THE DISTRIBUTION AND BIOMASS OF SEAGRASSES AND MACROALGAE IN THE SWAN-CANNING ESTUARY, WESTERN AUSTRALIA

January 1996

Julia Phillips [1] and Jane Wilshaw [2]

[1]Department of Environmental Management

Edith Cowan University

[2]Department of Botany

The University of Western Australia

TABLE OF CONTENTS

Abstract	1
Introduction	2
Materials and Methods	5
Survey area	5
Study sites	5
Physical parameters	5
Distribution	5
Biomass	6
Mapping	6
Data analysis	6
Results	7
Physical parameters	7
i) Salinity	7
ii) Temperature	8
iii) Dissolved oxygen	8
Distribution	9
i) Seagrasses	9
ii) Macroalgae	10
Biomass	11
Discussion	16
References	18
Appendix I	19
Appendix II	20
Appendix III	22
Appendix IV	23

ABSTRACT

The Swan-Canning Estuary is situated in south-west Western Australia and is bordered by the Perth Metropolitan Area. This study aimed to map the distribution and abundance of seagrass and macroalgae in the Swan-Canning Estuary in December 1995. In addition, physical parameters such as salinity, temperature, and dissolved oxygen were recorded. The distribution of seagrass was similar to that mapped in 1982 by Hillman *et al.* (1985) with an overall loss of approximately 137 ha. Total seagrass biomass was 346.51t DW. Three seagrass species were recorded; *Ruppia* sp., *Zostera mucronata*, and *Halophila ovalis*. *Zostera mucronata* was confined to the inlet channel of the estuary; salinity was thought to be the controlling factor in its distribution. *Halophila ovalis,* the dominant seagrass in the estuary, was most prominent in the estuarine basin. The distribution of *H. ovalis* was thought to be limited upstream by higher turbidity levels (i.e. reduced light penetration). Downstream, *H ovalis* distribution may have declined as a result of competition with *Z. mucronata*. or physical disturbance which allowed *Z. mucronata* to grow in the area where *H. ovalis* previously occupied. Epiphytic, benthic and free-floating algae were surveyed and distribution was seen to approximate that of seagrass. When compared to a study by Allender (1970) algal communities were noted to have declined, with a total loss in some areas. Total algal biomass recorded was 408.53 t DW.

INTRODUCTION

The Swan-Canning Estuary is situated in south-west Western Australia, and runs through the Perth metropolitan region. The estuary is fed by two major freshwater catchments (Avon and Swan coastal catchments) and discharges into coastal waters at Fremantle Harbour (Thurlow *et al.*, 1986).

The upper estuary is predominantly freshwater in winter, characterised by low salinity, low temperatures and high turbidity as freshwater flows downriver from the catchments (Allender, 1970). In winter the lower estuary becomes stratified, with less dense freshwater forming a layer over denser seawater (Thurlow *et al.*, 1986; Riggert, 1978). Stratification allows little light penetration to the deeper waters. These low light conditions result in reduced photosynthetic activity, and deoxygenation may occur as a result of biological activity (Thurlow *et al.*, 1986; Riggert, 1978).

In spring and summer there is little freshwater input, leading to higher salinity and temperature levels. The lower estuary is typically marine at this time, becoming hypersaline (Thurlow *et al.*, 1986). The tides in spring and summer push marine water into the upper estuary (Riggert, 1978), forming a 'salt wedge' below a lens of freshwater. Summer winds generate mixing of the two water masses and the upper estuary gradually becomes marine (Thurlow *et al.*, 1986; Riggert, 1978). These conditions in summer, coupled with higher light intensities, result in greater primary productivity in the estuary (Allender, 1970; Hillman, 1985)

The Swan-Canning Estuary is used extensively by the Perth community for recreational and commercial purposes. These activities include watersports such as fishing, boating and swimming, as well as commercial fishing. The estuary is also used directly and indirectly as a means of waste disposal (Thurlow *et al.*, 1986). Nutrients may enter the estuary as a result of agricultural activities in upper catchments, as run-off from parks and gardens, or as seepage from septic systems and old rubbish dumps. Untreated sewerage may also spill into the estuary. Between July 1993 and May 1994, a total of 2 295 000L of untreated sewerage from five accidental spills was released into the river (Swan River Trust, 1993/94).

The health of the estuary is important not only for the preservation of flora and fauna but also to protect the health of the surrounding population that is in direct or indirect contact with the estuary. It is imperative that the health status of the estuary is monitored, for the purposes of developing suitable management practices for the estuary and its catchments. Better management may involve controlling agricultural, industrial and domestic inputs to the system.

The effects of recreational use should also be considered as benthic communities may be physically disturbed or destroyed in some areas by activities such as windsurfing and prawn trawling.

The primary aim of this study was to map the distribution of seagrasses and macroalgae in the Swan-Canning Estuary. In addition, the biomass of seagrass and macroalgae was investigated at several sites to give an estimate of the total plant biomass at the time of the study. Such information will contribute to the existing database, against which future changes in distribution and biomass (resulting from either natural or human-induced events) can be monitored. Physical factors such as salinity and temperature were also recorded as previous studies suggest that these factors play a key role in plant productivity.

