CHAPTER 3.

SPATIAL PATTERNS IN THE SEAGRASSES

3.1. Introduction

Moreton Bay is an important dugong habitat in southern Queensland (Heinsohn et al., 1978; Marsh et al., 1990; Preen et al., 1992). An understanding of the seagrass resource of Moreton Bay is central to understanding the ecology of its dependent dugongs. Habitat selection, diet, distribution, movements and home range of the dugongs are likely to be related to the spatial distribution and abundance of seagrass species.

Relative to many areas in Australia, the seagrasses of Moreton Bay have been well studied (Poiner and Roberts, 1986). Most of the studies have focused on the seagrasses of the littoral fringe of the Bay (Kirkman, 1975; Kirkman, 1976; Kirkman, 1978; Poiner, 1980, 1984a, 1984b; Young, 1978; Young and Kirkman, 1975) or seagrass metabolism (Boon, 1986; Boon et al., 1986a, 1986b). Only Hyland et al. (1989) have attempted to determine the distribution of seagrasses throughout the Bay. However, the available maps of the seagrasses of Moreton Bay lack the resolution and accuracy (Hyland et al., 1989; Kirkman, 1975; Young and Kirkman, 1975) or the coverage (Poiner, 1984a, 1984b) required to explain the observed patterns of dugong distribution. Hence, it was necessary to map in detail the seagrasses in my study areas. A secondary objective was to produce an accurate and detailed seagrass map suitable for assessing future change.

3.2. Methods

3.2.1. Aerial photography

Vertical aerial photographs were used to map the seagrass communities of the study areas. The photographs were taken in September 1989 by commercial aerial mapping consultants. I assembled the colour photographs into montages of each study area at a scale of approximately 1:20,000.

The boundaries of 157 tracts of seagrass, representing 27 strata were determined from the montages. Tracts were continuous areas of the seagrass with the same appearance, while strata were (presumed) seagrass communities.

3.2.2. Sampling design

Funds allowed for the collection and sorting of 1,000 samples. Earlier work in Moreton Bay and Torres Strait suggested that two 'standard shovel' quadrats (0.05 m^2) would adequately characterise a sample site (I. Poiner, pers. comm.), thus permitting a total of about 500 sampling sites.

The number of sampling sites allocated to each stratum was proportional to its area and its relative importance to the dugongs. The number of sites allocated to individual tracts within strata was based on their size relative to the total area of the appropriate stratum. The areas of tracts and strata were determined from a provisional seagrass map digitised from the aerial photo montages. The importance of each stratum to the dugongs was based on the distribution of dugongs recorded during 24 aerial surveys of the study areas (see Chapter 5), the home ranges of tracked dugongs (Chapter 5) and the distribution of my encounters with dugongs in the study areas.

The distribution of sites within tracts was established using an overlay of random points on the digitised map. The position of each site was defined by the intersection of three to six bearings from navigation beacons and prominent topographic features incorporated into the map. These bearings were corrected for magnetic variation and used to locate each site in the field. The locations of the 512 sites that were sampled are plotted in Appendix 1.

3.2.3. Sampling

3.2.3.1. Quantitative

The seagrasses at each site were randomly sampled by excavating two quadrats ($0.05\ m^2$) located at the ends of a 3 m rod thrown from the boat. All material to a depth of 5-10 cm (depending on root depth and sediment type) was removed, rinsed in a dive bag (5 mm mesh) to remove sediment and stored on ice.

In the laboratory, samples were thoroughly washed in fresh water. They were not acid-washed (Poiner et al., 1987) as there was generally little contamination by epiphytes or sediment. When necessary, epiphytic algae were scraped from the leaves. The samples were sorted into species, and the number of shoots counted. The mean widths of shoots from Zostera capricorni and Halodule uninervis were estimated by measuring a sub-sample of approximately 30 leaves. The samples were separated into above- and below-ground components which were oven-dried at 60-65° C to a constant weight. The separation of the above- and below-ground components was made at the point of divergence of the shoots from the rhizome.

The data from the two quadrats from each site were averaged and multiplied by 20 to provide an estimate of shoots or biomass/m^2.

3.2.3.2. Semi-quantitative

In areas where seagrasses show marked patchiness, the two $0.05\ m^2$ quadrats did not sample all the species present at each site (Table 3.1). This limits the usefulness of these samples for defining the seagrass community at each site. In anticipation of this limitation, a semi-quantitative assessment of the above-ground abundance of each species of seagrass was also made in the vicinity of each of the 512 sites. Abundance was assessed within a 5 m radius of the boat using the following logarithmic scale: 0: absent, 1: very sparse, 2: sparse, 3: medium, 4: dense. Such a logarithmic scale provides a level of accuracy appropriate to rapid visual estimates of abundance (Gauch, 1982). I also noted if a species was 'patchy' within the sampling area. A species was considered 'patchy' if it occurred in clumps which were 2-10 m apart.

3.2.3.3. Depth

The water depth at each site was measured (to nearest 0.1 m) using a sounding line. See section 2.4 for details of sampling, data manipulation and map generation.

3.2.3.4. Period of sampling

Most sites (465) were sampled between 23 November and 23 December 1989. The remaining 47 sites, all from the West study area, were sampled between 6 and 14 January 1990.

3.2.4. Number of species and morphs of seagrass

Moreton Bay contains seven species of seagrass (Table 3.1; Hyland et al., 1989). Based on leaf width, Poiner (1984a) recognised three size morphs for Z. capricorni (<2 mm, >2 to <4, >4 mm) and two size morphs for Halophila ovalis at two inter-tidal locations in Moreton Bay. The distribution of Z. capricorni morphs corresponded to their degree of exposure: the smallest morphs occurred in the shallowest areas. On the main seagrass banks of the East study area Z. capricorni and H. uninervis, but not H. ovalis, showed morphologic variation in leaf width: Z. capricorni **thin** and H. uninervis **thin** had leaf widths of ≤1 mm, while Z. capricorni **broad** and H. uninervis **broad** had leaf widths of >1 mm. Thus, nine species/morphs of seagrasses were recognised (Table 3.1).

3.2.5. Data analysis

3.2.5.1. Identification of seagrass communities

Pattern analysis (Clifford and Stephenson, 1975) was used to group the sites into seagrass communities. Input data were the semi-quantitative log abundance scores from the 417 sites that contained seagrass out of the 512 sites sampled. Apart from the uncommon Halophia decipiens and Cymodocea serrulata, the abundance scores were significantly correlated with log-transformed shoot density and with log transformed shoot biomass (Table 3.1) and hence, provide a reasonable description of the seagrasses at each site. Where species were recorded as 'patchy', I deducted 0.5 from the abundance score. This assumes that the patches occupied about 30% of the area.

The PATN program (Belbin, 1988) was used to perform an agglomerative hierarchical classification using the Bray and Curtis association index and the flexible Weighted Pair Group Arithmetic Averaging (WPGMA; $\beta = 0$) as the fusion algorithm. The Bray and Curtis index was used as it has consistently performed well in simulations with a variety of data (Belbin, 1988). The WPGMA is recommended when it is known that some communities are very unequally represented in the data (Pielou, 1984). A classification was also performed using the Manhattan metric and the flexible Unweighted Pair Group Arithmetic Averaging (UPGMA) options. While confirming the general pattern of communities, this classification did not fit the data as well as that generated by the Bray-Curtis and WPGMA.

I classified the sites into 417 clusters and into 25 groups. The distribution of sites within the 25 groups was plotted, and compared with the provisional map of strata. The raw data were then examined to determine the effects of the classification decisions. As a result, several pairs of the 25 groups were amalgamated where the separation was based on very minor differences in abundance between species. One group which had been diluted across two groups was separated to form a new group. A total of 15 seagrass communities was finally recognised. I characterised these communities on the basis of the median abundance score of each species. (The median is more appropriate than the mean for approximately log scale data. This was confirmed by plotting the data. However, a species had to be present in over 50% of sites within a community before it could score a median value greater than zero).

