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Literature and Information Review of the Benthic Flora of Port Phillip Bay, Victoria, Australia

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SUMMARY

This literature and information review of the benthic flora of Port Phillip Bay in relation to nutrients and toxicants has been prepared as a precursor to the Port Phillip Bay Environmental Study under the management of CSIRO. A total of 58 documents containing information on the benthic vegetation of Port Phillip Bay have been identified; of these, 28 contain information on attached macroalgae, 7 contain information on unattached macroalgae, 34 contain information on seagrasses and 6 contain information on microalgae. Brief information on mangrove vegetation from 4 documents also is included. Extant maps and databases pertaining to the distribution of benthic vegetation of Port Phillip Bay have also been identified.

The review has been organized into seven major sections:

1. The benthic vegetation of Port Phillip Bay;
2. Attached macroalgae;
3. Unattached macroalgae;
4. Seagrasses;
5. Non-planktonic microalgae;
6. Mangroves; and
7. Conclusions and recommendations.

Algal mats and turfs have been dealt with in conjunction with attached macroalgae (section 2); there have been no studies in Port Phillip Bay which have dealt exclusively with such algae. Lists of macroalgae, microalgae and seagrasses reported to occur in Port Phillip Bay are included in Appendices I-III following the references.

This analysis has led to 34 conclusions and 11 recommendations designed to assist in achieving the level of knowledge required to predict the impact of 50% increase in nutrients and/or toxicants on the benthic flora of Port Phillip Bay. These are summarized in section 8 of this report.

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1.0 INTRODUCTION

This literature and information review of the benthic flora of Port Phillip Bay in relation to nutrients and toxicants has been prepared as a precursor to the Port Phillip Bay Environmental Study under the management of CSIRO. It was commissioned on 31 July 1992 and submitted on the due date: 21 September 1992. The objectives of the review as stated in the task specifications are:

1. to document the state of present knowledge of the benthic flora in Port Phillip Bay;
2. to identify and where possible quantify possible key physical, chemical or biological processes controlling the natural interactions of the benthic flora with nutrients and toxicants; and
3. to identify the key processes and level of knowledge needed to predict the impact of a 50% increase in nutrients and/or toxicants on the benthic flora in Port Phillip Bay.

The task specifications for this review also include the following:

> "The work will review the literature on macro-algae, micro-algae and seagrasses in Port Phillip Bay. The review should focus on identifying the nature and extent of knowledge of this flora (excluding phytoplankton) in Port Phillip Bay, and on identifying the major aspects where additional knowledge is needed with respect to the objectives of the Port Phillip Bay Environmental Study."
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> "Within the general objectives described above, the Benthic Flora review is expected to address the dynamics (space, time) of the relevant populations, their biomass and productivity, and their role in nutrient and toxicant cycling (including information on residue concentrations). The focus for the review should be the benthic populations of macroalgae (attached and unattached), algal mats and turfs on soft and hard substrates, and the seagrasses of Port Phillip Bay. Of specific interest will be any existing information on the species composition, the distributions of populations in space and time, their natural fluctuations, and any documented interactions between nutrients and toxicants. The review should also assess the properties of any existing datasets for determining the effects of nutrient and toxicant inputs to the bay and the implications for future monitoring and detection of changes."
>
> "Elements of the review should identify (with respect to nutrients and toxicants): a tabulated synopsis of historical research, major strengths of previous and current research, and major gaps in historical data collection."

The review has been organized into seven major sections:

1. The benthic vegetation of Port Phillip Bay;
2. Attached macroalgae;
3. Unattached macroalgae;
4. Seagrasses;
5. Non-planktonic microalgae;
6. Mangroves; and
7. Conclusions and recommendations.

Algal mats and turfs have been dealt with in conjunction with attached macroalgae; there have been no studies in Port Phillip Bay which have dealt exclusively with such algae. Lists of macroalgae, microalgae and seagrasses reported to occur in Port Phillip Bay are included in Appendices I-III following the references. A map of Port Phillip Bay showing all localities mentioned in the text appears at the end of this report.

2.0 THE BENTHIC VEGETATION OF PORT PHILLIP BAY

2.1 Historical Overview

Historical information relating to the benthic marine vegetation of southern Australia has been reviewed by Lucas (1936), Levring (1953), Womersley (1959, 1984) and Ducker (1981, 1990). An historical account of phycological work in Port Phillip Bay is provided by Spencer (1970, pp. 42-47), and the the history of phycological work at Port Phillip Heads has been analyzed by Ducker (1983). These historical accounts relate mainly to floristics and systematics rather than to ecology.

There have been four major biological surveys and environmental studies involving Port Phillip Bay. J. Bracebridge Wilson, the then head-master of Geelong Grammar School, participated in the first biological survey of Port Phillip Bay which was instituted by the Royal Society of Victoria in 1886. Wilson dredged for algae near Port Phillip Heads from the period 1879 to 1895, gathering extensive collections which were described by J.G. Agardh and listed by Wilson (1886, 1889, 1890, 1892, 1895). Wilson published catalogues of algae collected at or near Port Phillip Heads (Wilson 1886, 1889, 1892), which was added to by Lucas (1891). Unfortunately, Wilson's studies provided no indication of plant distributions or abundances, nor were the species lists exhaustive. Wilson's death in 1895 marked the end of the survey.

During the period 1957-1963, the National Museum of Victoria in conjunction with the Department of Fisheries and Wildlife undertook a major environmental study of Port Phillip Bay. As part of this investigation, Willis (1966) produced an account of the marine angiosperms of the Bay and Womersley (1966) published a systematic list of the subtidal algae. Womersley's algal list was based on both specimens collected and forwarded to him by Miss J. Hope Macpherson, Co-ordinator of the Study, and also from personal collections. Lack of time and other resources, together with the large area to be surveyed also precluded a detailed account of the distribution of most species. However, a map of the weed beds was later prepared by Hope Macpherson and appended to the final survey report (Hope-Black, 1971). King *et al.* (1971) published an account of the intertidal ecology of Port Phillip Bay, producing a systematic list of plants and describing the various patterns of distribution and zonation. This report was published as Part II of the Port Phillip Bay Environmental Study, 1957-1963.

The third major environmental study of Port Phillip Bay was undertaken, during the period 1968-1971, by the Melbourne and Metropolitan Board of Works (now Melbourne Water) in conjunction with the Fisheries and Wildlife Department of Victoria. Results from this study were presented in the report *Environmental Study of Port Phillip Bay - Report on Phase One* (Anonymous, 1973). Spencer (1970, 1972) and Ducker and Spencer (in Anonymous, 1973) undertook the marine botany component of this study, describing and quantifying the marine plant communities at Carrum, Altona and Werribee.

Based on recommendations from the Phase One Study, Port Phillip Bay Phase Two (the Werribee Study) was undertaken by the Victorian Ministry for Conservation, Marine Studies Branch, during the period 1975-1978. In an attempt to determine the fate of nutrient discharge from the Werribee Treatment Complex (WTC) and its effects on the biota of Port Phillip Bay, community composition, biomass, and productivity in the Werribee region of the Bay were compared with that in Bay areas more remote from effluent discharge. Several aspects from the findings of the Phase Two Study were summarized by Axelrad *et al*. (1981), and the benthic macroalgal and seagrass components of this study are reported in Brown *et al.* (1980).

2.2 An Analysis of the Literature relating to the Benthic Vegetation of Port Phillip Bay

A total of 58 documents containing information on the benthic vegetation of Port Phillip Bay have been identified during the present review (see references and Tables 1-4). Of these, 28 contain information on attached macroalgae, 7 contain information on unattached macroalgae, 34 contain information on seagrasses and 6 contain information on microalgae. Brief information on mangrove vegetation from 4 documents is also included. Of the 58 documents, 9 are books, chapters in books or pamphlets; 18 are journal articles; 21 are unpublished reports; and 10 are unpublished honours, MSc or PhD theses. Most of these studies are based on qualitative (non-numerical) rather than quantitative (numerical) data (see Tables 1-4).

Sixteen maps pertaining to the benthic vegetation of Port Phillip Bay have been identified; data on these maps are summarized in Table 5.

There are also at least two other unpublished data bases The first (Davies and Brown, 1990), which deals with benthic monitoring studies off the WTC in 1983-1984, exists within Melbourne Water but has yet to be fully validated, analyzed and interpreted. The data in this base consists of macroalgal, microalgal and seagrass species composition and macroalgal and seagrass biomass estimates at 12 sites sampled in April 1983, October 1983, April 1984 and October 1984. The second data base (G. Parry, pers. comm.) involves a considerable body of unanalysed data on drift algae in Port Phillip Bay and is housed at the Marine Science Laboratories at Queenscliff. According to Parry, trawls have been taken at 22 stations at three monthly intervals between March 1990 and March 1991, and a further sample was obtained in March 1992. A majority of the material obtained is of a drift nature, but the biomass and species composition have not been determined.

3.0 ATTACHED MACROALGAE

3.1 General Aspects

Data on the macroalgal vegetation in Port Phillip Bay are contained in a number of published papers, unpublished theses, technical reports, and other documents (Table 1). In the present review, data on Port Phillip Bay are organized into the following sections: general aspects (floristic studies, community composition and distribution, zonation, seasonality); ecological processes (colonization-recruitment, growth, competition); biotic interactions (epiphytism, epizoism); productivity (biomass, primary production, blooms); interactions with nutrients; and interactions with toxicants.

3.1.1 Floristic Studies

There is no comprehensive, up to date floristic treatment of attached macroalgae occurring in Port Phillip Bay. During the 1957-1963 Port Phillip Survey, 317 stations were visited; six were outside Port Phillip Heads and 311 were within Port Phillip Bay. From this survey, 24 Chlorophyta, 73 Phaeophyta and 169 Rhodophyta were recorded (Hope-Black, 1971); however the intertidal portion of this survey (King *et al.*, 1971) dealt only with 14 stations in detail, and minute epiphytic algae and uppermost subtidal algae were dealt with incidentally or omitted from the account of subtidal benthic macroalgae (Womersley, 1966). Thus the 1957-1963 Port Phillip Survey does not contain a complete inventory.

A number of additional species have been recorded since the 1957-1963 survey. Appendix 1 contains a referenced list of Port Phillip Bay macroalgae reported in the major documents surveyed for the present review. A detailed survey of relevant herbaria almost certainly would turn up additional records, especially of such groups as the crustose coralline red algae, most of which have only been identified to genus. It also is possible that isolated records of a few additional species occur scattered in the scientific literature, but it is unlikely that any such species constitute a major ecological component of the attached macroalgal flora of the Bay.

The identification of green algae and brown algae in Port Phillip Bay has been facilitated by the publication of the first two volumes of *The Marine Benthic Flora of Southern Australia* (Womersley, 1984, 1987). Three volumes covering the Rhodophyta are planned but have yet to be published, and thus the identification of many Rhodophyta from Port Phillip Bay still poses problems.

3.1.2 Community Composition and Distribution

Using data from the 1957-1963 Port Phillip Survey, Womersley (1966), Hope-Black (1971) and King *et al*. (1971) have provided bay-wide surveys of community composition and distribution. In addition, surveys at selected localities have been undertaken by Spencer (1970, 1972 - Werribee, Altona, Carrum), Brown *et al*. (1980 - Werribee), Davey and Woelkerling (1980 - Corio Bay, Williamstown), Watson (1972 - Hobsons Bay), O'Brien (1975 - Altona Bay), Lewis (1975, 1977, 1983 - Williamstown, Portarlington, Hobsons Bay), Huisman (1980 - Portsea), White (1982 - Portsea) and Watson (1992 - Corio Bay). Except for Lewis (1983) and Davey and Woelkerling (1980), all of the local surveys are contained in unpublished theses, consultant reports or technical reports. The 19th century surveys of Wilson (1886, 1982) are only of historical interest.

3.1.2.1. *Bay-wide studies*

Using data from the 1957-1963 Port Phillip Survey, Womersley (1966) recorded 173 species of attached, subtidal macroalgae. These include 27 Chlorophyta, 49 Phaeophyta and 97 Rhodophyta. Most species were confined to the Heads region where strong wave action and clean oceanic water persist. A few species, however, were confined to Corio Bay or to the Swan Bay-Bellarine Peninsula regions.

Womersley (1966) examined subtidal specimens only; intertidal and just subtidal algae were considered incidental, and minute epiphytic algae were omitted from his study. He attributed the low species richness recorded inside the Bay, as compared to the adjacent coast, to the relatively shallow water, more variable and often higher water temperatures, more suspended matter and a greater level of pollution from shipping and from the city of Melbourne. One particularly important environmental factor leading to reduced species richness within the Bay was attributed to the lack of hard substrata in this environment. Amongst the macroalgae present, only species of the green alga *Caulerpa* are capable of growing anchored in unstable sediments. Womersley (1966) found that *C. remotifolia* occurs in most parts of the Bay, while *C. geminata* and *C. longifolia* f. *crispata* occur mainly in the very calm Corio Bay and in the Swan Bay-Bellarine Peninsula regions. The distribution of *Caulerpa* varied with location; sometimes *Caulerpa* covered many square metres, forming monospecific or mixed species stands; often, however, species of *Caulerpa* occurred mixed with the seagrass *Heterozostera* (as *Zostera*). Womersley (1966) described the general distributions of attached macroalgae algae within Port Phillip Bay as follows:

Fairly general within the Bay - *Ulva lactuca, Caulerpa remotifolia*, probably *Codium harveyi and Cutleria multifida, Solieria robusta, Griffithsia teges, Wrangelia protensa, Polysiphonia cancellata, Dictymenia harveyana, Laurencia filiformis.*

Largely restricted to Corio Bay, the calm western coast, and in some cases the northern Bay - *Caulerpa geminata, C. longifolia* f. *crispata, Acetabularia peniculus, Dictyota dichotoma, Caulocystis uvifera, Rhabdonia coccinea, Rhodoglossum foliiferum, Botryocladia obovata, Lophothalia verticillata, Jeannerettia pedicellata.*

Around the Bay, excluding the central bay and very calm western areas *Caulerpa brownii, Dictyopteris muelleri, Ecklonia radiata, Cystophora retroflexa, Sargassum paradoxum, Sargassum verruculosum*.

Using data published by Womersley (1966), Hope-Black (1971) analyzed the attached, benthic communities in relation to their distribution with depth and substrate. Hope-Black (1971) reported extensive beds of *Caulerpa brownii* and *C. remotifolia* along the north-west shore, on the southern shore of Corio Bay and in areas between Frankston and Mornington. Hope-Black (1971) reiterated Womersley's comments concerning the importance of hard, stable substrata in relation to macroalgal abundance, diversity and distribution in Port Phillip Bay and discussed the extent to which reefs of differing rock type occur throughout the Bay. Hope-Black (1971) summarised the distribution of reef types within Port Phillip Bay as follows:

1) The dune limestone of the Heads region. These platforms are very rich in both species and abundance. Being south of the Nepean Bay bar, they have the benefit of the daily flushing of the tide. J.B. Wilson (1886, 1992, 1895) collected from this region. Hope-Black (1971) also included the Popes Eye Annulus (an artificial structure of basalt blocks) in this category; it also supports a diverse and abundant macroalgal flora.

2) The Oligocene basalt of the north west shore from Corio Bay to Williamstown dips under the bay floor and forms outcrops as comparatively soft reefs. These outcrops also harbour a high diversity of macroalgae.

3) Tertiary ironstone of the Miocene clays and sandstones of the north and east shores.

4) The granites of Martha Point extend seawards and form off-shore reefs.

Hope-Black (1971) concluded that more than 100 years of intensive population pressure along the shores of Port Phillip Bay had done little to alter the marine environment. According to Hope-Black (1971), "The greatest single change that the Bay has suffered in recent years has been the intensive scallop fishing in the early 1960's ... . The extent of the alteration has not yet been fully assessed, but some spot dredging has shown that the *Caulerpa* community has been spread to the west of its previous limits ... . This is probably due to the dredges moving the skeletal material of the western sands on to the silty sand and so providing a firm substrate".

King *et al*. (1971) analyzed the distribution of intertidal vegetation at 14 stations within Port Phillip Bay, representing all regions and major geological formations. A total of 171 species of macroalgae were reported, including 39 Chlorophyta, 64 Phaeophyta and 68 Rhodophyta. King *et al*. (1971) used the intertidal flora to divide the Bay into two main biological areas: the open coast area of the Heads and the Bay proper. This division is not as clear, however, on the eastern margin of the Bay. The main difference in the intertidal flora is the reduced number of species found within the Bay; 68 species of algae were confined to the Heads region and were not recorded in the Bay proper, with many of these species characteristic of rough coasts. Most of the Bay species also occurred at the Heads; however the reverse was not true. *Caulerpa scapelliformis* occurs at the Heads and on the eastern coastline south of Schnapper Point, but is completely replaced elsewhere by a densely pinnate form of *Caulerpa remotifolia*. Several species occur throughout the Bay but occupy different ecological niches under differing environmental conditions. *Ecklonia radiata* occurs subtidally in the Bay, but is said to be restricted to deep pools and other positions of local shelter at the Heads.

3.1.2.2. *Corio Bay*

Data on attached macroalgae in Corio Bay are scant. As part of the bay-wide survey, Womersley (1966) listed 10 species which he considered to be largely confined to Corio Bay, the calm western coast and the northern Bay (see list above). Similarly, King *et al*. (1971, p. 97, Table 3) recorded 12 species from the intertidal and upper subtidal at Corio Bay North.

Seedsman and Marsden (1980) investigated the distribution of benthic vegetation in Corio Bay with the aim of determining possible relationships with sediment patterns. Their resulting vegetation map (Seedsman and Marsden, 1980, fig. 6) is largely uninterpretable and contains few detailed data on macroalgal distributions. Indeed, Seedsman and Marsden (1980, pp. 10, 11) explicitly state that the map does not attempt to provide an accurate description of species on the bottom, and they only indicate that *Caulerpa* is restricted to deeper areas of Corio Bay but that other algae are widespread.

As part of a study of algal communities associated with mangroves in Victoria, Davey and Woelkerling (1980) examined the communities at Hovells Creek in Corio Bay. Three species were found: the green algae *Percurasria percursa* (at that time a new record for southern Australia) and *Rhizoclonium riparium*, and the red alga *Caloglossa leprieurii*. They concluded that the estuarine nature of the Hovells Creek habitat led to the low diversity of species present.

Based on a single underwater sled run on 29 January 1992, Watson (1992) reported that the macroalgal flora of the Corio Bay outer harbour (Geelong Arm) spoil ground was depauperate, composed mainly of scattered plants of *Caulerpa flexilis* and *Caulerpa scapelliformis*.

3.1.2.3. *Werribee region*

As part of the Port Phillip Bay Environmental Study 1968-71 (Anonymous, 1973), Spencer (1970) examined the subtidal flora of the Werribee Region to determine the ecological basis of species distributions. Spencer recorded 43 species of attached macroalgae; associations between the green algae *Caulerpa longifolia* f. *crispata* and *Caulerpa remotifolia*, the red algae *Polysiphonia nigrita* and *Acrosorium uncinatum*, and the red algae *Solieria robusta* and *Rhabdonia coccinea* were considered characteristic of the area; and the red alga *Ceramium* was abundant at Werribee.