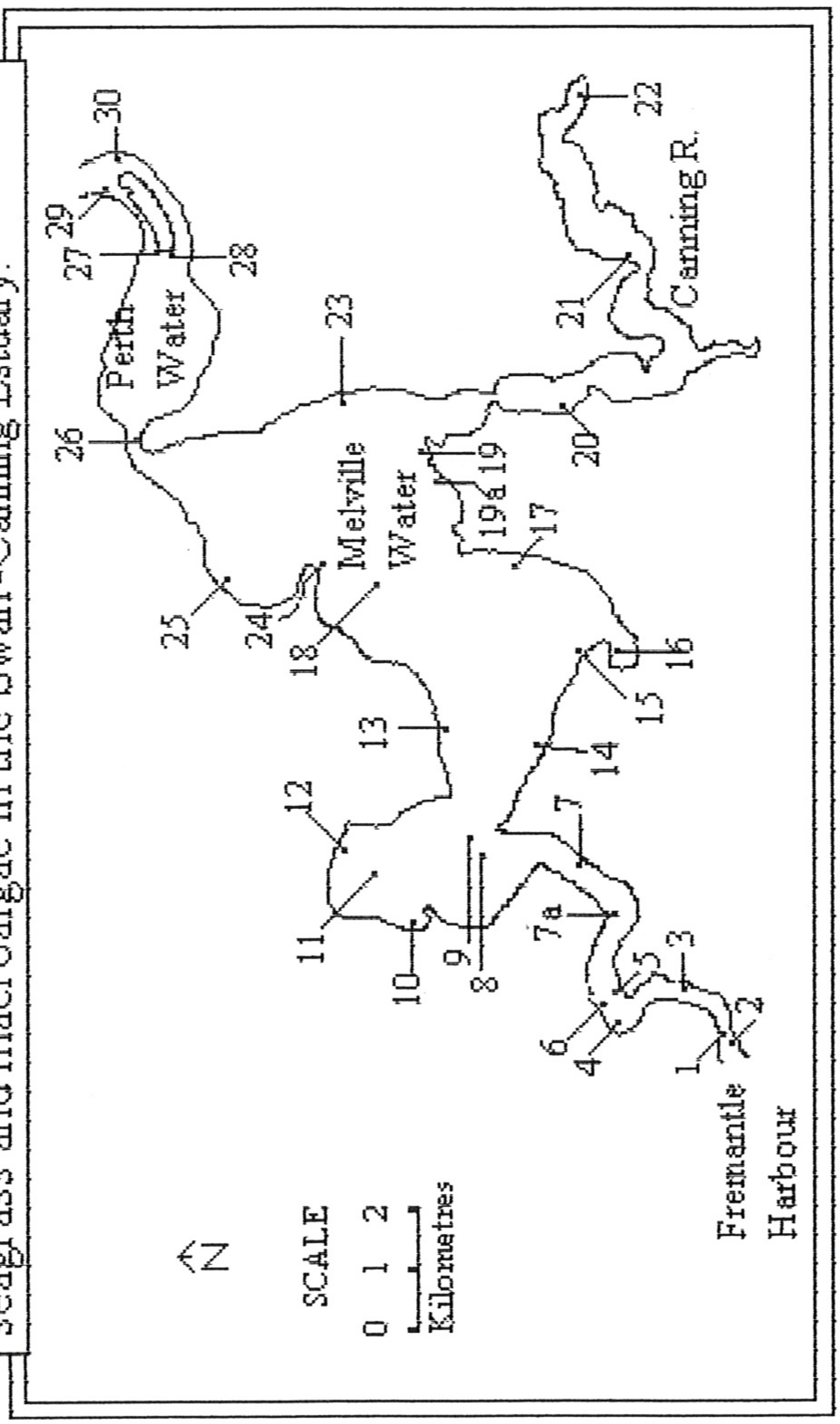


Figure 1. Location of sites selected for assessing biomass of seagrass and macroalgae in the Swan-Canning Estuary.

MATERIALS AND METHODS

Survey area

The survey was carried out in the Swan-Canning estuary. The area surveyed extended from Heirisson Island (115° 53´E, 31° 58´S) in the Swan Estuary, and from Mt Henry Bridge (115° 51´24´´E, 32° 02´18´´S) in the Canning Estuary, downriver to the Fremantle traffic bridge at Fremantle Harbour (115° 45´24´´, 32° 02´30´´S) (Figure 1).

Study sites

Aerial photographs were to be the basis for choosing groundtruthing sites to evaluate distribution and abundance of seagrass and macroalgae in the Swan-Canning Estuary. However, due to a delay in the aerial photographs and time restrictions of the survey, sites were chosen based on vegetation maps prepared by Hillman (1985) and Allender (1970). To maximise the survey area covered and represent a range of biomass levels, 30 sites were selected. Site locations were then re-evaluated on arrival of the aerial photographs. Two sites (7A and 19A) were subsequently added to the survey. The general position of all sampling sites are shown in Figure 1, and their specific location (GPS located) listed in Appendix 1.

Physical parameters

Temperature, salinity and dissolved oxygen readings were taken at the 25 sites shown in Figures 6 - 8, between the 8th and 22nd of December. The Intelligent Analyser (model 611, Yeo - Kal Electronics) provided the data for these three variables at most sites. For sites 15, 16, 17, 24, and 25 however, a temperature-salinity bridge (model 602, Yeo-Kal instruments) and a portable oxygen meter (model 630, Yeo-Kal instruments) were used. Readings for all variables were recorded at the surface, 0·5 m, 1 m, and every meter thereafter. Light readings were obtained for sites 1- 5 only, using a Licor Underwater Quantum Sensor (model LI-188B), as the sky was overcast when other sites were visited. The light readings for these five sites are shown in Appendix 2. Light penetration was recorded at the remaining sites using a Secchi disc (Appendix 2).

Distribution

The distribution of seagrass and macroalgae was mapped using aerial photographs taken on the 10th December 1995 (scale 1:10 000). The photos were taken by Kevron Aerial Surveys Pty Ltd using infrared sensitive colour film (KC756). To minimise glare and reflection, photographs were taken when the angle of the sun was below 40° (approximately 0930 hrs). The density of the seagrass was categorised into four classes; 5 - 25%, 25 - 50%, 50 - 75%, and 75 - 100% cover. These categories are considered adequate to show the actual status of seagrass meadows and allow for comparisons in future studies. In shallow clear water, groundtruthing of photographs was carried out using a glass bottom bucket held over the side of the boat. In deeper or turbid water, SCUBA or snorkelling techniques were employed.

Biomass

Biomass of macrophytes was sampled at 26 sites (Figure 1) between the 8th and 22nd of December (sites 1, 22 and 26 - 30 were found to be 'barren' and hence no data were collected). Five cores of seagrass and/or algae were taken at each site using a cylindrical Perspex corer (64 cm^2 in area). Where algae was attached to hard substrates, five quadrats (0.04 m^2) were taken in place of core samples. Corers were inserted into the sediment approximately 5 - 15 cm depending on the depth of root material. The core samples were sieved in situ (1 mm sieve), bagged and stored in an esky. On return to the laboratory all samples were washed to remove remaining sediment, shell and animal material. For seagrass samples epiphytes were scraped off blades and bagged separately. Samples were placed in paper bags (both root and shoot material) and oven dried to a constant dry weight at 80°C. Samples were then placed in a dessicator and weighed on an electronic balance (to three decimal places).

Mapping

Preliminary maps of seagrass and macroalgae distribution and biomass estimates were produced using aerial photographs and groundtruthing data. These maps were then digitised using Microstation (Bentley Systems) and then transferred to ERMS (Environmental Resources Mapping System) (NSW National Parks and Wildlife Service, 1991). This GIS package was used for editing, image composition and calculation of area of coverage of seagrasses and macroalgae.

Data analysis

Total biomass was calculated by converting the mean of five replicate samples to grams/m^2 for each site where samples were collected. Sites were then grouped according to percentage cover category (i.e. 5-25%, 25-50%, 50-75% and 75-100%) and mean biomass for each category calculated. These values were then multiplied by the midpoint of the ranges of each percentage cover category (Hillman *et al.*, 1995) to give mean biomass of each cover class for both seagrass and macroalgae. Total biomass estimates for the area surveyed were derived by multiplying mean biomass values by the area (in hectares) occupied by each percentage cover category.

RESULTS

Physical parameters

i) Salinity

A salinity gradient existed with three distinct zones evident, relating to distance from the mouth of the estuary (Figure 2). Surface and bottom salinity were higher in the inlet channel (sites 1-6), although readings at site 5 were lower than other sites in the channel. Salinity in the estuarine basin, from Point Walter to the Narrows Bridge (sites 7-19a and 23-26), showed little variation between surface and bottom readings and were generally lower than in the inlet channel (with the exception of site 18). A marked drop in both surface and bottom salinity was recorded at sites 20 and 21 in the Canning River.

