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DISTRIBUTION AND SUMMER STANDING CROP OF SEAGRASSES AND MACRO-ALGAE IN WESTERN PORT, VICTORIA

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Abstract: The distribution of seagrasses and macro-algae in Western Port was mapped from aerial photographs and observations made by SCUBA diving. The angiosperm, *Heterozostera tasmanica*, was the dominant macro-benthic plant in Western Port accounting for 54% of the area covered by seagrasses and macro-algae. The angiosperms *Amphibolis antarctica* (8% of the area) and *Zostera muelleri* (16%), and the alga *Caulerpa cactoides* (19%) were also common. Above sediment biomass of these plants was estimated during summer by stratified cluster sampling in each of five segments of the bay. Within beds of seagrasses and macro-algae organic weight of all plants averaged 168 g/m². The seagrass, *A. antarctica,* occurred only in the Western Entrance segment where above-sediment organic weight averaged 514 g/m². The largest area of seagrasses and macro-algae was in the northern section of Western Port where large intertidal areas were covered by extensive stands of *H. tasmanica.* Algae made up 27% of the total macro-benthic standing crop in the bay and dominated the vegetation in the eastern segments of Western Port.

INTRODUCTION

Western Port is a 680 km² coastal inlet off Bass Strait located 50 km south-east of Melbourne, Victoria. Extensive beds of seagrasses and benthic macro-algae have been reported in the bay and studies on fish, birds and other fauna have indicated that these macro-benthic plants are important to the Western Port ecosystem (Loyn & Bingham 1978, Robertson 1977, Robertson & Howard 1978, Smith *et al.* 1975).

McRoy and McMillan (1977) have reviewed the literature on seagrass standing crops. Their figures indicate a range for temperate species from 6 to 5160 g dry weight per m² with means ranging from 89 to 1900 g/m². Within Australia, standing crops have been estimated for *Posidonia australis* in Cockburn Sound, Western Australia (Cambridge 1975) and in Botany Bay, New South Wales (Larkum 1976), and for several seagrasses in Tin Can Inlet and Moreton Bay, Queensland (Dredge *et al.* 1977, Kirkman 1978). The standing crops for various macro-algae in South Australia have also been determined (Shepherd & Womersley 1970, 1976). However, there are no published estimates of the standing crop of any seagrasses along the southern Australian coast. The objectives of this study were to determine the distribution of the dominant macro-benthic plants in Western Port and to estimate their summer standing crops.

METHODS

The seagrasses and macro-benthic algae of Western Port were mapped at a scale of 1:15 000 by Natural Systems Research Pty. Ltd., from colour aerial photographs taken at a height of 2290 m during 1973 and 1974 and from field checking carried out in July 1974 (unpublished report to the Western Port Bay Environmental Study, Ministry for Conservation, Victoria). These maps were modified in the present study using the results of a preliminary survey in December, 1974. This preliminary survey indicated that all of the area of Western Port covered by macro-benthic plants could be divided into five classes on the basis of the dominant species. An area designated as dominated by one species could contain small patches (up to 3 ha) of other species and/or low densities of minor species mixed with the dominant. In order to estimate distribution, Western Port was divided into five segments as in Harris *et al.* (1979): Western Entrance, Lower North Arm, Upper North Arm, Corinella Segment and Rhyll Segment (Fig. 1). All areas with seagrasses and macro-algae were thus divided into 25 categories