Spencer (1970) attributed the nature and distribution of the subtidal flora of the Werribee region to the interaction of three environmental factors: (a) the degree of exposure to wind, currents and sediment transport processes; (2) substrate stability; and (3) light availability as determined by water depth. The presence of substantial numbers of molluscs and ascidians and more importantly the occurrence of basaltic reefs in the Werribee region provide stable substrata for large populations of subtidal algae. Like Womersley (1966), Spencer (1970) reported *Caulerpa* spp. to occur anchored in sediment type substrates.

Spencer (1970) noted that *Ulva lactuca* occurred abundantly at stations close inshore, that *Caulerpa geminata* occurred at depths of 10-15 m and that *Caulerpa remotifolia* and *Caulerpa longifolia* f. *crispata* rarely occurred in depths exceeding 10 m. Throughout the study no attached macrophyte growth was observed at depths greater than 15 m. The relationship of occurrence of *Caulerpa* spp. with water depth was a result consistent to that reported by Seedsman and Marsden (1980). The discharge of nutrient enriched freshwater from the WTC appeared to have little influence on the subtidal flora of this area. Closer inshore, however, the green alga *Ulva lactuca*, the brown algae *Colpomenia sinuosa* and *Cutleria multifida*, and the red algae *Grateloupia filicina*, *Jeannerettia pedicellata* and *Rhodoglossum proliferum* exhibited prolific growth.

The attached benthic algal communities in the Werribee region were the subject of a further investigation in 1978-1979 (Brown *et al*., 1980). Brown *et al.* (1980) reported the presence of two major communities in the Werribee area: one occupying basalt reef (Kirk Point) and the other, sand. The extensive, stable basalt reefs supported a more diverse and rich flora (62 species) than did the unstable sand (28 species). The intertidal basalt reef community was dominated by the red alga *Centroceras clavulatum* and the green algae *Ulva lactuca*, *Enteromorphora compressa* and *Chaetomorphora aerea*. The subtidal basalt reef community, in contrast, was dominated by the green algae *Caulerpa remotifolia*, *Caulerpa longifolia*, *Ulva lactuca* and the red algae *Acrosorium uncinatum*, *Grateloupia filicina*, *Polysiphonia* spp. and crustose coralline algae, with several other species exhibiting seasonal abundance. Epizoism featured prominently in the basalt reef communities and molluscs, sponges and ascidians served as important substrata for algae. The sand and shelly sand community was dominated by the green algae *Caulerpa remotifolia*, *Caulerpa logifolia*, *Caulerpa brownii* and *Ulva lactuca*, and to a lesser extent the red algae *Rhodoglossum proliferum*, *Ceramium* spp., *Griffithsia teges*, *Acrosorium uncinatum*, *Dasya capillaris*, *Polysiphonia* spp. and *Pterosiphonia pennata*.

These algae were commonly associated with, and epizoic upon, the sedentary benthic fauna, and thus may have been dependent on this substrate for initial establishment prior to invading the surrounding sands.

Brown *et al*. (1980) concluded that distribution of marine algae in the Werribee region was determined by substratum, wave action, depth, currents and proximity to effluent drains in the area. Wave-affected sand (less than 0.5 km offshore) was highly mobile during choppy seas and seemed too dynamic for the establishment of algal sporelings. However, further offshore, where water depth increased beyond 1.5 m, the effects of wave action were sufficiently attenuated to permit the basal rhizome system of *Caulerpa* spp. to anchor in the sand. Sedentary benthic fauna in this habitat also provide appropriate stable substrata (epizoism) for several macroalgae other than *Caulerpa* spp..

Brown *et al*. (1980) explained an anomalous distribution of algae in an area proximate to two major effluent drains (145 W and Borrie Drain, WTC) on the basis of probable nutrient enrichment of the nearby area. Similarly, the existence of east-west bands of macrophytes occurring offshore from the WTC may be explained by the predominant currents running along the coastline; mass water movements in this direction may take with it the nutrient inflow from drains and rivers.

Brown *et al.* (1980), like Spencer (1970) and Seedsman and Marsden (1980), reported *Caulerpa* spp. giving way to a mixed algal community as depth increased. *Caulerpa* spp. were confined to areas less than 3.5 m deep in the Werribee region. Brown *et al.* (1980) attributed this species transition to the inability of *Caulerpa* spp. to exist in conditions of reduced light.

In discussing the species composition of the basalt reef at Kirk Point (Werribee) in relation to basalt reefs elsewhere in Port Phillip Bay, Brown *et al.* (1980) reported a decreased species richness at Kirk Point (62 taxa) as compared to Williamstown (89 taxa; Lewis 1977). Brown *et al.* (1980) reported an absence of large brown algae of the orders Laminariales (*Ecklonia radiata*) and Fucales (*Caulocystis cephalornithos*, *Sargassum* spp., *Cystophora* spp. and *Hormosira banksii*) at Kirk Point. These algae feature prominently in the subtidal zones of basalt reefs elsewhere in Port Phillip Bay, including Williamstown (King *et al*., 1971), Altona (Spencer, 1972) and Portarlington (Spencer, 1972). They also occur on sandstone reefs at St. Leonards (King *et al*., 1971) and on limestone reefs in Corio Bay (King *et al*., 1971). According to Brown *et al*. (1980), the absence of large brown algae on suitable substrata near sewage outfalls has been attributed to several factors including reduced light intensity, a smothering effect of the plant surface due to suspended silt and organic particles, toxicity of certain components of effluent and grazing pressures due to increased herbivore density. However, the implications of these factors on the macroalgal flora of the Werribee region remains unstudied.

3.1.2.4. *Altona Bay-Hobsons Bay*

Spencer (1970) investigated the composition and distribution of the attached subtidal flora of Altona Bay as part of the Port Phillip Bay Environmental Study, 1968-71 (Anonymous, 1973). Spencer (1970) found 70 species in Altona Bay, considerably more than were found at Werribee (43 species) during the same survey. As at Werribee, Altona was characterised by associations between *Caulerpa longifolia* f. *crispata* and *Caulerpa remotifolia*, *Polysiphonia nigrita* and *Acrosorium uncinatum*, and *Solieria robusta* and *Rhabdonia coccinea*; and *Ceramium* was also abundant. However, *Ulva lactuca* was less abundant at Altona as compared to Werribee, but in both regions it was confined to inshore stations.

Wind exposure, substrate stability and light availability determined the composition and distribution of the subtidal benthic flora at Altona (Spencer, 1970). As at Werribee, basalt reef and a dense distribution of molluscs and ascidians provided suitable substrata for an abundant and diverse subtidal flora. In addition, the distribution of *Caulerpa* spp. was limited by water depth (light availability), and no attached macroalgae occurred deeper than 15 m.

Lewis (1977, 1983) recorded a subtidal macroalgal community associated with an artificial basalt boulder mound which once supported the now demolished Gellibrand Light off Williamstown. Lewis (1977, 1983) noted that only 21 of the 60 species found were recorded during the 1957-1963 Port Phillip Survey (Womersley, 1966; King *et al*., 1971). Lewis (1983) found four species not previously recorded from Australia: *Scottera nicaeenis* (Lamour. ex Duby) Guiry & Hollenberg, *Stictyosiphon soriferus* (Reinke) Rosenv., *Medeiothamnion lyalli* (Harvey) Gordon and *Deucalion levringii* (Lind.) Huisman and Kraft. He attributed their existence to the proximity of regular international shipping movements to the study site.

Lewis (1977, 1983) concluded that the macrobenthic algal community at Gellibrand was primarily determined by substrate. Continual turnover of *Mytilus edulis planulatus* individuals - which serve as the major substrate for algal growth in the area - in conjunction with high siltation rates creates an unstable environment whereby annual and pseudoperennial species predominate. Opportunistic species persist in the community as free substrate becomes available. Lewis (1977, 1983) acknowledged that additional factors may influence community composition at this site and these relate to the area's proximity to river inputs and the associated fluctuations in salinity, temperature, turbidity and nutrient load which can affect plant growth. However, these factors, in relation to community composition, were not investigated in the study nor was any quantitative assessment made of algal abundance.

Lewis (1975) also examined the ecology of the red alga *Grateloupia filicina* in relation to the communities occurring on a reef at Gloucester Reserve in Williamstown. Lewis (1975, pp. 27-29) recognized five communities on the reef: the *Corallina officinalis-Rhodymenia australis* community; the *Caulerpa* community; the *Sargassum* community; the *Ecklonia radiata* community and a sand-patch community. Within the Gloucester Reserve reef complex, *Grateloupia filicina* was not dominant in terms of cover but was the largest and most conspicuous fleshy red alga present.

Watson (1972) investigated the western section of Hobsons Bay (covering the greater part of the Yarra Delta) in relation to potential effects of thermal pollution from the operation of the State Electricity Commission of Victoria's Newport C Power Station. Watson (1972) reported a depauperate macroalgal algal flora (10 species), attributing this to environmental factors such as a lack of firm substrata, reduced light transmission through the water column and a level of nutrient and sedimentation non-conducive to most algal species' occurrence. In the area surveyed, algae were restricted to sites providing shallow reef, rockwork or shallow water shell beds. There was a noticeable absence of brown algae. Red algae include *Gracilaria confervoides* and *Solieria robusta* occurring on dead mollusc shells. Green algae were represented by *Ulva lactuca* and *Enteromorpha* sp., with *Bryopsis* sp. and *Cladophora* sp. having a sporadic distribution. Watson (1972) observed *Ulva lactuca* growing favourably in wide range of environmental situations including differing substrata, elevated water temperatures, low salinities and varying degrees of nutrient enrichment. *Enteromorphora* sp., however, was confined to the intertidal zone and it occurred only during winter. Watson (1972) stated that *Enteromorpha* remained attached throughout its life-span and even under optimum conditions, never achieved the size or luxuriance of *Ulva lactuca*. This contrasts with Brown *et al.* (1980) who found *Enteromorpha* to feature prominently in epibenthic drift offshore from the WTC.

Watson (1972) reviewed water temperature records for Hobsons Bay and concluded that the shallow waters along the Williamstown foreshore, and particularly Greenwich Bay, often approach and may even exceed the theoretical lethal temperature limit during the summer months. Despite this feature of the area, the subtidal community is well established and the organisms occurring in it are well adapted to the elevated temperatures.

Watson (1972) commented on the tolerance of *Ulva* and *Gracilaria* to decreased salinities and felt that this tolerance allows these algae to grow near the mouth of the Yarra River in Hobsons Bay.

O'Brien (1975) investigated two distinctive algal habitats on the western side of Hobson's Bay, recording a rich subtidal algal flora of high species diversity (55 species) constituting numerous community associations along an open coast reef; and an unattached algal community of few species (6 species) in a shallow, enclosed eutrophic habitat composed of a mud substratum.

In a study of algal communities associated with the mangrove ecosystems of Victoria, Davey and Woelkerling (1980) recorded *Enteromorpha clathrata* and *Ulva lactuca* attached to the pneumatophores of *Avicennia marina* at Kororoit Creek, Hobsons Bay. As in Corio Bay, there appears a marked decline in mangrove algal diversity in estuarine environments.

3.1.2.5. *Carrum*.

Spencer (1970) investigated the subtidal benthic flora at Carrum as part of the Port Phillip Bay Environmental Study, 1968-71 (Anonymous, 1973), and compared its composition, distribution and ecology to subtidal sites at Werribee and Altona. Carrum exhibited a marked reduction in species richness (24 species) compared to Altona (70 species) and Werribee (43 species). The macroalgal flora at Carrum was vastly different to that reported at Werribee and Altona. Spencer (1970) attributed this to the geographic distances between the three sites and environmental conditions (bathymetry, substrate, nutrient levels) these two areas shared compared to Carrum. Carrum was characterised by a sparse occurrence of a red algal community consisting of *Falkenbergia*, *Wrangelia* and *Antithamnion* whereas Werribee and Altona were characterised by associations between *Caulerpa longifolia* f. *crispata* and *Caulerpa remotifolia, Polysiphonia nigrita* and *Acrosorium uncinatum*, and *Solieria robusta* and *Rhabdonia coccinea*. The red alga *Ceramium* was abundant in all three regions.

Spencer (1970) attributed the nature and distribution of the subtidal flora of Carrum to the same factors operating at Altona and Werribee: 1) wind, currents and sediment transport processes, 2) substrate suitability and 3) light availability as determined by depth. Sediment transport, poor substrate and deep water close inshore were characteristic of Carrum and contributed to a depauperate algal growth compared to that occurring at Werribee and Altona where a proliferation of epizoic substrates and basalt reef provided firm substrata for large and diverse macroalgal communities. No macroalgal growth was recorded in water depths exceeding 15 m at Carrum, Werribee or Altona.

3.1.2.6. *Portsea*

Two unpublished honours theses include information on community composition and distribution of selected members of the red algal order Ceramiales at the Portsea. Huisman (1980) recorded 26 species of the Ceramiaceae from the Portsea Jetty during the period March to October 1980 and provided information on their habitats and reproductive periodicity. White (1982) undertook an intensive study of the ecology of *Jeannerettia lobata* on the pilings of the Portsea Pier. White (1982) concluded that the distribution of this species was controlled by light intensity (low light reduces occurrence and abundance), competition for space with animals (removal of ascidians by grazing fish allows the species to develop), and that water movement and sand scour control the upper and lower limits of plant occurrence on the pilings. White (1982) also found 27 species of plants and 11 species of animals growing on plants of *Jeannerettia lobata* and provided a list of species found on the Portsea Jetty pilings.

3.1.3. ZONATION

Zonation patterns on basalt reefs in Port Phillip Bay have been examined by King *et al*. (1971), O'Brien (1975) and Brown *et al*. (1980). In intertidal regions, King *et al*. (1971) found that zonation was not as well developed in the Bay as compared to the Heads and that under more sheltered conditions, no supratidal or subtidal fringes occurred. Poor intertidal zonation within the Bay also was attributed to the poor development of rocky platforms and to a tidal range of 1 m or less for most of the Bay as compared to a 1.7 m tidal range at the Heads.

O'Brien (1975) reported distinct zonation on a subtidal basalt reef at Gloucester Reserve. The upper subtidal included *Ulva lactuca*, *Caulerpa brownii*, *Caulerpa simpliciuscula*, *Caulerpa longifolia* f. *crispata*, *Bryopsis plumosa*, *Sargassum bracteolosum*, *Corallina officinalis*, *Grateloupia filicina*, *Acrosorium uncinatum* and *Polysiphonia mollis*, with *Gracilaria secundata* confined to deeper sandy holes in the spring. The lower subtidal, in contrast, was dominated by *Ecklonia radiata* and *Sargassum bracteolosum* with an understorey of *Lithothamnion* sp.; *Gelidium pusillum*, *Acrosorium uncinatum* and *Phycodrys* sp. occurred as epizoic growths on mussels and ascidians.

At certain times of the year the distal portions of *Ecklonia radiata* fronds were epiphytized by *Ulva lactuca*, *Enteromorphora intestinalis* and *Griffordia mitchellae*. *Caulerpa brownii* occurred seasonally and *Caulerpa remotifolia* occurred in the deeper sandy areas at the seaward extremity of the reef.

Brown *et al*. (1980) found little zonation at Kirk Point, Werribee. The intertidal algal profile was dominated by submerged *Centroceras clavulatum* and to a lesser extent *Ulva lactuca* and *Enteromorpha compressa* on the basalt boulders. A turf of *Chaetomorphora aerea* formed on the upper surfaces of boulders. Taxa characteristic of subtidal environments, including *Caulerpa* spp., appeared in the lower intertidal in habitats with permanent inundation. The subtidal algal profile was dominated by *Ulva lactuca, Caulerpa longifolia, Caulerpa remotifolia.* Less dominant taxa included *Acrosorium uncinatum*, *Grateloupia filicina, Polysiphonia* spp., *Phymatolithon* spp. and *Lithophyllum* sp. (as *Tenarea*).

3.1.4. SEASONALITY

Information relating to seasonal changes in macroalgal communities in Port Phillip Bay are limited to unpublished data from the Werribee region (Brown *et al*., 1980), Gloucester Reserve (Altona Bay) (O'Brien, 1985), Williamstown and Portarlington (Lewis, 1975), and Portsea (Huisman, 1980; Fletcher, 1980); and to published and unpublished data from the Point Gellibrand region (Altona Bay-Hobsons Bay) (Lewis, 1977, 1983).

Brown *et al*. (1980) recorded a high degree of seasonality on a basalt reef macroalgal community occurring at Kirk Point Werribee; most algal species (including *Centroceras clavulatum*, *Grateloupia filicina*, *Gigartina brachiata*, *Polysiphonia* sp., *Dasya capillaris*, *Ceramium isogonum*, *Ulva lactuca*, *Enteromorphora compressa*, *Dictyota* spp. and *Chondria*) exhibited maximum abundance, as measured by biomass, in spring/summer/autumn. *Caulerpa remotifolia* reached maximum abundance in autumn although the upright fronds disappeared during winter. The resulting available space during winter was colonised by small fine algal species including *Polysiphonia* sp., *Heterosiphonia gunniana*, *Griffithsia teges*, *Centroceras clavulatum*, *Goniotrichum* sp.and *Cladophora fascicularis*. *Caulerpa* spp. (excluding *Caulerpa remotifolia*), *Corallina officinalis* and crustose coralline algae did not exhibit seasonal periodicity.

Species diversity decreased from autumn to winter; particular species appear unable to grow under winter conditions (Brown *et al.*, 1980). A marked increase in the number of species occurred during early spring when water temperature and light levels increased. Species diversity per unit area decreased from spring to summer with the growth of larger over-storey species such as *Ulva lactuca*, *Dictyota* spp. and *Caulerpa remotifolia* dominating over the smaller annual filamentous species. This situation remained unchanged over the following summer and autumn period with no apparent change in species richness (Brown *et al*., 1980). According to Brown *et al*. (1980), the basalt reef at Kirk Point also appeared much more dynamic, supporting a greater proportion of fast-growing annual species as compared with other basalt reefs in the Bay (see King *et al*., 1971).

Macroalgal seasonality was also assessed in an unstable sand community at Werribee in 1978-79 (Brown *et al.*, 1980). *Caulerpa longifolia* was dominant during winter and during spring the erect assimilators increased markedly in length such that by early summer they had almost all dislodged leaving bare areas of rhizomes. This coincided with the occurrence of a heavy drift of *Caulerpa longifolia* assimilators on the beach and in the adjacent shallow water. At the beginning of the following winter this species was again abundant, exhibiting cover estimates up to 60% in some areas. *Ulva lactuca* also exhibited a marked seasonal periodicity in this sand community; during winter the plants appeared small, stunted and uncommon whereas by the end of spring plants were up to 1m long and attached to loose shells in the sand.

In both the basalt reef macroalgal community at Kirk Point and the adjacent unstable sand community at Werribee Brown *et al*. (1980) did not observe sexual reproduction in *Caulerpa* species throughout the entire study period.

Brown *et al*. (1980) observed a population of grazing animals at Kirk Point with reduced macrophyte cover in winter. The extent to which grazing animals structure the existing macrophyte communities in this region requires in-depth study.