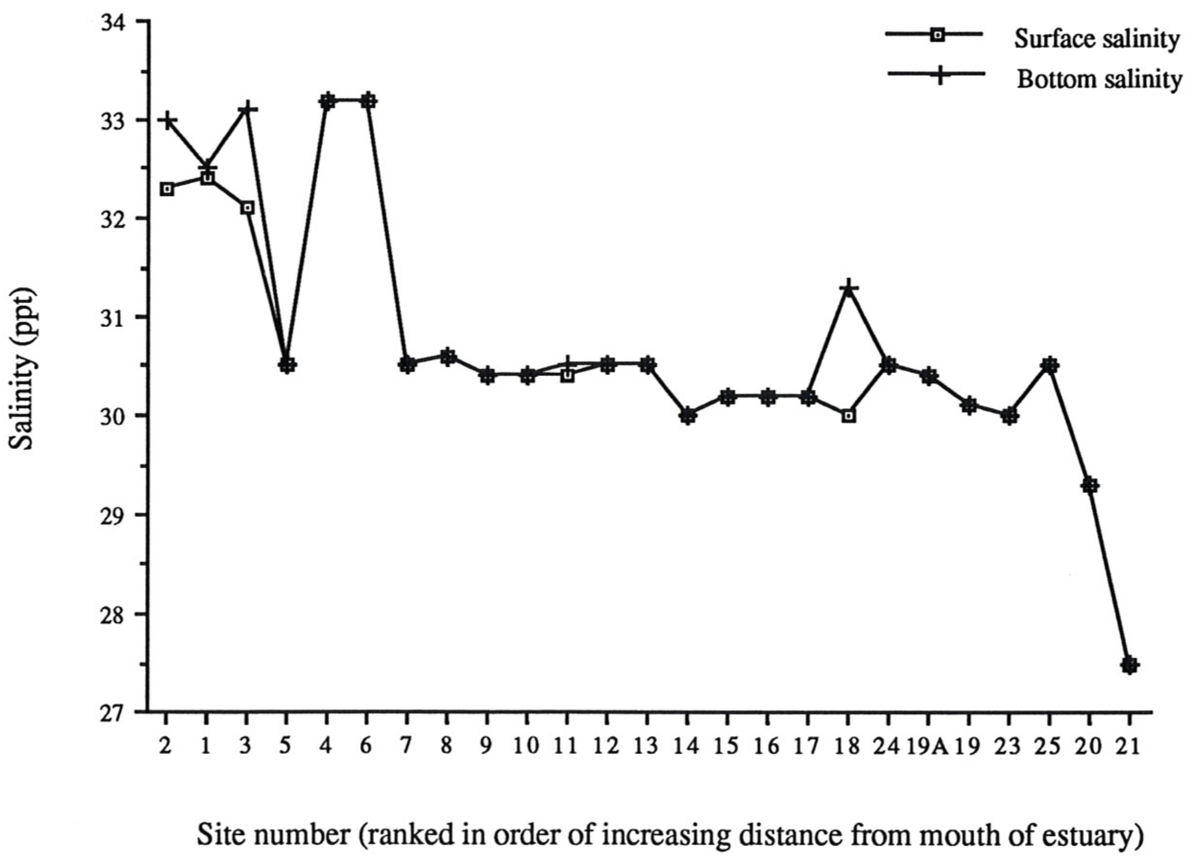


Figure 2. Surface and bottom salinity with increasing distance upstream in the Swan-Canning Estuary, December, 1995.

ii) Temperature

Little variation was seen between surface and bottom temperature readings at all sites (Figure 3), indicating no temperature stratification. Sites 18 and 3 showed the largest variation in surface and bottom temperatures (0.7°C), but were also the deepest sites (3.1 m and 2.5 m respectively). Sites upriver generally had higher temperatures than those downriver, although variability between upriver sites was greater. Maximum temperature recorded was 25.3°C in the Canning River (site 21), whilst the lowest was 21.5°C at site 3 (Stirling Bridge).

iii) Dissolved oxygen

A similar trend in dissolved oxygen (DO) levels is shown in Figure 4, with little variation between surface and bottom levels at all sites. No significant change was seen in DO levels with distance upriver, and most readings were between 6 and 8 mg/L. Site 15 had the highest surface and bottom DO levels (8.7 mg/L and 8.9 mg/L respectively). Site 24 had considerably lower surface and bottom DO when compared with other sites. The greatest variation between surface and bottom DO was recorded at site 18 where water depth was 3.1 m.

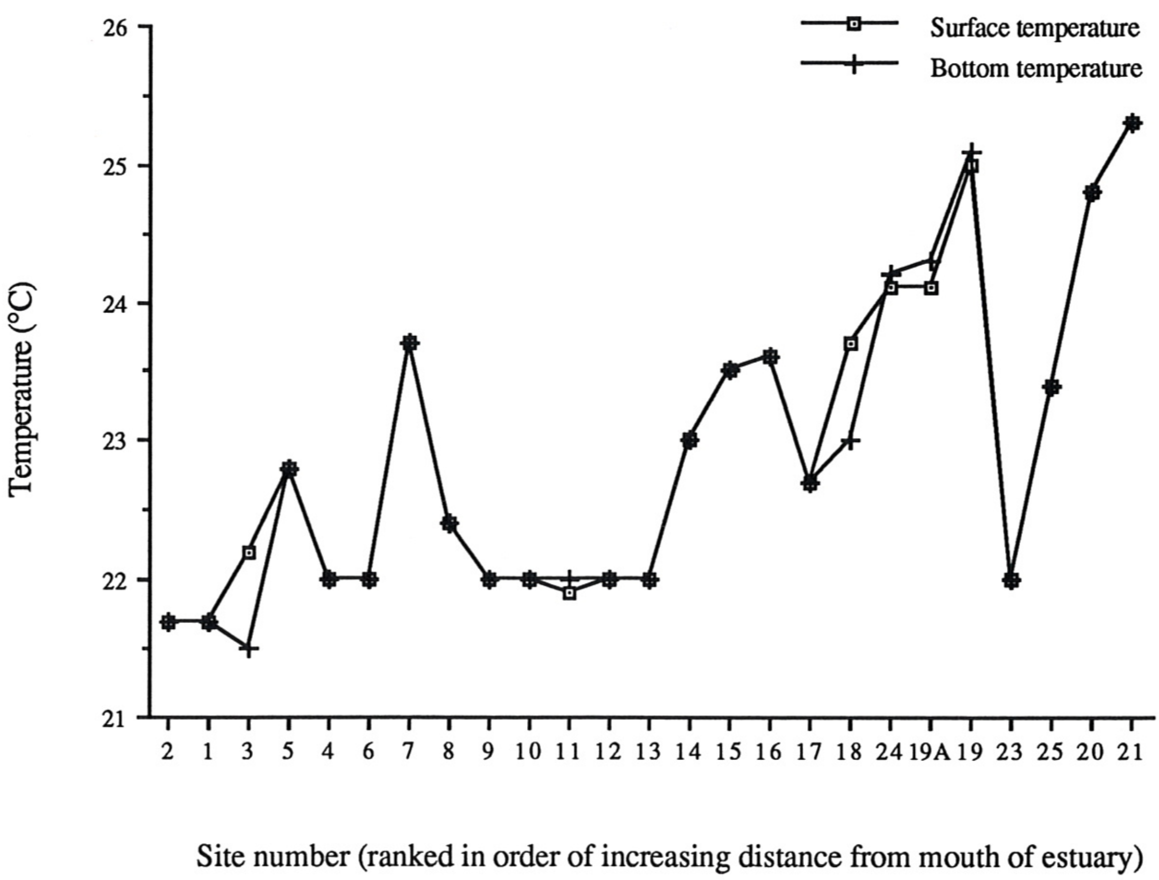


Figure 3. Surface and bottom temperature with increasing distance upstream in the Swan-Canning Estuary, December, 1995.

