THE PEEL-HARVEY ESTUARINE SYSTEM STUDY (1976 - 1980)

TECHNICAL REPORT

NUTRIENT RELATIONS OF THE FRINGING WETLANDS

AUGUST 1980

T.W. Rose and A.J. McComb

DEPARTMENT OF CONSERVATION AND ENVIRONMENT
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A TECHNICAL REPORT to

THE PEEL-HARVEY ESTUARINE SYSTEM STUDY (1976-1980)

NUTRIENT RELATIONS OF THE WETLANDS FRINGING THE PEEL-HARVEY ESTUARINE SYSTEM

by

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PUBLICATIONS:
THE PEEL-HARVEY ESTUARINE SYSTEM STUDY (1976-1980)

This report is one of 14 technical reports that were presented to the Environmental Protection Authority's Estuarine and Marine Advisory Committee as part of the Peel-Harvey Estuarine System Study (1976-1980).

The publications arising from the study are listed below and are available from the Department of Conservation and Environment, 1 Mount Street, Perth WA 6000.

- The Peel-Harvey Estuarine System Study (1976-1980). A report to the Estuarine & Marine Advisory Committee December 1980. E.P. Hodgkin, P.B. Birch, R.E. Black, and R.B. Humphries, Department of Conservation and Environment, Report No. 9.
- The Peel-Harvey Estuarine System Study. A report by the Estuarine and Marine Advisory Committee to the Environmental Protection Authority, March 1981. Department of Conservation and Environment, Bulletin No. 88.

TECHNICAL REPORTS

BULLETIN No.

89 The Peel Inlet and Harvey Estuary System Hydrology and Meteorology. R.E. Black and J.E. Rosher. June 1980.

90 Sediments and Organic Detritus in the Peel-Harvey Estuarine System. R.G. Brown, J.M. Treloar and P.M. Clifton. August 1980.

91 The Ecology of *Cladophora* in the Peel-Harvey Estuarine System. D.M. Gordon, P.B. Birch and A.J. McComb. 1981.

92 The Decomposition of *Cladophora*. J.O. Gabrielson, P.B. Birch and K.S. Hamel. October 1980.

93 The Control of Phytoplankton Populations in the Peel-Harvey Estuarine System. R.J. Lukatelich and A.J. McComb. 1981.

94 Cyanobacteria and Nitrogen Fixation in the Peel-Harvey Estuarine System. A.L. Huber. October 1980.

95 Phosphatase Activities in the Peel-Harvey Estuarine System. A.L. Huber. October 1980.

96 The Sediment Contribution to Nutrient Cycling in the Peel-Harvey Estuarine System. J.O. Gabrielson. 1981.

97 Aspects of the Biology of Molluscs in the Peel-Harvey Estuarine System, Western Australia. F.E. Wells, T.J. Threlfall and B.R. Wilson. June 1980.

98 The Fish and Crab Fauna of the Peel-Harvey Estuarine System in Relation to the Presence of *Cladophora*. I.C. Potter, R.C.J. Lenanton, N. Loneragan, P. Chrystal, N. Caputi and C. Grant. 1981.

99 Phosphorus Export from Coastal Plain Catchments into the Peel-Harvey Estuarine System, Western Australia. P.B. Birch. October 1980.

100 Systems Analysis of an Estuary. R.B. Humphries, P.C. Young and T. Beer. 1981.

101 Peel-Harvey Nutrient Budget. R.B. Humphries and R.E. Black. October 1980.

102 Nutrient Relations of the Wetlands Fringing the Peel-Harvey Estuarine System. T.W. Rose and A.J. McComb. August 1980.

CONTENTS

CHAPTER 1

EXTENT AND NATURE OF THE FRINGING MARSHES

1.1 INTRODUCTION

Wetlands are important for a number of reasons, and can be evaluated in as many ways - for example, their role as bird habitats, in stabilizing shorelines, as scenic attractions, and in nutrient exchange and primary productivity. This study is concerned with one aspect, the possibility that the fringing wetlands of the Peel-Harvey Estuarine System are important to the nutrient relations of the open water. It is therefore concerned with the general extent of the vegetation, with its approximate nitrogen and phosphorus content, and by using published data, with providing some estimate of the rate at which the nutrients may 'turn over' each year as plants grow and senesce. Attention is also given to the frequency with which these fringing marshes are flooded, as such inundation would provide an important mechanism for nutrient exchange with the open water.

Backshall (1977) examined the peripheral vegetation of the Peel-Harvey system, including the fringing marshes dealt with here, using a phtyosociological approach of the Braun-Blanquet type. The vegetation units he obtained were then ordinated using Principal Axes Ordination, and the ordination overlayed with environmental data. From this analysis he concluded that changes in salinity, elevation and soil profile development most clearly accounted for gradient trends. The work described below does not attempt to extend Backshall's observations on species associations and their relationships with environmental variables, but is concerned with grosser aspects of the amount of marsh vegetation and the nutrients which it may contain and exchange.

1.2 MATERIALS AND METHODS

(a) The General Extent of the Wetlands

This was determined using colour aerial photographs, which were examined for changes in elevation and vegetation type. A map was produced and checked by ground inspection, particularly where the larger areas of marsh were concerned. The extent of the marsh vegetation was also examined for Goegerup Lakes.

(b) Floristics

Throughout the study specimens were collected and pressed. Identification was performed using the University of Western Australia Herbarium, and Blackall and Grieve (1974). Voucher specimens of many of the more common plants have been lodged with the University of Western Australia Herbarium.

1.3 RESULTS AND DISCUSSION

(a) Area and Distribution of Marsh

The extent of the marshes is summarised in Fig. 1.1. From this and more detailed inspections of aerial photographs, the area of the wetlands likely to be involved was calculated to be 12.8 km^2. This can be compared with the surface area of the open water of the estuary, 115 km^2. If we consider the marshes and open water as an integrated system (total area 128 km^2), the marshes represent 10% of the whole.

(b) Composition of Marsh Vegetation

A comprehensive list of species is presented by Backshall (1977). The present study commenced after the major flowering season, and there are no additions to be made to Backshall's list.