O'Brien (1985) reported little seasonal fluctuation in the biomass of major species (*Ulva lactuca*, *Caulerpa brownii*, *Caulerpa simpliciuscula*, *Corallina officinalis*, *Sargassum bracteolosum* and *Ecklonia radiata*) on a subtidal basalt reef at Gloucester Reserve (Altona Bay). However, among the less common taxa, 8 species (*Cladophora fasicularis*, *Chaetomorphora linum*, *Enteromorphora intestinalis*, *Dictyota alternifida*, *Dictyota dichotoma*, *Pterocladia capillacacea*, *Hypnea* sp. and *Ceramium* sp.) were not recorded in September whereas 4 species (*Caulerpa remotifolia*, *Giffordia mitchellae*, *Scytosiphon lomentaria* and *Punctaria* sp.) were not recorded in June. Five species (*Phycodrys* sp., *Colpomenia sinuosa*, *Rhodymenia australis*, *Centroceros clavulatum* and *Polysiphonia mollis*) were considered more abundant in terms of biomass in June than in September.

Lewis (1977, 1983) reported that maximum abundance and spore production of most species occurred during late spring and summer on a subtidal basalt boulder mound which once supported the now demolished Gellibrand Light off Williamstown. Species richness was maximal in January (34 species) and minimal in July (18 species). Lewis's methods of assessing abundance were qualitative and unclear in terms of scale.

Lewis (1975) also examined the ecology of the red alga *Grateloupia filicina* at Williamstown and Portarlington during the period March-September 1975. He found that between March and September the ranges of horizontal and vertical distribution, mean plant height and cystocarp production decreased. Plants collected in September were more shrubby in habit than those collected in autumn and early winter. At Portarlington this species grew in a more sheltered, sand-dominated site than at Williamstown, and the plants were lighter in colour and finer in texture.

At Portsea, Huisman (1980) provided information on the reproductive periodicity of 26 species of Ceramiaceae (Rhodophyta), while Fletcher (1980) reported that plants of the brown alga *Ecklonia radiata* grew significantly faster during July-September than in April or June.

3.2 Ecological Processes

Only unpublished data appear to be available on colonization/recruitment and growth for macroalgae growing in Port Phillip Bay.

3.2.1. COLONIZATION/RECRUITMENT

Spencer (1972) deployed artificial substrates *in situ* at Werribee and Carrum between March 1971 and May 1972 to investigate plant (and animal) colonization in relation to depth, light, temperature, currents, substrate siltation, proximity to reproducing populations, season and competitive growth. Both macroalgae and microalgae were examined. The colonizing sequence in Port Phillip Bay was best explained as a succession modified by temporal, seasonal and depth factors which, in the majority of cases, led to a climax community dominated by *Mytilis*. After 3 weeks immersion an algal turf consisting of *Polysiphonia* and the benthic colonial diatom *Navicula grevilleana* was present at both sites; the amount of material decreased with increasing depth. After 2-3 months the shallow sites were characterised by an abundance of *Ceramium* sp.1 and *Polysiphonia*. *Navicula grevilleana* was less abundant and joined by the diatoms *Bacillaria paxillifer*, *Trachyneis aspera*, *Biddulphia pulchella* and *Nitzschia panduriformis* which remained on the substrates throughout the course of the study.

The shallow nearshore site at Werribee exhibited the greatest development of macroalgae. *Acrosorium uncinatum*, *Caulerpa remotifolia*, *Ceramium* sp.1, *Cladophora repens*, *Dictyota dichotoma*, *Giffordia* spp., *Griffithsia teges*, *Heterosiphonia gunniana*, *Neomonospora griffithsioides*, *Polysiphonia abscissa*, *Polysiphonia nigrita* and *Ulva lactuca* dominated the flora. This flora increased to a maximum in the summer months when *Cladophora repens* proliferated the substrates. Algal abundance and diversity then rapidly declined and a transition took place whereby the substrates harboured a faunal community dominated by *Mytilis planulatus*. In the early winter of the following year the macroalgal community was reduced to *Cladophora* and *Ceramium* growing epizoically on *Mytilis*.

The nearshore site at Carrum was characterised by fewer brown and green algae. *Ceramium* sp.1, *Ceramium* sp.2, *Antithamnion divergens*, *Griffithsia teges*, *Polysiphonia abscissa*, *Polysiphonia nigrita* and *Cladophora repens* dominated the flora at this locality.

In general, macroalgae at both sites exhibited:

1) a reduction in species diversity and biomass with increasing water depth;

2) a more rapid growth of plants at the shallow sites;

3) the occurrence of algal growth only on the upper surfaces of the artificial substrates;

4) the absence of algal growth either on or in the vicinity of the artificial substrates in water depths exceeding 15 m; and

5) a good representation of those algal species known to occur in the two areas (13 of the major 20 and more than half of the total number) colonized the artificial substrates.

At Portsea, White (1982), studying the ecology of the red alga *Jeannerettia lobata* between March-October 1982 , suggested that spore settlement on the Portsea Pier jetty pilings occurred in late June or July as recruitment of juveniles was not evident until August.

3.2.2. GROWTH

Growth studies have been conducted on the green alga *Ulva lactuca* and the brown alga *Ecklonia radiata.*

In order to understand the seasonal growth and reproduction of *Ulva lactuca* in Port Phillip Bay, Spencer (1972) cultured this species in the laboratory under various conditions (temperature, light intensity, daylength and nutrient concentrations). *Ulva lactuca* attains a high abundance and large size near the effluent outfalls of the WTC (Spencer, 1970).

Both light intensity and temperature had a significant effect on the growth of *Ulva lactuca* germlings and frond disks; the highest light intensity (2700-3200 lx) and temperature (21^{o}C) tested in the laboratory produced the most rapid growth of germlings and frond discs, although growth occurred over the full range of light intensity (600-3200 lx) and temperature (11 to 21^{o}C) tested. Zoospore release occurred at the highest light intensity and temperature. The growth of *Ulva lactuca* germlings and discs was greatest in a nutrient-rich media containing organic extracts (modified Erdschreiber media) and decreased successively in seawater collected from Werribee ('polluted') and Point Lonsdale ('unpolluted'), demonstrating this species' sensitivity to the nutrient environment. The growth of frond discs were maintained for more than 23 days over a pH range of 6-10. Optimal growth was at pH 8, corresponding to that found in the natural environment. By simulating water movement via agitating the culture medium, rapid growth of frond discs was achieved and the growth of germlings encouraged. Agitation, however, did not encourage normal thallus morphogenesis.

Fletcher (1980) reported no significant difference in the length of plants of the brown alga *Ecklonia radiata* occurring at various depths on the Portsea pier and on an adjacent reef. There was, however, a significant difference in *Ecklonia radiata* plant weight, degree of bushiness and secondary blade length:axis length ratio. Fletcher reported no significant differences in *Ecklonia radiata* growth rates in relation to depth and substrate.

3.2.3 COMPETITION

Information involving macroalgal competition in Port Phillip Bay is scant; the only information encountered involves populations of the red alga *Jeannerettia lobata* growing on pilings at Portsea Pier (White, 1982). In this study, White (1982) suggested that space competition occurred between the alga and ascidians, and he indicated that the selective removal of ascidians by grazing fish provided space for the settlement of *Jeannerettia* spores.

3.3 Biotic Interactions

3.3.1. EPIPHYTISM

Epiphytism is a common and widespread phenomenon, but very few data exist for communities in Port Phillip Bay. Womersley (1966, p. 133), in dealing with the macroalgal flora of the Bay, explicitly omitted minute epiphytic species from his analysis.

In a study of the ecology of the red alga *Jeannerettia lobata* on the pilings of Portsea Pier, White (1982) recorded 27 species of plants and 11 species of animals that grew epiphytically on *Jeannerettia.*

Brown *et al*. (1980) reported *Acrosorium uncinatum* occurring as an epiphyte on several algae species in a subtidal basalt reef environment offshore from the WTC. Brown *et al*. (1980, p. 156) also reported a heavy epiphytic growth of the diatom *Striatella unipunctata* on many species of macroalgae during the late winter and early spring of 1978, which they felt effectively shaded the hosts and reduced growth rates. At other times the diatom was found only in small numbers.

3.3.2. EPIZOISM

Few data exist on macroalgal epizoism in Port Phillip Bay. Spencer (1970) noted that the subtidal flora of Werribee, Altona and Carrum increases in cover according to the quantity of zoobenthos acting as algal substrata. Algae were epizoic on *Pyura* and *Mytilus* and also occasionally occur on Pecten and Ostrea molluscs. In contrast, algae were not found on echinoderms, porifers or ascidians (Spencer, 1970).

Brown *et al*. (1980) reported algal epizoism in a subtidal basalt reef environment (*Acrosorium uncinatum*, *Phymatolithon* sp. and *Tenarea* sp. occurring on *Mytilis edulis planulatus*) and a subtidal unstable sand environment (*Caulerpa remotifolia*, *Caulerpa longifolia*, *Caulerpa brownii* and *Ulva lactuca* occurring on *Pyura stolonifera*) offshore from the WTC. In the sand community at the same site, *Pyura stolonifera* and *Mytilis* were substrata for a variety of other algae, particularly *Ulva lactuca, Rhodoglossum proliferum, Ceramium* spp, *Griffithsia teges, Acrosorium uncinatum, Dasya capillaris, Polysiphonia* spp and *Pterosiphonia pennata..*

3.4 Productivity

Productivity data for Port Phillip Bay are dealt with under three headings: biomass, primary production and blooms.

3.4.1. BIOMASS

Most biomass data for macroalgal communities in Port Phillip Bay are based on the studies of Brown *et al*. (1980) in the Werribee region. On a basalt reef at Kirk Point, Brown *et al*. (1980) did not detect significant seasonal changes in total dry weight biomass of the macroalgal community during 1978 (90-207 g m^{-2}). However, a significant increase did occur from the summer of 1978-79 to the autumn of 1979 (192 g m^{-2} to 312 g m^{-2}). Dry weight biomass per unit area paralleled changes in the biomass of *Caulerpa* spp.

Red algae exhibited strong seasonal fluctuations in biomass with a minimum in winter (15 g m^{-2}) and a maximum as primary colonisers in spring (87 g m^{-2}). The biomass of the green alga *Ulva lactuca* decreased markedly during winter (4 g m^{-2}); over the rest of the study period it had a mean biomass of 38 g m^{-2}. Brown *et al*. (1980) reported green algae (60-90%) to be the most important biomass contributors in the basalt reef macrophyte community during the study period. Red algae were important contributors during autumn and spring (30%) and to a lesser extent during other seasons (8-15%) whereas brown algae were a relatively insignificant component of the biomass of this area (< 1%).

In a macroalgal community occurring in an unstable sand environment at Werribee, *Caulerpa longifolia* underwent rapid growth from early winter to early spring (93 g m^{-2} to 399 g m^{-2}) (Brown *et al*., 1980). By the end of spring the biomass fell to 105 g m^{-2} when *Caulerpa longifolia* assimilators were lost from the rhizomes.

In the 40 km^2 area from the Werribee River to Point Wilson, Brown *et al*. (1980) estimated the total standing crop biomass of all macrophytes to be 1.458 x 10^6 kg. Brown *et al*. (1980) acknowledged the possible presence of epibenthic drift making up part of the algal biomass in the Werribee region. No attempt was made to distinguish this material from the attached benthos.

Brown *et al*. (1980) also examined the *in situ* rate of loss of biomass (decomposition) for the green alga *Ulva lactuca* at Kirk Point when it became dislodged from the substratum. *U. lactuca* persisted much longer in the subtidal (up to 10 weeks) than the intertidal environment (3 - 6 weeks depending on prevailing weather conditions). For those plants placed subtidally, Brown *et al.* (1980) made particular mention of an initial increase in biomass during the first week of the experiment, and even after 10 weeks a substantial amount of the plant material had remained.

Small amounts of biomass data also are available for Gloucester Reef (Altona Bay) and Greenwich Bay (Hobsons Bay). On a subtidal basalt reef at Gloucester Reserve, O'Brien (1975) reported a mean total wet weight algal biomass of 3.1 kg m^{-2} for June and 3.4 kg m^{-2} for September. Mean percent dry weight was 20% $\pm$ 10% wet weight for all algal species excluding *Corallina officinalis*. *Corallina officinalis* exhibited dry weights as high as 60% of wet weights before decalcification; hence, their inclusion would have added bias to the final results. In Greenwich Bay, O'Brien (1975) reported wet weight algal biomass values of 3.9 kg m^{-2} and 4.8 kg m^{-2} for June and September respectively.

3.4.2. PRIMARY PRODUCTION

Based on laboratory work and *in situ* data collected by McMillan (1978), Brown *et al*. (1980) calculated annual productivity rates of macroalgae occurring in the Werribee region. On a basalt reef at Kirk Point, macroalgae (excluding *Caulerpa* spp.) exhibited an overall net productivity rate of 477 g C m^{-2} yr^{-1} whereas *Caulerpa remotifolia* (the dominant reef inhabiting algae of the area) exhibited a net productivity of 593 g C m^{-2} yr^{-1}. In the unstable sand community at Werribee (composed of *Caulerpa longifolia*), Brown *et al*. (1980) estimated an annual productivity of 371 g C m^{-2} yr^{-1}. The annual production rate for the benthic flora of the entire Werribee region (40 km^2 extending from the Werribee River to Point Wilson) was in the vicinity of 2.3 x 10^6 kg C yr^{-1} with an error term of 1.0 x 10^5 kg (Brown *et al*., 1980).

Many assumptions and approximations were made in arriving at the productivity values and these are largely acknowledged by the authors. The calculations assume that areas are 100 percent vegetated. Daily, seasonal and environmental variations are not considered when rates are extrapolated to yearly figures; light intensity as determined by water depth, cloud cover, and their interaction is represented as a mean value and fails to take into account temporal variation; *in vivo* experiments utilized small pieces of single plants; results may not be representative of responses shown by the population as a whole; and the light intensity used *in situ* may have been so high as to inhibit photosynthesis in some species (Brown *et al*., 1980).

3.4.3 BLOOMS

Macroalgal blooms in Port Phillip Bay have been observed at Kirk Point (Brown, 1980; Brown *et al*., 1980; Spencer, 1972) and Corio Bay (Brown, 1980; Watson, 1992).

In the late spring of 1977 and 1978, Brown *et al.* (1980) recorded a proliferation of *Cladophora* sp. which resulted in large masses of filaments floating in the water column. Small plants of *Cladophora fascicularis*, which appeared to be the same species as the bloom plant, were observed overwintering on mussels and Brown *et al*. (1980) postulated that these plants grow rapidly with increased light and temperature during spring, became detached, and entered the water column as viable free-floating plants. Brown *et al.* (1980) also found that rapid growth of detached field collected plants occurred when they were placed in nutrient culture in the laboratory. A heavy drift along the Werribee foreshore resulted from these blooms.

Brown *et al*. (1980) also reported a large 'bloom' of detached plants of the red algae in shallow waters (3-5 m) of the Werribee shoreline in late autumn of 1979. *Griffithsia* and *Ceramium*, the principal components of the bloom, grew sufficiently large in the deeper waters to become dislodged from their subtrata In the calm shallow waters of Werribee, the warm sunny weather would have encouraged their growth as would have the abundance of nutrients in the area, according to Brown *et al*. (1980). A similar bloom of *Griffithsia teges* was recorded in April 1971 in the Werribee region by Spencer (1972, p. 94).

In Corio Bay, Brown (1980) recorded the decaying remains of a bloom of *Cladophora* at depths of 1.5 m and more in the Cunningham Pier area on 30 November 1977. Subsequently, Watson (1992) reported that in January 1991 communities of the seagrass *Halophila ovalis* in the southern half of Corio Bay were infested with a fine, unidentified, filamentous brown alga which completely covered the bed to a depth of 30 cm. Watson (1992) also indicated that this alga commonly occurred in quiet water conditions in Port Phillip Bay during summer.

3.5 Interactions with Nutrients

Based on the abundance and large size of *Ulva lactuca* plants near effluent outfalls of the WTC, Spencer (1972) undertook experiments to determine the effects of increased nitrogen and phosphorus on the growth of this species. Although Spencer (1972) placed limitations on the accuracy of methods employed, he inferred that high concentrations of nitrogen with or without high concentrations of phosphorus have no marked effect on the growth of this species. However, high concentrations of phosphorus, in the absence of high nitrogen concentrations, appear to inhibit growth.

Spencer (1972) also compared the growth of *Ulva lactuca* discs and germlings placed in hormone-enriched media. The growth response to ardenosine was highly significant for both frond discs and germlings indicating that this hormone did stimulate the growth *U. lactuca*. Kinetin had no apparent effect on the growth of *U. lactuca*.

Lewis (1973) analysed the nitrogen and phosphorus content of macroalgae, sediments and water at five sites (Point George Light and Drysdale on the Bellarine Peninsula, Borrie Drain and Weribee in the Werribee region and Altona) in an attempt to determine their relationship and to investigate the temporal and spatial trends in nitrogen and phosphorus content. Results indicated that the nitrogen content of macroalgae was affected by season (higher nitrogen in winter), location (higher nitrogen in inshore areas of excessive eutrophication) and species (higher in *Ulva lactuca*, *Caulerpa brownii*, *Caulerpa remotifolia*, *Jeannerettia pedicellata* and *Heterosiphonia gunniana*) whereas the phosphorus content of macroalgae was shown to be relatively stable with respect to time, locality and species. The concentrations of both nitrogen and phosphorus in macroalgae appears to be dependent on the nutrient status of the ambient water rather than that of the sediments. Mean N:P ratios for dominant species occurring at nutrient rich sites (Werribee) indicated that net nitrogen uptake from ambient seawater was higher than net phosphorus uptake from ambient seawater. Unfortunately Lewis's experimental design and replication are not statistically robust and the results must be interpreted accordingly.

Based on tissue nitrogen levels in the dominant species occurring at Werribee, Brown *et al.* (1980) found that plants exhibit an elevated nitrogen content at nutrient enriched sites as compared to sites with lower nutrient levels in the water. This is consistent with the findings of Lewis (1973). Whether certain nutrients limited the growth of marine algae at Werribee remains unclear, however. Data generated by Lewis (1973) and Brown *et al.* (1980) indicate that nitrogen may not limit algal growth in the nearshore region at Werribee; plants having particularly high tissue nitrogen levels may exhibit luxury consumption (Brown *et al.*, 1980). Brown *et al.* (1980) compared this to the situation in the offshore zone where algae had lower tissue nitrogen levels and thus may have been on the borderline of luxury consumption.

Brown *et al.* (1980) also felt that seawater temperature and light limited growth of annual macroalgae because tissue nitrogen levels remained elevated during winter and thus the nitrogen content of the water probably was not growth-limiting.