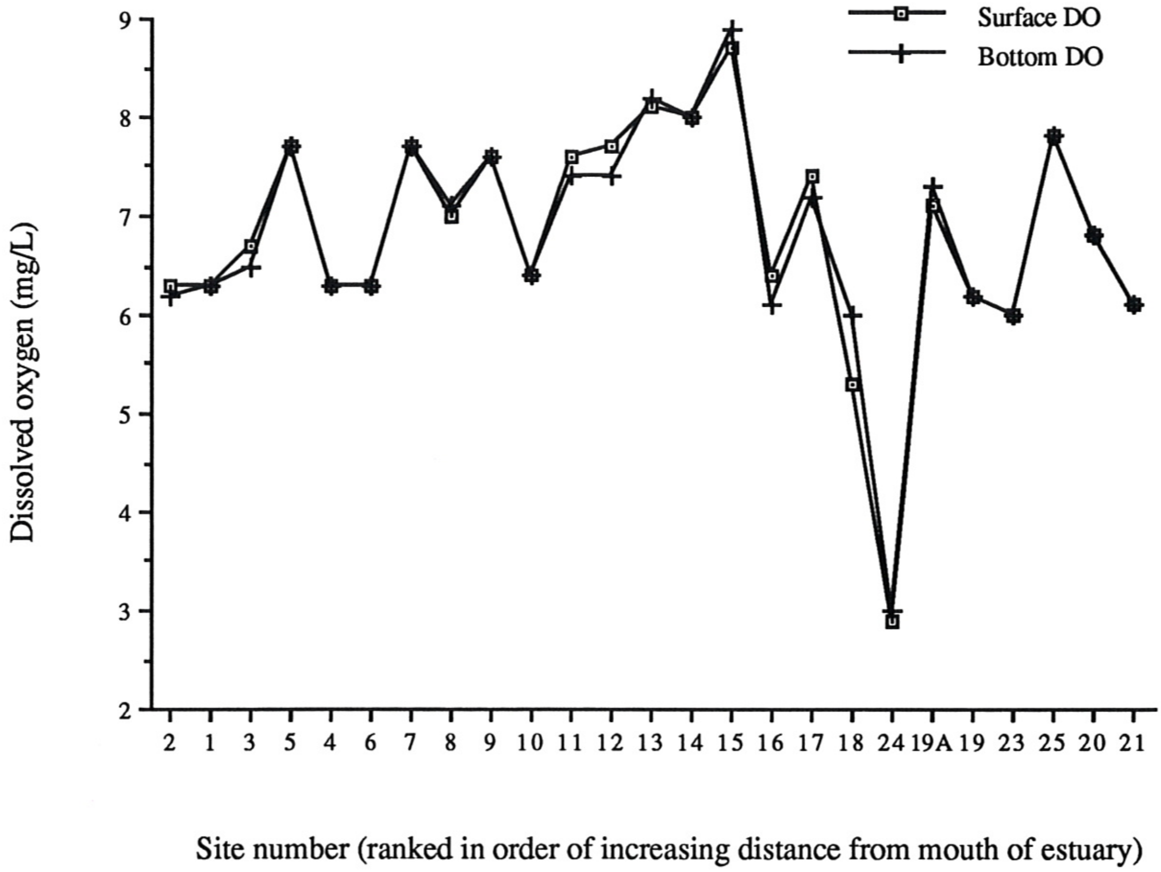


Figure 4. Surface and bottom dissolved oxygen levels with increasing distance upstream in the Swan-Canning Estuary, December, 1995.

Distribution

i) Seagrasses

Three seagrass species were recorded; *Halophila ovalis*, *Zostera mucronata* and *Ruppia* sp., occupying a total of 460.9 ha (Table 1). Distribution was confined to the inlet channel and the estuarine basin (Figure 5), although one small isolated patch of *H. ovalis* was seen in the Canning River, downstream of site 21 (this was too small to be mapped in Figure 5). No seagrass was recorded in Perth Water. Most seagrass beds occurred on shallow banks, although *Halophila ovalis* was recorded at a depth of 3.1 m at site 18.

Zostera mucronata extended from site 3 in the inlet channel through to site 15 in the estuarine basin. *Halophila ovalis* distribution began slightly further upstream, at sites 4 and 6 in the channel, and continued throughout the estuarine basin. *Ruppia* sp. was recorded only at site 15.

ii) Macroalgae

Macroalgae distribution shown in Figure 6 includes epiphytes, drift algae and algae attached to rocks and hard substrates. Distribution approximated that shown for seagrasses in Figure 5, with the major exception being macroalgal distribution throughout much of the Canning River. Macroalgae occupied a total of 543.7 ha (Table 2).

A complete inventory of macroalgae species was not compiled due to time restrictions of the survey, although a list of dominant species at several sites is included in Appendix IV.

Table 1. Estimated total biomass of seagrass in the Swan-Canning Estuary.

% Cover	Area (ha)	% of total	Estimated biomass (tonnes dry weight)
5-25%	148.5	32.2	32.62
25-50%	176.9	38.4	130.69
50-75%	99.0	21.5	100.17
75-100%	36.5	7.9	83.03
TOTAL	460.9	100.0	346.51

Table 2. Estimated total biomass of macroalgae in the Swan-Canning Estuary.

% Cover	Area (ha)	%of total	Estimated biomass (tonnes dry weight)
5-25%	255.1	46.9	14.13
25-50%	156.9	28.9	65.38
50-75%	98.7	18.1	210.07
75-100%	33.0	6.1	118.75
TOTAL	543.7	100.00	408.33