3.2.5.2. Seagrass biomass and standing crop

The term biomass refers to the dry weight of seagrass per unit area and is recorded as g/m^2. Standing crop refers to the dry weight of seagrass in a specified area and is recorded in kilograms or tonnes. Unless stated otherwise, biomass and standing crop refer to the combined dry weight of the above- and below- ground components of the seagrass. Dugongs feed on both the rhizomes and leaves of seagrass (section 6.3.2.2) and are likely to select on the basis of both.

The mean biomass of a community was estimated by averaging the biomass of all seagrass at sites within tracts of that community.

The standing crop of a community was estimated as follows:

1. The mean biomass of seagrass was estimated for each tract of that community type.
2. The standing crop of each tract =
   biomass of the tract * area of the tract (from the final seagrass maps).
3. The variance of the standing crop of each tract =
   variance of biomass * area^2.
4. The standing crop of the community =
   Σ standing crop of each tract.
5. The standard error (SE) of the estimate of community standing crop =
   $\sqrt{}$(Σ variance of each tract).

See Norton-Griffiths (1978) for details of variance manipulations for stratified samples.

The standing crop of seagrass in a study area was estimated by summing the standing crops of all the communities. The standard error of this estimate was derived by:

$\sqrt{}$(Σ variance of every tract).

Some small tracts contained no sample sites (Appendix 1), so the biomass and variance values from a nearby, similar tract of the same community were assumed.

Some tracts contained only one sample site (Appendix 1), and, therefore, provided no variance estimate. Consequently, the final estimates of the standard error of the standing crop of each community and study area will be underestimates. As these tracts were small, and contributed little to the total standing crop, this bias would be minor. However, this problem is avoided if community, rather than tract is used as the smallest spatial unit. Details of this alternative method, which is also problematic, and the estimates derived by it, are presented in Appendix 2. There are virtually no differences between the means derived by the two methods (eg. the estimated standing crop in the East study area was 0.8% less when calculated by the alternative method). The alternative method results in smaller standard errors for most estimates of community standing crop (eg. 287 t for community ZB2 in the East study area compared to 1,322 t estimated by the first method), but a larger standard error of the estimates of the standing crop of the study areas (eg. 2,910 t for East study area compared to 1,520 t calculated by the first method). Compare Tables 3.3 and A.2.1.

The standing crop of the above- and below-ground components of each species/morph were calculated by the tract-based method detailed above. The alternative method (Appendix 2) could not be used as species occurred in more than one community, so tract was the appropriate spatial unit.

3.2.6. Seagrass maps

3.2.6.1. Communities and biomass

The provisional seagrass maps, based on the aerial photo montages, were redrawn to reflect the results of the sampling and pattern analysis. Final seagrass maps were drawn for each study area showing the tracts of each seagrass community.

The distribution of seagrass biomass was mapped using seagrass tracts as the minimum spatial unit.

3.2.6.2. Accuracy

Navigation beacons could be identified on the aerial photographs and the location of these provided good ground control for the mapping. However, there were several sources of error which limit the accuracy of the seagrass maps. The aerial photographs overlapped by only 30%, forcing me sometimes to use the edge area of photographs, where the image suffers some distortion. Locating sites in the field, using back-bearings and a hand-held compass, from a small boat (4.3 m) is a very tedious and slow procedure. Movements of the boat caused by wave action often limited the accuracy of the bearings to 1-2°. Due to these sources of error, the maps are considered to be accurate to within 100-300 m.

3.2.7. Data storage

The negatives of the aerial photographs are archived with Aerometrix Pty. Ltd., 266 Kelvin Grove Road, Kelvin Grove 4059. Copies of the raw data from the sampling will be lodged with the Environmental Studies Unit, James Cook University.

3.3. Results

Halophila ovalis was the most widespread species of seagrass, occurring at 61% of the 417 sites that contained seagrass. Halophila spinulosa occurred at 50% of sites and Z. capricorni broad at 41%. The most restricted species was Cymodocea serrulata, which was found in only 1.2% of sites (Table 3.1).

3.3.1. Seagrass communities

The 15 recognised communities of seagrass, defined by the median abundance of each species, are described in Table 3.2. A single species characterised five (33%) communities, six communities (40%) were characterised by a combination of two species, and a mix of three species characterised four (27%) communities (Table 3.2).

Halophila ovalis occurred in seven communities. Halophila spinulosa occurred in six communities, Z. capricorni broad in five, H. uninervis broad in three, S. isoetifolium, Z. capricorni thin and H. uninervis thin each in two communities and Halophila decipiens and C. serrulata each occurred in one community.

All 15 communities were represented in the East study area, while only eight communities occurred in the West (Figure 3.1 a and b).

The 15 communities collapsed into five broader community-groups (Table 3.2). Groups C and S contained the restricted, mono-specific communities Cymodocea serrulata and Syringodium isoetifolium respectively. Group ZB was characterised by the dominance or co-dominance of Z. capricorni broad and included communities ZB1 to ZB5. Group H was dominated by species of Halophila, and contained six communities (H1-H6). Group ZT was defined by the dominance of Z. capricorni thin and contained two communities (Table 3.2; Figure 3.1).

3.3.2. Area

Seagrasses covered a total of 133.4 km^2 in the study areas: 110.5 km^2 in the East and 22.8 km^2 in the West. The area of each community ranged from 0.5 km^2 for community C to 22 km^2 for community ZB2 (East and West areas combined; Table 3.3).

The community-group dominated by the Halophilae, group H, occupied the greatest area (51% of total), followed by group ZB (38%), group ZT (10%) group S (0.5%) and group C (0.4%; Table 3.4).

3.3.3. Biomass

Community ZB1 contained the greatest biomass (287 g/m^2, SE = 36; Table 3.3) while Community H3 in the West study area contained the least (0.3 g/m^2, SE =

0.2; Table 3.3). The highest biomass occurred in a tract of community ZB1 vegetation west of Crab Island (sites 141 and 144, Appendix 1): it averaged 521 g/m^2 (SE = 170).

At the community-group level, the highest biomass occurred in groups S, ZB and C (those areas characterised by S. isoetifolium, Z. capricorni broad, and C. serrulata respectively) which is reflected in Figure 3.2. Community-group H, characterised by the Halophilae, had the lowest biomass levels.

The roots and rhizomes of Z. capricorni, especially the broad-leafed morph, are apparently slow to decompose. Approximately 49% (SE = 2.1) of biomass of all root and rhizome material of this species is dead (section 4.3.6). Although this dead material is not part of the living plants, it is completely mixed with the living, and from a dugong's perspective they are inseparable. Therefore, the live and dead components of the seagrass were not separated.

3.3.4. Standing crop

The total dry weight standing crop of seagrass in the study areas was 12,808 t. The East area contained 10,872 t (SE = 1519) and the West contained 1,936 t (SE = 348; Table 3.3).

Zostera capricorni broad contributed 7,468 t: more than all the other species combined (Figure 3.3, Table 3.5). In terms of standing crop, the most important seagrass community was ZB2, which contained 3,853 t in the East study area and 1,197 t in the West (Table 3.3). Consequently, community-group ZB contained the vast majority of the seagrass (75% of total). It was followed by group ZT (14%), group H (9%) and groups S (1.4%) and C (0.8%; Figure 3.4).

3.3.5. Water depth

The mean water depth (relative to Port Datum) of communities ranged from -4.8 m for community H6 (dominated by H. decipiens), to +0.9 m for community ZT2 (containing Z. capricorni thin), both in the East study area (Table 3.6;

Figure 3.5). At the community-group level, group H occupied the deepest areas, group ZT the shallowest, with groups ZB, S and C in between (Table 3.6).

The average depth of each seagrass community in the West study area was shallower than the average depth of the equivalent community in the East. In the West, communities averaged 0.86 m (SE = 0.32) shallower than the same communities in the East. Due to the small number of sites in each community in the West and the wide range of depths occupied by some communities (often due to the presence of inter-tidal pools), the depth difference between study areas was significant for only three of the eight communities and one of the three community-groups occurring in both areas (Table 3.6).

