0.3	7.6 ± 0.1	6.1 ± 0.8	6.9 ± 0.5
range	8.6 - 8.7	7.8 - 8.3	6.8 - 7.3	7.4 - 7.7	5.1 - 7.0	6.1 - 7.3
Secchi disc (cm) $\bar{x} \pm 2$ s.e.	52 ± 13	92 ± 46	-	42 ± 17	65 ± 7	55 ± 1
range	40 - 70	50 - 160	-	20 - 70	60 - 70	50 - 60
SRP (µg ℓ^{-1}) $\bar{x} \pm 2$ s.e.	0.8 ± 0.6	2.7 ± 1.3	11.7 ± 12.8	3.0 ± 2.8	2.6 ± 2.0	3.5 ± 3.1
range	<1 - 2	1.6 - 5.1	3 - 34	<1 - 10	<1 - 6	<1 - 8.7
TP (µg ℓ^{-1}) $\bar{x} \pm 2$ s.e.	63.7 ± 9.4	42.0 ± 9.8	86 ± 0 - 67.2	61.4 ± 12.1	17.2 ± 13.6	28.3 ± 10.4
range	50 - 73	25 - 48	24 - 196	31 - 85	3 - 45	3 - 39
NO_3N (µg ℓ^{-1}) $\bar{x} \pm 2$ s.e.	28.2 ± 4.8	43.0 ± 22.9	154.0 ± 120.7	94.4 ± 34.5	54.5 ± 16.0	71.0 ± 41.5
range	23 - 32	13 - 70	28 - 325	36 - 174	37 - 77	28 - 137
Chlorophyll α (µg ℓ^{-1}) $\bar{x} \pm 2$ s.e.	20.2 ± 18.5	46.5 ± 57.5	-	29.3 ± 19.1	-	8.8 ± 13.4
range	6 - 52	13 - 146	-	6 - 59	-	0.5 - 32

measured in the lagoon from February 1980. Although there is evidence of unsystematic variation in concentration, the figures obtained using the very sensitive cadmium reduction method, showed that the levels of this plant nutrient are well below those which would direct attention to serious organic pollution. The levels obtained varied between 7-60 $\mu g \ell^{-1}$.

The same general tendency was found in Eilandvlei, while in Langvlei and Rondevlei, total phosphorus reached levels of 66 and 117 $\mu g \ell^{-1}$ respectively. But even with these comparatively high levels of TP, only occasionally did SRP reach levels (20 $\mu g \ell^{-1}$) at which (if all other factors were propitious) marked algal growth could occur. The fact that these changes occurred contemporaneously with changes in the use of the floodplain by large numbers of water birds, shows that we must understand the proximate causes of 'deleterious' water quality change before drawing often unsubstantiated conclusions about the effect of man-made damage upon water quality.

As might be expected, the changes in the concentration of α chlorophyll in the lakes and the pattern found follow almost exactly that found for phosphate. α chlorophyll varied from 3 $\mu g \ell^{-1}$ in the Wilderness lagoon to 10 $\mu g \ell^{-1}$ in Eilandvlei, reaching a value of 37 $\mu g \ell^{-1}$ in Langvlei and Rondevlei. These values are not maintained as they are in truly eutrophic waters, but vary downwards from these maxima to often less than 3 $\mu g \ell^{-1}$.

Flood conditions

Monitoring of the physico-chemical conditions in the floodplain was continued during the summer, autumn and winter of 1980/81 and has provided unequivocal support for the view that the inflowing streams are the most important sources of both inorganic nitrogen and phosphorus. Rondevlei, which has no feeder streams or rivers, shows virtually no increase in nitrogen or phosphorus levels following floods (Table 3, 4b). The effect of floods during January, March and April, 1981, is recorded in Tables 2b, 3 and 4a, b.

Table 3. Changes in soluble reactive phosphorus, total phosphorus and nitrate (N) at 5 stations in the Touw River floodplain between December and January 1980/81.

	Touw River (Station 3)		Eilandvlei (Station 5)			Channel (Station 9)		Langvlei (Station 6)		Rondevlei (Station 8)	
	8/12	26/1		8/12	26/1	8/12	26/1	8/12	26/1	8/12	26/1
SRP	1	2	s	<1	1.4	<1	5	<1	2	<1	<1
			b	<1	<1						
TP	16.2	18	s	3.6	47	48	84	37	47	70	50
			b	6.7	66						
NO_3N	10	62	s	4	102	7	325	3	70	20	24
			b	3	51						

The events recorded in these tables show the importance of river inflow following flooding upon the quality of the surface waters of the floodplain. From the evidence available, it would seem that an important source of nitrate-N and phosphate-P input is via the Duiwe River. The catchment of this stream, which enters Eilandvlei on its eastern shore, is highly developed agriculturally. In this respect, the catchment of the Touw River is more pristine, and this difference is reflected in the water quality at the Touw River (Station 3) and in Eilandvlei (Station 5).

Table 4a. Some important physico-chemical changes in the Touw River floodplain during March and April 1981 as a consequence of heavy rain in the catchment of the Touw and Duiwe rivers.

	Wilderness Station 1		Touw River Station 3		Serpentine Station 4	
	23.3*	28.4	23.3	28.4	23.3	28.4
Salinity °/oo	10	0-1	0-17	0	10-12	3
Temp. °C	23.5	16	22-24	15	24.5-25.0	18
Dissolved O_2 $mg\ell^{-1}$	-	8.3-8.5	7.5-4.1	9.5-4.5	5.8-4.1	7.3-6.6
Chlorophyll $\mu g\ell^{-1}$	2.2	0.9	-	-	1.3	11.3
SRP $\mu g\ell^{-1}$	1	2.1	1	6.5	1	3.5
TP $\mu g\ell^{-1}$	2.8	45	14	39	18	59
NO_3N $\mu g\ell^{-1}$	33	74	16	77	11	85
Secchi disc	-	-	-	-	-	-

Note:-

*23.3.81 Just prior to floods.
28.4.81 At near peak flooding.

Rainfall
January 166
March to April 260
Jan-April 426 mm

Touw River estuary opened naturally 25.1.81.
Closed artificially 2.3.81.
Opened naturally 25.3.81 and remained open until April 1982.

Table 4b. Some important physico-chemical changes in the Touw River floodplain during March and April 1981 as a consequence of heavy rain in the catchment of the Touw and Duiwe rivers.

	Eilandvlei Station 5		Langvlei Channel Station 9		Langvlei Station 6		Rondevlei Station 8	
	23.3	28.4	23.3	28.4	24.3	29.4	24.3	29.4
Salinity °/oo	4	4	-	-	8	7	13	12
Temp. °C	25-26	19-18.5	-	-	24	18	24	19
Dissolved O_2 $mg\ell^{-1}$	8.1-3.0	-	-	-	7-6.7	7.8-7.2	-	-
Chlorophyll $\mu g\ell^{-1}$	16.5	23.4	-	-	13.9	8.5	13	12.6
SRP $\mu g\ell^{-1}$	1	2.1-1	1	34	1	1.6	1	1
TP $\mu g\ell^{-1}$	17	68-52	33	196	38	25	52	60
NO_3N $\mu g\ell^{-1}$	39	97-36	45	210	6	60	33	34
Secchi disc	1.4	0.4	-	-	1.2	0.5	0.6	0.4

Note:-

Station 9 - this channel receives some backflow when the Duiwe River is in flood.

The chlorophyll (or total pigment) concentrations in Langvlei, Eilandvlei and Wilderness during the last summer would be cause for alarm, if it were not for the repeated observations that these eutrophic conditions have in the past been short-lived. The floodplain is obviously an efficient phosphorus sink because of the maintained high levels of oxygenation of its waters which keep redox values above +300 mv, so effectively locking these rich phosphorus inputs into the sediments of the floodplain.