Biomass

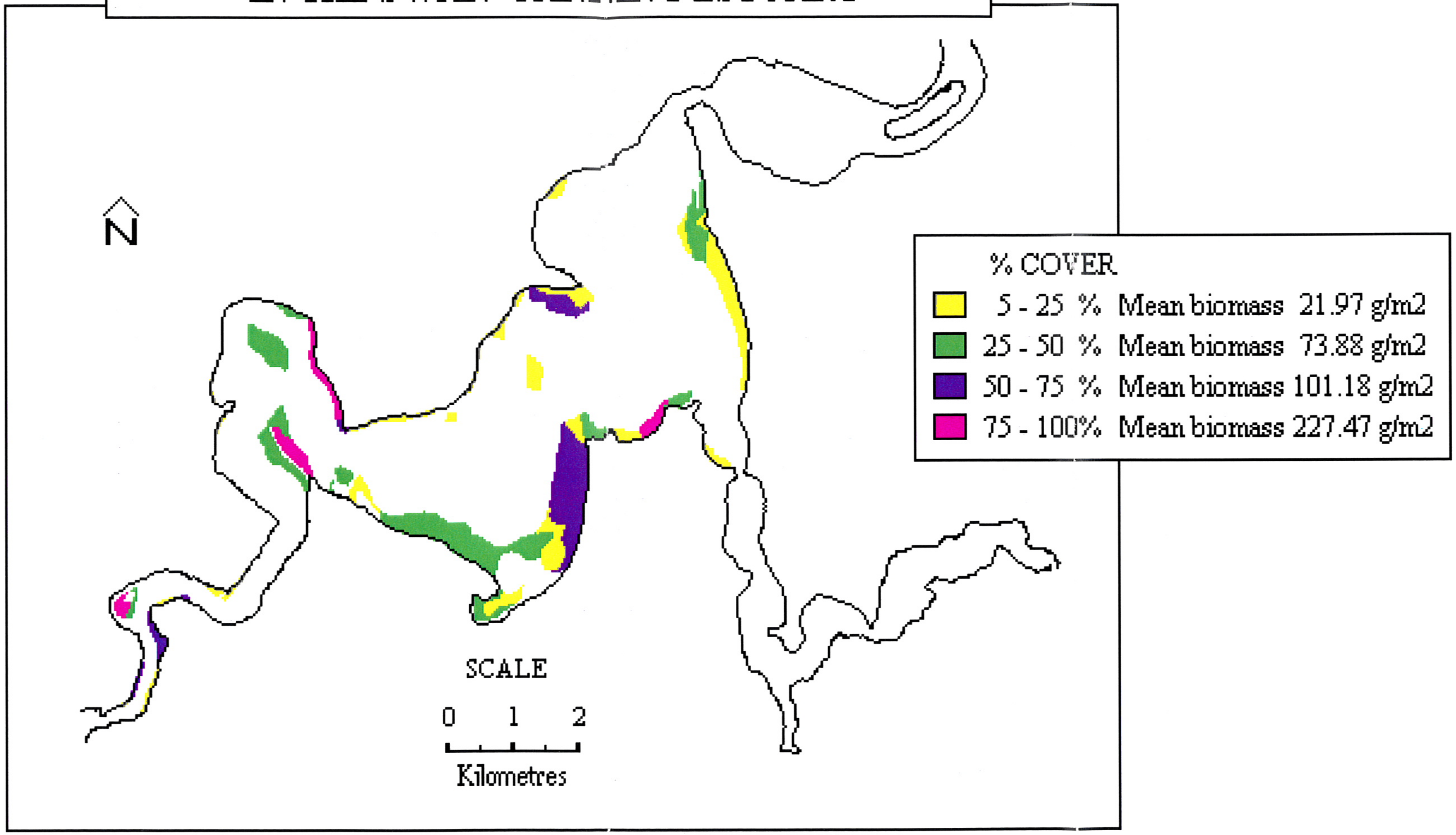
Total macrophyte biomass in the Swan-Canning Estuary was 754.84 tonnes dry weight (t DW) at the time of the survey. Total seagrass biomass was 346.51 t DW (Table 1). Mean biomass for each percentage cover class is shown in Figure 5 and ranged between 21.97 g/m^2 and 227.47 g/m^2. For macroalgae, total biomass was 408.33 t DW (Table 2) and ranged from 5.54 g/m^2 (5-25% cover) to 359.84 g/m^2 (75-100% cover) (Figure 6).

Seagrass biomass at selected sites (Figure 7) shows that biomass was highest in the inlet channel. Within the estuarine basin there was greater variation between biomass at different sites. Lowest biomass for seagrass was recorded at site 19 (east of Point Heathcote). The reverse situation existed for biomass of epiphytes growing on seagrass, with lowest biomass recorded in the inlet channel and increased biomass in the estuarine basin. Highest epiphytes biomass was recorded at Point Walter (sites 8 and 9), either side of an extensive sand spit.

Macroalgal biomass was low in the inlet channel (with the exception of site 7 along Blackwall Reach) and lowest at sites 18 and 19 in the estuarine basin (Figure 8). Highest algal biomass was recorded at site 16 (Alfred Cove). High biomass was also recorded from both sites in the Canning River (sites 20 and 21).

Figure 5. The distribution and biomass of seagrasses in the Swan-Canning Estuary, shown as percentage cover with mean biomass of each cover class, December 1995.

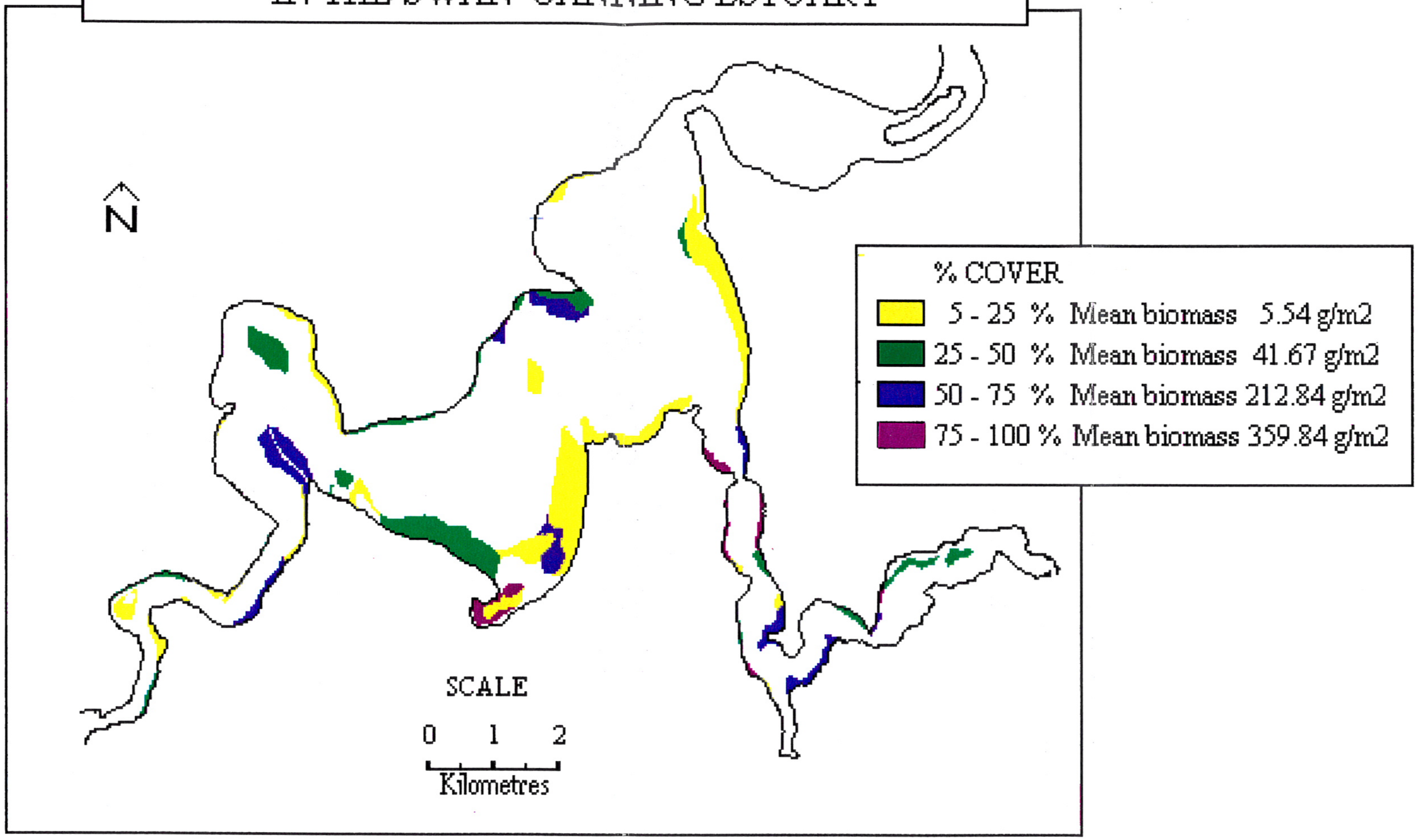
SEAGRASS DISTRIBUTION AND MEAN BIOMASS IN THE SWAN-CANNING ESTUARY



DATA SOURCE : AERIAL PHOTOGRAPHY, DECEMBER 1995

Figure 6. The distribution and biomass of macroalgae in the Swan-Canning Estuary, shown as percentage cover with mean biomass of each cover class, December 1995.