The vegetation consists of a complex mosaic which cannot be sensibly described in detail without resorting to a phyto-sociological analysis of the type used by Backshall (1977), concerned with the suites of species which most commonly occur together. Nevertheless, we can point out some major components:

(i) *Sarcocornia* marsh: This is the most extensive type of marsh, and is dominated by *Sarcocornia blackiana*. (The generic name *Salicornia* has been used in the past, but the taxonomy has recently been revised by Wilson, 1980).

It occurs in most localities where relief is low. Where it occurs away from the waters edge, the lowest areas, which often have salt crystals on the soil surface, are dominated by Arthrocnemum halocnemoides. Closer to the waters edge Atriplex paludosa and Suaeda australis are found in association with the Sarcocornia. The most extensive areas of Sarcocornia marsh occur along the eastern edge of the Peel Inlet between Fauntleroy and Greenlands Drains, and at the southern end of the Harvey Estuary.

(ii) Scirpus maritimus: Scirpus maritimus grows in many places along the eastern shores of the Peel-Harvey system. There is usually only a thin zone, possibly attributable to recent invasion by water-borne corms. There are large Scirpus maritimus meadows at the southern end of the Harvey Estuary, which extend from the present waterline to the extensive Sarcocornia marshes behind, and appear to cover an area once dominated by Juncus kraussii. Some very small islands, close to the waters edge, are still dominated by J. kraussii in this area.

(iii) Juncus kraussii: Pure strands of J. kraussii do not occur as extensive meadows. There are small meadows of this species near the Yunderup Canals, just south of Boggy Bay and in other places along the south-eastern

Harvey estuary. *J. kraussii* occurs with a patchy distribution around most of the estuary, often as a thin discontinuous zone which is only three or four clumps wide.

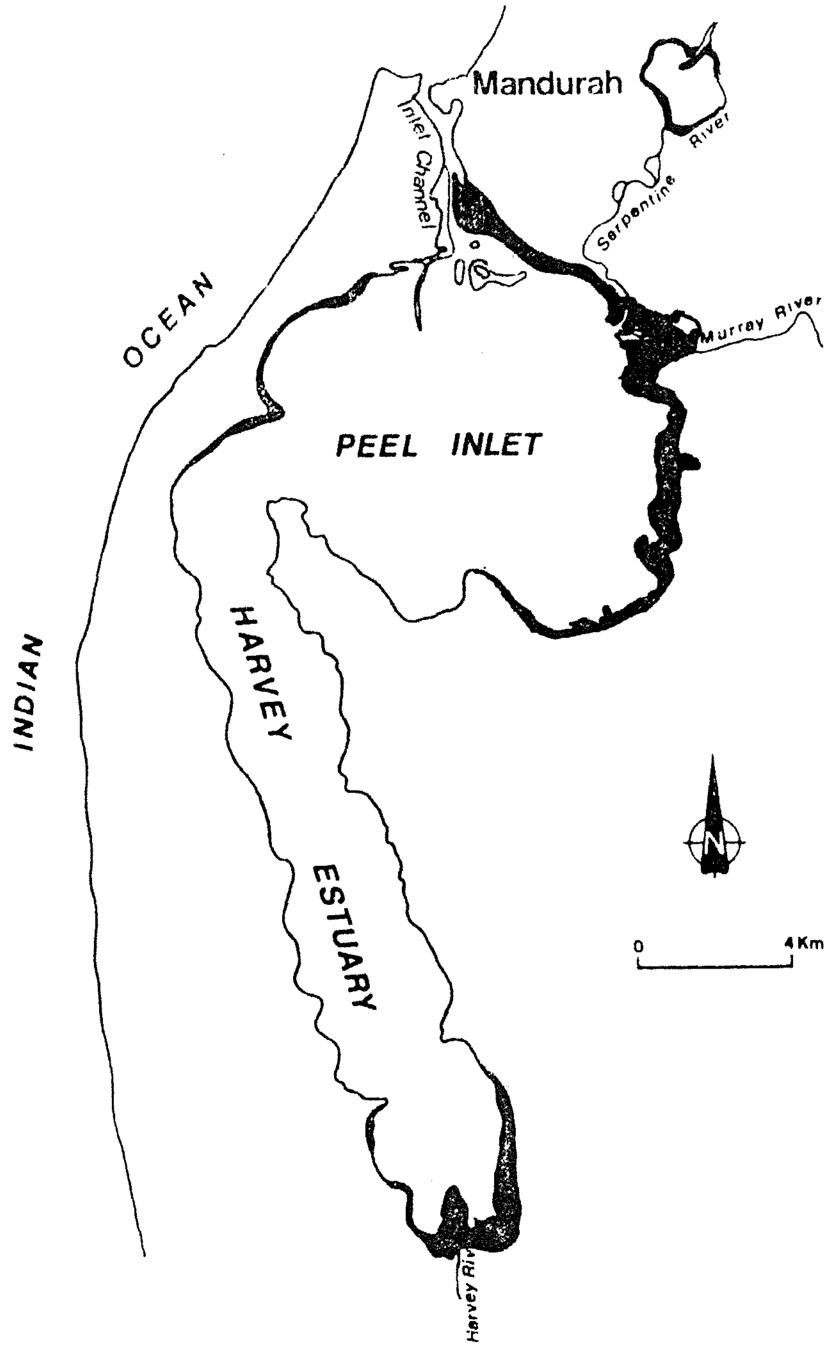


Figure 1.1 Marsh vegetation of the Peel-Harvey System.

Much of the waters edge carries a thin fringe of marsh; more extensive areas are shown in black.

CHAPTER 2

INUNDATION OF THE FRINGING MARSHES

2.1 INTRODUCTION

Tides at Fremantle have a daily range of only about 1 m, and the extreme range of sea level is about 1.3 m. Because of barometric effects, the mean monthly sea level is about 0.3 m higher in winter than in summer, though there is a large variation from year to year (Hodgkin and Di Lollo, 1956). Within the Peel-Harvey estuary the amplitude of the tides is damped because of the restriction on water flow exerted by the narrow inlet channel, so that much of the observed changes in water level are due to barometric effects coupled on occasions with river flow.

A study of tides is being carried out as part of the main Peel-Harvey project, and so the opportunity was afforded to work out the frequency with which fringing marshes may be inundated.

2.2 MATERIALS AND METHODS

(a) Transects

The vegetation was recorded along several transect lines (Fig. 2.1) placed through marsh vegetation, and levels taken with a theodolite ane staff. It was possible to work out the absolute elevation of one of these transect lines with reasonable precision, using the Public Works Department bench mark BM A901 (1.717 m above the Mandurah tide gauge 0.0 m).