3.4. Discussion

3.4.1. Area, community structure, standing crop and distribution of seagrasses

The Moreton Bay study areas contained 133.4 km^2 of seagrass. This is substantially more than the 103.7 km^2 estimated by Hyland et al. (1989). This difference is unlikely to be due to any change in the extent of seagrass during the 2 years between studies, as the seagrasses in Moreton Bay are relatively stable over time (section 4.3.2; Poiner, 1984a, but see Kirkman, 1978). The difference is due primarily to the methods and intensity of the two studies. Using diver-transects and spot dives, Hyland et al. (1989) mapped a much larger area at a lower sampling intensity. Based on the maps of Hyland et al. (1989), the East and West study areas contain approximately 45% of the total area of seagrass in Moreton Bay.

The seven species of seagrass in Moreton Bay formed 15 communities on the basis of the abundance of nine species/morphs. These 15 communities pooled into five community-groups (Table 3.2). Based on the presence/absence of six species of seagrass at a limited number of predominantly inter-tidal, shoreline sites, Young and Kirkman (1975) recognised five communities of seagrass in Moreton Bay. They did not examine the main seagrass banks of the East study area (although their map includes this area; Young and Kirkman, 1975; I. Poiner, pers. comm.). At two inter-tidal, littoral sites in Moreton Bay, Poiner (1984a) recognised five species groups composed of nine seagrass species/morphs. Table 3.7 compares the communities identified by Young and Kirkman (1975) and Poiner (1984a) with the results of the present study.

Community-groups C (pure C. serrulata) and S (pure S. isoetifolium) had a very limited distribution, occurring principally in the protected lagoon of the Wanga Wallen Bank (Figure 3.1). Group ZT contained sites in the most elevated locations (mean depths of +0.5 and +0.8 m in the East and West study areas respectively) and was correspondingly characterised by thin-leafed morphs of Z. capricorni and H. uninervis. Group ZB contained all communities dominated or co-dominated by Z. capricorni broad, and generally occupied a zone seaward of, and deeper than Group ZT. Group H was characterised by the Halophilae and typically occurred in the deeper areas. This group also occurred in some shallow areas that were frequently disturbed by grazing dugongs (see section 8.1).

The two study areas contained an estimated 12,808 t of seagrass (Table 3.3). Due to the differences in the biomass and spatial abundance of different species, this standing crop was unevenly distributed among communities (Table 3.3; Figure 3.4). Community-groups C and S together occupied just 0.9% of the area of seagrass, and contributed 2.2% of the total standing crop of seagrass. Group ZB occupied only 38% of the area of seagrass, but accounted for 75% of the total standing crop (Figure 3.4). Group ZT accounted for a further 14% of the standing crop, while occupying 10% of the area. Community-group H, which contained the most widespread, and lowest biomass species, occupied 51% of the area of seagrass, but contributed less than 9% to the total seagrass standing crop (Figure 3.4). In terms of standing crop, Z. capricorni is the dominant seagrass in Moreton Bay (Figure 3.3; Table 3.5).

The biomass at individual sites was highly variable, ranging from zero to 690 g/m^2 (site 144, Appendix 1). On average, sites with seagrass contained 102.4 g/m^2 ($SE = 6.5$, $n = 390$). For comparison, the biomass of seagrasses at some locations around Australia and in other countries is summarised in Table 3.8. Results from different studies, however, are often not comparable due to different treatment of samples, non-random sampling strategies, different values being quoted (maximum, mean etc.), and different definitions being applied to the same terms (Walker, 1989). However, it is clear that the biomass of the seagrasses in Moreton Bay is unexceptional.

Seagrasses were found in the study areas at depths ranging from 1.4 m above to 8.1 m below Port Datum. The mean sea level in Moreton Bay is 1.24 m above Port Datum (Queensland Department of Harbours and Marine, 1989). Seagrasses at depths of approximately +0.5 m would be fully emersed during spring lows but immersed during neap lows (MLWS = 0.3 m, MLWN = 0.7 m; Figure 3.5). Spring lows are sometimes as small as 0.2 m in Moreton Bay, thus exposing sites as deep as +0.2 m.

Seagrasses reached their greatest biomass at sites occurring between 1 m above and 1 m below Port Datum: the lower inter-tidal and shallow sub-tidal areas (Figure 3.6). While this zone included sites of both high and low biomass, sites below about -1.3 m supported only low seagrass biomass (Figure 3.6).

3.4.2. Factors determining the distribution of communities

Kirkman (1975) attributed the restricted sub-tidal distribution of seagrasses in Moreton Bay to high turbidity, which restricts light penetration. Young and Kirkman (1975) concluded, on sparse correlative evidence, that the distribution of the five littoral seagrass communities, which they identified from Moreton Bay, was determined by depth, salinity, turbidity and substrate characteristics. Poiner (1984b) proposed that the relative distributions of two species in Moreton Bay (C. serrulata and Z. capricorni) could largely be explained by differences in their physiological tolerance to exposure. Birch and Birch (1984) and Bridges et al. (1982) have also suggested that zonation patterns, in the inter-tidal, may be determined to a large extent by degree of tolerance to desiccation during emersion. The data collected during this study support the suggestions that exposure at low tide and water turbidity are important factors determining the distribution of some communities.

3.4.2.1. Exposure

Elevation, and therefore, the extent of exposure at low tide, is correlated with the width of Z. capricorni leaves in Moreton Bay (Poiner, 1984a). Kuo et al. (1990) documented the structural differences between thin leafed inter-tidal and wide leafed sub-tidal Z. muelleri plants and McMillan (1983) demonstrated that H. uninervis and H. ovalis/minor produce small-leafed morphs in intertidal sites and large-leafed morphs in sites not exposed to air. In the present study, thin leafed morphs of Z. capricorni and H. uninervis occurred in only three communities (ZT1, ZT2 and H5), which had average respective elevations in the East study area of 0.9, 0.4 and 0 m above Port Datum (Table 3.6; Figure 3.5). The mean height of low spring tides (MLWS) in Moreton Bay is 0.3 m, so two of these communities are regularly exposed.

Communities ZB1, ZB3, and in the West ZB2, are also very shallow, occurring at mean depths above the level of spring low tides (Figure 3.5; Table 3.6). Although these communities should be exposed regularly, they were characterised by broad-leafed morphs of Z. capricorni and H. uninervis (Table 3.2). In the case of communities ZB1 and ZB3 in the East, this anomaly is due to the low relief of the Coonungai Bank where these communities principally occur, and to the high density of the seagrass. These factors combine to restrict the loss of water during the ebb tide, creating vast perched lakes, about 15 cm deep. As a result, these communities are never exposed at low tide and consequently support broad leafed morphs. Community ZB2 often occurs in inter-tidal pools in the West study area, and in these situations is also protected from desiccation during low tides.

3.4.2.2. Turbidity and depth

The amount of light received by seagrasses also influences the distribution of communities (Kenworthy et al., 1991). Below the inter-tidal zone, the depth to which a seagrass grows is largely attributable to the attenuation of light (Dennison, 1987; Duarte, 1991). Thus, water turbidity influences the distribution of seagrass communities. Changes in turbidity have been shown to limit the survival and recovery of seagrasses (Giesen et al., 1990). The two study areas in

Moreton Bay have markedly different levels of water clarity due to their different sediments and proximity to stream outfalls (section 2.3). The West study area typically had turbid waters (horizontal under-water visibility of 0.1 to 1 m), while the waters in the East were relatively clear (visibility of 1 to 5 m). Consequently, the penetration of light is more restricted in the West than the East. The effect of this is seen in the maximum and average depths of communities in the East and West study areas. Each of the eight communities which occurred in both study areas was found at shallower depths in the West than the East (Table 3.6, Figure 3.5). The maximum depth at which seagrass was found in the East was 8.1 m below datum, compared with 3.0 m in the West.

Further evidence for the effect of light attenuation on seagrass growth is seen in the ratio of above- to below-ground components of the seagrass. This ratio has been shown to increase with increasing depth (Lipkin, 1979), yet in Moreton Bay, this ratio increased from East to West (Table 3.5), despite the lower mean depth in the West (Figure 3.5; Table 3.6).