It is clear from these data that the floodplain should be given reasonable proection from increased phosphorus and nitrogen loads from the inland catchments. But before jumping to adverse conclusions, we should continue to minotor these edaphic events, their duration and the factors which may be bringing about slow deleterious changes in the floodplain. Obviously negative activities by man, particularly in the catchments of the influent rivers, may well exacerbate the rate at which these changes occur. Our responsibility is to identify them and determine their effects.

5. PLANT COMMUNITY OF THE LAKES AND FLOODPLAIN

The aquatic and floodplain vegetation of the Wilderness lakes prior to the construction of the sluice gate has been described by Howard-Williams (1980), Jacot Guillarmod (1979, 1971, 1982) and Weisser & Howard-Williams (1982). A total of 320 plant species have been recorded from the Wilderness lakes system and the more important species, together with the areas they occupied in 1978, are shown in Table 5.

Table 5. The main types of plants and the areas they occupied in the Wilderness lakes system prior to the construction of the sluice gate (modified from Weisser & Howard-Williams, 1982).

Component	Mapping Unit	Area (ha)	Percentage
Aquatic Zone	Characeae	197,7	30,1
	Najas marina	0,5	0,1
	Potamogeton pectinatus	42,7	6,8
	Ruppia cirrhosa	3,9	0,6
Semi-aquatic Zone	*Phragmites australis*	102,1	16,4
	Scirpus littoralis	37,0	5,9
	Typha latifolia	13,3	2,1
	Afforestation	2,0	0,3
	Grasslands and Fields	66,1	10,6
	*Juncus kraussii**	116,7	18,7
	Scrub	51,8	8,3
TOTAL		623,8	

*This species also occurs in the semi-aquatic zone.

The vegetation of the Wilderness system may be divided into three major components:

(a) Aquatic plants of the lakes and channels, which grow on sandy soils with a relatively low organic content;

(b) Semi-aquatic flora of low lying areas adjacent to the lakes and channels. This vegetation grows in soils rich in alluvium, are poorly drained and normally inundated at high water levels;

(c) Degraded coastal fynbos which grows on the sandy soils, lacking in humus and which drain rapidly.

For the purposes of section 5.1 the aquatic and semi-aquatic vegetation components are examined together.

5.1. The water plants and the macrophyte encroachment problem

The most important submerged plants of the Wilderness lakes were the Characeae (*Chara globularis*, *Lamprothamnium papulosum*), *Potamogeton pectinatus* and *Ruppia cirrhosa*, whilst emergents *Phragmites australis*, *Scirpus littoralis* and *Typha latifolia* dominated the semi-aquatic zone. Free-floating plants such as *Salvinia molesta* have been recorded from the system but are unable to survive the relatively high salinities of the lakes. However, if the salinity of Eilandvlei continues to decline as a result of freshwater input and reduced tidal inflow, there is a danger that *Salvinia* may become a major problem in this lake.

Howard-Williams (1980) has examined the structure of the submerged and emergent plant community of the Wilderness system. He found that while *Phragmites*, *Scirpus* and *Ruppia* decreased in biomass from the Wilderness Lagoon towards Rondevlei, *Typha* increased in biomass in the same direction. *Potamogeton* standing crops increased from the Wilderness Lagoon towards Eilandvlei and then declined from Eilandvlei towards Rondevlei. The Characeae attained a maximum biomass in Langvlei.

The annual production of the above species during 1978/79 is shown in Table 6, of which more than 1000 tonnes was contributed by the reed *Phragmites*. A total of almost 2000 tonnes of organic material was produced in a single year, which represents a major input into the system. Therefore it is essential that management proposals take cognisance of the productive role of the water plants in the aquatic food web.

Before examining the aquatic macrophyte encroachment problem, it is necessary to emphasize that the Wilderness lakes area is a wetland system which is ecologically based upon natural fluctuations. In the history of lake management there has been a tendency to manage by avoiding extremes, e.g. avoiding very low water levels and extreme high levels through regulation of water flow. This has usually led to a decrease in vegetation dynamics and a decrease in species diversity, as plants acting as pioneers tend to disappear. This may indirectly affect the wildlife. If management is geared for a higher species diversity, room must be left for extreme ecological situations. Sometimes what seems to be a disaster from the human point of view is part of the natural cycle.

The following example from Langvlei illustrates the cyclical nature of plant changes within the Wilderness system. When the vegetation of Langvlei was mapped by Howard-Williams & Longman in 1975, the water level was low and the lake was clear. The entire bottom of the vlei was covered by dense beds of *Chara globularis* and *Lamprothamnium papulosum* (Weisser & Howard-Williams, 1982). Although still

	SPECIES							
WATER BODY	*T. latifolia* t a^{-1}	*P. australis* t a^{-1}	*S. littoralis* t a^{-1}	Characeae t a^{-1}	*R. cirrhosa* t a^{-1}	*P. pectinatus* t a^{-1}	TOTAL	%
Wilderness Lagoon	0	10,8	0	0	0,3	0,1	11,2	0,6
Touw River	1,6	76,4	20,1	+	0,1	1,5	99,7	5,1
Serpentine	26,0	677,5	78,3	+	0,1	47,7	829,6	42,4
Eilandvlei	20,0	131,4	32,1	1,0	0,7	231,2	416,4	21,3
Eilandvlei/Langvlei Channel	6,0	18,9	2,6	0	0	4,8	32,3	1,7
Langvlei	32,9	157,8	192,3	45,6*	+	0**	428,6	21,9
Langvlei/Rondevlei Channel	1,7	6,0	2,3	0	0	1,0	11,0	0,6
Rondevlei	94,6	7,2	23,9	0	+	+	125,7	6,4
TOTAL PREDICTION	182,8	1086,0	351,6	46,6	1,2	286,3	1954,5	

*In 1975 this was 422,4 t a^{-1}

**In 1975 this was 50,9 t a^{-1}

Table 6. Above ground annual production (tonnes per annum) of the six major water plants in the various water bodies of the Wilderness lakes system during 1978/79 (after Howard-Williams, 1980).

present during April 1978, the charophyte beds had virtually disappeared by March 1979. Observations by Coetzee & Palmer (1982) and Weisser & Howard-Williams (1982) suggested a shading out of the Characeae at the bottom of Langvlei by a dinoflagellate bloom. In 1975 the lake bottom was clearly visible at 4 m whereas the mean Secchi disc value for January-December 1978 was 0,8 m (Coetzee & Palmer, 1982). Declining phytoplankton stocks within Langvlei during 1982 contributed to an increase in transparency of this lake and resulted in the recovery of the submerged plant beds. The vegetation cycle of Langvlei appears, therefore, to have turned a full circle.

Weisser & Howard-Williams (1982) were able to detect localized increases of emergent macrophytes such as *Phragmites australis*, *Typha latifolia* and *Scirpus littoralis* in the Wilderness Lagoon, Touw River, Serpentine, Eilandvlei, Eilandvlei/Langvlei Channel, Langvlei and Rondevlei. These authors attributed the increase of emergent macrophytes in the Wilderness Lagoon to the artificial opening of the estuary mouth, which resulted in lower average water levels during past decades. However, they did not foresee any acute encroachment problem because *Phragmites australis* is limited to the edges and any expansion would be restricted because of water depth, floods, occasional high salinities and recreational activities. The important role of *Phragmites* in protecting the banks from waves caused by speedboats was emphasized. Filamentous algal blooms often develop in the Wilderness lagoon and are a nuisance to recreational activities in the area. However, these blooms are not unique to the Wilderness system but also occur regularly in the nearby Swartvlei estuary (Liptrot & Allanson, 1978).