This elevation was transferred to an area between the Greenlands and Fauntleroy Drains (Roberts Bay), using a theodolite and two depths gauges measured simultaneously by two observers.

In this way elevation transects taken in the region of Roberts Bay were calibrated against the Mandurah tide gauge. Other transects were documented but these could not be related exactly to the Mandurah level. These transects were, however, taken on the same day, within 6 hours of that at Roberts Bay, with which they were therefore related in an approximate manner.

(b) Tide Information

The proportion of the year during which particular points would be inundated was provided by Mr. D. Wallace, Public Works Department (Fig. 2.2). The data were for several sites in the estuary, and were for the year 1979.

2.3 RESULTS AND DISCUSSION

Transect lines are shown in Fig. 2.3 which illustrates some typical areas of vegetation; one may note the *Sarcocornia* marsh at the lower levels fringing the open water, and also the prominence of *Scirpus maritimus*. The figures also include a scale showing percentage inundation, read from Fig. 2.1; these are accurate for Fig. 2.3a, but more approximate for the other two transects. The data are for a year, and it will be recalled that water levels would on average be some 0.3 m higher in winter than summer. There are also fluctuations in mean sea level from year to year. Nevertheless, it is clear that the marsh vegetation is heavily inundated, especially in winter.

The Sarcocornia marsh is inundated 65-95%, the Juncus up to 80% of the time, but to as little as rarely inundated at the upper part of the transect shown in Fig. 2.3c.

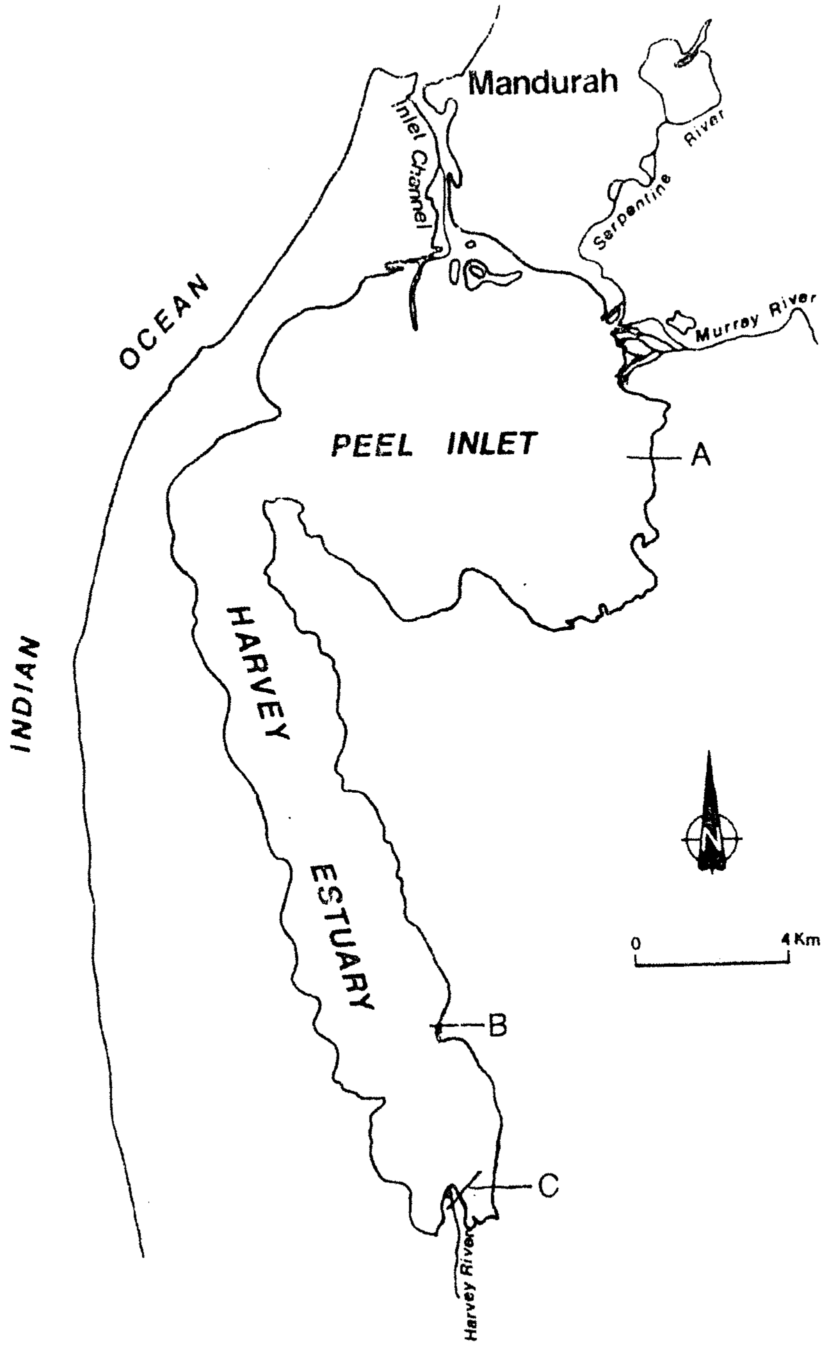


Figure 2.1 The location of the three transect lines, A, B and C, shown in Fig. 2.3