3.4.2.3. Disturbance

The role of natural disturbance in structuring seagrass communities has been discussed by Birch and Birch (1984), Kirkman and Kuo (1990) and Poiner et al. (1989). They considered the influence of cyclones and storms on seagrass communities. In Moreton Bay, the main disturbances appear to be caused by floods and grazing. The impacts of reduced salinity and rapid sedimentation during floods can have a significant impact on seagrass communities in the inshore, river influenced areas of the Bay (4.3.1). In the East study area, the regular and intense grazing by large herds of dugongs is a significant source of disturbance which may be responsible for the maintenance of pioneer species in some areas (section 8.1). Bridges et al. (1982) alluded to the possible role of grazing in the maintenance of seagrass distribution patterns in Torres Strait, and the localised impact of grazing by turtles (Bjorndal, 1979), reef fish (Hay, 1984; Randall, 1965) and urchins (Hay, 1984; Larkum and West, 1990; Ogden et al., 1973) has been documented. Frequent disturbances at the same site select for rapidly developing species (Clarke and Kirkman, 1989). In Moreton Bay, the areas of community type H4 and H5, characterised by very sparse H. ovalis and H. uninervis thin, are regularly disturbed by dugongs (see section 8.1). Bridges et al. (1982) note that these species persist in relatively unstable sediments, and Kirkman and Kuo (1990) consider H. ovalis to be a primary coloniser. Birch and Birch (1984) consider the presence of H. ovalis and H. uninervis to be indicative of past disturbance.

Table 3.1. Frequency of occurrence (%) of each species/morph of seagrass at 512 sites, the number of sites at which each species was recorded by each sampling method and by both sampling methods (n), and results of correlations between the semi-quantitative assessment of seagrass abundance and (1) the density of shoots and (2) the biomass of above-ground material ($\log_{10}(n+1)$).

Species/morph	Percentage of all sites with species[1]	Number of sites at which species was recorded			Correlation with semi-quantitative abundance score			
		Semi-quantitative samples	Quantitative samples		Shoot density (shoots/m^2)		Dry weight (g/m^2)	
				n[2]	r	p	r	p
Halophila ovalis	60.7	251	187	185	0.504	0.000	0.596	0.000
Halophila spinulosa	50.3	209	168	167	0.640	0.000	0.610	0.000
Halophila decipiens	4.8	20	13	13	0.692	0.008	0.420	0.155
Zostera capricorni broad	40.8	161	125	119	0.590	0.000	0.600	0.000
Zostera capricorni thin	7.2	28	21	19	0.667	0.002	0.759	0.000
Halodule uninervis broad	22.3	90	71	68	0.700	0.000	0.646	0.000
Halodule uninervis thin	11.5	45	33	30	0.695	0.000	0.754	0.000
Cymodocea serrulata	1.2	5	5	5	0.833	0.079	0.852	0.067
Syringodium isoetifolium	6.0	25	17	17	0.950	0.000	0.932	0.000

[1] At some sites, a species was detected in the semi-quantitative samples, but not the quantitative samples, and vice-versa.

[2] The number of sites at which the species was recorded in **both** the semi-quantitative and quantitative samples.

Table 3.2. The median abundance of each species/morph of seagrass in the 15 communities. The 15 communities collapse into 5 community-groups: C (C. serrulata), S (S. isoetifolium), ZB (dominated by Z. capricorni broad), H (dominated by Halophila species) and ZT (dominated by Z. capricorni thin). Abundance was scored on a 5 point, approximately logarithmic scale: 0 = absent; 1 = very sparse; 2 = sparse; 3 = medium; 4 = dense. For clarity, zero scores have been replaced by periods.

Community Group	Community	# sites	Seagrass species/morph								
			Cymodocea serrulata	Syringodium isoetifolium	Halodule uninervis broad	Zostera capricorni broad	Halophila ovalis	Halophila spinulosa	Halophila decipiens	Halodule uninervis thin	Zostera capricorni thin
C	C	5	4.0	.	.	.	.	.	.	.	.
S	S	4	.	4.0	.	.	.	.	.	.	.
ZB	ZB1	17	.	3.5	3.5	3.5	.	.	.	.	.
	ZB2	65	.	.	1.5	3.5	.	.	.	.	.
	ZB3	47	.	.	2.0	3.5	2.0	.	.	.	.
	ZB4	7	.	.	.	2.5	.	2.0	.	.	.
	ZB5	17	.	.	.	2.5	3.0	3.0	.	.	.
H	H1	64	.	.	.	.	2.8	3.0	.	.	.
	H2	45	.	.	.	.	2.0	2.0	.	.	.
	H3	57	.	.	.	.	.	2.0	.	.	.
	H4	11	.	.	.	.	2.0	.	.	.	.
	H5	25	.	.	.	.	2.0	.	.	2.0	.
	H6	18	.	.	.	.	.	1.3	2.0	.	.
ZT	ZT1	28	.	.	.	.	2.0	.	.	1.0	3.0
	ZT2	7	.	.	.	.	.	.	.	.	1.5

Table 3.3. Species composition, biomass, standing crop and area covered by the 15 community types in the study areas.

Community	Species/morph[1]	# sites	Area (km^2)	Biomass[2] (g/m^2) mean	SE	Standing crop[2] (tonnes)	SE
East study area (428 sites)							
C	Cs	5	0.54	202.0	52.3	108.98	45.13
S	Si	4	0.63	250.5	61.3	175.56	56.92
ZB1	Si,Hub,Zcb	17	3.65	287.1	35.8	945.01	285.12
ZB2	Hub,Zcb	53	15.28	260.0	18.8	3852.90	1322.27
ZB3	Hub,Zcb,Ho	37	13.66	205.3	16.0	2853.60	547.59
ZB4	Zcb,Hs	7	2.10	45.7	31.3	91.21	106.31
ZB5	Zcb,Ho,Hs	14	2.63	66.9	10.1	179.39	88.49
H1	Ho,Hs	54	15.48	26.8	2.9	424.45	279.07
H2	Ho,Hs	44	11.50	8.6	1.3	104.02	43.32
H3	Hs	54	16.38	18.7	5.1	294.79	261.44
H4	Ho	11	4.86	2.6	0.7	11.52	12.27
H5	Ho,Hut	25	7.54	4.5	0.6	37.86	19.22
H6	Hs,Hd	14	3.24	2.5	0.6	7.37	4.95
ZT1	Ho,Hut,Zct	26	11.76	130.0	20.3	1770.80	77.90
ZT2	Zct	7	1.29	10.5	6.4	14.87	20.93
Total		372[3]	110.54			10872.33	1519.57
West study area (84 sites)							
ZB2	Hub,Zcb	12	6.69	173.6	38.0	1197.40	284.31
ZB3	Hub,Zcb,Ho	11	5.59	85.4	15.9	464.50	98.43
ZB5	Zcb,Ho,Hs	3	0.63	69.7	20.6	29.29	3.69
H1	Ho,Hs	11	4.54	44.0	13.4	199.89	175.34
H2	Ho,Hs	3	1.40	1.9	1.3	2.56	2.30
H3	Hs	4	1.70	0.3	0.2	0.37	0.20
H6	Hs,Hd	6	1.82	10.8	4.9	14.85	13.40
ZT1	Ho,Hut,Zct	2	0.44	81.9	14.3	26.47	
Total		52[3]	23.80			1936.03	348.52

[1] Seagrass species/morphs: Cs: Cymodocea serrulata, Si: Syringodium isoetifolium; Zcb: Zostera capricorni broad; Zct: Z. capricorni thin; Hut: Halodule uninervis thin; Hub: H. uninervis broad; Ho: Halophila ovalis; Hs: H. spinulosa; Hd: H. decipiens.

[2] Biomass is the dry weight of the above- and below-ground components of the seagrass per unit area. Standing crop is the total dry weight of seagrass in the total area occupied by each community.