For submerged macrophytes, the situation fluctuates from year to year and from one site to another, as does their nuisance potential in relation to recreational activities. The density and biomass of *Potamogeton pectinatus* shoots is highest during March and lowest during September, whereas the biomass of the Characeae changes with no direct seasonal influence (Weisser & Howard-Williams, 1982).

The commonest and most recent tendency noted within the Wilderness system was a decrease, rather than an increase in the area occupied by submerged macrophytes. Apart from the disappearance of the charophyte beds in Langvlei, there was also a major decline in *Potamogeton pectinatus* stocks in the same lake between 1973 and 1978 (Weisser & Howard-Williams, 1982). At Eilandvlei the *Potamogeton* zone receded by almost 40 m at the south-eastern side of the lake between 1976 and 1978. More recently (1979-1981) there was a complete die-back of submerged aquatic macrophytes in Eilandvlei, partly due to the silt laden waters of the Duiwe River which reduced water transparency within the lake and encouraged phytoplankton development through nutrient enrichment of the water column. The 1981 floods also appeared to have a major impact on the submerged plants of the Touw River. By April 1981 the dense beds of *Potamogeton* opposite the Siesta Caravan Park had completely disappeared and the *Ruppia/Potamogeton* stands above the Lakes Caravan Park were also absent. According to Weisser & Howard-Williams (1982) the high water level that the Lake Areas Development Board has been promoting, the planktonic algal blooms, development of periphyton on submerged plants and uprooting of plants during strong winds may have also been factors causing the submerged macrophyte decrease within the Wilderness lakes.

The Wilderness lakes system is complex and dynamic. The complexity results from the idiosyncrasy of each component of the system and the dynamism from the constant interplay of environmental factors (including man) with the communities present. What in common language have been described as "water weeds" are all natural plants and essential components of the ecological system. The plants may be controlled locally in areas of intense use, but need to be maintained, respected and protected for their basic rôle in supporting life in the Wilderness lakes.

5.2. Floodplain vegetation with particular emphasis on the status of exotic species

The vegetation of the Wilderness floodplain occupies that area between normal water level and the 5 m contour a.m.s.l. (Jacot Guillarmod, 1981). It is sharply divided into two main constituents with minor areas where the natural forest comes below the 5 m contour line.

(a) Semi-aquatic vegetation

This vegetation type is dominated by reeds (*Phragmites australis*), sedges (*Scirpus littoralis* and Cyperaceae generally) and bulrushes (*Typha latifolia*). The rushes (e.g. *Juncus kraussii*) occupy a transitional zone between the semi-aquatic and terrestrial environments, which is inundated only during very high water levels. The above species are all of a similar morphological type, adapted above normal water level to withstand a raised water level without damage and to resist being uprooted by water currents through inter-twined and extensive underground systems (Jacot Guillarmod, 1981).

The semi-aquatic vegetation is also adapted to alternating periods of relative dryness or of excessive water supply and provides a permanent cover for the soil, under a natural regime. However, if the water table were to be permanently altered, this would bring about a change in the species of plants capable of growing on the alluvial soil. Those naturally occurring there at present are sensitive to long-term alterations in water supplies (Jacot Guillarmod, 1981).

(b) Terrestrial vegetation

The well drained sandy soil of the floodplain is the site of typical coastal maccia or fynbos vegetation, including Restionaceae, ericoid-leaved plants such as *Metalasia muricata*, various Compositae (e.g. *Helichrysum* species), *Carpobrotus*, *Delosperma*, *Chironia*, species of *Pelargonium* and other constituents also to be found on the nearby sand dunes. The permeability of the soil and the fact that it is often disturbed by dune moles, means that only deep-rooted plants survive, though there may at some seasons be growth of rapidly maturing annuals (Jacot Guillarmod, 1981).

The fynbos vegetation is also sensitive and cannot easily be restored if it is disturbed. Rapidly growing exotic weeds can enter this vegetation zone and an advance of these was observed by Jacot Guillarmod (1981). Further disturbance of the fynbos may easily lead to greater weed invasion.

The status of exotic species within the Wilderness floodplain has been detailed by Jacot Guillarmod (1979, 1981). According to

Jacot Guillarmod (1979) the herbaceous weeds are not a major problem, since they occur mainly in disturbed areas (e.g. roadsides) and do not penetrate areas of natural vegetation such as reeds, sedges and rushes. There are, however, several exotic tree and woody shrub species which represent a major threat to the indigenous flora of the floodplain and therefore require special attention.

The stinkbean *Albizia lophantha* has become a serious problem in the Wilderness area within the last 10 years (Jacot Guillarmod, 1979). This species is a threat to the reed beds surrounding the lakes as well as the indigenous forests of the area. Seedlings of *Albizia* are capable of setting seed in less than two years and can invade and smother the natural flora within four years.

The rooikrans *Acacia cyclops* is a common constituent of the vegetation on the southern side of the Wilderness system. It grows mainly on new and old sand dunes which are well drained but specimens of this weed have been found in wet soil among the reeds (Jacot Guillarmod, 1979).

Sesbania punicea is a noxious weed which spreads rapidly in moist soils and was found by Jacot Guillarmod (1979) at three localities on the Wilderness floodplain. According to Jacot Guillarmod (1979) *Sesbania* and *Albizia* represent the two most important priorities in a weed eradication programme for the area. Other invasive weeds and eradication methods for all weed species are outlined by Jacot Guillarmod (1979).

According to Jacot Guillarmod (1981) there is a direct relationship between man's presence and the degraded state of the vegetation in many places. As the lakes area depends for its scenic beauty on the mountain background, water bodies and the floodplain flora, a compromise needs to be reached as to how much interference can be allowed without altering the composition of the vegetation. The National Parks Board, which has recently become involved in the management of the floodplain, has a responsibility which is both national and scientific, in preserving the unique scenic and floristic amenities of the area under its jurisdiction.

6. ANIMAL COMMUNITY OF THE LAKES AND FLOODPLAIN

The rôle of the aquatic, semi-aquatic and terrestrial plants in maintaining the diversity and biomass of the animals within the Wilderness system has been mentioned in Section 5.1 and will be enlarged upon below. Aquatic and semi-aquatic vegetation constitute the basis of the food web for the fauna, which are directly or indirectly dependent upon these plants for food, shelter and therefore survival. To destroy the plants, particularly the aquatic macrophytes, is equivalent to narrowing the base of the food pyramid within the Wilderness system and will ultimately lead to an impoverished animal community.

The second factor of vital importance to the aquatic fauna of the Wilderness lakes concerns the maintenance of a link with the marine environment. Evidence will be presented below to show that the zooplankton, macroinvertebrates and fishes are dominated by marine/estuarine species which will largely disappear if salinities decline below 2°/₀₀ and/or the marine link is broken or impaired.

6.1. The zooplankton of the lakes

According to Coetzee (1983) the zooplankton of the Wilderness system supports an estuarine fauna which, during 1976, was dominated by lamellibranch veliger larvae and copepods. The two most important copepod species were *Acartia natalensis* and *Pseudodiaptomus hessei*, both of which have disappeared from nearby Groenvlei (salinity 2-3°/₀₀) because this lake has lost its estuarine connection (Coetzee, 1980).