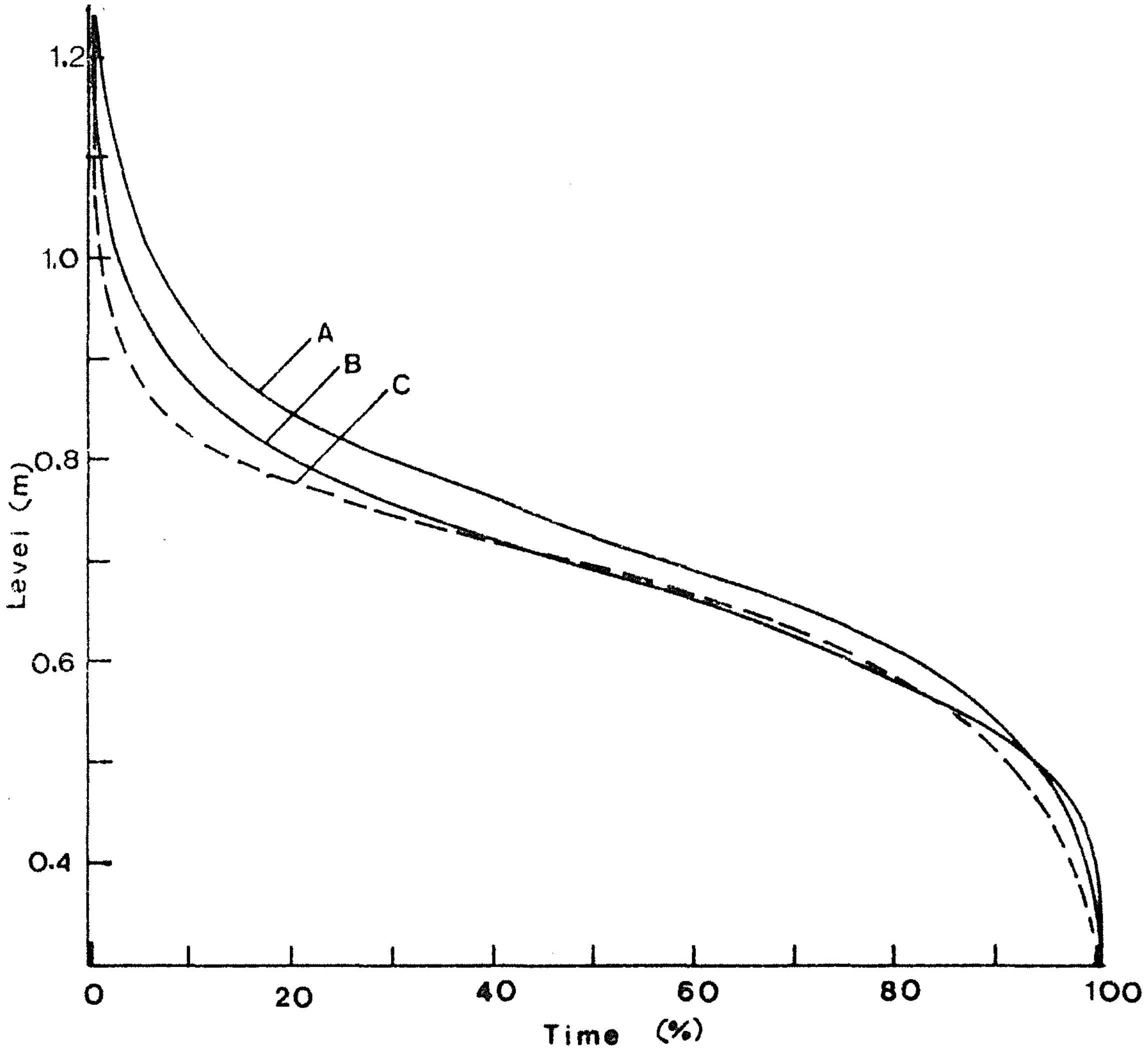


Figure 2.2 The amount of time during which particular levels are covered by water. Time is expressed as % of the year, and water level is in relation to Mandurah Datum. Curves are for A, Mandurah; B, Coodanup; C, Falcon. Data provided by Mr. D. Wallace, Public Works Department.

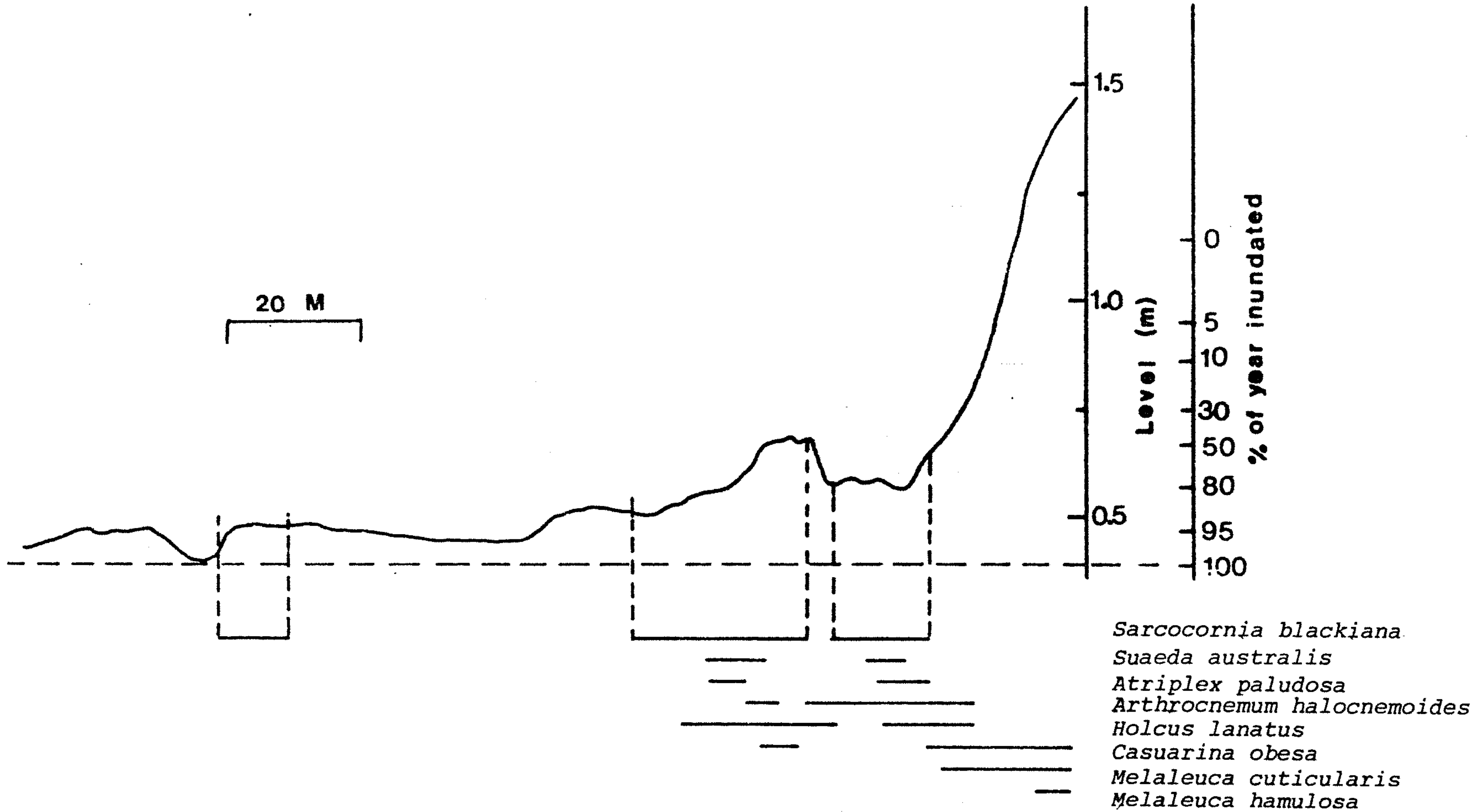


Figure 2.3 Transects through fringing plant communities. A, the profile at A, Fig. 2.1. The level is accurately depicted in relation to the Mandurah Datum, and % inundation is taken from Fig. 2.2.