[3] Some tracts of seagrass included sites that contained no seagrass, hence 372+52 > 417 (total number of sites that contained seagrass; see text)

Table 3.4. Standing crop and area covered by the five community-groups in the study areas.

Community Group	No. sites	Area (km²)	Standing crop (tonnes) estimate	SE
East study area (428 sites)				
C	5	0.54	108.98	45.13
S	4	0.63	175.56	56.92
ZB	128	37.32	7922.11	1465.83
H	202	59.00	880.01	385.55
ZT	33	13.05	1785.67	80.66
West study area (84 sites)				
ZB	26	12.91	1691.89	300.89
H	24	9.46	217.67	175.86
ZT	2	0.44	26.47	

Table 3.5. Standing crop (and standard error of estimate) of each species/morph of seagrass in the East and West study areas of Moreton Bay.

Species/morph	Estimated standing crop (tonnes)				Ratio above:below components
	Above-ground		Below-ground		
	estimate	SE	estimate	SE	
East study area					
Halophila ovalis	224.85	83.93	299.19	93.60	0.75
Halophila spinulosa	293.45	101.89	328.90	125.14	0.89
Halophila decipiens	2.62	2.34	2.81	1.90	0.93
Zostera capricorni broad	1294.60	357.91	4618.80	1289.28	0.28
Zostera capricorni thin	219.68	61.45	904.97	343.37	0.24
Halodule uninervis broad	468.38	199.65	1393.40	602.20	0.34
Halodule uninervis thin	61.41	8.03	139.07	40.29	0.44
Cymodocea serrulata	33.43	16.22	75.55	29.42	0.44
Syringodium isoetifolium	180.23	64.38	312.43	132.74	0.57
West study area					
Halophila ovalis	72.00	58.22	66.03	33.34	1.09
Halophila spinulosa	103.64	71.52	67.50	37.73	1.54
Halophila decipiens	0.37	0.29	0.41	0.29	0.91
Zostera capricorni broad	437.80	113.87	1116.80	257.33	0.39
Zostera capricorni thin	4.39		12.65		0.35
Halodule uninervis broad	5.85	6.76	15.14	18.02	0.39

Table 3.6. Mean, standard error (SE) and range of depths of each community and community-group in the East and West study areas. Results of one-way analyses of variance testing for a difference in the mean depth of communities in each study area are also presented. Depths are relative to Port Datum.

Community	Depth (m)							ANOVA results		
	East study area			West study area			Mean diff			
	Mean	SE	Range	Mean	SE	Range	E-W	df	F	p
C	-0.5	0.4	-1.1 - +0.7							
S	0.0	0.1	-0.2 - +0.1							
ZB1	+0.6	0.1	+0.2 - +1.0							
ZB2	+0.2	0.1	-1.3 - +1.1	+0.8	0.1	+0.3 - +1.3	0.6	1,63	10.37	0.002
ZB3	+0.4	0.1	-1.8 - +1.2	+0.6	0.1	+0.2 - +0.9	0.2	1,45	1.30	0.260
ZB4	-0.8	0.3	-2.2 - -0.3							
ZB5	-0.6	0.2	-2.1 - -0.1	-0.3	0.2	-0.6 - +0.2	0.3	1,15	0.83	0.378
H1	-1.1	0.1	-3.6 - -0.2	-0.4	0.1	-1.2 - +0.2	0.6	1,62	7.70	0.007
H2	-1.2	0.2	-4.2 - +0.2	-0.7	0.1	-0.8 - -0.5	0.5	1,44	0.56	0.460
H3	-3.0	0.2	-6.9 - -0.4	-2.1	0.5	-3.0 - -0.9	0.9	1,55	1.39	0.243
H4	+0.1	0.1	-0.5 - +0.3							
H5	0.0	0.1	-0.7 - +0.3							
H6	-4.7	0.4	-8.1 - -3.1	-1.6	0.4	-2.7 - -0.6	3.2	1,16	31.39	0.000
ZT1	+0.4	0.1	-0.4 - +1.2	+0.8	0.1	+0.8 - +0.9	0.4	1,26	3.13	0.089
ZT2	+0.9	0.1	+0.5 - +1.4							
Community Group										
C	-0.5	0.4	-1.1 - +0.7							
S	0.0	0.1	-0.2 - +0.1							
ZB	+0.1	0.1	-2.2 - +1.2	+0.6	0.1	-0.6 - +1.3	0.4	1,151	8.64	0.004
H	-1.7	0.1	-8.1 - +0.3	-1.0	0.2	-3.0 - +0.2	0.6	1,219	3.22	0.074
ZT	+0.5	0.1	-0.4 - +1.4	+0.8	0.1	+0.8 - +0.9	0.3	1,33	1.38	0.249

Table 3.7. Comparison of the seagrass communities identified in Moreton Bay by Young and Kirkman (1975) and Poiner (1984a) with the communities recognised in this study.

[1] Seagrass species/morphs: Cs: *Cymodocea serrulata*, Si: *Syringodium isoetifolium*; Zc: *Zostera capricorni* (b = broad, m = medium); Hu: *Halodule uninervis*; Ho: *Halophila ovalis*; Hs: *H. spinulosa*.

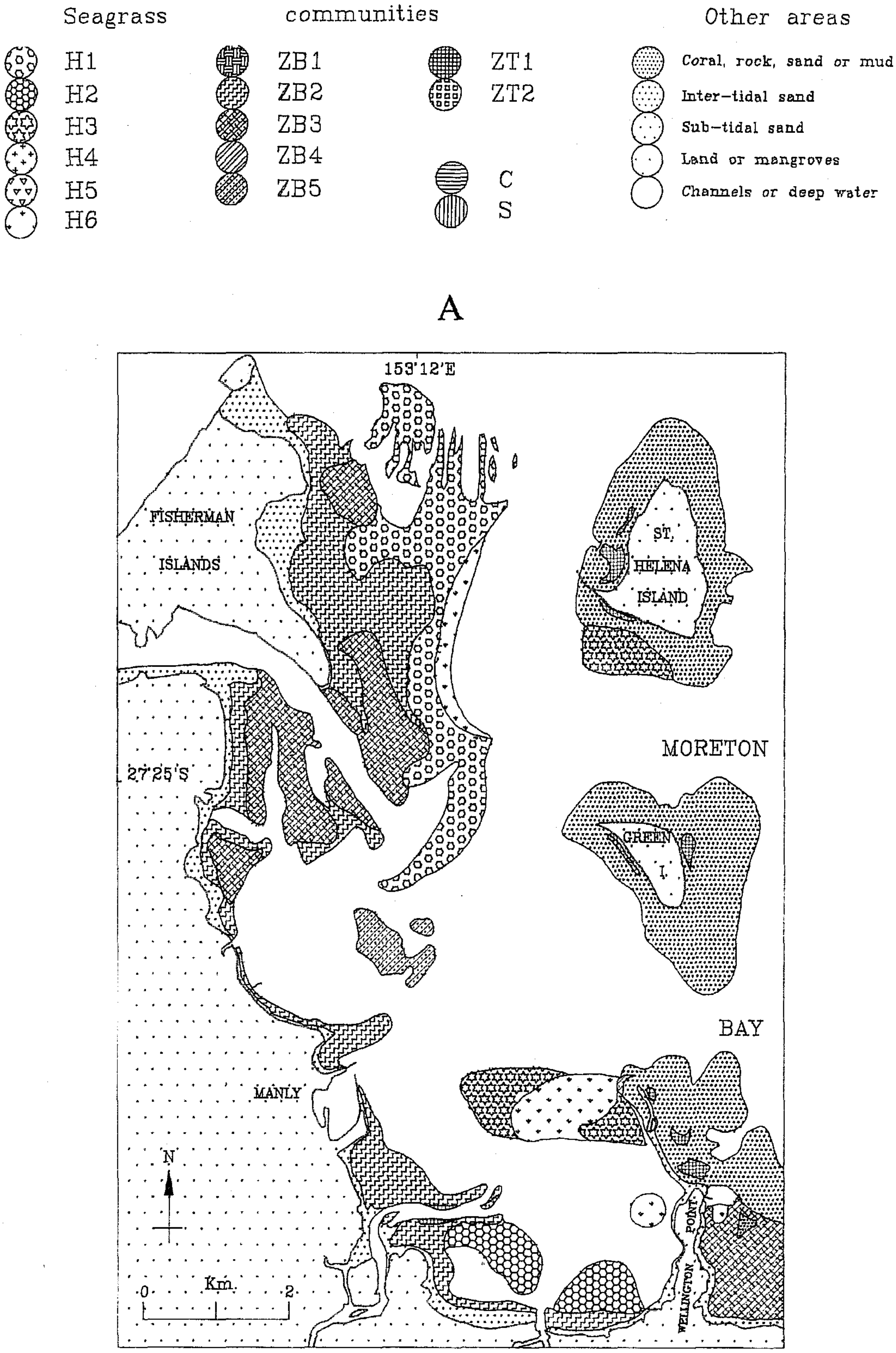
Table 3.8. Seagrass biomass values for a selection of species from a variety of locations in Australia and other areas. Biomass is dry weight g/m², except where stated. Bracketed numbers represent standard errors.