During periods of high rainfall, freshwater organisms (e.g. cladocerans) are flushed into the Wilderness system and marine zooplankton enter the estuary when it is open to the sea. The largest variety of zooplankton occurs in those areas closest to the estuary mouth but the highest mean daytime numbers were recorded from Eilandvlei (14 641 individuals m^{-3}) and Rondevlei (13 108 individuals m^{-3}). According to Coetzee (1983) Langvlei yielded the highest mean daytime standing crop (17 mg dry mass m^{-3}) for the year, followed by Rondevlei (15 mg m^{-3}) and Eilandvlei (6 mg m^{-3}). At night there was a general upward migration of zooplankton and benthic organisms in the water column, thus increasing the numbers in the surface layers.

6.2. Macroinvertebrates

The aquatic macroinvertebrates of the Wilderness system are almost all estuarine and would largely disappear if the lakes were to become freshwater environments. The dominant marine/estuarine species include the amphipoda *Corophium triaenonyx*, *Grandidierella lignorum* and *Melita zeylanica*, isopoda *Exosphaeroma hylecoetes* and *Cyathura estuaria*, bivalve *Musculus virgiliae*, polychaete *Ficopomatus enigmatica*, crab *Hymenosoma orbiculare* and prawn *Callianassa kraussi*. The Chironomidae were the most important freshwater/ estuarine component, and all the above invertebrates feed predominantly on detritus (particulate organic matter and associated microorganisms) which is derived from the Wilderness catchments, floodplain, lakes and sea. The submerged plants *Potamogeton*, *Ruppia* and Characeae produce 334 tonnes of organic matter per annum (Table 6), most of which will enter the detritus food web via the particulate feeding invertebrates.

Table 7 shows that most of the zoobenthos occurs on submerged aquatic plants such as *Potamogeton*. Weed cutting conducted by the Lakes Area Development Board in the Serpentine during 1979 caused a complete collapse of invertebrate stocks in this area (Davies, 1981). The die-back of the *Potamogeton* beds in Eilandvlei during 1979/80 also resulted in a major decline in the epifauna of this lake from 297 g dry mass m^{-2} in May 1979 to 23 g dry mass m^{-2} in May 1980 (Davies, 1981).

Apart from their rôle as detritus producers, submerged plants also act as attachment sites for suspension feeding invertebrates such as *Musculus* and *Ficopomatus*. Davies (1981) found that emergent macrophytes in the Wilderness Lagoon and Langvlei do not support a large zoobenthos population (<1 g dry mass m^{-2}). However, these plants are important because they produce 83% of the organic material in the Wilderness system (Table 6). Only a portion of the 1620 tonnes per annum produced by the emergent macrophytes enters the lakes as detritus, but the importance of these plants to the aquatic macroinvertebrates cannot be overemphasized because of their

Table 7. The mean biomass of macroinvertebrates from the Wilderness lakes system between January 1979 and June 1980 (after Davies, 1981).

Locality		Invertebrate biomass (g dry mass m^{-2}) Sediments	Potamogeton
Wilderness Lagoon		19,2	-
Lower Touw River		13,0	128,9
Western Serpentine		4,3	91,0
Eastern Serpentine		4,6	35,7
Eilandvlei		5,9	54,8
Langvlei (inshore)		9,9	-
Langvlei (offshore)		14,7	-
Rondevlei (inshore)		19,5	-
Rondevlei (offshore)		23,5	-
Wilderness System	Mean	12,7	77,6

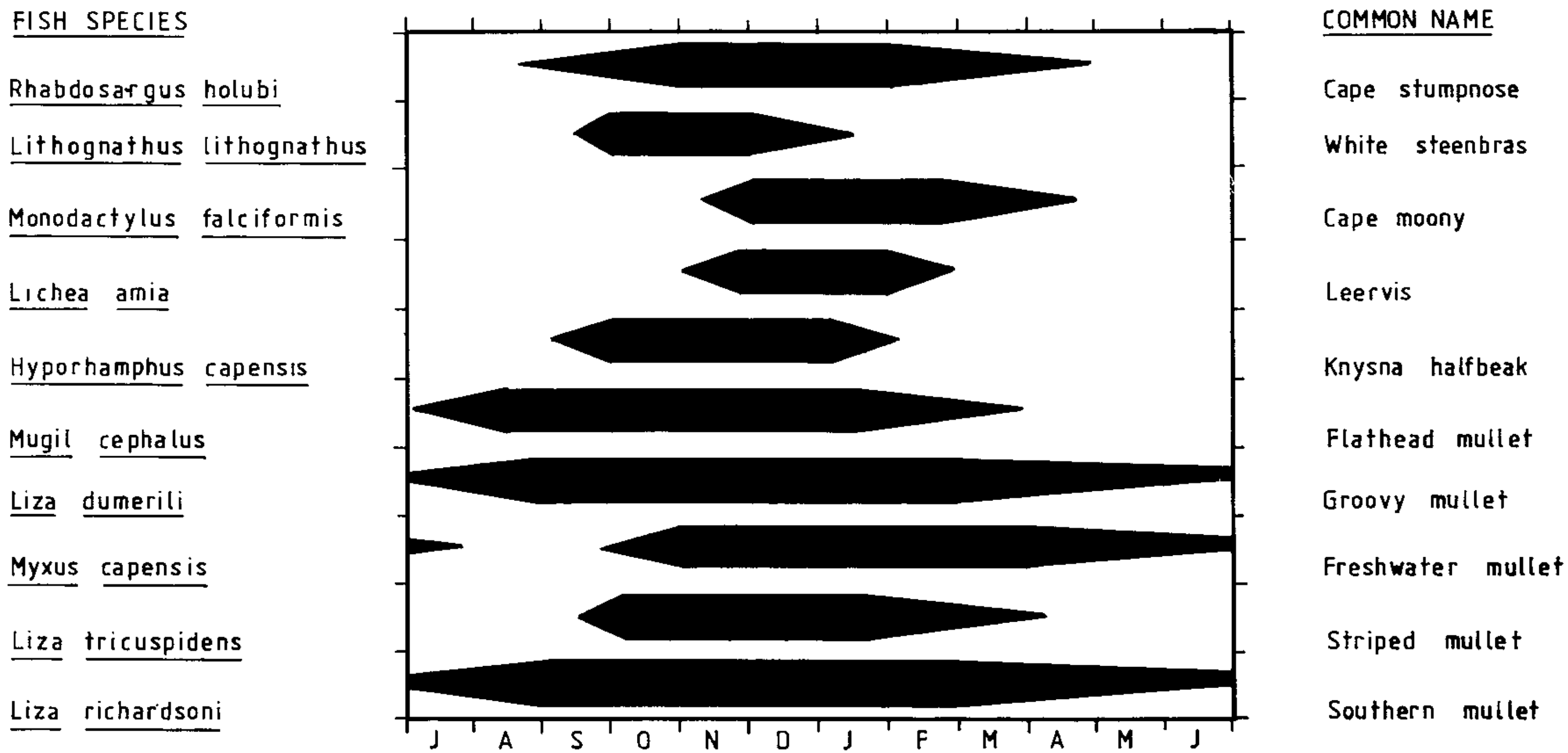

Figure 3. Juvenile recruitment periods of the dominant marine/estuarine fish species into the Wilderness lakes system (Kok, pers. comm.).