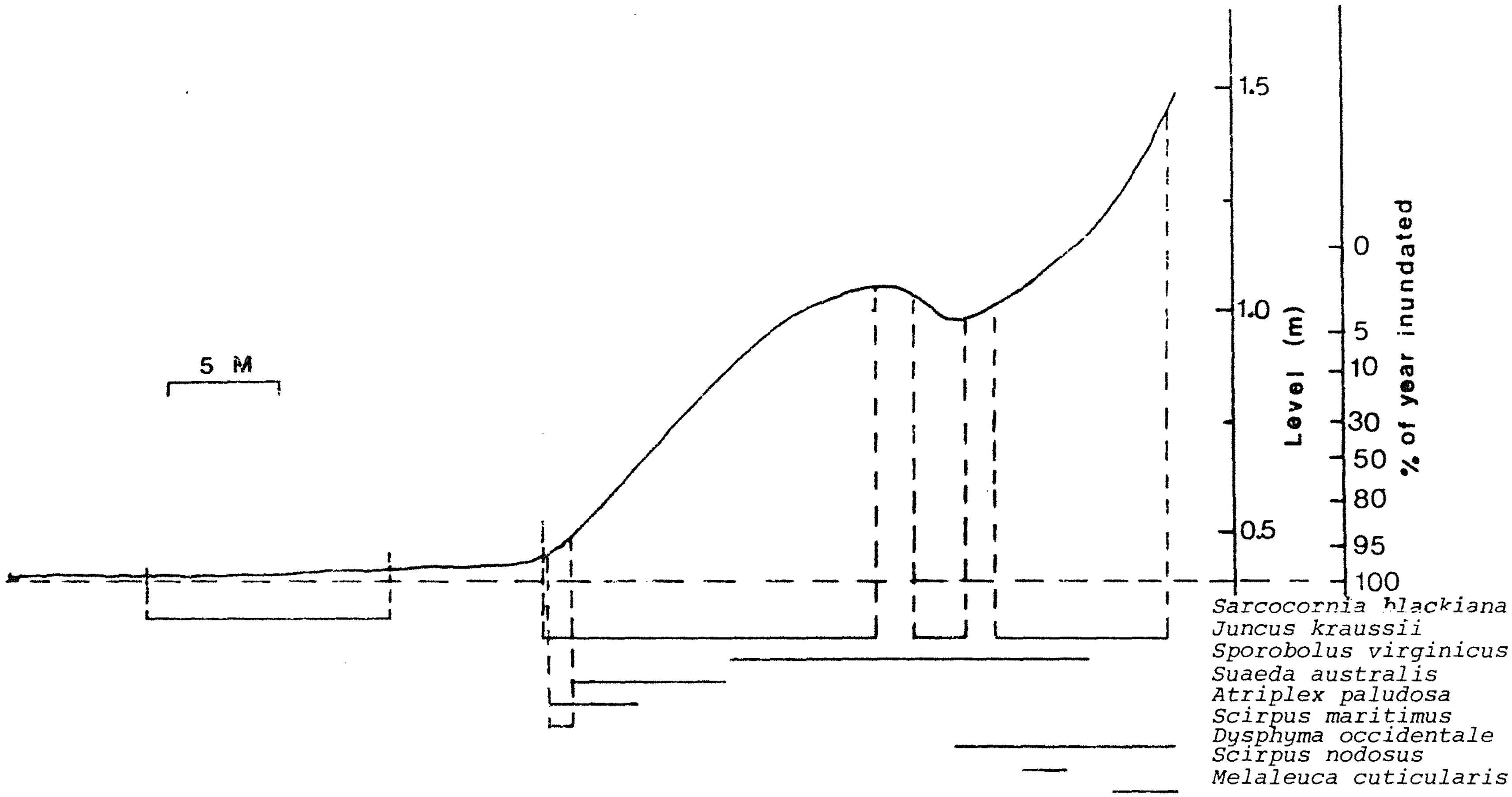


Figure 2.3 (continued). B, the profile at transect B, Fig. 2.1. Relationships with Mandurah Datum are more approximate than in A.