As part of the Werribee Study, Axelrad *et al.* (1981) compared macroalgal community composition on a basalt reef at Kirk Point, Werribee (as reported in Brown *et al.*, 1980) to data collected in nutrient-poor areas elsewhere in the Bay (as reported in King *et al*., 1971 - Portarlington, and Lewis, 1977 - Williamstown) to determine the effects of nutrient discharge on macroalgal communities. Axelrad *et al*. (1981) reported a decreased species diversity at all distances along the zonation profile and an absence of distinctive subtidal zone forming species (viz. *Ecklonia radiata*, *Sargassum* spp.and *Corallina officinalis*) at Werribee compared to Williamstown and Portarlington. Axelrad *et al*. (1981) concluded that the Werribee macrophyte community exhibits similar features to other communities occurring in nutrient-rich environments elsewhere in temperate regions, namely: 1) a reduction in species diversity, particularly of brown and red algae; 2) a high percentage of fast growing species (e.g. *Ulva lactuca* and *Cladophora*); 3) occurrence of a structurally simple community with little zonation; and 4) loss of kelps and fucoid brown algae.

In Hobsons Bay, Watson (1972) reported that the green algae *Ulva* and *Bryopsis* occurred commonly and grew luxuriantly, and she interpreted this as a response to nutrient enriched waters.

In an laboratory study, Brown *et al*. (1977) observed significant growth inhibition in three species of geniculate coralline red algae cultured in media enriched with orthophosphate. Growth was only obtained in a medium consisting of a four-fold decrease in phosphate concentration to that normally used in culturing other groups of marine plants. Brown *et al*. (1977) correlated these laboratory observations with the distribution of these algae within and around Port Phillip Bay and reported a depauperate (occasionally absent) coralline red algal flora in those areas subject to elevated levels of phosphate in seawater. Brown *et al*. (1977) related these observations to several previous studies demonstrating that phosphates act as crystal inhibitors of calcification and made mention of this algal group's potential role as a biological indicator for relative levels of phosphates in seawater. The conclusions of Brown *et al*. (1977), however, seem at variance with those reached by Brown *et al*. (1980, p. 177) where they indicate that the diversity of crustose coralline red algae was not reduced on basaltic reefs in the Werribee region.

In summarizing past nutrient work on Port Phillip Bay, Brown (1988) concluded that "... no comprehensive study has been carried out to specifically determine nutrient limitation in Port Phillip Bay; rather the findings of various studies carried out at different times, often in different areas, have been used to assess nutrient limitation in the bay on an *ad hoc* basis."

3.6 Interactions with Toxicants

The 1976 report on heavy metal contamination in Port Phillip Bay and Western Port (Negilski, 1976) contains no data relating to the interactions of toxicants with macroalgae.

Brown algae can actively bio-accumulate several radio-nuclides from the water column to a factor of 10^4 (Aarkrog *et al*., 1988; Dave *et al.,* 1973). Wood *et al.* (1990) reported a good correlation between calculated I^{131} at an ocean outfall in Western Australia - where this radionuclide originates in city hospitals and is discharged through the sewer system - and the concentration of I^{131} within the tissues of *Ecklonia radiata* when decay-corrected to the same time. B. Light (unpublished) sampled attached *E. radiata* plants for the presence of I^{131} from several sites within Port Phillip Bay in an attempt to determine the distribution of this radio-nuclide and its use as a tracer to determine mass water movement and possible plume characterisation in the Bay. A single replicated sampling event in February 1992 indicated high levels (suitable for tracing purposes) of I^{131} (mean: 46 fCi g^{-1}) at a site in the Werribee region whereas levels below detectable limits were obtained at South Channel Fort (mean: < 3.8 fCi g^{-1}). These results are indeed positive and the development of an appropriate experimental design to quantify the temporal and spatial distribution of I^{131} in the Werribee region has considerable merit.

4.0 UNATTACHED MACROALGAE

The extent, distribution, biomass, productivity and general ecological importance of unattached macroalgae in Port Phillip Bay is largely unknown. According to V. Brown (pers. comm.) large quantities of unattached macroalgae occur over extensive areas of Port Phillip Bay and these algae appear to be healthy and capable of active growth. There have, however, been virtually no studies of the ecology or physiology of these unattached communities. Indeed only seven unpublished documents appear to contain data on unattached macroalgae in Port Phillip Bay (Table 2); three (Spencer, 1970; Watson, 1972; Watson, 1992) include information on unattached epibenthic macroalgae, and four (Spencer, 1972; Brown *et al*., 1980; Davies and Brown, 1986; Brown, 1987) contain information on unattached macroalgae washed up on beaches (i.e. drift algae).

4.1 Unattached Epibenthic Macroalgae

Along the Werribee foreshore, Spencer (1970) recorded three epibenthic macroalgal species which were particularly abundant. Although often attached, the green alga *Ulva lactuca* was found drifting in large quantities in the shallow water. Spencer (1970) reported that plants of *U. lactuca* attained surface areas of 3-4 m^2 in close proximity to the WTC outfalls, indicating that this species may be a product of eutrophication. Large quantities (up to 30 cm deep) of the unattached red alga *Botryocladia obovata* blanketed vast areas of substrate. Spencer (1970) felt that the material of *Botryocladia obovata* was static rather than constantly drifting. As a result, large areas of substrate beneath the *B. obovata* were devoid of other vegetation except for occasional isolated patches of the seagrass *Halophila ovalis*. The third species to feature prominently in epibenthic drift at Werribee was the brown alga *Cutleria multifida*. This species formed a significant free-floating biomass close inshore during the summer months.

In Hobsons Bay, Watson (1972) found unattached populations of the green alga *Ulva lactuca*. According to Watson (1972) the plants become detached from a substrate at an early age and then settle on the bottom and continue to grow for an unknown period. Tidal movements, currents and wind gradually carry the plants into Greenwich Bay where they form standing crops up to 2.5 kg m^{-2}. Watson (1972) also felt that the extremely sheltered position of Greenwich Bay prevented the plants of *Ulva* from being cast ashore in nuisance quantities.

Watson (1972) also found that the red alga *Neomonospora elongata* occurred prolifically on mussel beds and sporadic outcrops of shallow reef bordering Port Melbourne Beach. These plants grow larger than their point of attachment can support and eventually become inadvertantly detached from the substrate and ultimately end up as drift deposited on the local beach

Data on *Caulerpa longifolia* (Brown *et al*., 1980) in the Werribee Region are presented in the following section, and information on unattached macroalgal blooms is presented in the section on macroalgal productivity (see above).

Watson (1992) reported the occurrence of detached algae - mostly small red species - which were intermittently abundant in the Corio Bay outer harbour (Geelong Arm) during January 1992.

4.2 Drift (Unattached Macroalgae Deposited on Beaches)

Spencer (1972) investigated drift weed at a number of localities in Port Phillip Bay in terms of its composition, source, degree of dispersion and seasonal periodicity. He concluded that:

1) the Bellarine Peninsula (including St. Leonards, Indented Head and Portarlington) was characterised by the periodic deposition of the seagrass *Heterozostera* (as *Zostera*) rather than macroalgae;

2) the north-western coast (including Werribee, Altona and Williamstown) was subject to local variability in weed composition but major components of deposition were the green algae *Ulva lactuca* and *Caulerpa* sp., the brown alga *Ecklonia*, and the red algae *Jeannerettia* and *Centroceras*;

3) the eastern coast (including St Kilda, South Melbourne, Sandringham, Brighton, Mordialloc, Mentone, Carrum and Frankston) was characterised by a predominance in the drift of the red algae *Ceramium*, *Griffithsia*, *Polysiphonia* and *Medeiothamnion*;

4) the weed deposited on beaches was predominately subtidal in origin and could be traced to local sources, except at Ricketts Point where the majority of the weed originated on the nearby intertidal/subtidal rock platform;

5) the quantities and location of weed deposits were determined by the local supply of weed, the prevailing wind conditions and local Bay physiology;

6) weed deposition on beaches was greatest during summer months when the growth of many species was at a maximum; and

7) the beaches worst affected by weed deposition were Portarlington, Werribee, Altona, St Kilda, Ricketts Point and Mentone.

Brown *et al*. (1980, pp. 105, 111, 122) reported a considerable epibenthic drift development of *Caulerpa longifolia* in water 3-5 m deep off the 145W Drain in the Werribee Region. The upright portions of the plants had become detached from the rhizomes and considerable quantities of material were washed up on beaches in the vicinity of the 145W Drain.

Davies and Brown (1986) monitored weed deposition on a monthly basis, between 1983 and 1984, at 6 locations in northern Port Phillip Bay. They also attempted to relate plant morphology to net productivity based on the functional-form hypothesis. This hypothesis states that in terms of productivity, plants with a sheet like morphology are the most productive while crustose plants are the least productive. On the assumption that sheet-like > filamentous > coarsely branched > jointed-calcarious > thick-leathery > crustose in terms of productivity, and that seagrasses were between coarsely branched and thick-leathery, the following conclusions were drawn:

(a) Along the Werribee coast the dominant green alga - *Caulerpa* - belongs to the 'coarsely-branched' group. Other commonly occurring taxa belong to the 'sheet-like group' and include the green algae *Ulva lactuca* and *Enteromorpha* spp, and the red algae *Rhodoglossum proliferum, Acrosorium uncinatum, Jeannerettia pedicellata,* and Porphyra *lucasii*.

(b) At Altona seagrass comprised half the drift recorded by weight, with *Polysiphonia decipiens, Ulva lactuca, Centroceras clavulatum, Chaetomorphora* sp, *Enteromorphora* sp and *Cladophora* sp also common. Seagrass usually comprised at least half the drift although occasional large drifts comprised almost entirely of algae, particularly 'sheet' and 'filamentous' forms, were also recorded.

(c) At Point Cook the most abundant species were *Centroceras clavulatum, Polysiphonia decipiens* and *Ceramium* sp whilst *Ecklonia radiata, Heterozostera tasmanica, Botryocladia obovata, Ulva lactuca* and *Caulerpa brownii* were also common. The 'filamentous' and 'coarsely-branched' forms were the most abundant.

(d) The 'coarsely-branched' *Botryocladia obovata* was the dominant plant deposited at Werribee South whilst *Ceramium* sp, *Polysiphonia decipiens, Jeannerettia pedicellata, Caulerpa brownii* and *Laurencia filiformis* were also common. The 'coarsely-branched' and 'filamentous' forms were the most abundant.

(e) At 145 W beach, *Jeannerettia pedicellata* ('sheet' group) comprised 40% of the plants by weight, with *Caulerpa brownii, Laurencia filiformis, Heterozostera tasmanica, Caulerpa remotifolia* and *Polysiphonia decipiens* also common.

(f) At Kirk Point *Ulva* comprised 25% of the weed deposited with *Ceramium* sp, *Jeannerettia pedicellata, Centroceras clavulatum, Heterozostera tasmanica, Caulerpa brownii, Caulerpa remotifolia, Acrsorium uncinatum* and *Caulerpa longifolia* also common. 'Sheet' and 'filamentous' forms comprised most of the drift.

Davies and Brown (1986) offered the following conclusions from their study:

1) "the species of plants deposited on the beaches were the same as those occurring in offshore weed beds, indicating that the drift is derived from local marine areas and thus confirming the findings of Spencer (1972);

2) "Large accumulations of weed were common on beaches which gently grade into shallow offshore waters that harbour extensive weed beds on the sediments (Altona and Corio Bay) or are in close proximity to shallow basalt reefs (Kirk Point). Beaches subject to generally higher wave energy, as indicated by the mobile beach sediments, or that are distant from offshore weed beds generally received lower amounts of weed (Point Cook, Werribee South, 145 W);

3) "The high proportion of seagrass, predominantly *Heterozostera tasmanica*, in the drift at Altona and Corio Bay reflects the close proximity of seagrass beds to these beaches. These beds occur on a shallow sandy topography, which is characteristic of Altona and Corio Bay and changes in this configuration (and hence seagrass drift potential) are unlikely in the foreseeable future; and

4) "Weed drifts deposited on the beaches along the WTC coast (145 West and Kirk Point beaches), containing high proportions of 'sheet' like algae, may be attributed to nutrients in the effluent discharged from the WTC, thus promoting the growth of this particular type of algae in this area."

Brown (1987) investigated drift along the west coast of Port Phillip Bay and corroborated conclusions drawn in other studies. The drift deposited on beaches in Port Phillip Bay was characteristic of the the flora occurring in the adjacent subtidal. The weed deposits at sites along the Werribee coast were dominated by algae whereas those deposits in the Geelong Arm were dominated by seagrass. Data on the moisture content, age and state of decomposition of all samples were provided in a series of tables.

Finally, G. Parry (pers. comm.) has indicated that a considerable body of unanalysed data on drift algae in Port Phillip Bay is housed at the Marine Science Laboratories at Queenscliff. According to Parry, trawls have been taken at 22 stations at three monthly intervals between March 1990 and March 1991, and a further sample was obtained in March 1992. A majority of the material obtained is of a drift nature, but the biomass and species composition have not been determined.

5.0 SEAGRASSES

5.1 General Aspects

The term seagrasses is used here in the sense of Robertson (1984, p. 57) to include all species of flowering plants capable of growing submerged in marine environments.

Data on the seagrass vegetation in Port Phillip Bay are contained in a number of published papers, unpublished theses, technical reports and other documents (Table 3). In contrast, the recent general treatise on the biology of seagrasses (Larkum *et al.*, 1989), in which the Australian region receives special emphasis, includes virtually no information on Port Phillip Bay communities. In the present review data on Port Phillip Bay are organized into the following sections: general aspects (floristic studies, community composition and distribution, zonation, seasonality); biotic interactions (epiphytism, epizoism); productivity (biomass, primary production, leaf turnover); interactions with nutrients; and interactions with toxicants.

5.1.1 Floristic Studies

There has been no comprehensive monographic account of the seagrasses in Port Phillip Bay. Records and references to reported species are summarized in Appendix II.

5.1.2 Community Composition and Distribution

Seagrass community composition and distribution has been dealt with on a bay-wide basis by Willis (1966), Hope-Black (1971), King *et al.* (1971), Spencer (1972) and Bulthuis (1981a). None of these studies, however, includes data on all of the seagrass species known to occur in Port Phillip Bay.

Information for particular localities/regions is provided by Spencer (1970, Werribee, Altona), Watson (1979, Bellarine Peninsula), Brown *et al.* (1980, Corio Bay, Werribee Region), Seedsman & Marsden (1980, Corio Bay), Kerr (1983, Swan Bay), Parry & Collett 1985, Rosebud-Rye), Denning *et al.* (1986, Swan Bay), Brown & Davies (1991, Bellarine Peninsula, Werribee Region, Altona Bay-Hobsons Bay), Brown (undated, Corio Bay & Werribee Region). Kerr (1983) and Denning *et al.* (1986) were published in journals; the remaining documents constitute unpublished theses, consultant reports or technical reports.

5.1.2.1. *Bay-wide studies*

Three of the four bay-wide studies (Willis, 1966; Hope-Black, 1971; King *et al*., 1971) were based on data collected during the 1957-1963 Port Phillip Survey whereas the Bulthuis (1981a) report was prepared independently. Some additional data are contained in Spencer (1972).

Bulthuis (1981a) examined seagrass distribution in Port Phillip Bay for the period 1978 to 1981 from aerial photography followed by field investigations and compared these results with past seagrass distribution data for the Bay. The most extensive areas of seagrasses were recorded in Swan Bay, Prince George Bank (as St. Georges Bank) - east of Portarlington - and along the southern margin of Corio Bay and the Geelong Arm. Smaller isolated patches (representing less than 5% of the total seagrass area in Port Phillip Bay) occurred along the nearshore zone, west of Point Wilson into Corio Bay. Bulthuis (1981a) reported that 95% of seagrasses in Port Phillip Bay occur at depths of less than 5m. In three areas (east and west of Point Henry, west of Portarlington and between Rye and Rosebud), seagrass distribution and density increased between 1947-50 and 1978-81 while a decrease occurred in two areas (around Point Wilson and the northshore of Corio Bay). Bulthuis (1981a) also concluded, however, that little major change in the general distribution of seagrasses in the Bay had occurred since 1957-63.

Based on data in Womersley (1966) and Spencer (1970), Spencer (1972, fig. 43) produced a map showing the distribution of *Heterozostera* (as *Zostera*), *Halophila*, and several sorts of algae in Port Phillip Bay. The precise boundaries and extent of *Heterozostera* and *Halophila* beds in Port Phillip Bay, however, cannot be determined from this map.

Willis (1966) and Bulthuis (1981a) recorded the same four species: *Amphibolis antarctica* (syn.*Cymodocea antarctica*), *Halophila ovalis*, *Heterozostera tasmanica* (syn. *Zostera tasmanica*), and *Zostera muelleri*. According to Willis (1966), *Amphibolis antarctica* is confined to the southern part of Port Phillip Bay near The Heads and the few areas that support it are too small to be mapped. The species usually grows subtidally on sand or mud but can also occur in intertidal pools. Frequently the stems and leaves are encrusted with various polyzoa and algae. Bulthuis (1981a) reported a similar distribution, noting that plants characteristically occur in areas of strong water movement.

Statements of Willis (1966) and Bulthuis (1981a) concerning *Heterozostera tasmanica* and *Zostera muelleri* are somewhat at variance. Thus, according to Willis (1966), *Zostera muelleri* is more common than *Heterozostera tasmanica*. The two species are dominant over a large area of the sandy shallows; their distribution extends around the north and south shores of Corio Bay, throughout the whole of Swan Bay and northward to Indented Head, with isolated occurrences off mud Island, Rye, the Werribee River estuary and Altona. The whole eastern shoreline has only a few small, isolated and inconsequential beds of *Zostera*. In contrast, Bulthuis (1981a) concluded that *Heterozostera tasmanica* was the dominant seagrass species in Port Phillip Bay and within seagrass designated waters had a distribution from the intertidal to 9m below mean water. *Zostera muelleri*, according to Bulthuis (1981a), generally occurs higher in the intertidal area than *Heterozostera tasmanica* and was common in Swan Bay. Willis (1966) conservatively estimated the total area of Port Phillip Bay covered by *Zostera* and *Heterozostera* to be at least 47 square miles. Willis (1966) also noted that about 1.5 miles east of Indented Head, *Zostera* beds extend out beyond the 5 fathom line to where the seafloor begins to slope more abruptly toward 10 fathoms. This occurrence, at depths exceeding 30 feet, must mark the absolute limit of low-illumination tolerance.

According to Willis (1966), *Halophila ovalis* is largely confined to the western side of Port Phillip Bay; a belt 0.5 mile offshore occurs parallel to the eastern coast of the Bellarine Peninsula; a longer zone is said to occur 3-4 miles off the mouth of the Werribee River, and Corio Bay is said to support several smaller occurrences. Bulthuis (1981a) concluded that *Halophila ovalis* generally occurs subtidally and is common in Corio Bay and the Geelong Arm.

Willis (1966) also noted that *Halophila ovalis* grows subtidally in deeper water than *Zostera* and will tolerate illuminations as low as 5-10 % of the light intensity in surface layers. Additionally, Willis (1966) concluded that *Halophila* occupies only a small fraction of the area covered by *Zostera*, occurring chiefly as narrow bands along the outward fringe of *Caulerpa* (Chlorophyta) and *Zostera* beds, and that this pattern may merely reflect an inability of *Halophila* to compete successfully with the other genera in shallower water.

The two other bay-wide studies contain fewer data. Hope-Black (1971) reported *Zostera* beds occurring on sand in Capell Sound and on the eastern shores of the Bellarine Peninsula as well as on the silty and clayey sands of Swan and Corio Bays. These beds were usually fringed on their seaward side by *Amphibolis antarctica* (as *Cymodocea*) and *Halophila ovalis*, which line the deeper channels.