Species[1]	Location	Biomass (g/m²)			Comment	Reference
		Total	Above ground	Below Ground		
Zcb,Hub	Moreton Bay	690			Maximum	This study
Various	"	102.4 (6.5)			Mean	"
Zc,Ho	Moreton Bay	185.4			Mean	Young, 1978
Cs	"	314.9			Mean	"
Si	"	314.9			Mean	"
Zc,Hu,Ho	"	181.6			Mean	"
Ho,Hs	"	66.8			Mean	"
Cs	Great Sandy Strait, Qld	417.6			Mean	Dredge et al., 1977
Ho,Hu	"	17.8			Mean	"
Zc,Ho,Hu	"	146.2			Mean	"
Cs,Hu,Ho, Hoa	Townsville, Qld	99-186 (23-28)			Mean	Birch and Birch, 1984
Various	Cape York, Qld	335.8	99.6		Maximum	Coles et al., 1987
Hut	Gulf of Carpentaria, NT and Qld		11.9 (3.4)		Mean	Poiner et al., 1987
Hut&b, Ho,Ea,Th, Cs,Si	"		158.3 (33.6)		Mean	"
Zc	Botany Bay, NSW	330	141	189	Mean of 'mature stands'	Larkum et al., 1984
Zmu	Port Phillip Bay, Vic.		2.2-86	30-115	Mean	Kerr & Strother, 1990
Aa	Shark Bay, WA		1,850 (170)		Average maximum	Walker, 1985
Pa	Botany Bay, NSW		250		Mean	Larkum & West, 1990
Ht	Victoria		27-173		Mean	Bulthuis & Woelkerling, 1983
Th	Papua New Guinea	242-986 (19-77)	50-159	192-827	Mean Ash-free dry weights	Brouns, 1985a
Tc	Indonesia		611-838		Mean	Brouns, 1985b
Zma	Massachusetts USA		252-570		Maximum	Roman & Able, 1988
Hst	Red Sea	23-74.5	11.8-48	11-26	Mean	Wahbeh, 1988
Zma	Alaska	62-1840			Mean	McRoy, 1970
Hst	Red Sea	350	160	190	Mean	Lipkin, 1979

[1] Species: Aa: Amphibolis antarctica, Cs:Cymodocea serrulata, Ea: Enhalus acoroides, Ho: Halophila ovalis, Hoa: Halophila ovata, Hs: Halophila spinulosa, Hst: Halophila stipulacea, Hu: Halodule uninervis (t=thin, b= broad), Ht: Heterozostera tasmanica, Pa: Posidonia australis, Si: Syringodium isoetifolium, Tc: Thalassodendron ciliatum, Th: Thalassia hemprichii, Tt: Thalassia testudinum, Zc: Zostera capricorni (b=broad), Zma: Zostera marina, Zmu: Zostera muelleri.

Figure 3.1. The distribution of seagrass communities in the (A) West and (B) East study areas. Hatches represent communities. See Table 3.2 for a description of each community. Colours represent community groups:

Colour	Community-group	Dominant species
pink	C & S	Cymodocea or Syringodium
orange	ZB	Z. capricorni broad
blue	H	Halophila
green	ZT	Z. capricorni thin



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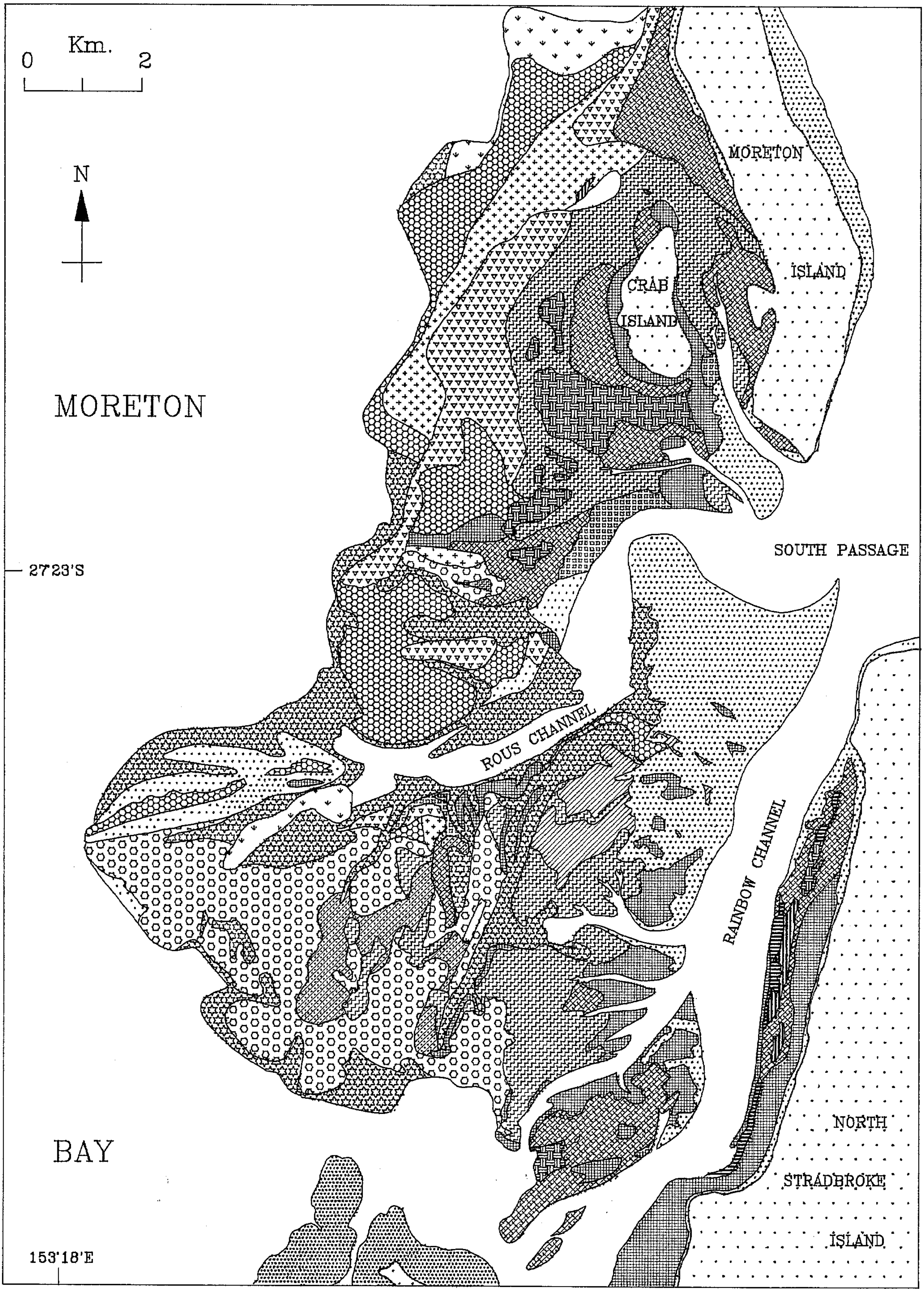
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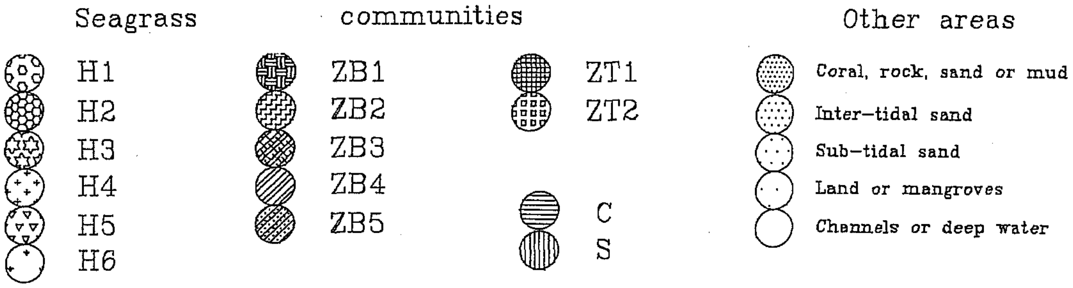
27°23'S
ROUS CHANNEL
RAINBOW CHANNEL
NORTH
STRADBROKE
ISLAND
153°18'E