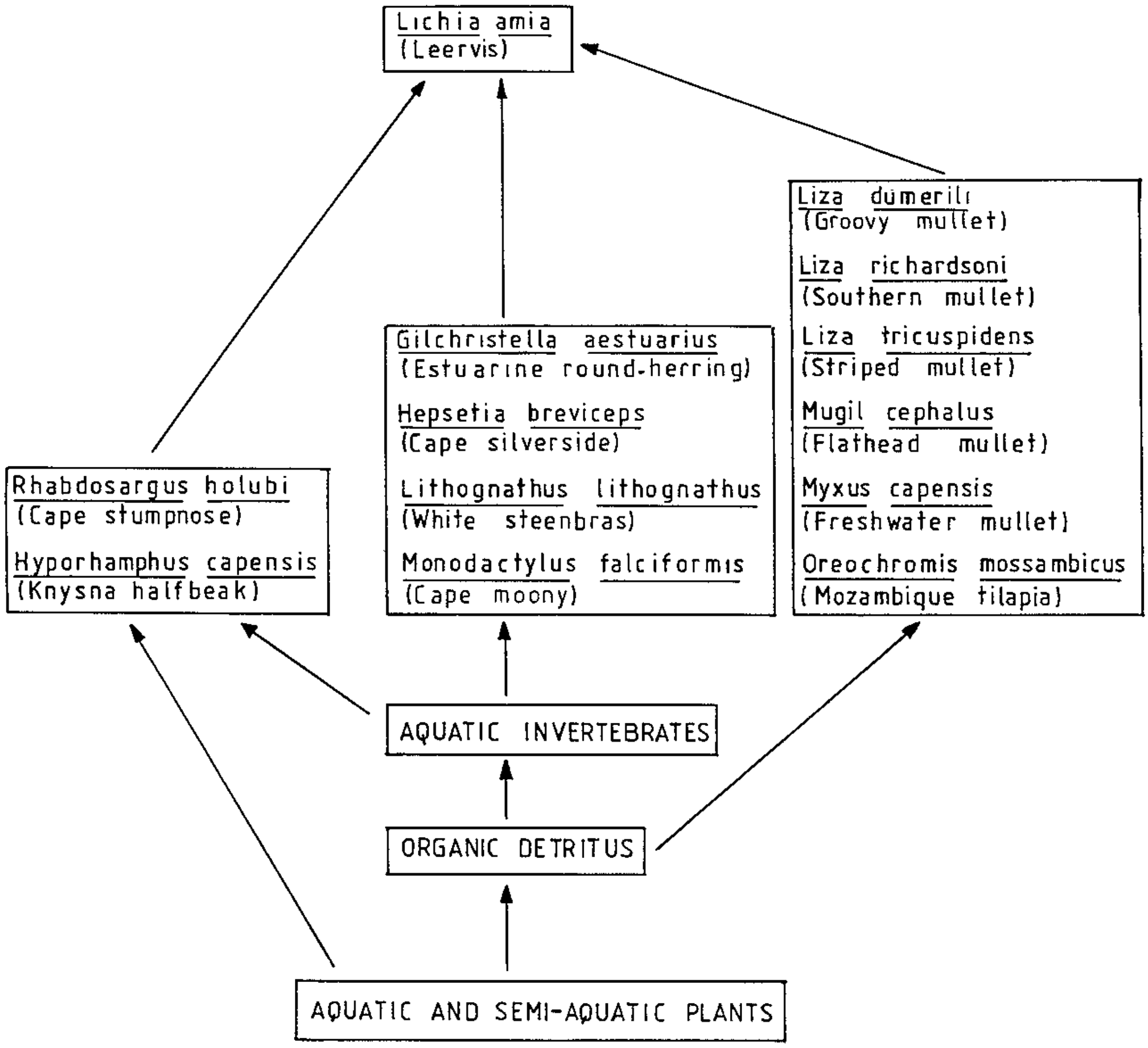

Figure 4. Simplified food web of the dominant fishes of the Wilderness lakes showing the main energy pathways.

high organic production. Fluctuating lake levels, which generate water movements between the reedbeds and lakes, will facilitate a greater input of detritus into the aquatic environment than a constant artificially maintained water level.

6.3. The dominant fish fauna

The fishes of the Wilderness lakes, prior to the construction of the Serpentine sluice, were dominated by marine/estuarine species (Table 8) which enter the estuary from the sea as small juveniles. The recruitment periods of the above species along the Cape south coast are shown in Figure 3 and indicate that the immigration occurs mainly during summer (October-March). Once a juvenile fish (1-3 cm standard length) enters the Wilderness Lagoon, it migrates against the outflowing water until it reaches the upper lakes.

Residence time in the various lakes varies according to the fish species growth cycle and waterdepth of the interconnecting channels. In a permanently open estuary (e.g. Knysna) juveniles normally migrate back to the sea with the onset of adolescence, which often occurs at an age of 1-2 years. These sub-adult fish then inhabit marine inshore areas where they join adult spawning populations once they mature.

Between 1972-1975 Rondevlei was isolated from the rest of the system because of drought conditions which virtually dried up the Rondevlei/Langvlei Channel. During this period marine/estuarine species such as *Mugil cephalus*, *Liza richardsoni* and *Rhabdosargus holubi* were unable to return to the sea and became adults within Rondevlei. The mean standard length of *Mugil cephalus* increased from 275 mm in 1972 to 474 mm in 1975 (van Wyk, 1977). Despite the fact that the Rondevlei *M. cephalus* in 1975 were estimated by van Wyk (1977) to be 5+ years old, no breeding of this or any other marine/estuarine species was recorded. If the Rondevlei/Langvlei Channel had not been mechanically reopened in August 1975, all marine/estuarine fishes would have eventually disappeared from Rondevlei because the marine link had been broken.

The estuarine and freshwater fishes shown in Table 8 are not dependent on a marine connection because these species are able to complete their entire life cycle within the system. Groenvlei, a coastal lake to the east of Rondevlei, was dominated by *Gilchristella aestuarius* and *Hepsetia breviceps* prior to the introduction of exotic angling species. All marine/estuarine fishes disappeared from Groenvlei when the lake lost its sea link and a similar situation would occur in the Wilderness system if the immigration of juvenile marine species was prevented.

All marine/estuarine species are able to tolerate salinity fluctuations but salinities below 2°/₀₀ are lethal to many fishes if they occur in conjunction with low temperatures (Whitfield *et al.*, 1981). In recent years the salinities of both Langvlei and Eilandvlei have declined below 5°/₀₀ due to heavy rains. If the saline input into Eilandvlei during the tidal phase of the estuary is prevented by the Serpentine sluice, then salinities within this lake will continue to decline and winter fish kills will become a regular occurrence.

Figure 4 illustrates the importance of the aquatic and semi-aquatic plants in providing food for the fishes of the Wilderness system.

Table 8. The dominant fish species in the Wilderness lakes system prior to the construction and operation of the Serpentine sluice gate (data from van Wyk, 1977; Ratte, pers. comm.).

