COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANIZATION

DIVISION of FISHERIES and OCEANOGRAPHY

Report No. 64

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## INTRODUCTION

The marine angiosperms are only sparsely represented throughout the world. The marine vascular plant known as seagrass is represented by one order, the Helobiae. The Australian coastline offers a great variety of conditions and the southern and eastern shorelines, particularly, afford large areas suitable for seagrass. The great climatic differences between southern Tasmania and Cape York Peninsula partly explain the large number of different species while the varied habitat types within a climatic group further explains the numerous species growing in Australian coastal waters.

Far too little is known of Australian seagrass. No comprehensive inventory exists and the extent of the range of many species is not known. It is becoming increasingly important to be able to say how much seagrass and what species grows in a particular place. As development of the foreshore, sand mining, canal development and dredge-fill operations are carried out the people involved and the departments responsible for decisions are continually calling for an assessment of seagrass areas. This awareness of the importance of seagrass beds must be substantiated by a documentation and quantitative study. "Everybody knows" that prawns, juvenile fish and other fauna frequent seagrass beds while they may be absent or much reduced in abundance in nearby bare areas; but "everybody knows" is not sufficient evidence nor do such statements go far enough when making representations and recommendations to governments, local governments and other administrative bodies.

The earliest documented work on seagrass in Australia was a list of Australian seagrasses (Ostenfeld 1915, 1916 and 1929). Wood (1959) gave an interesting and descriptive paper on the seagrass of southeastern Australia but his experience was somewhat limited. He attempted to cover an ecological survey of all southeastern Australian seagrass in one paper which necessarily only summarised and in some cases omitted important areas. Following from this work Blake (1964) grouped Queensland seagrasses and gave a rather poor key based on sterile material. His description of *Halophila decipiens* does not distinguish it from *Halophila ovalis* and as far as it is known *Zostera muelleri* is not found in Queensland or northern New South Wales. Den Hartog (1970) visited Australia in 1967, corrected the taxonomy of herbarium material and collected from many habitats himself. His monograph on seagrass is perhaps the most useful single description of seagrass and its ecology.

The most obvious and most cited exampled of the value of seagrass as a nursery area or habitat area for diverse and abundant fauna were shown in the 1930's when large areas of *Zostera marina* were killed by the sudden epidemic of the fungus *Labyrinthula* (Renn, 1937; Dexter, 1944, 1950; Milne and Milne, 1951; Stauffer, 1937) on the eastern coastline of the United States. The importance of seagrass was dramatically revealed. The content and value of these papers will be discussed elsewhere in this review.

Biologists have noticed, in various parts of Australia, that seagrass has declined in area or that it seems to be under some stress (Gillham, 1965). Sometimes this decline may be due to seasonal variation; it may be due to mechanical damage or to disease. Collectively biologists have called it "dieback". This review is an attempt to put together relevant literature on the ecology, the quantitative measurement of seagrass and the likely documented events which may cause "dieback" in seagrass beds.

## PLACE OF SEAGRASS IN AN ESTUARINE ECOSYSTEM

Seagrass communities are widely distributed along the coasts of temperate and tropical Australia, generally in sheltered bays or estuaries. Most of the seagrass communities inhabit sandy and muddy substrate but some, e.g. *Amphibolis* communities are characteristic of rocky shores with or without a layer of sand.

The function of seagrass as a primary producer is well known. Pomeroy (1960) showed the relative importance of turtle grass, phytoplankton and benthic macroflora as primary producers. For general consideration it is best to assume that the consumer population is ideally adapted to exploit the maximum accumulated net production. Production is the weight of new organic material created by photosynthesis. It is the increase observed plus any losses in the biomass of green plants over a period. Productivity is the production per unit time (Westlake, 1965). The maximum biomass is reached when the current daily net productivity becomes zero and this biomass is thus the maximum cumulative net production (Westlake, 1965). Westlake continues by saying that biomass difference over a short period is a valid measure of current net productivity. Measurements of the primary productivity of submerged vascular aquatic plants *in situ* have been meagre (reviewed in Wetzel, 1964). Techniques involving the changes in oxygen production of the water surrounding enclosed plants should be discarded or, at best, used with extreme caution (Wetzel, 1965).