Figure 3.2. The distribution of seagrass biomass (g/m²) in the (A) West and (B) East study areas. Hatches represent communities. See Table 3.2 for a description of each community. Colours represent biomass:

Colour	**Biomass** (g/m²)
purple	>200
pink	>100 to ≤200
red	> 50 to ≤100
blue	> 10 to ≤ 50
green	≤ 10



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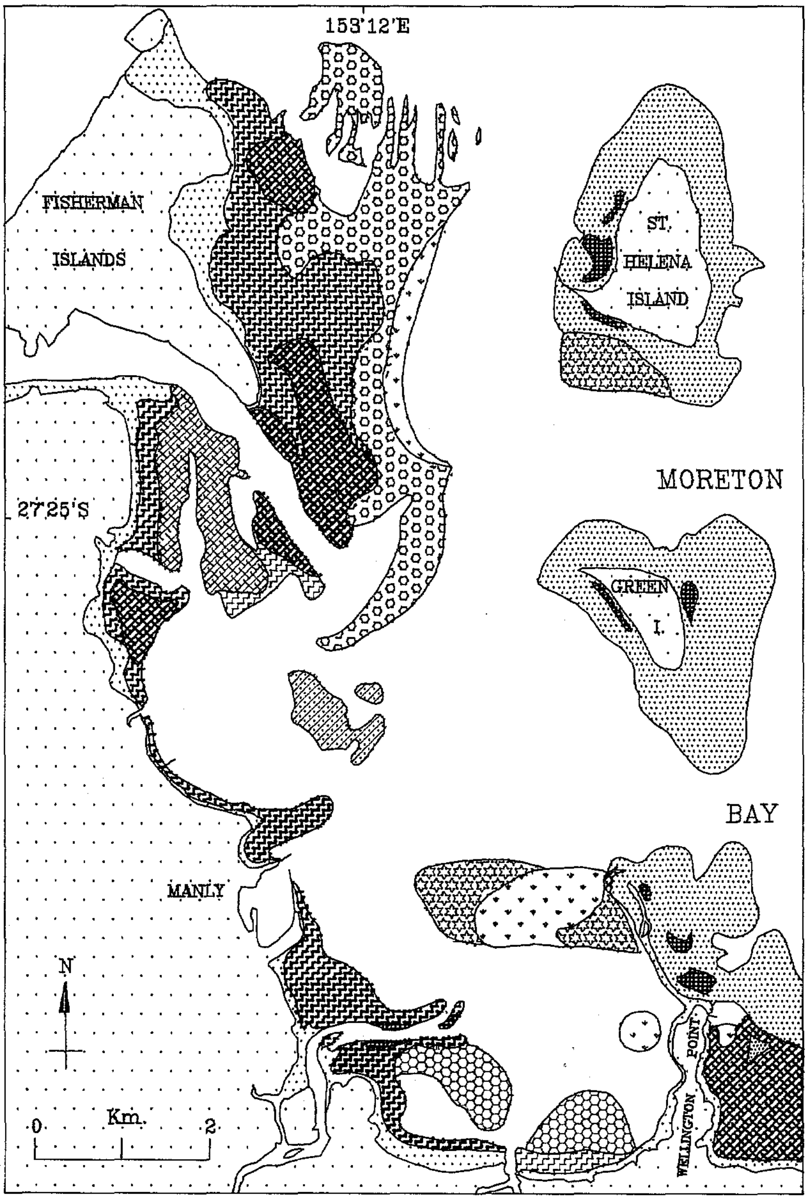

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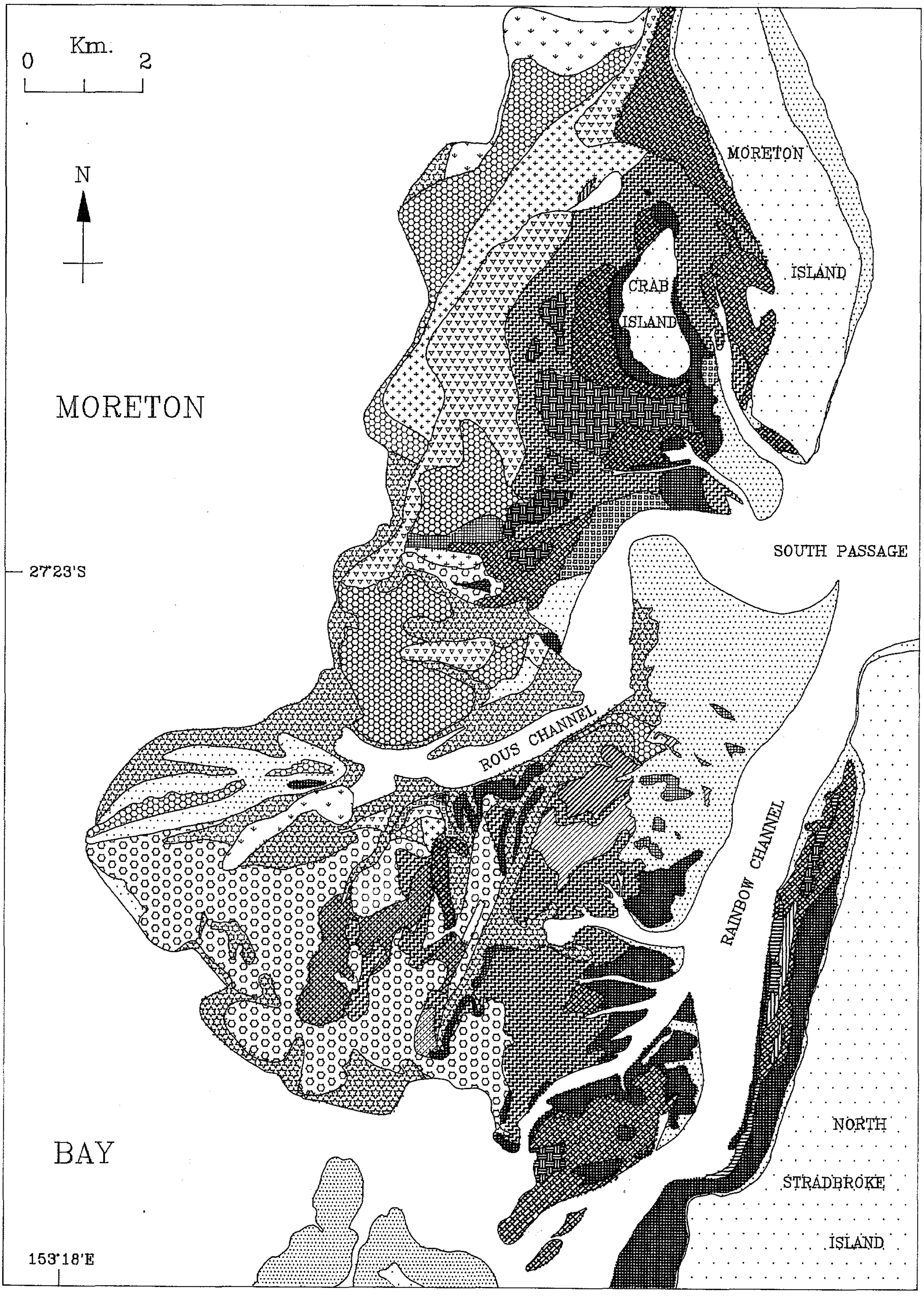
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ROUS CHANNEL
RAINBOW CHANNEL
NORTH
STRADBROKE
ISLAND

Figure 3.3.. Estimated standing crop of each species/morph of seagrass in the East and West study areas.