Family	Species	Common Name	Marine/Estuarine	Estuarine	Freshwater
Carangidae:	Lichia amia	Leervis	+		
Cichlidae:	Oreochromis mossambicus	Mozambique tilapia			+
Hemirhamphidae:	Hyporhamphus capensis	Knysna halfbeak	+		
Monodactylidae:	Monodactylus falciformis	Cape moony	+		
Mugilidae:	Liza dumerili	Groovy mullet	+		
	Liza richardsoni	Southern mullet	+		
	Liza tricuspidens	Striped mullet	+		
	Mugil cephalus	Flathead mullet	+		
	Myxus capensis	Freshwater mullet	+		
Sparidae:	Lithognathus lithognathus	White steenbras	+		
	Rhabdosargus holubi	Cape stumpnose	+		
Sphyraenidae:	Hepsetia breviceps	Cape silverside		+	
Stolephoridae:	Gilchristella aestuarius	Estuarine round-herring		+	
			10 (77%)	2 (15%)	1 (8%)

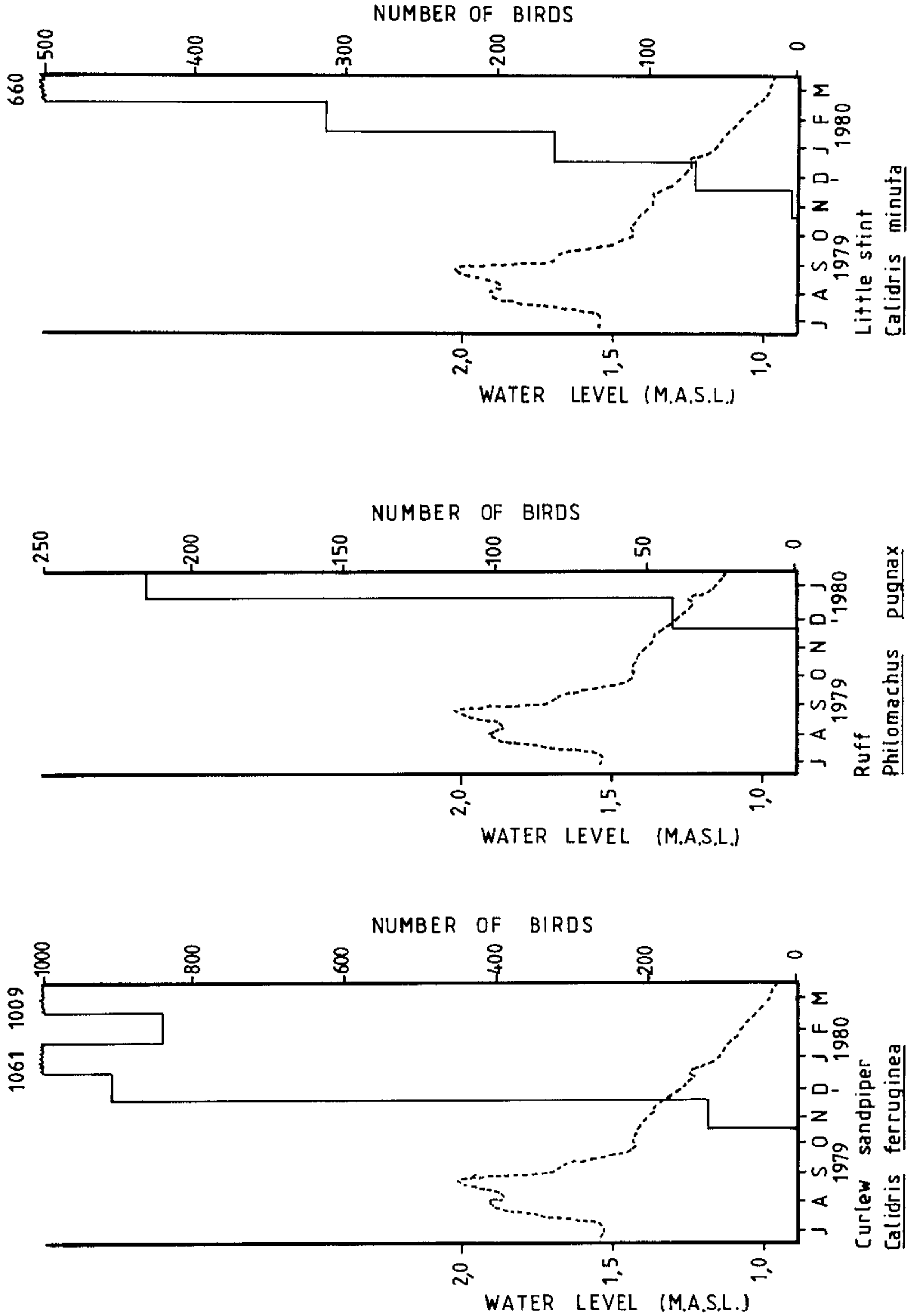

Figure 5. The occurrence of three species of Palearctic waters at Rondevlei during the pre-sluice phase, indicating the relationship between lake water level, season and numbers of birds (Boshoff, pers. comm.).

The mullet species and tilapia feed directly on the decomposed plant material (detritus) and therefore by-pass the invertebrate step in the food chain. All other species are dependent on aquatic invertebrates (zoobenthos and zooplankton), with the Cape stumpnose and Kynsna halfbeak also feeding directly on aquatic plants. The top predator in the food web (excluding piscivorous birds and man) is the leervis which feeds on juvenile fish of all species and the adults of the estuarine round-herring and Cape silverside.

6.4. Avifauna

According to Boshoff & Palmer (1981) the Wilderness lakes are one of the most important wetland areas in the Cape Province, in terms of permanently available habitat for waterbirds. The system is an important site for both Palearctic migrant waders, southern African waterfowl undergoing moult migrations and it supports large populations of herbivorous and piscivorous birds. The Wilderness lakes also provide a refuge and food supply for seabirds during adverse weather conditions off the southern Cape coast.

The importance of Langvlei as a rich waterbird area has been stressed by Underhill *et al.* (1980) and Boshoff & Palmer (1981). During a December 1978 survey, Underhill *et al.* (1980) recorded 2 061 duck of nine species, which represented the largest concentration of Anatidae (ducks and geese) along the southern and eastern Cape coasts. Boshoff & Palmer (1981) counted as many as 65 species of waterbirds at Langvlei, comprising more than 7 000 individuals. Four rare and endangered bird species have been recorded from the lake and as a result of the above evidence, the Cape Department of Nature and Environmental Conservation (CDNEC) has recommended that Langvlei be listed in terms of the Ramsar Convention as a 'Wetland of International Importance'.

According to Boshoff & Palmer (1981) Langvlei forms an important ornithological unit with nearby Rondevlei, as there is a constant interchange of waterbirds between the two lakes. Consequently Rondevlei has also been proposed by the CDNEC for listing under the Ramsar Convention.

Observations by Boshoff & Palmer (1981) indicate distinct trends in the utilization of the various lakes by both resident and migrant bird species. For example, the piscivorous group shows marked preferences for particular lakes at certain times of the year. Similarly the migrant (Palearctic) waders use the exposed beaches and littoral zone of the lakes as roosting and feeding sites during the summer (Figure 5). If the Wilderness lakes were prevented from draining during late spring/early summer, when the mouth was open, this would have a deleterious impact on the wader populations in the area.

According to Boshoff & Palmer (1981) the peripheral vegetation of the lakes forms the breeding and foraging habitat for several species of waterbirds. In addition two rare (South African Red Data Book) and habitat sensitive species, viz. African Marsh Harrier *Circus ranivorus* and Grass Owl *Tyto capensis*, exclusively utilize this zone. Thus any management policy which involves the removal of this vegetation, either by bushcutting or burning, will be deleterious to the bird community of this particular habitat. Boshoff & Palmer (1981) also stress that the peripheral vegetation is a major source of detritus for the various food chains which, in most cases, culminate with the waterbirds. Thus if the vegetation is not kept in a healthy state, the productivity of the system will deteriorate through time, and this will be reflected by a decline in the bird populations (Boshoff & Palmer, 1981).

6.5. The small mammals

The rodents and shrews of the Wilderness system have been investigated by Palmer (1979) who found four species which utilize the floodplain (Table 9). All species were most abundant in the low lying vegetation surrounding the lakes and channels where adequate food and cover were readily available. The vlei rat (*Otomys irroratus*) is the dominant prey item of the grass owl (*Tyto capensis*) which is listed by the South African Red Data Book on birds as rare. Elevated water levels cause the small mammals, including the vlei rat, to vacate the buffalo grass (*Stenotaphrum secundatum*) zone and forces them into the elevated fynbos habitat where both food and cover are limited. Prolonged high lake levels would result in increased predation by raptors and carnivorous mammals, together with artifically high densities of shrews and rodents in a habitat unable to support these populations for extended periods (Palmer, pers. comm.).