Odum (1957) performed oxygen change experiments on *Thalassia testudinum* by measuring the amount of oxygen in the water before it passed over the grass and afterwards. This method did not allow for the fact that oxygen is stored in lacunal spaces in the plant for use at times of oxygen stress, e.g. at night. Nor did it take into consideration the slow rate of diffusion of oxygen into water. As a result dissolved oxygen of the surrounding water is not proportional to the production of oxygen and photosynthetic rates. Measurements of the primary productivity of submerged vascular aquatic plants and macroalgae *in situ* have been meagre but widely used (reviewed in Wetzel, 1964). The ecology of primary production in a seagrass meadow is a complex subject involving at least the following six groups of plants:

(1) seagrass

(2) microepiphytic algae

(3) macroepiphytic algae

(4) benthic microalgae

(5) benthic macroalgae

(6) phytoplankton

No single study has measured all these components of organic matter formation in a seagrass meadow.

The reported rates of productivity for the seagrass alone range between 10 and 20 gm C fixed per square metre per day (Pomeroy, 1960; Taylor and Saloman, 1968). Wetzel (1965) has suggested the $C^{14}$ method of measuring photosynthesis as being more suitable than the oxygen "light and dark" chamber method because of the difficulty of measuring the source and destination of some of the oxygen. It is recommended (McRoy, 1973) that measurements of productivity and biomass in seagrasses should use comparable methods, yet unknown, for assessment.

From a more practical point of view Taylor and Saloman (1968) pointed out the loss of productivity and biomass of Boca Ciega Bay in Florida that resulted from hydraulic dredging and coastal development.

One of the most useful and simple pieces of work was done by Zieman (1968) when he measured production of *T. testudinum* by stapling the youngest leaf of a clump of grass and measuring its growth plus that of leaves produced after stapling during a period of twenty days. It has been suggested (McRoy, 1973) that this work should be used as a standard for future production studies. Zieman (1968) found that seagrass leaves, *viz. T. testudinum* have a rapid rate of growth (up to 9 mm/day, averaging 2-4 mm per day) and produce between 2.2 and 10 gm of dry leaf/$m^2$/day. The rate of growth of rhizomes from transplants and self propagating sprigs has been found to be very slow (personal observation). Kelly, *et.al.* (1971) give a figure of 20 cm per year or less for the spread of *T. testudinum*. Taylor *et.al.* (1973) have found that the leaves of *T. testudinum* grow rapidly once they have been harvested.

Seagrass in estuarine areas acts in several other ways to control or modify the ecosystem (Wood, *et. al.*, 1969).

1. It acts as food for a very limited number of organisms such as garfish (Randall, 1965), sea urchins and some nudibranchs (Wood, 1959), turtles (Hirth, *et. al.*, 1973), dugongs and swans. This list may well be expanded as more is learnt about the smaller fauna which inhabit seagrass beds. There is little definitive work on which animals actually eat and digest seagrass, and which ones eat but only digest epiphytes on it (Blaber, 1974).

2. It serves as a host for large numbers of epiphytes and epizoa which are grazed extensively, for example, by the mullets (Wood, 1959). These epiphytes and epizoa may be comparable in biomass with the seagrasses themselves (Humm, 1964). He also states that epiphytic blooms can significantly shade *T. testudinum*, but no actual evidence of this is given. March (1973) has described the epizoa of *Z. marina* in Virginia and found a maximum of 112 invertebrate animals. The epifauna were feeding on plankton, microorganisms on the leaf blades and epiphytes. Wood, *et. al.* (1969) quotes 13-33 mg of diatom epiphytes per gm of *Zostera* leaf and it must be remembered that these are subject to continual grazing so that the productivity would probably be higher than the standing crop. Blaber (1974) showed that juvenile *Rhabdosargus holubi* (Steindachner) which fed on aquatic vegetation were unable to digest vegetation due to the absence of cellulase or a method of breaking up the plant tissue. In fact these fish were digesting epiphytic diatoms and sessile ectoprocts.