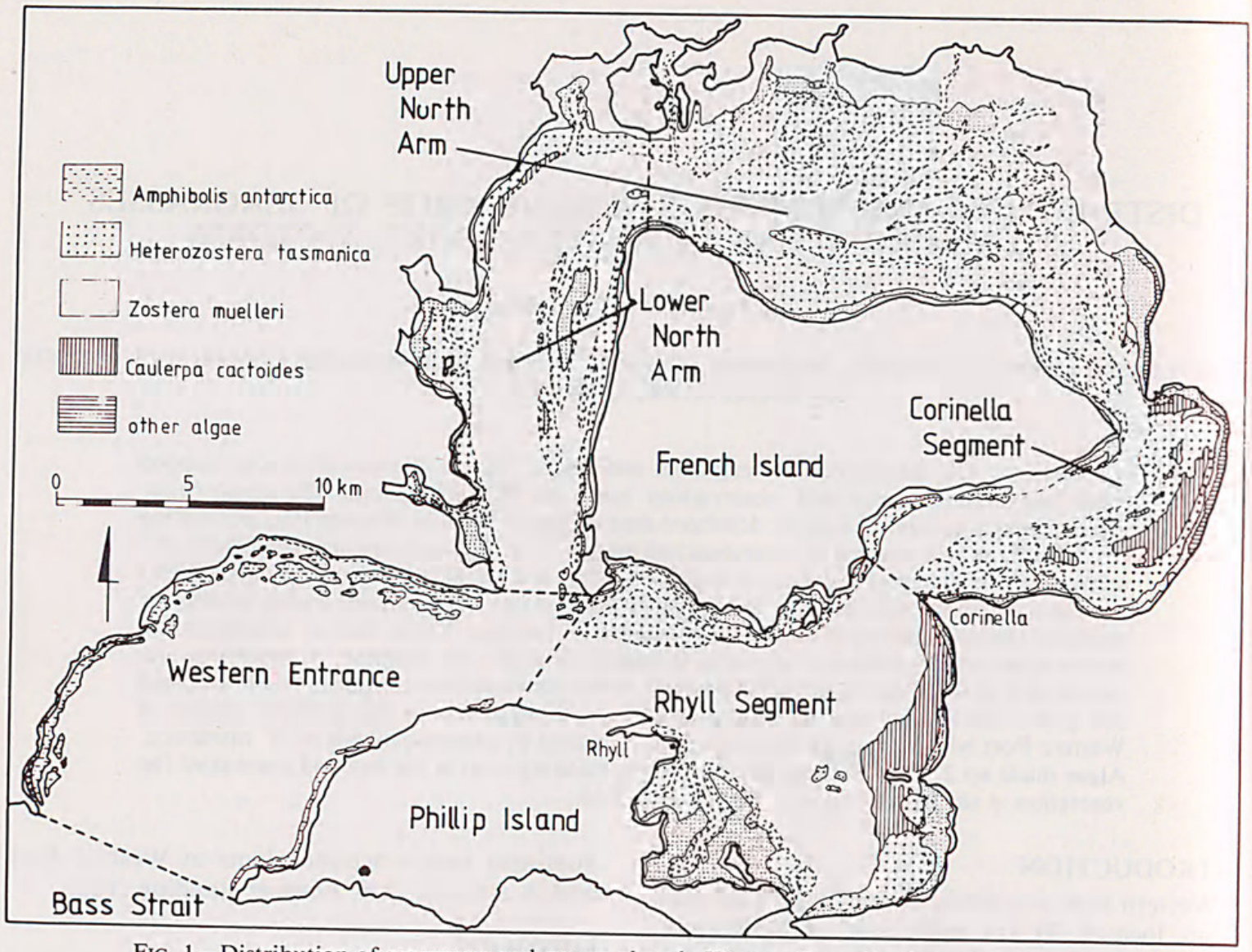

FIG. 1 — Distribution of seagrasses and macro-algae in Western Port. Sections of the bay from Harris *et al.* 1979.

or strata, defined by the segment of the bay in which it occurred and the plant that was dominant. The area of each of these strata was determined to the nearest hectare.

Most estimates of seagrass and macro-algal standing crop are based on a 'random' series of samples taken within pre-selected beds of seagrass and/or macro-algae. Extrapolation of the dry or fresh weight means thus obtained to include the total area estimated for the respective plant is fraught with uncertainty and lacks any method of defining the reliability of the estimate. In order to overcome these problems, stratified cluster sampling (Yamane 1967) was used in this study. Confidence limits could then be placed on all estimates of standing crop. Within each section of the bay 30 to 40 primary sampling sites of 2500 m² were allocated in proportion to the amount of area in each stratum. These primary sampling sites and the two or three samples within each site were randomly selected. Sample size was 0.0625 m², which size had the lowest variance/mean ratio of sample sizes ranging from 0.003 91 m² to 0.25 m² in a preliminary test (Kershaw 1973).