Table 9. Small mammals trapped along the Serpentine during April 1979 using 20 traps per night (Palmer, pers. comm.).

		Number of individuals trapped per four trap nights	
Species	Common name	Lower floodplain (Buffalo grass)	Upper floodplain (Fynbos)
Otomys irroratus	Vlei rat	9	1
Rhabdomys pumilio	Striped mouse	7	2
Crocidura flavescens	Red musk shrew	2	1
Myosorex varius	Forest shrew	1	0

7. THE HUMAN ACTIVITY AND ITS IMPACT UPON THE FLOODPLAIN

Human activities in the region to date have depended closely upon the resources of the floodplain and its adjacent areas. Gasson (1981) has dealt in detail with the utilization of these resources, and the following sections are derived from his synthesis.

The littoral is an area of spectacular and diversified coastline backed in parts (Wilderness and Plettenberg Bay) by dunes and dune cordons that enclose estuaries, lakes and their surrounding wetlands. Relatively constant river flow and direct rainfall recharge the surface water bodies and the more extensive ground-water bodies below. Poor sandy soils in the presence of a hot and dry climate support scrub and scrub-forest vegetation. All of these factors create a wider range of aquatic and terrestrial habitats than is found anywhere else in the region: marine, intertidal and estuarine; lake, wetland and river; dune and plateau.

This very diversity is simultaneously both an asset and a liability, for it makes possible a wide variety of recreational experiences, but by the same token generates increasing demands for them.

The presence of the four main resort settlements on the one hand and the numerous extensive nature reserves on the other reflects something of the ambivalence of human beings to their environment in this area : transformation versus conservation - which in essence describes the challenge presented in this area and suggests a careful, sensitive and graded allocation of human activities to those areas intrinsically suited to them and away from unsuitable areas.

The "development" concept for the littoral area is therefore one of marriage, a mutually enhancing symbiosis, between recreation/tourism on the one hand and conservation on the other. At certain levels of intensity these two activities are incompatible with one another so the concept should incorporate the idea of a gradient of intensities, ranging between areas given over entirely to tourism/recreation or entirely to conservation with a variety of areas of mixed recreation-conservation intensity between. Agriculture and forestry are not excluded as components of the concept but the generally low potential of the area suggests that they do not share equal importance with recreation and conservation.

The lower plateau is a dissected landscape, characterised by level top-slopes but steep sides that drop suddenly down to deeply incised river beds - which are the area's most important scenic assets. These characteristics hold at the cliffed coastline and along the landward edge of the littoral embayments and create very rapid vertical and horizontal transitions from the lower physiographic region to this one and within the plateau region itself. Potentially magnificant viewpoints exist at the point of slope transition. Habitat diversity is narrower than in the littoral but significant nevertheless.

The essential personalities of the area vary from the rurality of the cultivated agricultural areas to the wilderness nature of the indigenous forests and deep ravines and valleys.

The "development" concept for the area is an extension of the activities already present there. For obvious reasons, agriculture and forestry with related settlements remain the major activities but their expansion is limited by the fixed amount of land available and upper limits to yields per unit of that land. Conservation is implicit and explicit in the forestry programmes in general and in the indigenous areas in particular. Recreation is not ruled out but is relatively less important than in the littoral and is geared mainly to scenic driving and viewing, walking and picnicking.

The upper parts of the upper plateau together with the mountains are poorer, harsher areas than the lower plateau. The thin, stony Mispah and Glenrosa soils together with steep slopes and a cold wet climate sustain the wet high and scrub forests. This is an alpine area deriving its personality from a combination of forest and heathland set against the background of the Outeniquas. High vantage points offer views over the plateau down to the littoral 10-30 kms away. The "development" concept here consists of a mixture of forestry, water catchment management and low intensity wilderness recreation.

The central theme of the overarching concept when viewing the region from west to east and south to north is therefore one of rhythms and gradients in the intensity of human use of its parts. There is nothing particularly startling in this idea. It simply draws directly from the patterns of intrinsic suitabilities of the identifiable natural conditions, in combination with the human responses, and projects them farther into time and across space. The precise nature, location, intensity, integration/separation of particular uses in specific areas depends upon finer grain appreciation at smaller scales.

For the regional economy as a whole in the future, recreation and tourism are likely to become increasingly important. According to the evidence available, it is in the littoral that the greatest potentials and the greatest pressures for such development will be felt. It is here, too, for the same reasons of resource diversity that nature conservation is, and will become, increasingly important. The challenge is therefore one of development/transformation for human purposes within a necessary context of conservation - necessary in order to ensure that the resources and environmental qualities that draw people there in the first place will always be maintained for future generations.

This has important implications for the Wilderness Lakes Area which is a particularly well-endowed part of the region. In this region resort settlement has developed in V-formation eastwards from the original farm running, on the one hand, along the plateau slope capitalising on water access and views but compromising on comfort and construction costs. On the other hand, it runs along the dune where the narrowness and low elevation optimises water access to both sides and in certain instances relatively sheltered warmer north-facing slopes. Future expansion is projected eastward onto the higher wider parts of the dune. Recreation facilities - hotels, camping, picnicking, boat launching - are all concentrated in this general area including and west of Eilandvlei.

The transport network is well developed and its configuration which is concordant with the grain of the landscape, is basically that of a grid which provides high degrees of accessibility in the local area. It is differentiated according to role with the national road being the one of highest relative standard and greatest capacity carrying both local and through traffic. The lakes road along the foot of the plateau slope and the north-south connections across the lake corridor to the N2 vary in width, sinuosity and surface quality. The proposed new national road will be discussed later.

Nature reserve status exists in the Touw River valley upstream of the plateau face (Ebb and Flow) and at Rondevlei. Agriculture and forestry occur in patches, and the remaining surface area is under indigenous scrub and scrub-forest as well as exotic species.

Gasson, in the same chapter of the 1981 report on the Touw River floodplain, has rightly emphasised the threats to which the littoral is exposed. He argues that apart from the threats derived from storm and flow, the principal agent of environmental disturbance is man himself. A first threat lies in settlement expansion based upon traditional coastal township layout which mirrors suburban development in the city. In other words the one-house one-plot low density sprawling form of land conversion is transferred to the