King *et al.* (1971) dealt only with intertidal regions and reported four species: *Zostera muelleri* from various areas in the Bay, *Amphibolis antarctica* from The Heads, and *Ruppia maritima* and *Lepilaena cylindrocarpa* from Swan Bay. The latter two species were not recorded by Willis (1966) or Bulthuis (1981); Shepherd & Robertson (1989, p. 223) examined the herbarium vouchers of King *et al.* (1971) of these two species and found them to be referable to *Ruppia tuberosa* and *Lepilaena marina* respectively.

5.1.2.2. *Swan Bay*

As part of an environmental survey of Swan Bay, Kerr (1983) recorded *Zostera muelleri*, *Heterozostera tasmanica* and *Halophila ovalis*, mapped their distributions and estimated their individual biomasses between July and December 1978. *Lepilaena cylindrocarpa* and *Ruppia* sp. also were recorded but were considered as aquatic plants with a facultative ability to grow in saline water.

According to Kerr (1983), *Heterozostera tasmanica* is the dominant seagrass species in Swan Bay, forming extensive beds in the more sheltered regions. At its upper limit of growth, this species grades into a mixed community with *Zostera muelleri* and may be exposed to the air at low tide. Factors limiting the distribution of *Heterozostera tasmanica* in Swan Bay appear to be depth and turbidity (both of which reduce light) and the speed of the currents in the channels.

Kerr (1983) reported that *Zostera muelleri* occurs in the intertidal zone above the zone of *Heterozostera tasmanica*, where it may be exposed to the air at low tide for periods of up to four to five hours. Its minimum depth of growth is governed by the amount of exposure it can tolerate and its maximum depth of growth is probably related to its competitive interaction with *Heterozostera tasmanica*. In Swan Bay, *Zostera muelleri* grows in salinities close to those of seawater and in Yarram Creek it grows upstream to a point where the salinity is 8.5 ppt. Because of the shallow nature of Swan Bay, this species endures temperatures ranging from 4 - 40^{o}C.

Kerr (1983) found *Halophila ovalis* mainly in the north-west section of Swan Bay in areas where *Heterozostera tasmanica* was not dominant; these areas tended to have high turbidity and an unstable substrate. *Lepilaena cylindrocarpa*, in contrast, occurred in ephemeral pools around the perimeter of Swan Bay and occurs intermixed with *Zostera muelleri*. *Ruppia* sp. was found in and near Yarram Creek under somewhat estuarine conditions.

Except for *Ruppia megacarpa*, Denning *et al*. (1986) recorded the same species from Swan Bay as Kerr (1983) and mapped their distributions and measured their biomasses at 50 stations. *Heterozostera tasmanica* was the dominant seagrass species, occurring at 90% of the stations (both intertidal and subtidal), frequently in monospecific stands. *Zostera muelleri* was recorded at 44% of the stations where it was restricted to intertidal and shallow subtidal sites. This species was found in association with *Lepilaena cylindrocarpa* in areas of greatest exposure. *L. cylindrocarpa* occurred at 36% of the stations and was also found in monospecific stands in the pools and channels on the northern and western sides of Swan Bay. *Halophila ovalis* was found only at 22% of the the stations and was confined to the deeper sites in association with *Heterozostera tasmanica*. At several stations towards the centre of Swan Bay, *Halophila ovalis* was present in greater abundance than *Heterozostera tasmanica* .

5.1.2.3. *Bellarine Peninsula*

Watson (1979) mapped the extent of *Heterozostera tasmanica* associated with Point Richards Bank (between Point Richards and Spray Farm Road) and using available aerial photographs, traced its history from 1946-1977. Watson (1979) concluded that the relative stability of the bank, with little sediment deposition or movement, had allowed *H. tasmanica* to develop from a total cover of 2-3% in 1946 to 42% in 1962 and 75% in 1975. Little change occurred between 1975 and 1977. When a dredged cut was made into the *Heterozostera tasmanica* colonized central seaward margin of Point Richards Bank in the 1950's to early 1960's, the seagrass had not regrown in the channel; the seabed at a new depth of 7 m was presumably below the depth for seagrass photosynthesis (Watson, 1979).

In accordance with Bulthuis (1981a), Brown and Davies (1991) reported that 'healthy' seagrass beds still occur in the Portarlington region. However, Brown and Davies (1991, p. 46), citing a 1986 MSL memo of Axelrad, noted that there had been an apparent reduction in the cover (to < 5%) of *Heterozostera tasmanica* west of Clifton Springs in April 1986 as compared to the 5-100% reported by Bulthuis (1981a). Further west, towards Point Henry, the aerial extent of seagrass meadows also appeared to be markedly reduced. These observations were based on aerial photography taken in 1986 and ground-truth spot diving on 30 April.

5.1.2.4. *Corio Bay*

In conjunction with a study of sediment distribution and movement within Corio Bay, Seedsman and Marsden (1980) looked at the distribution and density of macrophytes in relation to sediment patterns. They reported that seagrasses were largely confined to areas less than 2 m deep. No seagrasses were found in shallow areas east of Point Henry Bar, only a few barren areas occurred along the western and southern shores of Corio Bay, and a large barren area occurred between Phosphate Wharf and North Channel. Aerial photographs of the Point Henry area indicated a much denser vegetation present in September 1977 compared with December 1970, but Seedsman and Marsden (1980) were uncertain whether this reflected seasonal variation or some longer-term increase in cover. Seedsman and Marsden (1980) also concluded that the seagrasses and algae assisted in preserving some of the mud in areas where sandy sediments were exposed to wave attack.

According to Brown *et al.* (1980, p. 70), "*Heterozostera tasmanica* occurs abundantly as a fringing vegetation in the protected waters of Corio Bay". Subsequently, Brown (1980, and undated) reported that plants of *H. tasmanica* up to 1 m tall occur in Corio Bay, and that monospecific stands occur in 2-3 m of water within 2-3 m of the shore and extend seawards 100-200 m. At greater depths, according to Brown (1980, and undated), *H. tasmanica* becomes patchy and occurs in association with *Halophila ovalis*. Near a Corio Bay stormwater drain *Heterozostera tasmanica* was replaced by a scattered green algal community, but with increasing distance from the drain and freshwater input *H. tasmanica* again became dominant with increasingly taller plants occurring.

The benthic ecology of Corio Bay is currently under investigation as part of an Environmental Effects Statement for the Port of Geelong Authority's proposed shipping channel improvement program. M. Batchelor, study manager of Maunsell Pty. Ltd., indicated (pers. comm.) data from this study will be released in October 1992. Watson (1992, pp. 22-30) used a diving sled towed behind a boat to undertake a preliminary inspection of the Corio Bay spoil ground in January 1991. According to Watson the major permanent vegetation in the southern half of the area was the seagrass *Halophila ovalis*, with plants being evenly distributed across the benthos. This seagrass bed grades into a more sparse distribution and finally disappears as water depth increases towards the north as a result of *Halophila ovalis* plants reaching their photosynthetic limit. Watson reported that the extent to which *Halophila ovalis* was observed in the area was unexpected (presumably referring to previous information from the area).

Finally, Brown (undated) indicated that an examination of herbarium collections of all Corio Bay plants identified as *Zostera muelleri* by Willis (1966) and King *et al*. (1971) showed that these specimens were really *Heterozostera tasmanica*.

5.1.2.5. *Werribee region*

The distribution of seagrasses in the Werribee region reported in the bay-wide study of Willis (1966; see above) was based on data collected during 1957-63. Spencer (1970, p. 77) reported that a 1969 diving survey showed that the 1957-63 distribution pattern had not changed noticeably but commented that spot dives for mapping purposes lack precision and that the boundaries of communities could not be determined with accuracy in a short period of time.

Brown *et al.* (1980, p. 70) concluded that seagrass beds were rare in the Werribee region and that the only substantial communities occurred in the nearshore zone at Kirk Point and off the Murtcaim Drain. These communities were composed of monospecific stands of *Heterozostera tasmanica* and were protected by surrounding basaltic reefs. They speculated that the general absence of seagrass communities in this region may be due to the exposed coastline with its approximately southerly aspect.

Subsequently, Brown and Davies (1991, pp. 45-6) noted that *Heterozostera tasmanica* was recorded offshore from the WTC between 1980-1987. It occurred within 50 m of the 15 East outfall where communities extended 2-3 km offshore, and at Murtcaim outfall where communities occurred in shallow nearshore areas amongst basaltic boulders. The beds appeared to be much less extensive in 1984-1985 but became re-established in subsequent years.

Brown (undated) reported that at Kirk Point, Werribee, *Heterozostera tasmanica* colonises much of the shallower shell-sand-mud substratum at 0.5-1.5 m depth, growing to a height of 0.5 m tall.

5.1.2.6. *Altona Bay-Hobsons Bay*

Willis (1966) reported isolated occurrences of *Heterozostera tasmanica* (as *Zostera*) off Altona. Subsequently, Spencer (1970, p. 76) indicated that these seagrass communities had not changed between the 1957-1963 survey on which Willis based comments, and 1969 when Spencer undertook a series of spot dives. The beds occurred about 5 km off Point Cook and about 1.5 km north of the mouth of Skeleton Creek. Brown and Davies (1991, p. 46) comment that *Heterozostera* meadows occur within 5 m of the treated effluent discharge from Western No. 2 treatment plant at Altona Bay.

Spencer (1972, p. 98) reported the occurrence of *Heterozostera* (as *Zostera*) beds to the east of Williamstown but did not comment on their extent.

5.1.2.7. *Rosebud-Rye*

A marked increase in the distribution and density of *Heterozostera tasmanica* was observed along the Rosebud-Rye shoreline throughout the 1960's (Parry and Collett, 1985). Parry and Collett (1985) reviewed historical time series aerial photography and established a negative correlation between the extent of inshore seagrass beds and areas where sandbars had been transversly cut for the purposes of providing sand for beach nourishment; the occurrence of transverse bars allows the dynamic process of sandbar formation and migration to proceed, creating an unstable sand environment non-conducive to seagrass growth.

Subsequently, Parry (1986) reported that within 12 months of constructing five 9 m wide sand bars perpendicular to the shore at Rosebud, the bars had expanded to a width of 40 m and smothered a considerable amount of the seagrass beds.

5.1.3. Zonation

There have been no detailed studies aimed explicitly at examining zonation in Port Phillip Bay seagrass communities. Incidental information on zonation in the bay-wide studies of Willis (1966), Hope-Black (1971), King *et al*. (1971), and Bulthuis (1981a) and in Corio Bay (Brown 1980) has been mentioned in section 5.1.2.

5.1.4. Seasonality

All seagrass communities are evident throughout the year, but marked seasonal changes can occur in above-ground standing crop, shoot density and leaf growth rate; these changes are detailed in the section 5.3.

According to Willis (1966), *Heterozostera* (as *Zostera*) flats may appear to be bare during autumn and winter because much of the foliage is shed at the end of summer after flowering has finished. This comment should be compared with data provided by Bulthuis and Woelkerling (1983) (see section 5.3).

Bulthuis (1981b, p. 4; 1984) commented that *Heterozostera tasmanica* may be most sensitive to changes in light level during autumn and least sensitive to such changes during spring. These comments were based on data from Western Port and were made in conjunction with a study investigating the use of bottom-covering screens to control the growth of *Heterozostera tasmanica* in Corio Bay. Bulthuis (1981b, 1984) concluded that control appeared to be the result of reduced light intensity and not the result of reduced dissolved oxygen concentration, but he felt that the relative sensitivity of *H. tasmanica* to decreases in light level throughout the year required further study.

5.2. Biotic Interactions

5.2.1. Epiphytism

On a world scale there is a considerable body of data on epiphytes associated with seagrasses. A review of the subject with special reference to Australia is provided by Borowitzka and Lethbridge (1989). However, for Port Phillip Bay only limited information appears to be available.

Watson (1979, pp. 22-25) found different epiphytes on sheltered and more exposed communities of *Heterozostera tasmanica* at Point Richards Bank. In a more sheltered region, *Heterozostera* plants were comparatively tall, grew in a substrate of sand, silty sand and mud, and harboured an epiphytic community composed of a variety of annual, filamentous red algae. According to Watson (1979), these red algal epiphytes are shed in quantity from the leaves in spring and then form extensive drifts which build up in hollows within the seagrass bed or are washed ashore. This contrasts with a more exposed region where the *Heterozostera* plants were comparatively short and wiry, grew in a compact substrate of shell, sand and mud, and harboured an epiphytic community composed chiefly of the green alga *Ulva lactuca*. Watson (1979) thought that the dense stands of *Ulva* close to Point Richards may be the result of nutrient inputs from the land and from local sewage discharge.

Watson (1979) also reported that the dominant seagrass, *Heterozostera tasmanica*, harboured populations of the bivalve *Electronia georgiana* ranging in densities from 10-1680 individuals m^{-2} in the same seagrass beds. The highest densities of *Electronia* occurred in areas of greatest water movement.

Brown *et al.* (1980) recorded the red alga *Acrosorium uncinatum* occurring as an epiphyte on the seagrass *Heterozostera tasmanica* in a subtidal basalt reef environment offshore of the WTC. However, based on a personal communication, Brown and Davies (1991, p. 46) comment that no extensive growth of epiphytes was observed at Werribee, and they speculated that this be the result of control by an abundance of grazers in the seagrass beds.

Based on a single visit (30 November 1977) to the Cunningham Pier area of Corio Bay, Brown (1980) found that the shoots of *Heterozostera tasmanica* provided a substratum for a variety of macroalgal epiphytes including species of the brown algae *Feldmannia* and *Sphacelaria*, the red algae *Antithamnion, Callithamnion, Ceramium, Champia*, *Chondria*, *Dasya*, *Hypnea*, and *Polysiphonia*, the green alga *Enteromorpha* and the cyanobacterium *Oscillatoria*. No quantitative data were collected, however.

5.2.2. EPIZOISM

There appears to be no detailed studies of epizoic macroalgae in Port Phillip Bay.

5.3. Productivity

The general analysis of seagrass productivity and nutrient limitation with special reference to the Australian region (Hillman *et al*., 1989) includes some data from Port Phillip Bay. In the present review information on productivity is presented under three headings: biomass; primary production; and leaf turnover.

5.3.1. BIOMASS

Data on seagrass biomass is limited to three regions: Swan Bay, the Bellarine Peninsula, and the Werribee Region.

5.3.1.1. *Swan Bay*

Bulthuis and Woelkerling (1983) compared standing crop, density and leaf growth rate of *Heterozostera tasmanica* occurring intertidally in Port Phillip Bay (Edwards Point) and Western Port. In both embayments, vegetative stems were present throughout the year, had a higher relative biomass in winter than summer, and accounted for 25-60% of the above sediment biomass. Edwards Point exhibited a bimodal seasonal pattern in which minimum biomass values occurred in mid-winter (leaf standing crop: 80-85 g dry wt. m^{-2} and density: 2210 leaf clusters m^{-2}) and mid-summer (leaf standing crop: 60 g dry wt. m^{-2} and density: 2460 leaf clusters m^{-2}) respectively. Maximum values were recorded in spring (leaf standing crop: 130 g dry wt. m^{-2} and density: 3660 leaf cluster m^{-2}) and autumn (leaf standing crop: 120 g dry wt. m^{-2} and density: 4580 leaf clusters m^{-2}) respectively. This is in contrast to a unimodal seasonal pattern exhibited by *H. tasmanica* occurring in Western Port where minimum leaf standing crop and density generally occurred during winter and maximum leaf standing crop and density occurred during summer. *H tasmanica* occurring at Edwards Point had a low mean shoot height (32 cm) compared to those plants occurring in Western Port. Bulthuis and Woelkerling (1983) attributed Port Phillip Bay's different seasonal pattern and lower mean shoot length to exposure and desiccation stress during spring low tides. This hypothesis is reinforced by leaf growth data collected in the same study; at Edwards Point the leaf growth rate per leaf cluster was similar to the Western Port sites (see section 5.3.2.), implying that the factor(s) causing the decrease in standing crop and density during summer at Edwards Point did not also cause a decrease in growth rate of the surviving leaf clusters.

Denning *et al.* (1986) reported biomass data for 4 species of seagrass in Swan Bay during the period July-December, 1978. Mean biomass estimates, with upper biomass limits indicated in parenthesis, were reported as 103.5 (405), 44.2 (151), 16.4 (71) and 15.4 (66) g m^{-2} dry weight for *Heterozostera tasmanica, Zostera muelleri, Lepilaena cylindrocarpa* and *Halophila ovalis* respectively. Total dry weight for all seagrass material sampled was *Heterozostera tasmanica*: 73.8%, *Zostera muelleri*: 44%, *Lepilaena cylindrocarpa*: 36% and *Halophila ovalis*: 22%.

In a subsequent report dealing with the same data set, Hudson and Strother (1988) noted that at two sites in Swan Bay where *Halophila australis* (syn.*ovalis*) was especially high in biomass (> 60 g dry wt m^{-2}), the biomass of *Heterozostera tasmanica* was extremely low (< 2 g dry wt m^{-2}). Hudson and Strother (1988) attributed this result to possible reduced competitive ability of *H. tasmanica* under low light intensities. This conclusion is consistent with the documented increase in growth of *H. australis* when the biomass of *H. tasmanica's* biomass is reduced by means of artificial light-reducing screens Bulthuis (1981b, 1984).

Kerr and Strother (1986, 1990) examined the seasonal variation in standing crop biomass of *Zostera muelleri* occurring at two sites. Shoot biomass was minimal in winter [August 1981 and June 1982 at Swan Bay Jetty (both 2.2 g dry wt m^{-2}); July 1981 and June 1982 at Tip Island (12.9 and 16.3 g dry wt m^{-2}, respectively)]. Peaks in shoot biomass occurred in February 1982 and October 1982 at Swan Bay Jetty (84.6 and 24.1 g dry wt m^{-2}, respectively) and in December 1981 and November 1982 at Tip Island (86.2 and 50.5 g m$^{-2,}$ respectively). Shoot standing crop increase from winter to summer by 7-fold at Tip Island and 40-fold at swan Bay Jetty. Root/rhizome biomass showed less seasonal variation, with a 2-fold increase at Tip Island and a 4-fold increase at Swan Bay Jetty from winter to summer. Changes in root/rhizome biomass paralleled those of shoot biomass. Root rhizome biomass was minimal in August 1981 and May 1982 at Swan Bay Jetty (30.3 and 35.1 g dry wt m^{-2}, respectively) and in May 1982 at Tip Island (50.6 g dry wt m^{-2}). Maxima occurred in February 1982 and November 1982 at Swan Bay Jetty (113.9 and 112.5 g dry wt m^{-2}, respectively) and in December 1981 and September 1982 at Tip Island (115.4 and 112.2 g dry wt m^{-2}, respectively). During winter, the root/rhizome biomass constitutes as high as 80-90% of total biomass whereas in summer it is approximately 50%. Kerr and Strother (1990) reported a high degree of correlation between leaf/sheath biomass and solar radiation, day length, and maximum temperature, but concluded that leaf growth rate, rather than biomass, is the best predictor of seasonal variation in *Z. muelleri* standing crop in Swan Bay.