MACROALGAE DISTRIBUTION AND MEAN BIOMASS IN THE SWAN-CANNING ESTUARY



DATA SOURCE : AERIAL PHOTOGRAPHY, DECEMBER 1995

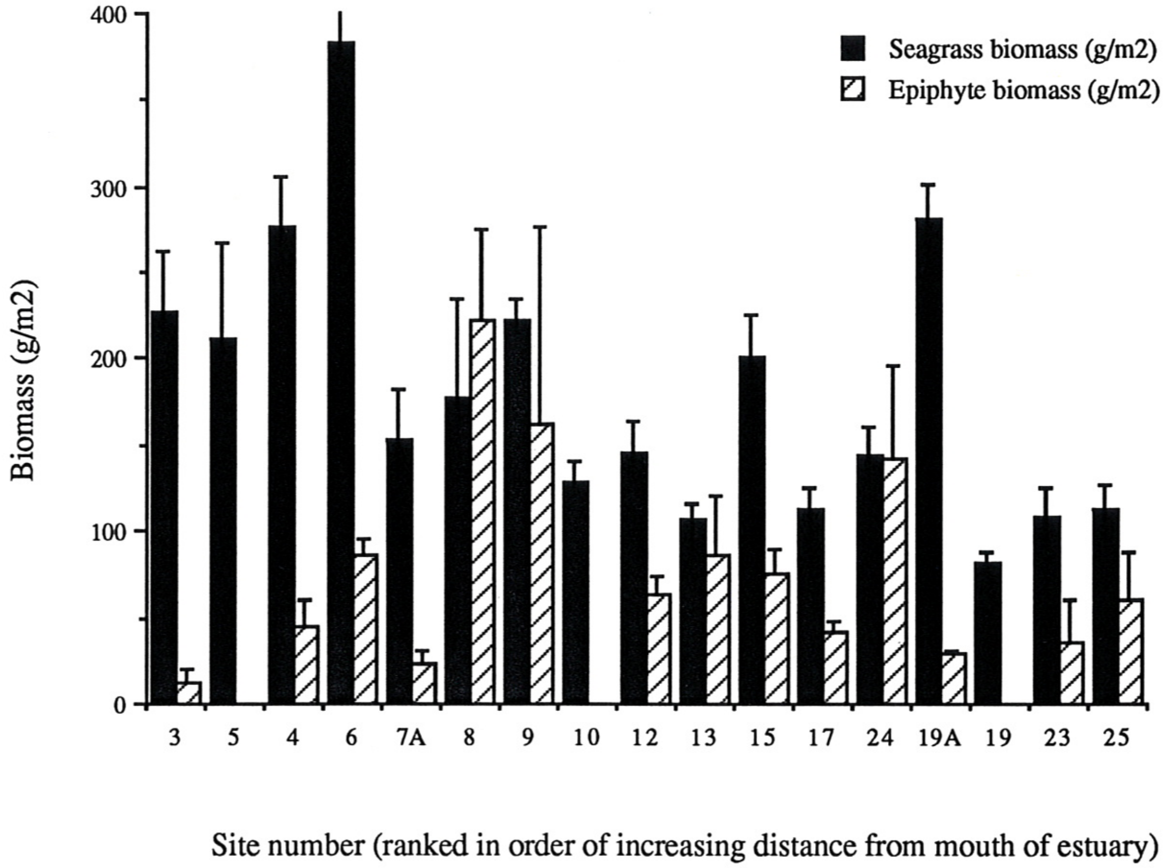


Figure 7. Mean seagrass biomass from collected cores in the Swan-Canning Estuary, December, 1995.

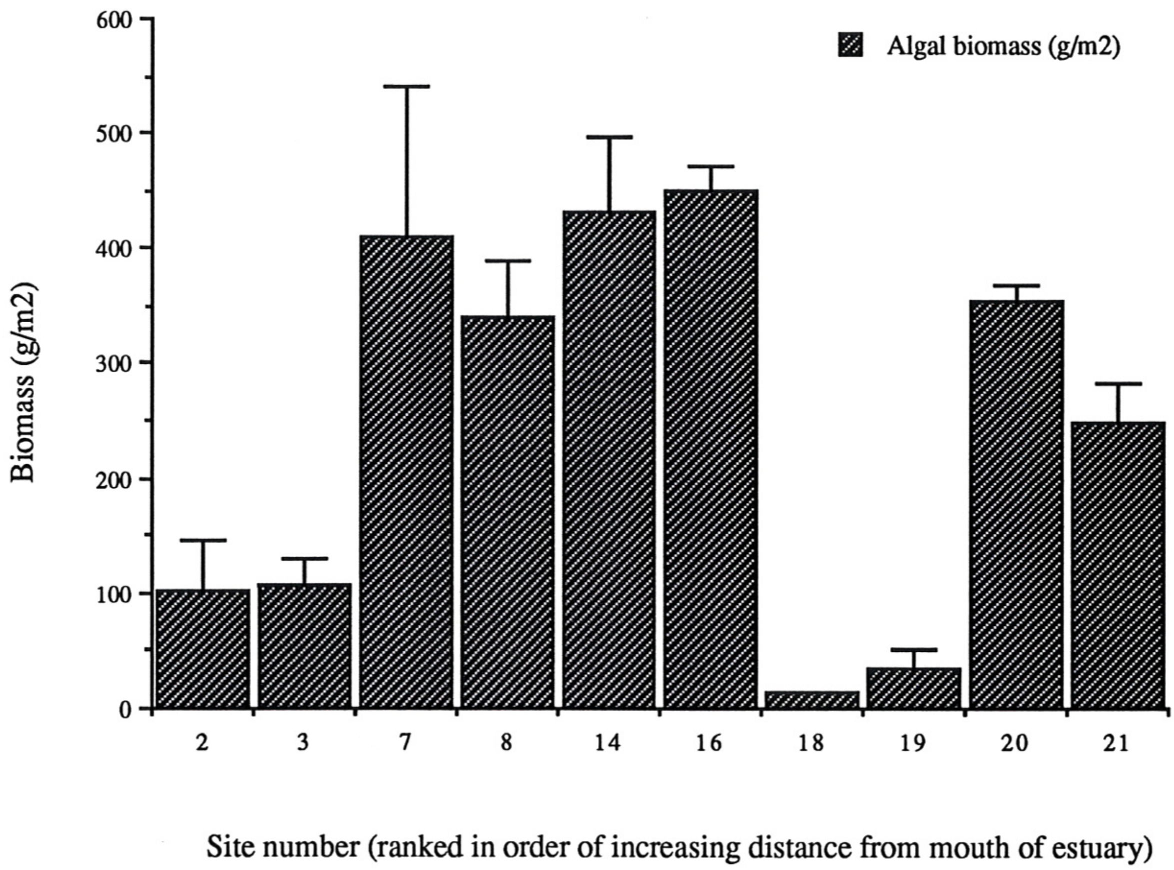


Figure 8. Mean macroalgal biomass from collected cores/quadrats in the Swan-Canning Estuary, December, 1995.