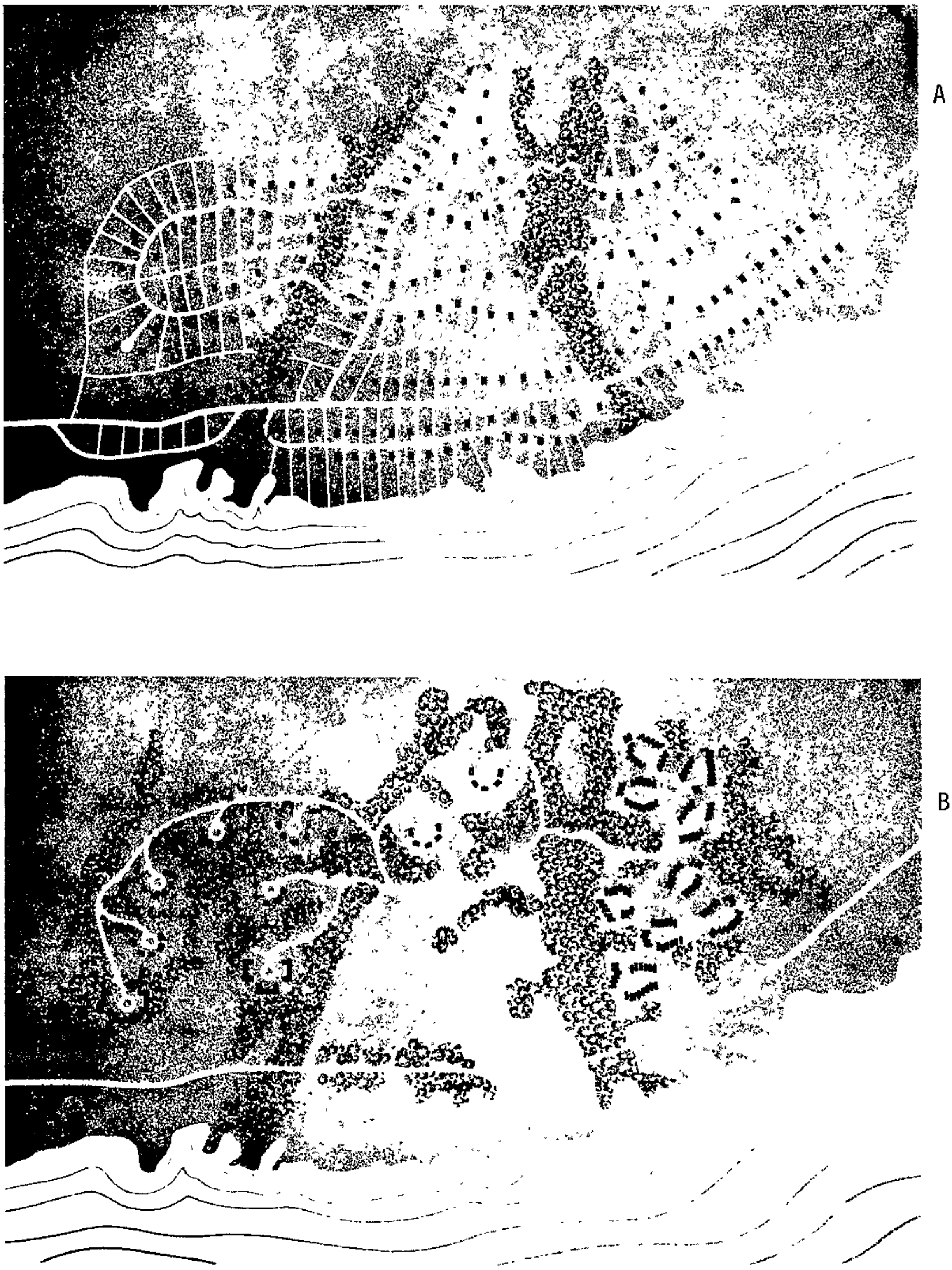

Figure 6. Contrasting patterns of coastal housing development. The pattern adopted in B is sensitive to the environment while allowing the same number of families to be accommodated as in A. From Outdoor Recreation Review Commission : Action for outdoor recreation for America, Washington, D.C., 1964, p. 20.

coast, or other recreational areas, creating coastal suburbs which are costlier to service and more indiscriminate in the use of scarce and sensitive environments than higher density clustered forms of housing which can aid in environmental conservation if sensitively planned from the outset. This possibility exists at Wilderness (and in different form in all other resorts along the South African coastline) with the proposed eastward expansion along the dune, which expansion brings no advantage to the recreationist and disadvantages to the rest of Wilderness for reasons mentioned earlier. The adoption of a new form for new areas and as a modification to existing areas still in an early stage of development implies, on the one hand, an extremely sensitive approach to land development (Figure 6). On the other hand, new approaches must be sought to the rights of individuals to develop their land. This brings in such important ideas as land banking by the local authorities or public bodies, or the transfer of development rights from owners in no-go areas to those in permissible development areas. These are being used overseas to grapple with the same problems (Strong, 1979; Rose 1975).

The second threat is the proposed national road which is problematic throughout the Garden Route area, and which, if constructed as originally proposed, would have devastating consequences for the Wildnerness Lakes Area. The visual and functional unity of the lakes corridor has already been stressed and the concepts of west-east and south-north gradients are believed to be realistic as over-arching concepts to guide recreational and tourist development here.

The alignment of the proposed road may well clash in every respect with this concept, although hopefully more recent decisions regarding the positioning of the highway have taken cognisance of the functional unity of the west-east and south-north gradients.

8. OVERALL SUMMARY AND RECOMMENDATIONS

In view of the complex nature of this floodplain, the recommendations which follow are grouped according to the principal components of which the floodplain, from a management viewpoint, is deemed to consist. The interaction between these components results in the floodplain as it exists today, and any major disturbance of any one component will result in changes (often deleterious) in the others, to the detriment of the ecosystem unit - the floodplain.

8.1. The primary concern of all management actions within the floodplain should be to improve water exchange wherever possible. Throughout the past 7 000 years there has been a slow segmentation of the coastal wetlands on the south coast. This has the effect of reducing water flow between what were originally contiguous bodies of water. We have, during the past 700 years increased the rate at which this process occurs. The consequence of this is that we see the need to maintain water exchange as a direct means of reversing this inevitable process of segmentation and infilling.

8.2. To effect improvement in water exchange, it is recommended that the channel between Langvlei and Rondevlei be dredged to 0.0 m MSL. Once this has been done, control of water level in Langvlei during periods when there is a net loss from the whole system, will require a sluice gate to provide a measure of water level control.

Associated with this development, and to provide some measure of flood control for floods of 1 in 50 year magnitude, it is required that the sand sill at the mouth of the estuary be kept at between 2.1-2.4 m MSL - refer to pages 4 and 6.

8.3. Due largely to the self purification role of the wetlands of this floodplain, the chemical quality of its lakes and channels is good. This role should not be impaired in any way. At no time have the nutrient elements of nitrogen and phosphorus reached levels of concentration (>30 $\mu g \ell^{-1}$ $PO_4(P)$ and 400 $\mu g \ell^{-1}$ $NO_3(N)$) which would give rise to algal blooms. The bacterial quality does, however, seem to be in doubt - but definitive evidence is not as yet available. Of more serious concern are suspensoids carried into the system by floods down the Duiwe River and to a lesser degree the Touw River. The lakes of the floodplain mirror the changes in the catchments of their influent rivers. The evidence so far available emphasises the importance of wise landuse in these catchments, particularly those montane portions which are being developed as afforestation areas - refer to pages 7-13.

8.4. The plant community structure is diverse and typical of coastal river floodplains. This floodplain remains one of the few left in South Africa in reasonable ecological condition, and should be retained in this condition. Encroachment has been contained to some degree but real fears have been expressed by the plant ecologists in the Working Group about the effect upgrading of the existing coastal road will have upon this fragile structure - refer to pages 13-18.

8.5. The fauna of the floodplain is diverse and the animal ecologists in the Working Group have reported in detail upon the structure and sensitivity of the three major faunal components: the macroinvertebrates of the sediments and open water, the fish which feed upon these rich resources and the birds which depend upon both fish and invertebrates as food. Consequently good water exchange is required at least during the spring and early summer when fish stocks are replenished from the sea, so demanding management of the estuary mouth at these crucial times. In effect this means ensuring that the mouth is open during these periods, which has the important derivative of allowing the upper floodplain to drain, exposing the shallow sand banks on which the migratory waders feed. More detailed commentary is given on pages 19-27.

8.6. All major anthropogenic activity must take into account the gradients of development which have developed over the years. There exists a quasinatural zonation in the floodplain at present, with human occupancy increasing westward. It is recommended that such occupancy of the floodplain and its associated periphery be restricted to the Wilderness area. By so doing the zonal axis of the system will be reinforced and maintained - refer to pages 27-31.

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