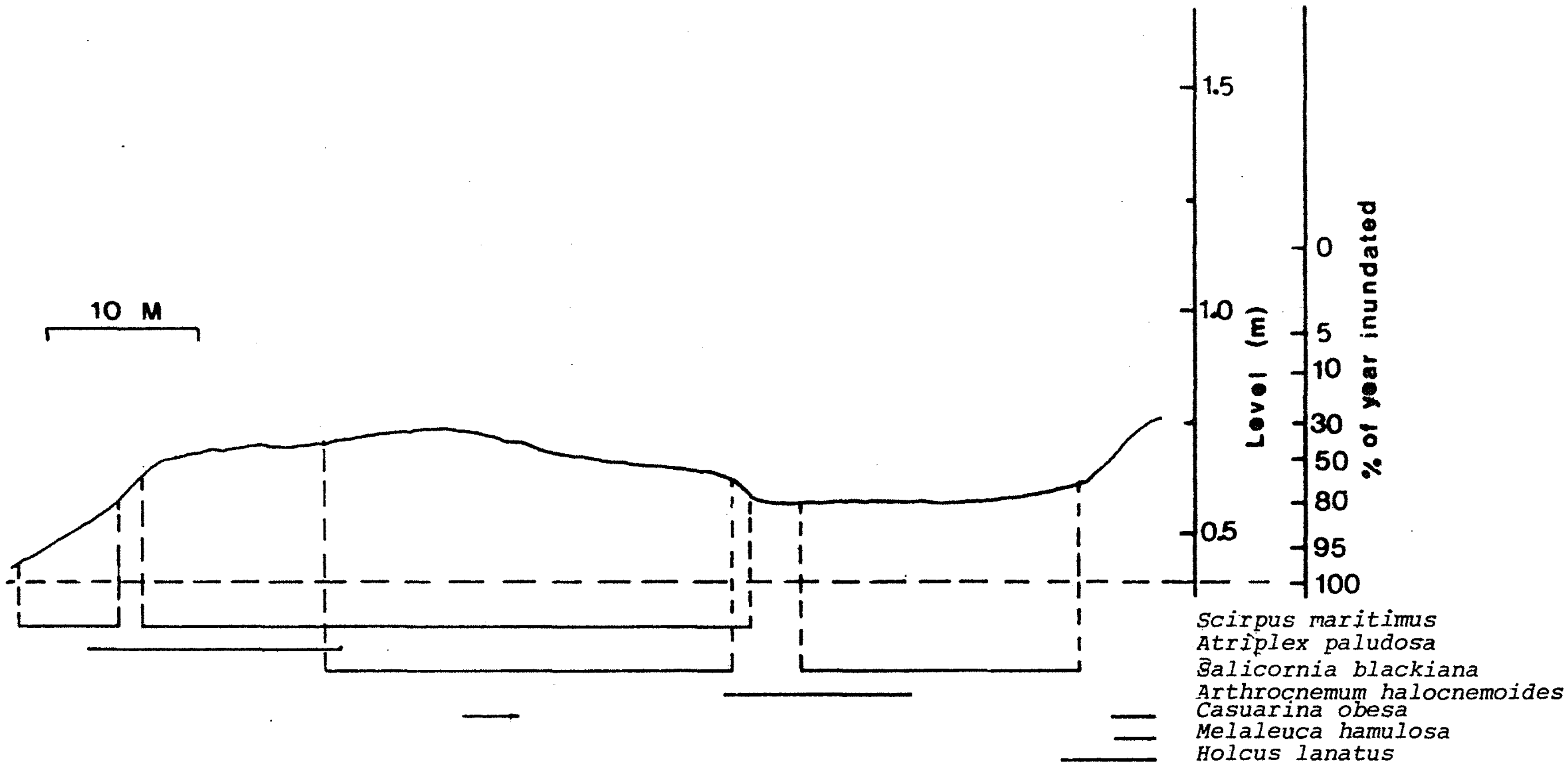


Figure 2.3 (continued). C, the profile at transect C, Fig. 2.1, at the southern end of the Harvey Estuary. The relationship with the Mandurah Datum is more approximate than in A.

CHAPTER 3

NUTRIENT CONTENT OF FRINGING VEGETATION

3.1 INTRODUCTION

The nutrient dynamics of the marshes were examined, particularly because of their possible relevance to the apparent trend of eutrophication in the Peel-Harvey system. Marshes may act as nutrient 'buffers', taking up nutrients and storing them in plant material, and conversely, contributing nutrients through decay. In this work a preliminary assessment was carried out, largely to discover if a significant nutrient pool might be present in the fringing marshes. The estimates were made for only two of the fringing plants, chosen to represent prominent vegetation of somewhat extreme growth form, *Scirpus maritimus* and *Sarcocornia blackiana*.

3.2 MATERIALS AND METHODS

Representatives of the two plants were harvested from dense stands, in the case of *Sarcocornia* from the shore of Roberts Bay, and for *Scirpus* near the mouth of the Harvey River. The harvested material was dried ($80^{o}C$, 72 hr) and weighed. Nitrogen and phosphorus contents were determined from ground material by standard techniques (Atkins, 1978).

The area of salt marsh likely to contribute to overall productivity was determined using the original large-scale version of Fig. 1.1.

3.3 RESULTS AND DISCUSSION

(a) Standing Crop

(i) Sarcocornia: The above ground crop of *S. blackiana* was 2.8 kg m^{-2}. This is higher than that obtained by Congdon and McComb (1980) (0.8 kg m^{-2}) for *Sarcocornia* growing at the Blackwood River estuary, Western Australia, and is also higher than that obtained by Mahall and Park (1976) for the related *Salicornia virginica* (0.55 - 0.96 kg m^{-2}) in the United States. *Sarcocornia* growing in the region from which the sample was collected appeared healthy, with thick green stems. The material was collected in February and was possibly at a maximum standing crop for the year.

(ii) *Scirpus maritimus*: The standing crop of this plant was 3.85 kg m^{-2}. This is higher than for *Sarcocornia* and is considerably higher than that obtained by Congdon and McComb (1980), 0.8 kg m^{-2}, for the Blackwood River estuary.

(b) Total Biomass

Using the values of Congdon (1977) for the ratio of above ground to below ground standing crop (*Sarcocornia* 4:1; *Scirpus* 1:3), the respective values for total biomass of 3.5 and 15.4 kg m^{-2} were obtained, indicating a considerably greater biomass of *Scirpus* as compared with

Sarcocornia. It might be noted that the areas sampled were relatively dense stands, and commonly values may range between 20% and 50% of these measured.

(c) Nutrient Content of Marsh Vegetation

(i) Nitrogen: The mean total nitrogen concentrations in above ground material of both species was 6.2 mg N g^{-1} dry wt. There was no significant difference between the two plants ($p<0.05$, 't' test). Replicate analyses showed little deviation from this figure. Using this mean value, and an estimated ratio of Scirpus to Sarcocornia of about 20 to 1, and the calculated area of marshland, a total nitrogen pool for the marsh can be calculated as shown in Table 3.1.

(ii) Phosphorus: The phosphorus concentrations were 1038 $\mu g\ g^{-1}$ dry wt. for Scirpus and 876 $\mu g\ g^{-1}$ dry wt. for Sarcocornia. These means were significantly different ($p<0.05$, 't' test). Replicate samples for each plant were in close agreement. An estimate of the total amount of phosphorus in the marshes was obtained in the same way as for nitrogen - Table 3.1.