DISCUSSION

Physical parameters such as salinity, light penetration and exposure to air influence the distribution and abundance of seagrass (Hillman *et al.*, 1985). *Halophila ovalis* was found to be the dominant seagrass in the Swan-Canning estuarine basin. The widespread distribution of this species in the estuary reflects its tolerance to the range of environmental conditions prevailing at the time of the survey . Salinity, for example, was as low as 27.5‰ in some areas where *H. ovalis* was recorded, which appeared to have no detrimental effect on its survival. This is in accordance with the findings of Hillman *et al.* (1985) who found that *H. ovalis* grew actively at salinities 10-40‰. The distribution of *Zostera mucronata*, however, was largely restricted to the inlet channel where salinity was higher than other areas of the estuary, suggesting that it is essentially a stenohaline species.

Since *H. ovalis* is known to tolerate a range of salinity (Hillman, 1985), another factor must be responsible for its disappearance from the lower estuary. In this survey *H. ovalis* was not observed further downstream than Rocky Bay (sites 4 and 6), yet Hillman *et al.* (1995) noted that it occurred as far downstream as Fremantle Harbour in both 1976 and 1985. *Zostera mucronata* has colonised area previously occupied by *H. ovalis*. *Zostera mucronata* may have out-competed *H. ovalis* or, alternatively, some environmental or physical factor has caused the death of *H. ovalis*, allowing *Z. mucronata* to inhabit newly available areas.

The upper reaches of the estuary contain more suspended particulate matter that is introduced with inflowing riverine water. This results in increased turbidity, which in turn reduces the light coefficient. It seems most likely that this increase in turbidity is the causal factor excluding seagrasses from the upper reaches of the estuary, rather than other environmental conditions since *H. ovalis* is known to tolerate a range of salinity and temperature (Hillman *et al.*, 1995). The most critical factor controlling growth and survival of seagrasses, however, is the amount of light reaching the leaf (e.g. McComb *et al.*, 1981; Simpson *et al.*, 1993). The hypothesis of light levels being a limiting factor in growth of seagrasses is supported by the near-absence of *H. ovalis* in the Canning River where high turbidity levels were recorded, and its complete absence in Perth Water where there are limited shallow banks and the photic zone is only 1 m (Hillman *et al.*, 1995). Smothering of seagrass leaves by the settling of fine particulate matter would also contribute to seagrass decline.

There has been a marked decrease in the area covered by seagrass in the Swan-Canning Estuary. A total area of 461 ha of seagrass was recorded in this December survey, 137 ha less than that recorded in March 1982 by Hillman *et al.* (1995). Seasonal differences would account for some variation as March is the period of peak productivity in the estuary (Hillman *et al.* 1995). Differences in mapping techniques and personal judgement may also be a source of variation in seagrass area. Nevertheless, it is apparent that there has been a significant reduction in the total area of seagrass between 1982 and 1995, although general distribution has remained similar. The reason(s) for such a decline may be increased physical disturbance resulting from human activity or a change in one or more environmental parameters.

The distribution of macroalgae in the Swan-Canning estuary is similar to that of seagrass, as it includes epiphytic as well as free-floating and benthic algae. Compared to distribution of main summer communities documented by Allender (1970) however, there has been a loss of macroalgae in some areas. Most notably, Mosman Bay, the west bank of Freshwater Bay, east of Matilda Bay, and Perth Water were essentially bare of algae at the time of this survey. Again, some of this variation in distribution can be attributed to seasonality, as it is unlikely that macroalgae growth had reached its peak summer growth in December. It is reasonable to conclude, however, that algal communities have exhibited an overall decline in the past 25 years.

No total macroalgae biomass data for the Swan-Canning Estuary was available from other studies for comparison. A comparison can be made, however, with the Peel-Harvey Estuarine System which lies 75 km south of Perth (Lavery, 1989). The total macrophyte biomass for this system was generally between 10-20 thousand tonnes dry weight during 1986-88 (Lavery, 1989), compared to 408 t DW in the Swan-Canning Estuary in December 1995. It must be taken into consideration, however, that the Peel-Harvey Estuary is approximately five times larger in area (P. Lavery, pers. comm.) and was eutrophic at the time (Lavery, 1989). In addition, algae occurring on vertical rock faces and in deep water in the Swan-Canning Estuary was not visible on the aerial photographs used and as such was not sampled for biomass.

For seagrass, Hillman *et al.*(1995) found that biomass followed a seasonal trend, and that peak biomass was reached in late summer/early autumn. These authors show that for December 1981 biomass ranged between 20-75 g/m^2 at six sites, and reached maximum levels of 60-120 g/m^2. The mean seagrass biomass of 75.17 g/m^2 for the Swan-Canning Estuary at the time of this survey is therefore considered to fit the seasonal trend of increasing biomass to a peak around March as described by Hillman *et al.* (1995).

ACKNOWLEDGMENTS

This study was funded by the Water and Rivers Commission and the Estuarine Research Foundation. We would also like to thank Anne Brearley, Dr Steve Connell, Kim Grey, Martin Heller, Dr Gary Kendrick, Dr Paul Lavery and Dr Di Walker.

REFERENCES

Allender, B.M. (1970). *The ecology of the marine algae of the Swan River Estuary, Western Australia.* M.Sc. Thesis, Botany Department, University of Western Australia.

Hillman, K. (1985). *The production ecology of the seagrass* Halophila ovalis *(R.Br) Hook. in the Swan-Canning Estuary, Western Australia.* Ph.D. Thesis, Botany Department, University of Western Australia.

Hillman, K., McComb, A.J. and Walker, D.I. (1995). The distribution, biomass and primary production of the seagrass Halophila ovalis in the Swan/Canning Estuary, Western Australia. *Aquat. Bot.*, **51**: 1-54.

Lavery, P.S. (1989). *Factors Controlling the Abundance and Dominance of Macroalgal Species in Eutrophic Estuaries.* Ph.D Thesis, Botany Department, University of Western Australia.

McComb, A.J., Cambridge, M.L., Kirkman and Kuo, J. (1981) The biology of Australian seagrasses. Pp. 258-253. In Pate, J.S. and McComb, A.J. (eds) *The Biology of Australian Plants*. University of Western Australia Press, Perth.

Riggert, T.L. (1978). *The Swan River Estuary Development, Management and Preservation.* Swan River Conservation Board, Perth, Western Australia.