5.3.1.2. *Bellarine Peninsula*

Watson (1979) mapped the standing crop of *Heterozostera tasmanica* associated with Point Richards Bank and concluded that a combination of water depth and the interaction of water and sediment movement have resulted in a distinct biomass distribution within the community. Watson (1979) reported a significant correlation between mean plant height and standing crop; shorter blade length and lower biomass (< 1 kg m^{-2} wet weight) occurred on plants situated at the periphery of the seagrass bed where wave energy was greatest, whereas taller plants and greater biomass (2.6 kg m^{-2} wet weight) occurred in the more sheltered central part of the bed where wave energy was very low. In all, Watson (1979) recognised four biomass zones (viz. <1, 1-1.5, 1.5-2 and >2 kg m^{-2} wet weight), all a function of exposure, sediment size, position in the seagrass community and water depth.

5.3.1.3. *Werribee Region*

At Kirk Point, Brown *et al.* (1980, pp. 137, 223) reported the dry weight of *Heterozostera tasmanica* (including rhizomes) to vary from a minimum of 451 g m^{-2} in the autumn of 1978 to a maximum of 2110 g m^{-2} in the summer of 1979.

5.3.2. PRIMARY PRODUCTION

Data on primary production for Port Phillip Bay appear to be limited to localities within Swan Bay. Bulthuis and Woelkerling (1983) reported similar leaf growth rates [6.5 mm (leaf clusters)$^{-1}$ day^{-1}] in plants of *Heterozostera tasmanica* growing at intertidal sites at Edwards Point (Swan Bay) and in Western Port. An approximate two-fold increase was observed in plants growing at a subtidal site in Western Port; however, a comparative subtidal site was not examined in Port Phillip Bay. Rates increased two-fold at Edwards Point during spring and were at a maximum during the summer months. Leaf dry weight per centimetre of leaf length for *H. tasmanica* occurring at Edwards Point was similar to that recorded for the site in Western Port.

Bulthuis and Woelkerling (1983) calculated mean monthly productivity of leaf dry weight [leaf dry weight (g cm^{-1}) x leaf growth rate (cm leaf cluster^{-1} day^{-1}) x leaf cluster density (No. m^{-2})] for *Heterozostera tasmanica* occurring at Edwards Point. Results indicated that a minimum rate (0.77 g m^{-2} day^{-1}) occurred during the autumn and winter months (April - July) whereas a maximum rate (4.2 g m^{-2} day^{-1}) occurred during summer. Although similar rates were recorded for this species in Western Port, productivity rates increased rapidly in spring and by November were at least five times the winter minima. These rates were maintained throughout the summer months. At Edwards Point, however, decreasing density during summer combined with increasing growth rates per leaf cluster caused peak productivity to occur during February and March. This was followed by a rapid decline during late autumn (April - May) as both density and leaf growth rate declined.

Bulthuis and Woelkerling (1983) conceded that light may be an important factor in determining seasonal leaf production in *H. tasmanica*.. This was particularly evident from autumn data in both Port Phillip Bay and Western Port intertidal sites where leaf productivity during April was less than one-third the productivity during March. This reflected decreases in density and leaf growth rate that were much greater than the reduction in total insolation.

Bulthuis and Woelkerling (1983) reported similar annual leaf production rates (daily productivity x No. days for each month) for *H. tasmanica* occurring intertidally in Port Phillip Bay (645 g m^{-2} yr^{-1}) and Western Port (568 and 634 g m^{-2} yr^{-1}). Despite minima of density and leaf dry weight during mid-summer at Edwards Point, annual leaf production was similar to the Western Port intertidal sites. At Edwards Point, relatively lower leaf productivity during summer was compensated by relatively higher leaf productivity during winter. An annual production rate of 414 g m^{-2} yr^{-1} was reported for plants growing at a subtidal site in Western Port; however, a comparable subtidal site was not examined in Port Phillip Bay.

Kerr and Strother (1985) examined the effects of irradiance, temperature and salinity on the photosynthesis of excised leaves of *Zostera muelleri* collected from Swan Bay. Results indicated that *Z. muelleri* can photosynthesize under extreme conditions of temperature (3 and 30^{o}C) and salinity (15% that of normal seawater). With increasing irradiance over the range 17-185 μE m^{-2} s^{-1} at 16^{o}C, *Z. muelleri* exhibited an increasing photosynthetic rate. The wide physiological tolerance exhibited by *Z. muelleri* is consistent with its occurrence in comparatively harsh intertidal habitats; *Z. muelleri* in Swan Bay must endure temperatures of between 5 and 40^{o}C and salinities of 25-100% that of seawater. Kerr and Strother (1985) commented, however, that the photosynthetic rates obtained from excised leaves may not reflect the *in situ* situation in the field.

Subsequently, Kerr and Strother (1989) described the seasonal variation in leaf growth rates of *Zostera muelleri* at two sites within Swan Bay. Summer leaf growth rate was 3.7 times the winter rate at Tip Island and 2.3 times the winter rate at Swan Bay Jetty. The maximum and minimum rates at Swan Bay Jetty were 7 mm shoot $^{-1}$ day^{-1} (December 1981 - January 1982) and 3 mm $shoot^{-1}$ day^{-1} (May, June, July 1982). At Tip Island the rates were 8.2 mm $shoot^{-1}$ day^{-1} (December 1981 - January 1982) and 2.2 mm $shoot^{-1}$ day^{-1} (June, July 1982). The plastochrone interval is inversely related to leaf growth rate, ranging from 7.3 to 28.7 days at Swan Bay Jetty (mean: 14.7 days) and 10.4 to 27.4 days at Tip Island (mean: 16.5). The winter mean (April-September) was 17.3 days at Swan Bay Jetty and 20.7 days at Tip Island whereas the summer mean (October-March) was 12.4 days at Swan Bay Jetty and 13 days at Tip Island. Average lifespan of leaves ranged from 17 to 89 days at Swan Bay Jetty (mean: 46.1 days) and from 40 to 90 days at Tip Island (mean: 57.9 days). The winter mean was 53 days at Swan Bay Jetty and 70.9 days at Tip Island whereas the summer mean was 40 days at Swan Bay Jetty and 46.6 days at Tip Island. Mean turnover rate was 1.8% day^{-1} at Tip Island and 2.5 % day^{-1} at Swan Bay Jetty. The winter mean was 2.1% day^{-1} at Swan Bay Jetty and 1.5% day^{-1} at Tip Island whereas the summer mean was 2.7% day^{-1} at Swan Bay Jetty and 2.2% day^{-1} at Tip Island. Calculating crop replacement time from leaf life span and turnover time gives estimates of 6.3 crops $year^{-1}$ at Tip Island and 7.9 crops $year^{-1}$ at Swan Bay Jetty. Kerr and Strother (1989) reported a stronger correlation between leaf growth rate and both irradiance and daylength than with temperature. Kerr and Strother (1989) attributed variation between the two sites to different environmental variables including exposure to wind, duration of seagrass emergence during the tidal cycle. Kerr and Strother (1989), however, did not indicate whether shoot density at the two study sites were similar, and thus comparisons between localities may be only of limited value.

5.3.3. LEAF TURNOVER

Bulthuis and Woelkerling (1983) reported no correlation between *Heterozostera tasmanica* leaf area and water depth for either Port Phillip Bay (Point Edwards) or Western Port. A maximum plastochrone interval (20 days) for this species was recorded during autumn and winter at Edwards Point whereas a minimum plastochrone interval (8 days) occurred during summer. Throughout their study (June 1978 - May 1979), *H. tasmanica* produced 30-31 leaves per year with a mean leaf turnover rate of 1.3-1.7% day^{-1} at all intertidal and subtidal study sites in both Port Phillip Bay and Westernport. The rate was marginally higher in Port Phillip Bay (1.7% day^{-1}) compared to Westernport (1.3 - 1.5 day^{-1}); at Edwards Point the low leaf standing crop during summer coincided with high leaf productivity.

Kerr and Strother (1986, 1989) reported that plastochrone interval in populations of *Zostera muelleri* in Swan Bay varied from 7.3-28.7 days with the shortest interval occurring in the summer months. They estimated the maximum leaf life span to be about 90 days.

5.4. Interactions with Nutrients

Hillman *et al*. (1989) provided a general review of seagrass interactions with nutrients in which the Australian region was emphasized, but very few data exist for seagrass communities in Port Phillip Bay.

Lewis (1973) analyzed an unidentified species of *Zostera* and the underlying surface sediments, along with adjacent unvegetated surface sediments from offshore Drysdale (Bellarine Peninsula) for nitrogen and phosphorus analysis to determine whether this species takes up and excretes phosphorus into the ambient water via both roots and leaves as occurs in *Zostera marina* (McRoy *et al*., 1972). The results obtained were inconclusive, however. A 2.5-3 fold increase in nitrogen and phosphorus content of leaves as compared to roots was evident. In addition there was a markedly higher phosphorus content in the *Zostera* leaves (0.3-0.5%) than in macroalgae (0.1-0.2%) analyzed in the same study. None of the sediment samples had detectable levels of phosphorus, however.

In *in situ* experiments conducted on *Heterozostera tasmanica* in Western Port, Bulthuis and Woelkerling (1981) found that ammonium enrichment of the sediments resulted in increased levels of nitrogen in the rhizomes and leaves and a 20% increase in leaf growth rate. Phosphate enrichment, in contrast, resulted in increased levels of phosphorous in the rhizomes but no increase in the leaves, and there was no increase in leaf growth rate. Bulthuis and Woelkerling (1981) suggested that nitrogen limits the growth of *Heterozostera tasmanica* in Western Port during spring and early summer, but that an increase of 5-100 times the control levels of nitrogen and phosphorus in the rhizosphere of these plants had minimal effect on the growth or standing crop of the plants during the first year of enrichment. Subsequently, Brown and Davies (1991, p. 46) incorrectly attributed these results to Port Phillip Bay plants growing at Edwards Point (Swan Bay).

In summarizing the nutrient studies carried out on Port Phillip Bay, Brown (1988) concluded that nitrogen is the overall primary limiting nutrient in the Bay. She noted, however, that "... no comprehensive study has been carried out to specifically determine nutrient limitation in Port Phillip Bay; rather the findings of various studies carried out at different times, often in different areas, have been used to assess nutrient limitation in the Bay on an *ad hoc* basis."

5.5. Interactions with Toxicants

A general analysis of the effects of metals in seagrass habitats with special reference to the Australian region was provided by Ward (1989), but no data from Port Phillip Bay were included. Similarly, the 1976 report on heavy metal contamination in Port Phillip Bay and Western Port (Negilski 1976) contained no data relating to the interactions of toxicants with macroalgae.

Fabris *et al.* (1982) conducted both *in situ* and laboratory investigations to examine cadmium uptake in *Heterozostera tasmanica* from Corio Bay. Utilizing a compartmented experimental chamber in the laboratory, Fabris *et al.* (1982) demonstrated that when exposed to soluble cadmium concentrations of 40 and 400 $\mu g\ l^{-1}$, the leaf portion of *Heterozostera* plants approached a constant cadmium level in 192 hours whereas the root-rhizome portion of the plants did not. Cadmium translocation between *H. tasmanica* leaves and root-rhizomes could not be demonstrated and thus it seems that cadmium transport in this manner does not appear to be a substantial mechanism for the cycling of cadmium in the coastal marine environment. *In situ* experiments showed that *H. tasmanica* plants concentrated cadmium principally in the leaves when transplanted from an environment containing little measurable sediment cadmium to an environment containing high seawater cadmium levels whereas both leaves and root-rhizomes containing high cadmium levels depurated when translocated to an environment containing low seawater cadmium levels. Fractionation experiments indicated that approximately 70% of the cadmium accumulated by *H. tasmanica* leaves was associated with interstitial cellular material whereas 20% was associated with cell fluids. The remainder was physically bound by the leaf surfaces (Fabris *et al.*, 1982).

Bond *et al*. (1985) and Bond (1986) examined the kinetics of lead (II) uptake in *Zostera muelleri* leaves from Port Phillip Bay. In laboratory experiments with living and dead leaves, they found that lead uptake was rapid (73% of the available lead was accumulated by the leaf within 12 h) and that epiphytes on the leaves facilitated the uptake of lead but made little difference to the total amount of lead accumulated by the leaves after 6 days.

6.0 NON-PLANKTONIC MICROALGAE

6.1. Floristic Studies

The non-planktonic microalgal flora of Port Phillip Bay is virtually unknown and no detailed taxonomic studies exist. Indeed, only six documents containing floristic data on non-planktonic microalgae in Port Phillip Bay have been found (Table 4), and in two cases (Axelrad *et al*., 1979; Brown *et al*., 1980), the algae are identified only to genus level. A list of taxa is included in Appendix III.

6.2. Community Composition

Spencer (1972) deployed artificial substrates *in situ* at Werribee and Carrum between March 1971 and May 1972 to investigate plant (and animal) colonization in relation to depth, light, temperature, currents, substrate siltation, proximity to reproducing populations, season and competitive growth. Both macroalgae and microalgae were examined; five species of diatoms were identified, and the results of these studies are summarized in the macroalgal section dealing with colonization/recruitment (see above).

Axelrad *et al.* (1979) obtained some data on non-planktonic microalgae at a shallow water nutrient rich site offshore from the WTC and a shallow water nutrient poor site near Portarlington. *Amphidinium* sp. and pennate diatoms co-dominated the community at Werribee whereas only pennate diatoms dominated the community at Portarlington. Common genera at both sites were *Achnathes*, *Amphidinium*, *Amphiprora*, *Biddulphia*, *Chlamydomonas*, *Nitzschia*, *Pleurosigma*, *Cymbella*, *Pinnularia*, *Rhabdonema*, *Surirella*, *Gymnodinium*, and *Oscillatoria*. Markedly greater numbers of epibenthic microalgae were found at Werribee compared to Portarlington throughout the sampling period.

Brown *et al*. (1980, p. 69) reported large numbers of the dinoflagellate, *Amphidinium*, and the diatom, *Pleurosigma*, inhabiting unstable sands offshore from the WTC. This substratum appeared too unstable for macrophytes to become established. The presence of non-planktonic microalgae in this habitat was often associated with a brown substratum surface layer. Brown *et al*. (1980, p. 156) also reported heavy growths of the diatom *Striatella unipunctata* as an epiphyte on various macroalgae during the late winter - early spring of 1978. At other times this diatom was present only in small numbers.

Watson (1992) reported the occurrence of patches of diatomaceous scum on the muddy bed of the Geelong Arm of Corio Bay during a single sled run on 29 January 1992. The Geelong Arm is mostly 9.5-10.5 m deep and was otherwise sparsely covered by plants of the green alga *Caulerpa*. The diatoms were not identified.

6.3. Biomass

Axelrad *et al.* (1979) reported " no apparent seasonal pattern in epibenthic microalgal biomass at Werribee or Portarlington. Chlorophyll ***a*** concentration of the surface centimetre of sediment at Werribee varied between 60 and 130 mg m^{-2} over the year and averaged 106 mg m^{-2}. The annual sedimentary chlorophyll concentration range for Portarlington was 12 to 28 mg m^{-2} with an overall annual mean of 18 mg m^{-2}. Mean chlorophyll concentration at Werribee was significantly greater than that for the corresponding sample at Portarlington for every sampling over the year".

6.4. Productivity

Axelrad *et al.* (1979) reported " increased epibenthic microalgal productivity during summer months at both Werribee and Portarlington. Productivity at Werribee varied annually from about 290 to 1060 mg C m^{-2} d^{-1} while at Portarlington the range was 50 to 340 mg C m^{-2} d^{-1}. Productivity at Werribee was significantly higher than productivity found for the corresponding sampling at Portarlington for all samplings over the year. Annual productivity, calculated by integrating daily productivity values over the year, was 236 ± 19 g C m^{-2} for Werribee and 46 ± 5 g C m^{-2} for Portarlington." Axelrad *et al.* (1979) commented that the annual figure for Werribee was the highest reported figure for shallow-water marine environments up to that time.

Brown and Davies (1991, p. 51) further interpreted the data presented by Axelrad *et al.* (1979), noting that non-planktonic microalgae at Werribee showed productivity levels 2.8 times greater than the planktonic microalgae while non-planktonic microalgae at Portarlington showed productivity levels only 1.2 times greater than the planktonic microalgae.

Brown and Davies (1991, p. 51) concluded from this that the non-planktonic microalgae at Werribee were responding to the local nutrient stimulus to a greater extent than the planktonic microalgae.

7.0 MANGROVES

Intertidal mangrove communities occur at several localities in Port Phillip Bay, but only limited data on these are available. Willis (1966) reported *Avicennia marina* under tidal influence in Swan Bay and at the mouth of Kororoit Creek. The Kororoit Creek population of *Avicennia* was virtually destroyed by oil discharged into the Bay in June 1950 (Fawcett, 1951; Willis, 1951). Davey and Woelkerling (1980) reported comparatively poor developments of *Avicennia marina*; in Kororoit Creek estuary the community consisted of one tree 2 m tall and 6 smaller individuals. At Hovells Creek, a small community of mangroves exists upstream from the creek outlet into Corio Bay.

8.0 CONCLUSIONS AND RECOMMENDATIONS

8.1. Strengths and Limitations of the Existing Data

The strengths and limitations of the existing data relating to the benthic vegetation of Port Phillip Bay may be summarised as follows:

8.1.1. GENERAL

1. In the context of Port Phillip Bay, more information is known about seagrasses than macroalgae, with virtually nothing known about non-planktonic microalgae. This information is largely unpublished but contained in technical/consultant reports, unpublished thesis, journal articles and book chapters.

2. With few exceptions, studies dealing with the benthic vegetation of Port Phillip Bay have been limited in scope, pertain to particular locations, and have had markedly different objectives. Past studies have mainly been based on single static sampling events or on a short series of sampling events covering varying time-spans. It is therefore virtually impossible to mesh extent data sets into a single meaningful and useful database which will adequately address the required temporal and spatial variation of benthic plant community composition and distribution as it relates to Port Phillip Bay.

3. The nature of the substrate is frequently mentioned as an important factor in determining the occurrence and distribution of benthic plant communities in Port Phillip Bay. Salinity, light availability, wind, current, sediment transport processes, exogenous nutrient sources, salinity and temperature have also been implicated as community determinants. However, there are far too few data and a lack of understanding of the interaction processes to extrapolate or speculate on a Bay-wide basis and draw any unequivocal conclusions.

4. Several authors have divided Port Phillip Bay into regions in the context of particular studies. Such divisions appear to be largely divisions of convenience and may not reflect physical, chemical or biological factors in any definitive sense.

5 Most data on the benthic vegetation of Port Phillip Bay are qualitative; very few quantitative data exist. This is particularly true with respect to macroalgae and non-planktonic microalgae. Furthermore, many of the study designs appear to lack the rigour required to generate reliable and accurate data and hence must be treated with caution.

6. No attached macrophyte growth has been observed beyond water depths of 15 m in Port Phillip Bay; the depths to which unattached macrophytes and non-planktonic microalgae occur is uncertain.