TABLE 3.1

Total Nitrogen and Phosphorus in Marsh Vegetation[1]

	Scirpus maritimus	*Sarcocornia blackiana*	Total
% of marsh occupied	5	95	100
Area occupied (m^2)	64×10^4	1216×10^4	1280×10^4
Above-ground standing crop (tonnes)	24.6×10^4	341×10^2	366×10^2
Total biomass (tonnes)	99×10^2	428×10^2	527×10^2
N content (mg g^{-1})	6.2	6.2	-
Total N, above-ground (tonnes)	15.2	210	225
[2]Total amount N (tonnes)	61	264	325
P content (mg g^{-1})	1.04	0.88	-
Total P, above-ground (tonnes)	2.56	30.0	32.6
[2]Total amount P (tonnes)	10.3	37.5	47.8

[1]Data based on relatively dense stands of vegetation.

[2]Assumes concentration is the same in above- and below-ground material.

CHAPTER 4

GENERAL DISCUSSION

4.1 NUTRIENT LEVELS OF MARSH AS A PROPORTION OF THE WHOLE ECOSYSTEM

Using the data of Table 2.1 and available information for the Peel-Harvey system as a whole, it was found that these fringing marshes account for some 20-30% of the nitrogen and phosphorus (Table 4.1) when sediment values are excluded. The levels are about the same in winter, and exceed in summer, those of the open water. As these calculations are based on vigorous stands, the real pool size will be smaller, and possibly a quarter of these values.

4.2 POSSIBLE PRODUCTIVITY AND NUTRIENT TURNOVER

Mahall and Park (1976) reported net production values as a percentage of above-ground standing crop ranging from 28.7% to 63.9% for *Salicornia virginica* around San Francisco Bay. These values were derived across a zone of *Salicornia*. In the absence of local measurements their mean value of 44% was used as a reasonable estimate of what might be occurring here.

When this is applied to the standing crop and nutrient content obtained in this study, a net production of 16,104 tonnes of dry matter is obtained, and this would involve the transfer of 92 tonnes of nitrogen and 13.2 tonnes of phosphorus into new growth each year. Some of this would be recycled within the plant, as probably some 60% of the nitrogen and phosphorus would be recovered by the plant from senescing tissue. Thus about 55 tonnes of N and 7.9 tonnes of P may be exchanged with the environment each year.

Scirpus loses its entire above-ground standing crop each year, surviving as perennating corms. The above-ground standing crop is 2460 tonnes dry weight, and as the material was already senesced when sampled, most corm retrieval had already taken place. Thus the turnover of N and P is about 15 and 2.6 tonnes respectively.

Overall, the turnover of these communities, in above-ground material, is some 70 tonnes N and 10.5 tonnes P. Turnover rates for below-ground material are probably much lower, and the nutrients are less readily exchanged with the open water.

4.3 THE FATE OF DRY MATTER AND NUTRIENTS LOST FROM PLANTS

These materials may be recycled within the marsh through the decay of plant material and nutrient uptake by growing plants; alternatively, they may be washed into the open water by rain in the form of particulate or dissolved material, or transported out by rising and falling water levels as large pieces of plant material, detritus, or in soluble forms. A direct investigation would be interesting, but some observations and speculations are relevant.

At the time of the study, when water levels were low, there was no litter on the ground immediately below plants which would have produced litter the previous season, apart from recently-senesced, above-ground material of Scirpus maritimus, nor was there litter in the sandy substratum. This suggests either rapid in situ decay (which appears unlikely), or transport of debris by water.

At no time was debris from the marshes observed floating in the estuary, but the presence of large amounts of Cladophora washed up on the shores of the estuary, and large amounts of plant debris at the high water mark, demonstrates transport by water both within and without the marsh, with associated rapid redeposition in wracks through wind effects. The wracks of plant material remain as water levels fall. They would release nutrients through decay, and it is useful to recall that the wracks include not only marsh-derived plant material, but also algae (especially Cladophora), and the benthic angiosperms Ruppia and Halophila. All this material would be transported by wind-induced currents to the shore.

As part of the nutrients required by Scirpus plants must be taken up from the substratum after corm dormancy breaks in spring, the remainder must be redeployed from the corms. Sarcocornia also probably grows in summer, and presumably takes up most of its nutrients during the growth period.

In an estuary undisturbed by man there would be large year to year changes in salinity and nutrients in an area with erratic rainfall, but over the longer term one must assume a reasonable degree of stability in the fringing plant communities. (In the very long term there may be some successional changes, brought about for example by encroachment of the fringing marshes into what was once open water). It follows that, on average, the annual input of nutrients balances the exports; if this were not so, the vegetation would not be in equilibrium with the environment. ('Inputs' here would include N-fixation; and 'exports' would include the permanent deposition of unavailable forms of nutrients in sediments). Speculative flows for the ecosystem are given in Fig. 4.1.

With cultural eutrophication, the size of the nutrient bank deposited in the vegetation has increased, largely through the growth and deposition of massive amounts of macro algae. In some regions the amount of material has smothered and killed fringing vegetation, (Backshall, 1977), producing, for example, 'rotten spots' in the Sarcocornia marsh.

The decay of the deposited material must have led to increased nutrient availability, and so no doubt to increased plant growth, which would incorporate some of the extra nutrients and recycle them within the marsh. The measurements made for this study are therefore presumably from an 'enriched' marsh. It is perhaps worth notring that the biomass of *Sarcocornia* and *Scirpus* is high compared to the other very few data available, and *Scirpus* appears to have expanded recently in the area; whether these effects are related in any way to the eutrophication remains a matter for speculation.

4.4 MANAGEMENT CONSIDERATIONS

The total marsh area, of 12.8 km^2, is not large by world standards, but is significant in view of the general paucity of wetlands in the State. It would be useful to assemble more information about the general significance of the marshes to the ecology of the Peel-Harvey system, for example to bird life and in reducing shore erosion, to allow informed management decisions to be made in the future. At present the marshes are disturbed by the addition of plant material (especially algal detritis) from the open water, and by the rapid spread of *Scirpus*.

The marshes comprise a small but significant part of the nutrient bank of the whole ecosystem. The size of this nutrient pool might be increased if different species were present - for example, plants with a higher biomass and a greater carryover of plant material from year to year - though the deliberate introduction of species which might trap nutrients would have to be considered very carefully, because of other possible environmental repercussions. The size of the nutrient pool in the marsh would also be increased if the area of marsh were increased. Conversely, destruction of the marshes would reduce the nutrient pool and might transfer nutrients to the open water.