The standing crop of seagrasses and perennial marine macro-algae in temperate climates usually fluctuates seasonally with a maximum in summer (Sand-Jensen 1975). This is also true for *Heterozostera tasmanica* in Western Port (Bulthuis, unpublished data). Field samples therefore were collected in mid-summer, January, 1975, when standing crops would be expected to be near their annual maxima. Sampling sites were located in the field by ship-borne radar and hand-held compass with reference to charted beacons and landmarks. All macro-benthic plants within the sampling area were cut at the mud surface, placed in a plastic bag and kept on crushed ice for transport.

All samples were stored at 5°C in the laboratory until sorted. Within four days of collection the samples were washed free of sediment and detritus, divided into angiosperms and algae, and

dried at 105°C to constant weight. The living, dead and detrital stems of *H. tasmanica* were indistinguishable from each other and removed from the sample. Therefore, sixty additional samples of *H. tasmanica*, with the sediment intact, were taken to the laboratory where living stems and leaves were carefully sorted from the remainder of the sample. Linear regression of leaf dry weight against leaf plus living stem dry weight of these samples was used to estimate leaf plus living stem dry weight of all *H. tasmanica* samples. Subsamples of each sample greater than 1 g (which included about 70% of the samples) were muffled in pre-heated aluminium foil at 550°C to constant weight. The percent ash-free dry weight or organic weight (Westlake 1963) of each subsample was used to calculate the total organic weight of the sample.

The total organic weight of seagrasses and macro-algae in each stratum and segment of the bay with its variance and 95% confidence limits was calculated by the formulae for stratified cluster sampling analysis in Yamane (1967).

RESULTS

Three seagrass species, *Amphibolis antarctica* (Labill.) Sonder & Aschers., *Heterozostera tasmanica* (Martens ex Aschers.) den Hartog and *Zostera muelleri* Irmisch ex Aschers., and one species of algae, *Caulerpa cactoides* (Turner) C. Agardh (Chlorophyta), dominated the macro-benthic vegetation in Western Port. In addition to strata dominated by these four species, a fifth stratum in each segment of the bay included areas dominated by algae other than *C. cactoides*. Numerous species of algae and other seagrasses were present in each stratum in addition to the dominant species. For example, *Zostera muelleri* was frequently present in the *Heterozostera tasmanica* areas, and *H. tasmanica* and *Caulerpa cactoides* formed mixed communities in the Corinella segment. The seagrass, *Haslophila ovalis* (R. Br.) Hook. f., occurred in small patches in most strata. Various algae were common in the seagrass strata including *Polysiphonia* sp., *Caulerpa sedoides* (R. Brown in Turner) C. Agardh and *Jeanerettia* sp. *Asperococcus bulbosus* Lamouroux and *Enteromorpha* sp. were present in most of the *Heterozostera tasmanica* areas of the Upper North Arm. Coralline algae were especially prominent growing on *Amphibolis antarctica*.

Seagrasses and macro-algae were distributed throughout Western Port covering a total of 251 km² or 37% of the bay's area (Fig. 1, Table 1). *Heterozostera tasmanica* was the dominant plant, accounting for 54% of the total area occupied by seagrasses and macro-algae. *Caulerpa cactoides* (19%), *Zostera muelleri* (16%) and *Amphibolis antarctica* (8%) covered most of the remaining area. Strata dominated by algae other than *Caulerpa cactoides* accounted for less than 3% of the area. Each segment did not have all species present. The algae dominated strata were mainly on the eastern side of the bay in the Corinella and Rhyll segments. In the Western Entrance the only macro-benthic plant covering more than 0.1 km² was *Amphibolis antarctica* and this species was rare in the other sections of Western Port. The Upper North Arm had the largest area of seagrasses and macro-algae while the Western Entrance had the smallest area.

Mean organic weight of the standing crop varied from 39 to 66% of the total dry weight for different plant species (Table 2). The algae had a lower percentage organic weight than did the angiosperms.