Simpson, C.J., Burt, J.S., Cary, J.L., D'Adamo, N., Masini, R.J. and Mills, D.A. (1993) *Southern Metropolitan Coastal Waters Study (1991-1994).* Technical series **53**. Environmental Protection Authority, Perth.

Swan River Trust. (1994). *Highlights of the Year (A Summary of the Annual Report) 1993-1994.* Swan River Trust, Western Australia.

Thurlow, B.H., Chambers, J. and Klemm, V.V. (1986). *Swan-Canning Estuarine System: Environment, Use and Future.* Report No. 9. Waterways Commission, Western Australia.

APPENDIX I. The location of 26 biomass sites on the Swan-Canning Estuary, determined using a Magellan GPS (Global Positioning System).

SITE	LOCATION		
	Zone	Easting	Northing
1	SH50	382353	6454238
2	SH50	382350	6454125
3	SH50	382989	6454795
4	SH50	382508	6455713
5	SH50	382934	6455424
6	SH50	382570	6455941
7	SH50	384811	6456336
7A	SH50	383933	6455898
8	SH50	385037	6457622
9	SH50	385067	6457796
10	SH50	383800	6458855
11	SH50	384785	6459324
12	SH50	385225	6459251
13	SH50	386290	6453306
14	SH50	386641	6457056
15	SH50	387885	6456358
16	SH50	388004	6455589
17	SH50	389006	6457070
18	SH50	388473	6459063
19	SH50	390711	6458794
19A	SH50	390363	6458481
21	SH50	393568	6455444
23	SH50	391426	6460081
24	SH50	389054	6460127
25	SH50	388671	6461472

APPENDIX II. Light readings and Secchi depths for 25 sites in the Swan-Canning Estuary.

SITE	Secchi depth (m)	Maximum depth (m)	Time of day
1	>2.4	2.4m	9.30am
2	3.5	5.1	9.45am
3	>2.1	2.1	11.15am
4	>0.4	0.4	12.00pm
5	>0.5	0.5	11.00am
6	>0.4	0.4	12.20pm
7	>0.5	0.5	10.00am
8	>0.5	0.5	8.15am
9	>0.5	0.5	8.45am
10	>0.5	0.5	9.50am
11	>2.0	2.0	10.30am
12	>1.0	1.0	11.05am
13	>1.0	1.0	11.40am
14	>1.0	1.0	1.25pm
15	>1.0	1.0	2.10pm
16	>1.0	1.0	2.35pm
17	>1.0	1.0	8.55am
18	2.8	3.1	10.10am
19	>0.4	0.4	11.00am
19A	>0.8	0.8	10.30am
20	>0.25	0.25	11.45am
21	>0.2	0.2	12.55pm
23	>0.25	0.25	9.30am
24	>0.5	0.5	12.15pm
25	>1.0	1.0	12.45pm

Site	Depth (m)	Light Reading ($uEms^{-1}$)
1	0	1863
	0.5	1317
	1	1055
	2	631
	3	552
2	0	1114
	0.5	903
	1	689
	2	604
	3	366
	4	264
	5	201
3	0	1838
	0.5	1159
	1	1059
	2	682
4	0	1440
	0.5	1440
5	0	1447
	0.5	1345
	1	1078

APPENDIX III. Seagrass and algal biomass recorded at selected sites in the Swan-Canning Estuary, December 1995.

SITE	Mean DW of seagrass (g/m^2)	Mean DW of epiphytes (g/m^2)	Mean DW of algae (g/m^2)
1*	-	-	-
2	-	-	101.81 (± 44.57)
3	227.19 (± 35.23)	12.19 (± 7.47)	106.26 (± 23.28)
4	276.62 (± 29.62)	45.53 (± 15.22)	-
5	211.47 (± 55.86)	-	-
6	383.25 (± 85.75)	23.22 (± 10.73)	-
7	-	-	410.89 (± 128.31)
7A	153.31 (± 29.05)	23.59 (± 7.59)	-
8	177.53 (± 56.60)	221.66 (± 52.5)	339.99 (± 48.40)
9	221.75 (± 12.52)	162.34 (± 113.63)	-
10	127.47 (± 13.82)	-	-
11*	-	-	-
12	144.81 (± 18.57)	62.84 (± 10.81)	-
13	106.25 (± 10.31)	87.13 (± 33.81)	-
14	-	-	429.75 (± 64.90)
15	201.41 (± 23.69)	75.91 (± 13.21)	-
16	-	-	449.76 (± 21.27)
17	112.31 (± 12.48)	42.28 (± 5.27)	-
18	-	-	12.87 (±1.63)
19	82.47 (± 6.08)	-	34.84 (± 16.62)
19A	281.53 (± 19.48)	28.81 (± 1.95)	-
20	-	-	354.21 (± 13.66)
21	-	-	246.88 (± 34.59)
22*	-	-	-
23	108.78 (± 15.66)	34.94 (± 25.09)	-
24	143.56 (± 17.22)	142.75 (± 53.20)	-
25	112.81 (± 14.20)	60.69 (± 28.10)	-
26*	-	-	-
27*	-	-	-
28*	-	-	-
29*	-	-	-
30*	-	-	-

* Sites at which either seagrass and macroalgae did not exist or were not collected.

APPENDIX IV. List of dominant macroalgae species recorded at selected sites in the Swan-Canning Estuary during December 1995.

SITE 2

CHLOROPHYTA
Ulvales
Ulva sp.

PHAEOPHYTA
Scytosiphonales
Colpomenia sinuosa (Roth) Derbes *et* Solier *in* Castagne
Dictyotales
Dictyota dichotoma (Hudson) Lamouroux

RHODOPHYTA
Gigartinales
Gelinaria ulvoidea Sonder
Rhodymeniales
Rhodymenia australis (Sonder) Harvey

SITE 3

CHLOROPHYTA
Ulvales
Ulva sp.
Siphonocladales
Dictyosphaeria sericea Harvey

RHODOPHYTA
Gigartinales
Grateloupia filicina J. Agardh

SITE 7

CHLOROPHYTA

Ulvales

Enteromorpha intestinalis (Linnaeus) Nees

Enteromorpha prolifera (Muller) J. Agardh

Siphonocladales

Dictyosphaeria sericea Harvey

PHAEOPHYTA

Ectocarpales

Ectocarpus siliculosus (Dillwyn) Lyngbye

Fucales

Cystoseira trinodis (Forsskal) C. Agardh

RHODOPHYTA

Gigartinales

Hypnea valentiae (Turner) Montagne

Gracilaria verrucosa (Hudson) Papenfuss

Ceramiales

Laurencia majuscula (Harvey) Lucas

SITE 7A

CHLOROPHYTA

Siphonocladales

Dictyosphaeria sericea Harvey

PHAEOPHYTA

Fucales

Cystoseira trinodis (Forsskal) C. Agardh

RHODOPHYTA

Ceramiales

Laurencia majuscula (Harvey) Lucas

<u>SITE 8</u>

CHLOROPHYTA

Ulvales

Enteromorpha prolifera (Muller) J. Agardh

Ulva rigida C. Agardh

RHODOPHYTA

Gigartinales

Grateloupia filicina J. Agardh

Hypnea charoides Lamouroux

Ceramiales

Laurencia clavata Sonder

Chondria succulenta (J. Agardh) Falkenberg