A reduction in the amount of plant material driven into the marsh from the open water could improve the status of the marsh.

4.5 CONCLUSIONS

1. The total area of the marshes of the System is about 12.8 km^2, representing 10% of the marsh plus open water.

2. The marshes represent about 5 to 20% of the nitrogen and phosphorus contents of the estuarine system, apart from sediments.

3. The standing crops of *Sarcocornia* and *Scirpus* are relatively high, at least in the few samples taken.

4. The marshes are typically inundated for a high proportion of the year, but especially in winter.

5. Large wracks of decaying marsh vegetation, algae and benthic angiosperms are driven into the marsh; there is apparently no export of plant material, though this is shifted within the marsh.

6. Decay of plant material releases nutrients for marsh growth, and is probably in part returned to the open water.

7. *Scirpus* has recently expanded in area, replacing *Juncus kraussii* as a dominant in the marshes of the Harvey River delta.

4.6 RECOMMENDATIONS

1. It would be useful to have a better understanding of the possible significance of the marshes to the general ecology of the area, including the bird life, and role in shoreline stabilization.

2. It would be interesting to have more information about decay and release of nutrients from these wetland plants, probably at the accurately-surveyed transect line. Any such studies should be coupled with an investigation of phenology (seasonality of plant growth and development).

3. A reduction of the trend towards eutrophication in the estuarine system would reduce the impact on the marsh of large amounts of decaying plant material.

Table 4.1

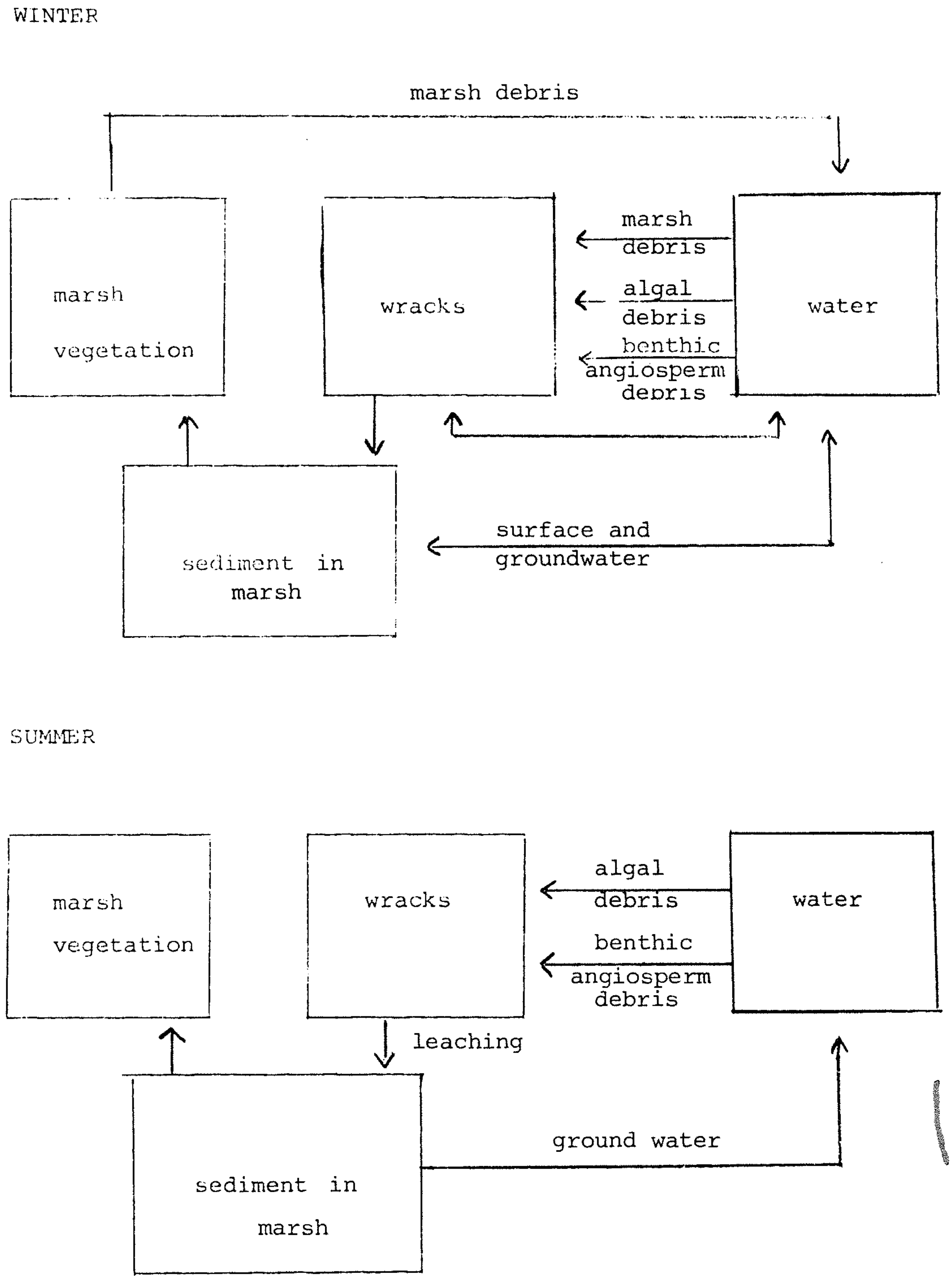
Pools of Nitrogen and Phosphorus in the System[1]

Pool	Date		Nitrogen		Phosphorus	
			tonnes	%	tonnes	%
Marshes	Feb.	1980	327	33	47.8	38
Water	March	1978	120	12	15.0[2]	12
<u>Cladophora</u>	March	1978	538	55	61.4	50
Total	March	1978	985	100	124.2	100
Marshes	Feb.	1980	327	21	47.8	24
Water	August	1978	297	20	47.6	24
<u>Cladophora</u>	August	1978	903	59	103.0	52
Total	August	1978	1527	100	198.0	100
Sediment	March	1978	2570		236.0	
(Upper 2 cm)	August	1978	2590		271.0	

[1]These are very approximate figures. The amount of nutrients in the fringing vegetation is assumed to be the same for summer and winter for these calculations, and the estimate for above- and below-ground material has been used. Data are based on dense stands, and are therefore overestimated by up to about four times.

[2]Estimate only at this stage.

Fig. 4 .1 Flow diagrams for nitrogen and phosphorus



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