Organic weight per square metre at any one primary sampling site (mean of two or three samples) varied from zero to 431 g in *Heterozostera tasmanica* dominated strata, from zero to 333 g in the *Caulerpa cactoides* strata and from 218 to 706 g in the *Amphibolis antarctica* strata. The mean values presented in Table 3 indicate large differences between strata dominated by the

TABLE 1

AREA (KM²) DOMINATED BY SEAGRASSES AND MACRO-ALGAE IN EACH OF FIVE SEGMENTS OF WESTERN PORT AS ESTIMATED FROM AERIAL PHOTOGRAPHY AND FIELD SAMPLING

Segments	*A. antarctica*	*H. tasmanica*	*Z. muelleri*	*C. cactoides*	Other algae	Total
Western Entrance	20.6	<0.1			<0.1	20.6
Lower North Arm	<0.1	20.4	9.6	4.5	<0.1	34.5
Upper North Arm		61.6	16.2	2.8	<0.1	80.6
Corinella Segment		29.1	4.6	23.9	1.0	58.6
Rhyll Segment		25.2	9.4	17.2	4.8	56.6
	20.6	136.3	39.8	48.4	5.8	250.9

TABLE 2
MEAN ORGANIC WEIGHT AS PERCENTAGE OF TOTAL DRY WEIGHT IN SEAGRASSES AND MACRO-ALGAE FROM WESTERN PORT

Plant	Mean	s.e.	n
A. antarctica	66.0	±2.16	12
H. tasmanica	65.4	±2.43	85
Z. muelleri	47.2	±1.62	52
C. cactoides	42.9	±1.19	25
Other macro-algae	39.0	±1.01	90

same species but located in different sections. These differences may indicate the suitability of the various sections for growth of the respective plants. Algae varied in importance within the angiosperm beds. In the *Heterozostera tasmanica* strata of the Rhyll Segment the organic weight of algae was nearly as large as the angiosperm weight, principally *Jeanerettia* sp., caught among the stems of *Heterozostera tasmanica.*

The mean organic weight per unit area and the area of coverage was used to estimate the total standing crops of seagrasses and macro-algae in Western Port (Table 4). *Heterozostera tasmanica* accounted for 58% of the total standing crop.

The upper North Arm had the highest standing crop followed by the Western Entrance and the Rhyll Segment. The total standing crop for the whole of the bay is 42 000 tonnes of organic weight which is equivalent to 61.8 g/m² averaged over the whole bay. The total dry weight was 85 100 tonnes or 125 g/m² averaged over the bay. When the algae present in the angiosperm dominated areas is added to the *Caulerpa cactoides* and "other algae" strata, the total organic weight of algae in the bay is 11 500 tonnes (27% of 42 000) compared to 30 500 tonnes (73%) for the angiosperms.

DISCUSSION

The distribution of seagrasses and macro-algae in Western Port reflects the sediments and bottom topography. The sediments of the Western Entrance are sandy and the coast is exposed to southerly winds and swell from Bass Strait. In this section of Western Port the primary macro-benthic plant is *Amphibolis antarctica* which according to den Hartog (1970), is generally found on "sandy bottoms . . . where the water is kept in continual motion by currents or wave action". *A. antarctica* did not occur, except in very small isolated patches, in the remaining sections of Western Port where bottom sediments, other than in the channels, are generally muddy. Excluding the Western Entrance, the distribution of seagrasses and macro-algae closely paralleled the intertidal area (Fig. 1). Thus, the Upper North Arm which has the largest intertidal area also had the largest area of seagrass and macro-algae (Table 1). *Heterozostera tasmanica* was the main macro-benthic plant on the intertidal mudflats with *Zostera muelleri* generally occurring higher in the littoral zone than *Heterozostera tasmanica. Caulerpa cactoides* usually occurred in the subtidal areas and only occasionally was present in shallow depressions in the intertidal zone. *C. cactoides* was thus found mainly in the Corinella and Rhyll Segments where there are large subtidal areas with a muddy sediment.

Most published reports of seagrass standing stocks are in terms of total dry weight including roots and rhizomes (McRoy & McMillan 1977). If the leaf dry weight data from this study is corrected to include roots (leaf dry weight × 1.65; McRoy 1970) the mean total biomass per m² during summer is estimated as 1100 g for *Amphibolis antarctica*, 460 g for *Heterozostera tasmanica* and 150 g for *Zostera muelleri.* This range of means is similar to the range of means, reported for *Zostera marina* (McRoy & McMillan 1977).