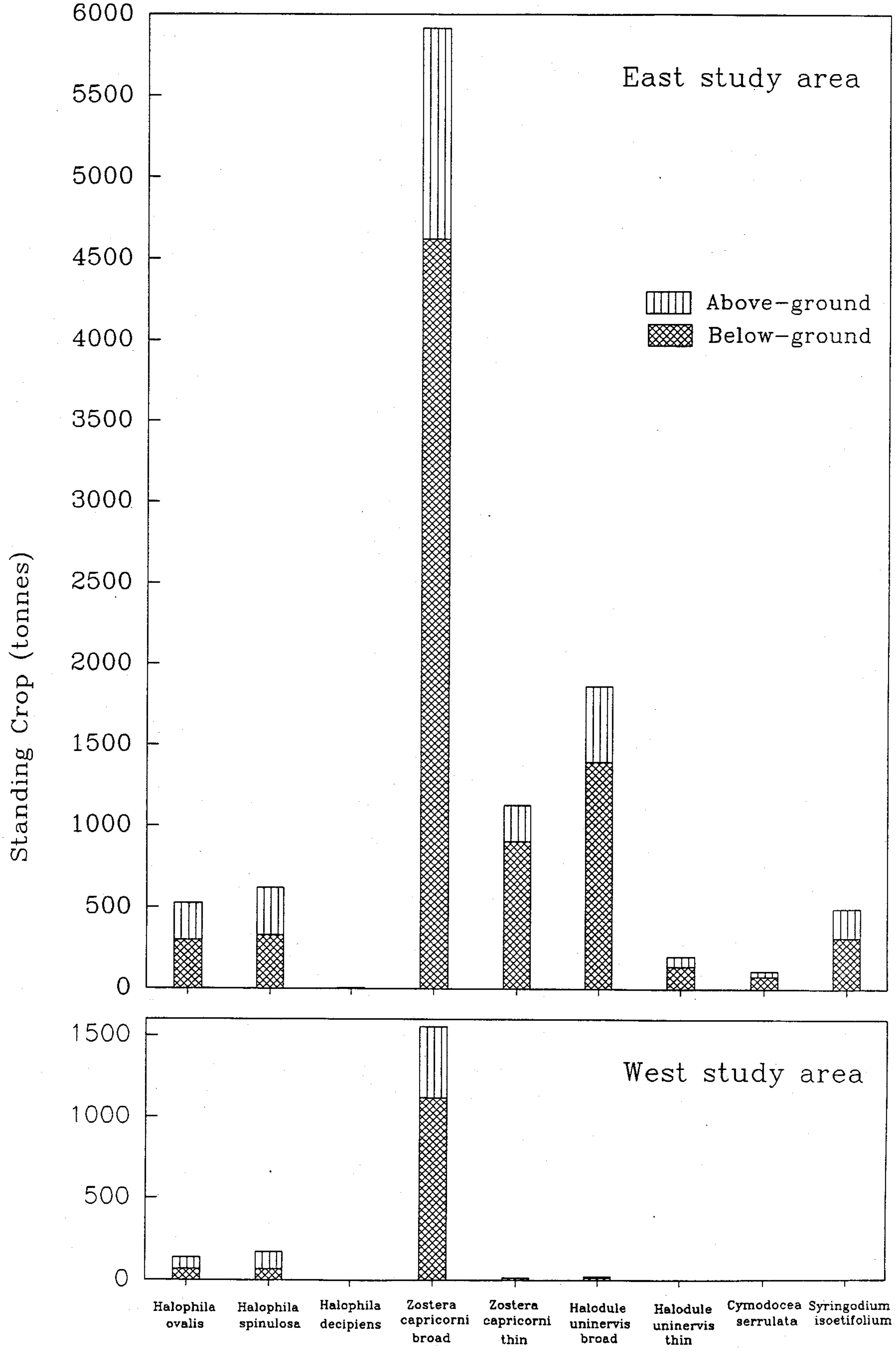

Figure 3.4. The importance of each seagrass community-group in terms of the percentage of the total area of seagrass (133 km^2) and the percentage of the total standing crop of seagrass (12,808 t). (East and West study areas combined).

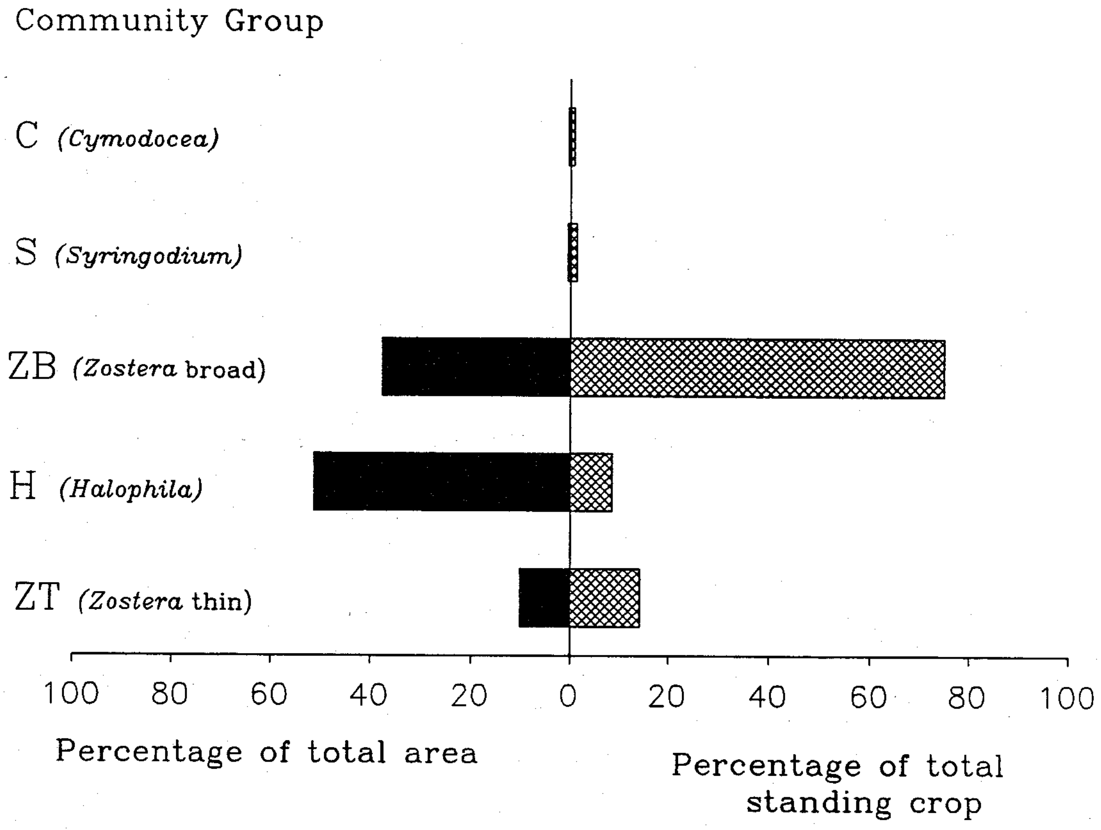

Figure 3.5.. Mean (plus SE) depth of seagrass communities in the East and West study areas. MLWN and MLWS indicate the mean water level, above Datum, during neap and spring low tides. Communities are described in Table 3.2.