8.1.2. MACROALGAE

7. The total number of macroalgal species in Port Phillip Bay is uncertain. Results from the 1957-63 Port Phillip Bay Survey suggested that macroalgal species diversity within the Bay was much lower than along the nearby coast. Subsequent, generally unpublished studies, however, have reported a number of additional species to be present in the Bay, and thus species richness in Port Phillip Bay is likely to be underestimated.

8. Species of the green alga *Caulerpa* commonly form a dominant component of the benthic flora at a number of localities in Port Phillip Bay. Species of *Caulerpa* form extensive beds in unstable, soft substrata which occur throughout most of the Bay.

9. In Port Phillip Bay, species of *Caulerpa* appear to grade into mixed algal communities as water depth increases.

10. There appears to be a noticeable absence of large brown algae near effluent outfalls in Port Phillip Bay. The reason for this is uncertain.

11. Data on macroalgal zonation in Port Phillip Bay is scant and inconsistent. Distinct subtidal zonation may or may not occur depending on the locality. The only study of intertidal regions within Port Phillip Bay suggests that little zonation is evident compared to sites just outside the Bay.

12. Seasonal variation in species composition and abundance (in terms of cover and biomass) appears to occur at all Port Phillip Bay localities at which this process has been studied. However, there appears no clear patterns evident from the available data. This can probably be attributed to the fact that most of the studies were undertaken over the course of 12 months or less.

13. Few data exist on macroalgae colonisation and growth for species occurring in Port Phillip Bay. Life history data for species reported as dominant are particularly scant.

14. Despite the seeming importance of an epiphytic and/or epizoic mode of existence for many species in Port Phillip Bay, there are virtually no data on these phenomena and no generalizations can be drawn.

15. Data on macroalgal biomass in Port Phillip Bay are limited to the Werribee region and areas within Hobsons Bay, and productivity data are limited to the Werribee region. The authors of these studies acknowledge that a number of assumptions and approximations were made in arriving at stated productivity values, and as such, these data must be treated with caution.

16. Several authors reported the occurrence of macroalgal blooms within Port Phillip Bay. However, insufficient data exist to determine the frequency of such blooms, the species involved and their importance in terms of nutrient cycling.

17. Tissue nitrogen content of macroalgae in Port Phillip Bay varies with season, location and species.

18. Data on the interactions between benthic macroalgal vegetation and nutrients in Port Phillip Bay is so scant that little can be said about the key physical, chemical and biological processes controlling such interactions.

19. Virtually nothing is known about the interactions between macroalgal vegetation and toxicants in Port Phillip Bay.

20. Various authors have indicated that there are substantial quantities of unattached macroalgae in Port Phillip Bay which can be traced back to a local subtidal attached source. However, the true extent of their distribution, biomass, productivity and general ecological importance in the Bay remains largely unknown.

8.1.3. SEAGRASSES

21. In Port Phillip Bay, the most extensive areas of seagrass occur in Swan Bay, Prince George Bank, east of Portarlington and along the southern margin of Corio Bay and the Geelong Arm.

22. Ninety-five percent of seagrass communities in Port Phillip Bay are said to occur in waters less than 5 m deep.

23. Seagrass distribution and density in Port Phillip Bay is dynamic in time and space; reflecting an interaction of particular species with environmental factors, especially sediments and sediment transport processes. Wave energy and light availability are also important.

24. *Heterozostera tasmanica* is generally considered the dominant seagrass in Port Phillip Bay and extends from the intertidal to depths of up to 9 m.

25. In Port Phillip Bay, *Zostera muelleri* generally occurs higher in the intertidal region than *Heterozostera tasmanica*; this is reflected in the wide physiological tolerance exhibited by *Zostera muelleri* in the lab. The lower limit of *Zostera muelleri* appears to be governed by its inability to compete with *Heterozostera tasmanica*.

26. *Halophila ovalis* generally occurs subtidally in Port Phillip Bay and is common in Corio Bay and the Geelong Arm.

27. The distribution of *Heterozostera tasmanica* in Port Phillip Bay appears to be limited by light availability.

28. Seagrass communities in Port Phillip Bay may exhibit marked seasonal changes in above-ground standing crop, shoot density and leaf growth rates.

29. Data on Port Phillip Bay seagrass biomass is limited principally to Swan Bay, with several limited data sets from the Bellarine Peninsula and Werribee regions. These data indicate that seagrass biomass changes with season, location and species.

30. Data on seagrass productivity in Port Phillip Bay are limited to *Heterozostera tasmanica* and *Zostera muelleri* in Swan Bay. Both species exhibit a winter minimum and summer maximum with respect to leaf growth.

31. Data on the interactions between benthic seagrass communities and nutrients in Port Phillip Bay are limited; the data involve few sites and have been generated across such different temporal and spatial scales that they are not deemed predictive without further studies.

32. Data on the interactions between seagrasses and toxicants in Port Phillip Bay is limited to a single study of cadmium uptake and a single study of lead uptake.

33. Nutrients and toxicants in Port Phillip Bay seagrasses appear to concentrate in the leaf/sheath component of the plant as opposed to the root/rhizome component. Studies on *Heterozostera tasmanica* have indicated that little nutrient/toxicant translocation takes place between the leaf/sheath and root/rhizome portions of plants, and hence cycling of nutrients and toxicants in this manner is unlikely to occur in this system.

8.1.4. NON-PLANKTONIC MICROALGAE

34. Most data on non-planktonic microalgae in Port Phillip Bay are derived from a single study in the Werribee and Portarlington regions. These data indicate the potential importance of this group in terms of productivity and nutrient cycling, but no generalizations can be drawn on a bay-wide basis. In addition little is known about non-planktonic microalgal community composition and distribution.

8.2. Recommendations for Further Research

Based on the above conclusions, and keeping in mind the task specifications outlined in section 1.0, the following recommendations are appropriate in moving towards the level of knowledge required to predict the impact of a 50% increase in nutrients and/or toxicants on the benthic flora of Port Phillip Bay:

1. Several authors have divided the Bay into defined areas for the purposes of managing and conducting a bay-wide study (King *et al.*, 1971; Womersley, 1966). However, there appears to be little ecological basis to these decisions. The interaction between hard substrate availability; light availability as determined by water depth; exposure to winds, currents and sediment transport processes; salinity and exogenous nutrient supply have been recognized by various authors as important environmental factors determining the composition and distribution of benthic vegetation communities in Port Phillip Bay. It is important that these environmental factors be used to derive environmental regimes for particular species/communities under study, and that these environmental regimes be used as rational for structuring any on-going study of the benthic vegetation of the Bay. Delimiting the Bay into ecological units based on recognized environmental regimes will not only provide a rational for hypothesis testing but will also reduce the total area under study into smaller and more manageable units. As a first step, considerable time and effort needs to be spent in collating existing bathymetric, light, meteorological and other data, and utilizing GIS data management procedures to generate appropriate map layers for the purposes of spatial trend analysis. This, in conjunction with the limited composition and distribution data for benthic vegetation in the Bay as identified in this review, can be used to delimit manageable ecological units for further investigation.

2. An adequate map of Port Phillip Bay vegetation is required - one which will accurately reflect the composition and distribution of benthic plant communities within the Bay.

3. Based on this map, target species and communities throughout Port Phillip Bay (as determined by dominance, known biology, *etc.*) should be strategically selected for further investigation in the context of the the overall objectives of the Port Phillip Bay study.

4. Target species and communities require investigation to elucidate reproduction, colonization/recruitment, growth rates, longevity, biomass and productivity in relation to key physical, chemical and biological factors in the context of nutrient and toxicant cycling. These processes should also be examined in relation to temporal and spatial change. Such studies should be quantitative and include:

   A. experiments to determine whether light availability influences the distribution of species of *Caulerpa*;

   B. determining the role of herbivores in the structuring of plant communities;

   C. determining the inhibiting effects of effluent outfalls on the growth of larger brown algae.

5. *In situ* nutrient and toxicant enrichment work on targeted species and communities like that conducted by Bulthuis (see references) with *Heterozostera* will lead to a better understanding of the interactions of these species with nutrients and toxicants in Port Phillip Bay.

6. Laboratory experiments designed to measure growth rates of selected target species under different nitrogen, phosphorus and light regimes is recommended to supplement and assist in the interpretation of results obtained from *in situ* studies.

7. The presence of growth promoting substances as a product of nutrient enrichment in Port Phillip Bay requires investigation, as does the effects of these hormones on the benthic vegetation in the Bay.

8. Studies are required to determine the ecological importance of algal epiphytism and epizoism in Port Phillip Bay and the relationship between these modes of existence and nutrient and toxicant cycling.

9. Thorough studies of unattached macroalgal communities are required to determine their roles in the Port Phillip Bay ecosystem in the context of nutrient and toxicant cycling.

10. Thorough studies of non-planktonic microalgal communities are required to determine their roles in the Port Phillip Bay ecosystem in the context of nutrient and toxicant cycling.

11. Macroalgal blooms in Port Phillip Bay require thorough investigation in terms of their occurrence and frequency in the context of nutrient and toxicant cycling.

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APPENDIX I. A List of Macroalgae Recorded from Port Phillip Bay

Appendix I contains a list of Chlorophyta (green algae), Phaeophyta (brown algae) and Rhodophyta (red algae) reported to occur in Port Phillip Bay. There undoubtedly are a number of additional species which grow in the Bay but which have not been cited in the literature used in the preparation of this review. There also are likely to be some published records which have escaped detection. Within each Division, taxa are listed alphabetically, and only references to occurrence in Port Phillip Bay are provided. Nomenclature is that used in the publications cited; except as noted, no attempt has been made to update name changes or address questions of synonymy.

Division Chlorophyta

Acetabularia peniculus (R. Br. ex Turner) Solms-LaubachHope-Black 1971: 130. King et al. 1971: 115. Womersley 1966: 138.

Apjohnia laetevirens HarveyKing et al. 1971: 113.

Bryopsis gemellipara J. AgardhKing et al. 1971: 113.

Bryopsis hypnoides LamourouxKing et al. 1971: 113.

Bryopsis plumosa (Hudson) C. AgardhAnonymous 1973: 369. Brown & Davies 1991: Table 19. Brown et al. 1980: 209. Davies & Brown 1986: Tables 3, 6, 8, 10. Hope-Black 1971: 130. Lewis 1983: 261. O'Brien 1975: 77. Spencer 1972: 78. Womersley 1966: 136.

Byopsis vestita J. AgardhKing et al. 1971: 113.

Bryopsis sp.Brown & Davies 1991: Table 19. Spencer 1970: Table 3. Spencer 1972: 114.

Caulerpa brownii (C. Agardh) EndlicherAnonymous 1973: 369. Brown & Davies 1991: Table 19. Brown et al. 1980: 209. Davies & Brown 1986: Tables 6, 8, 10. Hope-Black 1971: 130. King et al. 1971: 114. O'Brien 1975: 77. Spencer 1970: Table 3. Spencer 1972: 114. Womersley 1966: 136.

Caulerpa cactoides (Turner) C. AgardhHope-Black 1971: 130. King et al. 1971: 114. Womersley 1966: 136.

Caulerpa flexilis LamourouxAnonymous 1973: 369. Hope-Black 1971: 130. King et al. 1971: 114. Spencer 1970: Table 3. Womersley 1966: 136.

Caulerpa flexilis f. *muelleri* (Sonder) WomersleyHope-Black 1971: 130. King et al. 1971: 114. Womersley 1966: 136.

Caulerpa geminata HarveyAnonymous 1973: 369. Brown & Davies 1991: Table 19. Davies & Brown 1986: Table 8. Hope-Black 1971: 130. King et al. 1971: 114. O'Brien 1975: 77. Spencer 1970: Table 3. Spencer 1972: 114. Womersley 1966: 137.

Caulerpa longifolia C. AgardhBrown & Davies 1991: Table 19. Davies & Brown 1986: Tables 3, 6, 8, 10, 12. Hope-Black 1971: 130. King et al. 1971: 114.

Caulerpa longifolia f. *crispata* (Harvey) WomersleyAnonymous 1973: 369. Brown et al. 1980: 209. King et al. 1971: 114. O'Brien 1975: 77. Spencer 1970: Table 3. Spencer 1972: 114. Womersley 1966: 137.

Caulerpa obscura SonderHope-Black 1971: 130. King et al. 1971: 114. Womersley 1966: 137.

Caulerpa papillosa J. AgardhKing *et al*. 1971: 114.

*Caulerpa racemosa*Davies & Brown 1986: Table 12.
Caulerpa remotifolia SonderAnonymous 1973: 369. Brown & Davies 1991: Table 19. Brown et al. 1980: 209. Davies & Brown 1986: Tables 3, 6, 8, 10. King et al. 1971: 114. O'Brien 1975: 78. Spencer 1970: Table 3. Spencer 1972: 78. Womersley 1966: 137.
Caulerpa scalpelliformis (R. Brown in Turner) AgardhAnonymous 1973: 369. Hope-Black 1971: 130. King et al. 1971: 115. Spencer 1970: Table 3.
Caulerpa simpliciuscula (Turner) C. AgardhAnonymous 1973: 369. Brown & Davies 1991: Table 19. Brown et al. 1980: 209. Davies & Brown 1986: Tables 3, 8. King et al. 1971: 115. O'Brien 1975: 78. Spencer 1970: Table 3. Spencer 1972: 114. Womersley 1966: 138.
Caulerpa trifaria HarveyAnonymous 1973: 369. Brown & Davies 1991: Table 19. Davies & Brown 1986: Table 8. Hope-Black 1971: 130. King et al. 1971: 115. Spencer 1970: Table 3. Womersley 1966: 138.
Cauperpa sp. White 1982: 38.
Chaetomorpha aerea (Dillwyn) KuetzingBrown & Davies 1991: Table 19. Brown et al. 1980: 208. King et al. 1971: 112. Spencer 1970: Table 3. Spencer 1972: 114.
Chaetomorpha capillaris (Kuetzing) BoergBrown & Davies 1991: Table 19. Lewis 1983: 261.
Chaetomorpha darwinni (Hooker) KuetzingKing et al. 1971: 113. Hope-Black 1971: 130. Spencer 1972: 114. Womersley 1966: 135.
Chaetomorphora indica (Kuetzing) KuetzingBrown & Davies 1991: Table 19. Hope-Black 1971: 130. Spencer 1970: Table 3. Womersley 1966: 135.
*Chaetomorpha linum*O'Brien 1975: 77. Spencer 1970: Table 3.
*Chaetomorpha valida*Spencer 1970: Table 3.
Chaetomorpha sp.Davies & Brown 1986: Tables 8, 12. King et al. 1971: 113. Spencer 1972: 78.
Chlorodesmis buculifera (J. Agardh) DuckerKing et al. 1971: 115.
Cladophora bainesii HarveyAnonymous 1973: 369. Brown & Davies 1991: Table 19. Hope-Black 1971: 130. Spencer 1970: Table 3. Womersley 1966: 135.
Cladophora fascicularis (Mertens ex C. Agardh) KuetzingAnonymous 1973: 369. Brown et al. 1980: 209. Hope-Black 1971: 130. King et al. 1971: 113. Lewis 1983: 261. O'Brien 1975: 77. Spencer 1970: Table 3. Spencer 1972: 78. Womersley 1966: 135.
Cladophora feredayii HarveyAnonymous 1973: 369. Brown & Davies 1991: Table 19. Spencer 1970: Table 3.
*Cladophora hutchinsioides*Brown & Davies 1991: Table 19.
*Cladophora montagneana*Brown & Davies 1991: Table 19.
Cladophora repens (J. Agardh) HarveyAnonymous 1973: 369. King et al. 1971: 113. Spencer 1970: Table 3. Spencer 1972: 78.
Cladophora rugulos MartensKing et al. 1971: 113.
Cladophora valonioides SonderAnonymous 1973: 369. Spencer 1970: Table 3.
Cladophora sp.Brown & Davies 1991: Table 19. Brown et al. 1980: 209. Davies & Brown 1986: Tables 3, 6, 8, 10. Spencer 1972: 114. Womersley 1966: 136.
Codium australicum Silva in Silva et WomersleyKing et al. 1971: 113.
Codium capitulatum Silva et WomersleyKing et al. 1971: 113.

Codium duthiae Silva in Silva and WomersleyHope-Black 1971: 130. King et al. 1971: 113. Womersley 1966: 138.

Codium fragile (Suringar) HariotKing et al. 1971: 113. O'Brien 1975: 77. Spencer 1972: 114.

Codium fragile novaezelandiaeHope-Black 1971: 130.

Codium galeatum J. AgardhHope-Black 1971: 130. King et al. 1971: 114. Womersley 1966: 138.

Codium harveyi SilvaHope-Black 1971: 130. Spencer 1970: Table 3. Womersley 1966: 138.

Codium lucasii Setchell in LucasKing et al. 1971: 114.

Codium muelleri KutzingKing et al. 1971: 114.

Codium perrinae LucasHope-Black 1971: 130. King et al. 1971: 114. Womersley 1966: 138.

Codium promoides J. AgardhKing et al. 1971: 114.

Derbesia marina (Lyngb) SolDavies & Brown 1986: Table 6. Lewis 1983: 261.

Dictyosphaeria sericea HarveyKing et al. 1971: 113.

Enteromorpha clathrata (Roth) GrevilleDavey & Woelkerling 1980: 57

Enteromorpha compressa (Linnaeus) GrevilleAnonymous 1973: 369. Brown & Davies 1991: Table 19. Brown et al. 1980: 208. Lewis 1983: 261. Spencer 1970: Table 3.

Enteromorpha intestinalis (Linnaeus) GrevilleAnonymous 1973: 369. Brown & Davies 1991: Table 19. King et al. 1971: 112. O'Brien 1975: 77, 84. Spencer 1970: Table 3. Spencer 1972: 115.

*Enteromorpha linza*Brown & Davies 1991: Table 19.

Enteromorpha sp.Brown & Davies 1991: Table 19. Davies & Brown 1986: Tables 3, 8, 10. Spencer 1972: 78. Spencer 1972: 115.

Percursaria percursa (C. Agardh) RosenvingeDavey & Woelkerling 1980: 57.

Rhizoclonium riparium (Roth) HarveyDavey & Woelkerling 1980: 57.

*Ulothrix sp.*Brown et al. 1980: 208.

Ulva lactuca auct. (non Linnaeus) PapenfussAnonymous 1973: 369. Brown et al. 1980: 208. Davey and Woelkerling 1980: 58. Hope-Black 1971: 130. King et al. 1971: 112. O'Brien 1975: 77, 84. Spencer 1970: Table 3. Spencer 1972: 78. White 1982: 38. Womersley 1966: 135.

Ulva rigida C. AgardhLewis 1983: 261.

Ulva spathulata PapenfussKing et al. 1971: 112

Ulva sp.Brown & Davies 1991: Table 19. Davies & Brown 1986: Tables 3, 6, 8, 10, 12.

Division Phaeophyta

Acinetospora crinita (Carmichael ex Harvey) KornmannBrown & Davies 1991: Table 19. King et al. 1971: 115.

Acrocarpia paniculata (Turner) AreschougHope-Black 1971: 130. King et al. 1971: 119. Womersley 1966: 143.

*Bachelotia antillarum*Brown & Davies 1991: Table 19.

Bellotia eriophorum HarveyHope-Black 1971: 130. Womersley 1966: 141.