Westlake (1963) in his review of plant produc-

TABLE 3
STANDING CROP (ORGANIC WEIGHT IN G/M²) OF SEAGRASSES AND MACRO-ALGAE IN FIVE SEGMENTS OF WESTERN PORT IN JANUARY, 1975 (MEAN ± S.E.)

Plant and Segment	Angiosperm	Algae	n
A. antarctica stratum			
Western Entrance	469 ±70.0	46 ±12.0	18
H. tasmanica strata			
Lower North Arm	139 ±16.8	26 ± 5.2	63
Upper North Arm	190 ±21.5	33 ± 6.8	50
Corinella Segment	54 ±14.6	34 ± 6.8	26
Rhyll Segment	112 ±31.9	80 ±25.2	18
Z. muelleri strata			
Lower North Arm	36 ± 6.3	1.4± 0.74	27
Upper North Arm	32 ±14.1	11.1± 3.54	10
Corinella Segment	7.9± 2.99	14.9± 4.81	6
Rhyll Segment	71 ±23.2	3.6± 1.48	18
C. cactoides strata			
Lower North Arm	39 ±12.7	54 ±29.3	9
Corinella Segment	0.9± 0.43	66 ±14.8	14
Rhyll Segment	<0.1	134 ±27.5	18
Other macro-algae stratum			
Corinella Segment	0.4± 0.20	68 ±26.2	8

TABLE 4
TOTAL STANDING CROP OF SEAGRASSES AND MACRO-ALGAE IN FIVE SEGMENTS OF WESTERN PORT IN JANUARY, 1975 (ORGANIC WEIGHT IN TONNES ÷ 100)

Segments	*A. antarctica*	*H. tasmanica*	*Z. muelleri*	*C. cactoides*	Other macro-algae	Total	95% Confidence Limits
Western Entrance	106					106	69.9-142
Lower North Arm		33.7	3.6	4.2		41.5	29.5-53.5
Upper North Arm		138	7.0	2.6		147	113-181
Corinella Segment		25.7	1.0	15.9	3.3	43.4	26.7-60.0
Rhyll Segment		48.3	7.0	23.1	0.7	81.8	52.2-111
Total	106	245	18.6	45.8	4.0	420	
95% Confidence Limits	69.9-142	200-291	9.7-27.5	29.0-62.6	1.0-7.0		

tivity recommended that organic weight be adopted as the best general criterion of productivity. This has been used in the present study. The standing crop determined in this study was the above-sediment portion of the angiosperms and algae. The estimates of total organic weight in Table 4 indicate that *H. tasmanica* is the most important primary producer among the seagrasses and macro-algae. The stems of *Amphibolis antarctica* are perennial so the standing crop of this seagrass may include several years of growth. The high standing crop of this species, therefore, may be due to its particular growth habit rather than to a relatively high net productivity compared with the other macro-benthic plants in Western Port. The Upper North Arm has the highest standing crop in the bay and therefore probably makes the greatest contribution to baywide macro-benthic plant production. The Western Entrance and the Rhyll Segment are also important in terms of production.

Algae are an important component of the seagrass beds in Western Port as indicated by the proportion of total organic weight attributable to them (Table 3). Algae both within the seagrass beds and in extensive beds of their own, increased in importance in the eastern section of Western Port where they accounted for 62% and 57% of the organic weight in the Corinella and Rhyll Segments respectively.

CONCLUSIONS

1. *Heterozostera tasmanica* is the most important macro-benthic plant in Western Port, covering the greatest area and having the highest standing crop, 24 500 tonnes organic weight, and averaging 180 g/m².

2. *Amphibolis antarctica* has a total standing crop of 10 600 tonnes averaging 515 g/m² and occurs mainly in the Western Entrance of Western Port.

3. *Zostera muelleri* generally occurs higher in the littoral zone than *Heterozostera tasmanica*, averages 46 g/m² and has a total of 1860 tonnes organic weight in Western Port.

4. Algae form a significant proportion of the standing crop of macro-benthic plants and are the main plants on the eastern side of Western Port where *Caulerpa cactoides* occurs in large beds, averaging 95 g/m² with a total standing crop of 4580 tonnes/organic weight.

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