Carpomitra costata (Stackhouse) BattersHope-Black 1971: 130. Womersley 1966: 141.

Caulocystis cephalornithos (Labillardiere) AreschougHope-Black 1971: 130. King et al. 1971: 119. Womersley 1966: 143. Spencer 1972: 115.
Caulocystis uvifera (C. Agardh) AreschougHope-Black 1971: 130. King et al. 1971: 119. O'Brien 1975: 79. Spencer 1970: Table 3. Spencer 1972: 115. Womersley 1966: 143.
Cladostephus verticillatus (Lightfoot) C. AgardhHope-Black 1971: 130. King et al. 1971: 116. O'Brien 1975: 78. Womersley 1966: 139.
Colpomenia peregrina (Sauvageau) HamelAnonymous 1973: 369. Brown & Davies 1991: Table 19. Brown et al. 1980: 211. Davies & Brown 1986: Tables 3, 6. King et al. 1971: 118. Spencer 1970: Table 3.
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*Liagora wilsoniana*King et al. 1971: 120.
Lithoporella sp.Brown et al. 1980: 212.
Lithothamnion muelleri Lenormand in RosanoffKing et al. 1971: 121.
Lithothamnion sp.Anonymous 1973: 369. King et al. 1971: 121. Spencer 1970: Table 3.
*Lomentaria australis*Brown & Davies 1991: Table 19. Davies & Brown 1986: Table 3.
Lomentaria sp.Davies & Brown 1986: Table 8.
Lophothalia verticillata (Harvey) KuetzingHope-Black 1971: 131. Womersley 1966: 153.
Lophothalia sp.Hope-Black 1971: 131. Spencer 1970: Table 3. Womersley 1966: 154.
Lophothamnion comatum J. AgardhKing et al. 1971: 123.
*Lophurella hookeriana*Spencer 1970: Table 3. Womersley 1966: 153.
Lophurella periclados (Sonder) SchmitzAnonymous 1973: 369. Brown et al. 1980: 215. Davies & Brown 1986: Table 10. Hope-Black 1971: 131. King et al. 1971: 124. Lewis 11983: 262. Spencer 1970: Table 3. Womersley 1966: 153.
Macrothamnion pellucidum (Harvey) WollastonHuisman 1980: 39.
Malaconema roeana (Harvey) Womersley & ShepleyHope-Black 1971: 131. Womersley 1966: 152.
Mazoyerella arachnoidea (Harvey) Gordon-Mills & WomersleyHuisman 1980: 43.
Medeiothamnion lyalli (Harvey) GordonLewis 1983: 262.
Medeiothamnion protensum (Harvey) GordonAnonymous 1973: 369. Brown & Davies 1991: Table 19. Davies & Brown 1986: Tables 6, 8. Huisman 1980: 44. Spencer 1972: 78.
Medeiothamnion sp.Lewis 1983: 262.
Melanthalia obtusata (Labillardi_re) AgardhHope-Black 1971: 131. Womersley 1966: 147.
Mesophyllum sp.Brown et al. 1980: 212.
Metagoniolithon charoides (Lamouroux) Weber-van-BosseKing et al. 1971: 121.

Metagoniolithon stelligerum (Lamarck) Weber-van-BosseHope-Black 1971: 131. King et al. 1971: 121. Womersley 1966: 146.
Monosporus australis (Harvey) J. AgardhHuisman 1980: 44.
Monosporus sp.Huisman 1980: 44.
Mychodea carnosa J.D. Hooker & HarveyAnonymous 1973: 369. Spencer 1970: Table 3.
Mychodea compressa HarveyHope-Black 1971: 131. Womersley 1966: 149.
Mychodea foliosa (Harvey) J. AgardhHope-Black 1971: 131. Womersley 1966: 149.
Mychodea hamata Harvey Hope-Black 1971: 131. King et al. 1971: 122. Womersley 1966: 149.
Mychodea membranacea Harvey?Hope-Black 1971: 131. Womersley 1966: 149.
Myriogramme gunniana (Harv) KylinHope-Black 1971: 131. Womersley 1966: 152.
Myriogramme sp.Hope-Black 1971: 131. O'Brien 1975: 82. Womersley 1966: 152.
Nemalion elminthoides (Velley) BattersKing et al. 1971: 120.
Neomonospora griffithsoides (Sonder) SchmitzAnonymous 1973: 369. Hope-Black 1971: 131. Spencer 1970: Table 3. Spencer 1972: 78. Womersley 1966: 151.
*Nitophyllum gunnianum*Davies & Brown 1986: Table 10.
Nitophyllum parvifolium J. AgardhHope-Black 1971: 131. Womersley 1966: 152.
Nitophyllum sinuosum LucasLewis 1983: 262.
Nitophyllum sp.Brown & Davies 1991: Table 19. Brown et al. 1980: 215. Davies & Brown 1986: Table 10. Hope-Black 1971: 131. O'Brien 1975: 82. Spencer 1970: Table 3. Womersley 1966: 152.
Nizymenia australis SonderHope-Black 1971: 131. Womersley 1966: 148.
*Obelia australis*Hope-Black 1971: 131.
Pappenfussia sp.O'Brien 1975: 82.
Phacelocarpus labillardieri (Mertens) J AgardhHope-Black 1971: 131. Womersley 1966: 147.
Phaeocystis giraudii (Derbes et Solier) LagerheimKing et al. 1971: 124.
Phitymophora amansioides (Sonder) WomersleyKing et al. 1971: 123.
Phitymophora imbricata (Areschoug) J. AgardhHope-Black 1971: 131. Womersley 1966: 152.
Phycodrys sp.Brown & Davies 1991: Table 19. Lewis 1983: 262. O'Brien 1975: 82.
Phymatolithon sp. Brown et al. 1980: 212.
Platyclinia sp.O'Brien 1975: 82.
Plocamium angustum (J. Agardh) J.D. Hooker et HarveyAnonymous 1973: 369. Hope-Black 1971: 131. King et al. 1971: 121. Womersley 1966: 147.
Plocamium cartilagineum (Linnaeus) DixonAnonymous 1973: 369. Brown & Davies 1991: Table 19. Davies & Brown 1986: Tables 3, 6, 8.
Plocamium coccineum (Huds) LyngbyeHope-Black 1971: 131. Spencer 1970: Table 3. Womersley 1966. 147.
Plocamium costatum (J. Agardh) J.D. Hooker et HarveyAnonymous 1973: 369. Hope-Black 1971: 131. Womersley 1966: 147.
Plocamium leptophyllum KuetzingKing et al. 1971: 121. Spencer 1970: Table 3.
Plocadmium mertensii (Greville) HarveyHope-Black 1971: 131. Womersley 1966: 147.
Plocamium preissianum SonderHope-Black 1971: 131. Womersley 1966: 147.
Plocamium sp.Spencer 1970: Table 3.
Polyopes constictus (Turner) J. AgardhHope-Black 1971: 131. Womersley 1966: 146.

Polysiphonia abscissa J.D. Hooker & HarveyAnonymous 1973: 369. Spencer 1970: Table 3. Spencer 1972: 79.
Polysiphonia blandii HarveyAnonymous 1973: 369. Brown & Davies 1991: Table 19. Hope-Black 1971: 131. King et al. 1971: 124. Spencer 1970: Table 3. Womersley 1966: 153.
Polysiphonia brodiaei (Dillwyn) SprengelLewis 1983: 262.
Polysiphonia cancellata HarveyHope-Black 1971: 131. Womersley 1966: 153.
Polysiphonia constricta WomersleyLewis 1983: 262.
*Polysiphonia decipiens*Brown & Davies 1991: Table 19. Davies & Brown 1986: Tables 3, 6, 8, 10.
Polysiphonia fuscescens HarveyAnonymous 1973: 369. Spencer 1970: Table 3.
Polysiphonia infestans HarveyBrown & Davies 1991: Table 19. Davies & Brown 1986: Table 6. Lewis 1983: 262.
Polysiphonia isogona HarveyBrown & Davies 1991: Table 19. Lewis 1983: 262.
Polysiphonia mollis Hooker et HarveyO'Brien 1975: 82.
Polysiphonia nigrita SonderAnonymous 1973: 369. Spencer 1970: Table 3. Spencer 1972: 79.
Polysiphonia pungens HollenbergBrown & Davies 1991: Table 19. Davies & Brown 1986: Tables 8, 10. Lewis 1983: 262.
*Polysiphonia sertularioides*Brown & Davies 1991: Table 19.
Polysiphonia subtilissima MontagneBrown & Davies 1991: Table 19. Davies & Brown 1986: Table 10. Lewis 1983: 262.
Polysiphonia spp.Brown & Davies 1991: Table 19. Brown et al. 1980: 215. Davies & Brown 1986: Tables 3, 6, 8, 10, 12. King et al. 1971: 124.
Porphyra lucasii LevringBrown & Davies 1991: Table 19. Brown et al. 1980: 211.
Porphyra sp.King et al. 1971: 121. O'Brien 1975: 80. White 1982: 41.
Propagula secunda HuismanHuisman 1980: 41.
Protokutzingia australasica (Montagne) FalkenbergKing et al. 1971: 124.
Pseudolithophyllum sp. Brown et al. 1980: 212.
Pterocladia capillacea (Gmelin) Bornet et ThuretHope-Black 1971: 130. King et al. 1971: 120. O'Brien 1975: 80. Womersley 1966: 145.
Pterocladia lucida (R Br) J. AgardhHope-Black 1971: 130. Womersley 1966: 145.
Pterosiphonia pennata (J. Agardh) SchmitzAnonymous 1973: 369. Brown & Davies 1991: Table 19. Brown et al. 1980: 215. Davies & Brown 1986: Tables 6, 8, 10. Lewis 1983: 262. Spencer 1970: Table 3. Spencer 1972: 79.
Ptilocladia pulchra SonderKing et al. 1971: 123.
*Rhabdonia clavigera*Davies & Brown 1986: Tables 6, 8.
Rhabdonia coccinea Harvey ex Hooker and Harvey Anonymous 1973: 369. Brown & Davies 1991: Table 19. Brown et al. 1980: 213. Davies & Brown 1986: Tables 3, 6, 8, 10. Hope-Black 1971: 131. Lewis 1983: 262. Womersley 1966: 148. Spencer 1970: Table 3.
Rhabdonia nigrescens HarveyHope-Black 1971: 131. Womersley 1966: 148.
Rhabdonia robusta (Greville) J AgardhKing et al. 1971: 121.
Rhabdonia verticillata HarveyDavies & Brown 1986: Tables 6, 8. Hope-Black 1971: 131. King et al. 1971: 121. O'Brien 1975: 81. Womersley 1966: 148.

Rhodoglossum foliiferum (Harvey) J. AgardhAnonymous 1973: 369. Hope-Black 1971: 131. King et al. 1971: 122. Spencer 1970: Table 3. Womersley 1966: 150.
Rhodoglossum proliferum J. AgardhAnonymous 1973: 369. Brown & Davies 1991: Table 19. Brown et al. 1980: 213. Davies & Brown 1986: Tables 3, 6, 8, 10. Hope-Black 1971: 131. King et al. 1971: 122. Spencer 1970: Table 3. Womersley 1966: 150.
Rhodoglossum sp.Spencer 1970: Table 3.
*Rhodolophia strobilifera*Brown & Davies 1991: Table 19. Davies & Brown 1986: Table 8.
Rhodophyllis goodwiniae J. AgardhHope-Black 1971: 131. Womersley 1966: 148.
Rhodymenia australis SonderDavies & Brown 1986: Table 10. Hope-Black 1971: 131. O'Brien 1975: 81. Spencer 1970: Table 3. White 1982: 40. Womersley 1966: 150.
Rhodymenia sp.Brown & Davies 1991: Table 19. Brown et al. 1980: 213. Davies & Brown 1986: Table 10. Lewis 1983: 262.
Sarcotrichia dolichocystidea (J Agardh) Womersley & ShepleyHope-Black 1971: 131. Womersley 1966: 152.
Schottera nicaeenis (Lamouroux ex Duby) Guiry & HollenbergLewis 1983: 262.
Solieria mollis HarveyHope-Black 1971: 131. Womersley 1966: 148.
Solieria robusta (Greville) J. AgardhAnonymous 1973: 369. Brown & Davies 1991: Table 19. Davies & Brown 1986: Tables 8, 10, 12. Hope-Black 1971: 131. O'Brien 1975: 80, 84. Spencer 1970: Table 3. Spencer 1972: 79. Womersley 1966: 148.
Spermothamnion sp.Huisman 1980: 43.
Spongoclonium conspicuum SonderHope-Black 1971: 131. Huisman 1980: 44. Womersley 1966: 151.
Spongoclonium sp.Huisman 1980: 41. Lewis 1983: 262.
Spyrdia opposita HarveyAnonymous 1973: 369. Spencer 1970: Table 3.
Stenogramme leptophylla J. AgardhAnonymous 1973: 369. Hope-Black 1971: 131. Spencer 1970: Table 3. Womersley 1966: 149.
Sypridia opposita HarveyHope-Black 1971: 131. Womersley 1966: 151.
Tenarea sp.Brown et al. 1980: 212.
Tetrathamnion lineatum WollastonHuisman 1980: 42.
Tetrathamnion sp.Huisman 1980: 42.
Tiffaniella gracilis HuismanHuisman 1980: 44.
Trithamnion tetrapinnum WollastonHuisman 1980: 42.
Wrangelia protensa HarveyHope-Black 1971: 131. Spencer 1970: Table 3. Womersley 1966: 152.

APPENDIX II. A List of Seagrasses Recorded from Port Phillip Bay

Appendix II contains a list of seagrasses reported to occur in Port Phillip Bay. The term seagrasses is used here in the sense of Robertson (1984, p. 57) to include all species of flowering plants capable of growing submerged in marine environments. In the following list, taxa are listed alphabetically, and only references to occurrence in Port Phillip Bay are provided. Nomenclature is that used in the publications cited; except as noted, no attempt has been made to update name changes or address questions of synonymy.

Amphibolis antarctica (Labillardi_re) Sonder & Ascherson ex AschersonAston 1973: 302. Bulthuis 1981a: 4. Hope-Black 1971: 130. King *et al.*. 1971: 125. Willis 1966: 126 (as *Cymodocea*).

*Halophila australis*Brown & Davies 1991: Table 19. Hudson and Strother 1988: 4. Robertson 1984: 66.

Halophila ovalis (R. Brown) J.D. HookerAnonymous 1973: 369. Aston 1973: 221. Bulthuis 1981a: 4; 1981b: 3. Davies & Brown 1986: Table 12. Denning et al..1986: 139. Hope-Black 1971: 130. Hudson & Strother 1988: 5. Kerr 1983: 60. Watson 1992: 22. Willis 1966: 126.

Heterozostera tasmanica (Martens ex Ascherson) de HartogAston 1973: 325. Axelrad 1986: 1. Brown et al. 1980: 215. Brown & Davies 1991: Table 19. Bulthuis 1981a: 4. Bulthuis 1981b: 2. Bulthuis & Woelkerling 1983: 111. Davies & Brown 1986: Tables 3, 6, 8, 10, 12. Denning et al..1986: 139. Fabris et al..1982: 829. Hope-Black 1971: 130. Hudson and Strother 1988: 5. Kerr 1983: 60. Parry and Collett 1985: 2. Robertson 1984: 109. Watson 1979: 7. Willis 1966: 126 (as *Zostera*).

Lepilaena cylindrocarpa (K_ornicke ex Walpers) BenthamDenning et al..1986: 139. Hudson & Strother 1988: 5. Kerr 1983: 60. King et al..1971: 125. Robertson 1984: 77.

*Lepilaena marina*Robertson 1984: 80.

Lepilaena preissii (Lehman) F. MuellerAston 1973: 318.

Ruppia maritima LinnaeusKing *et al.*. 1971: 125.

*Ruppia megacarpa*Denning et al.. 1986: 139. Hudson and Strother 1988: 5.

Ruppia sp.Kerr 1983: 60.

Zostera muelleri Irmisch ex AschersonAston 1973: 332. Bond et al..1985: 1. Brown et al..1980: 215. Bulthuis 1981a: 4. Denning et al..1986: 139. Hope-Black 1971: 130. Hudson and Strother 1988: 5. Kerr 1983: 60. Kerr and Strother 1985: 177; 1986: 17; 1989: 131; 1990: 369. King et al..1971: 125. Robertson 1984: 116. Willis 1966: 126.

Zostera sp.Anonymous 1973: 369. Lewis 1973: 8.

APPENDIX III. A List of Non-planktonic Microalgae Recorded from Port Phillip Bay

Appendix III contains a list of microalgae belonging to the Chlorphyta (green algae), Chrysophyta (sometimes referred to as golden-brown algae and including the diatoms),Cyanophyta (the cyanobacteria, formerly known as the blue-green algae) and the Pyrrophyta (dinoflagellates) reported to occur in Port Phillip Bay. Extant data is very scant and undoubtedly numerous other non-planktonic microalgae occur both in the sediments and as epibenthos. In the following list, taxa are listed alphabetically within each Division/Class, and only references to occurrence in Port Phillip Bay are provided. Nomenclature is that used in the publications cited; except as noted, no attempt has been made to update name changes or address questions of synonymy.

Division Chlorophyta

Chlamydomonas sp.Axelrad et al..1979: 6.

Division Chrysophyta

Class Bacillariophyceae

Achnathes sp.Axelrad et al..1979: 6.
Amphiprora sp.Axelrad et al..1979: 6.
*Bacillaria paxillifer*Spencer 1972: 53.
*Biddulphia pulchella*Spencer 1972: 53.
Biddulphia sp.Axelrad et al..1979: 6.
Cymbella sp.Axelrad et al..1979: 6.
Licmophora sp.Brown et al..1980: 209.
Melosira sp.Brown et al..1980: 209.
*Navicula grevilleana*Spencer 1972: 53.
Navicula sp.Axelrad et al..1979: 6. Brown et al..1980: 209.
*Nitschia panduriformis*Spencer 1972: 53.
Nitzschia sp.Axelrad et al..1979: 6.
Pinnularia sp.Axelrad et al..1979: 6.
*Pleurosigma*Axelrad et al..1979: 6.
Rhabdonema sp.Axelrad et al..1979: 6.
*Striatella punctata*Brown *et al.*. 1980: 156.
Surirella sp.Axelrad et al..1979: 6.
Synedra sp.Brown et al..1980: 209
*Trachyneis aspera*Spencer 1972: 53.

Class Prymnesiophyceae

Phaeocystis giraudii (Derb_s et Solier)LagerheimKing *et al.*. 1971: 124.

Division Cyanophyta

Calothrix confervicola (Roth) C. AgardhKing *et al.*. 1971: 124.
Lyngbya sp.King *et al.*. 1971: 124.
Merismopedia sp.Brown et al..1980: 208.
Oscillatoria sp.Axelrad et al..1979: 6. Brown et al..1980: 208.
Rivularia firma WomersleyKing *et al.*. 1971: 124.
Spirulina sp.Brown et al..1980: 208.

Division Pyrrhophyta

Amphidinium sp.Axelrad et al..1979: 6. Brown et al..1980: 69.
Gymnodinium sp.Axelrad et al..1979: 6.