3. Seagrass provides large quantities of detrital material which serve as food for certain animal species and for microbes. Zieman (1968) describes the breakdown as occurring near torn ends first and the leaf cells are acted upon by protozoans and bacteria. As the decay proceeds, more bacteria and fewer protozoans are found. Intact leaves were much slower to decompose but once the cuticle was broken down decomposition was much more rapid. The number of organisms on the detritus and its rate of oxygen consumption are approximately proportional to the total surface area (Fenchel, 1970). An amphipod was found by Fenchel to be feeding on detrital particles and on its own fecal pellets though only digesting the microorganisms of them. If measurements of respiratory rates of the amphipods are made, then a much too low estimate of their total role in the ecosystem is given. Milne and Milne (1951) discuss the usefulness of seagrass as a sediment trap for sewage and the difference in substrate of a *Z. marina* bed and bare sand nearby is described by Marshall and Lucas (1970).

4. Seagrass provides organic matter to initiate sulphate reduction and an active sulphur cycle (Wood, 1953). Sulphate reduction causes the formation of felts of purple sulphur bacteria and blue green and other algae which are capable of photoreduction and which are usually associated with an abundance of small fish and fish larvae (Wood, *et al.*, 1969).

5. It binds the sediments and prevents erosion (Bernatowicz, 1952). *T. testudinum* acts as a baffle, trapping sediment and stabilising sand (Ginsburg and Lowenstam, 1958). Not all seagrass does this, however, some species, for example, *Halodule uninervis* and *Halophila ovalis* have very slender soft rhizomes and small roots. The grass baffle can modify sedimentation in two ways. Firstly, it can stabilise sand sized sediment and secondly, a dense grass carpet produces a layer of semimotionless water through which fine sediment can settle out that would normally be bypassed. Seagrass by its calming action also preserves the microbial flora of the sediment and the sediment water interface.

6. It probably protects juvenile fish and juvenile penaeids from their predators by offering cover and camouflage. This is a very difficult point to prove but perhaps work with artificial seagrass and carefully controlled bare areas may be useful. The epiphyte load on the artificial grass will confound such experiments as the animals may be there to feed on epiphytes or they may be there for cover. Some fish, e.g., pipe fish (*Syngathoides biaculeatus* (Bloch)) and the fan bellied leather jacket (*Monocanthus chinensis* (Osbeck)) are extremely well camouflaged and are not found outside seagrass beds. Juvenile grass sweetlip (*Lethrinus fletus* Whitley) are carnivorous and are restricted to seagrass where their colouring acts as camouflage, but whether this camouflage is against predators or to help them approach their prey is a difficult question.

In established coastal ecosystems the seagrasses already occupy all suitable niches. Consequently very little is known about the actual establishment of seagrass communities; in most cases we do not even know whether the first settlement takes place by seeds, detached shoots or rhizome fragments. Den Hartog (1971) gives a survey of the dynamics of terminal succession stages and the vegetation patterns which develop under the influence of various hydrodynamic conditions. McRoy and Bridges (1974) discuss interesting theories of succession and the place of a coral reef in seagrass ecosystems. The wasting disease of the thirties has given us an ideal "experiment" to observe succession.

Aleem (1955) has considered the succession and ecology of sublittoral *Posidonia* and *Cymodocea* as well as the place of algae in the communities. In Australia different species and different associations make it difficult to obtain an idea of the state of a community, i.e. whether at terminal or in dynamic succession.

## DISEASES OF SEAGRASS

With the virtually complete loss of *Zostera marina* along the eastern coast of the United States in the 1930's it was dramatically revealed to marine biologists the important part played by seagrass in the marine ecosystem. Such was the importance of the epidemic that it was referred to as the "Black Death" of *Z.marina* (Milne and Milne, 1951) wiping out 90% of the population it attacked. According to plant pathologists (Stevens, *et. al.*, 1950) this mortality was "the most destructive in the history of plant pathology".

Rasmussen (1973) summarises and reviews the cause(s) of the destruction of *Zostera* pointing out that there are strongly diverging opinions on the matter. This excellent summary is reproduced here:

"Most agreement is found concerning attack by a fungus and a slime mould. In *Zostera* plants with the characteristic symptoms there is generally a mycelium of *Ophiobolus halimus* Mounce and Diehl (H. Petersen, 1933, 1934a, b, 1935; Mounce and Diehl, 1934, Tutin, 1934).

More or less at the same time , diseased *Zostera* plants were found to contain a slime mould, *Labyrinthula macrocystis* Cienkowski (Hopkins, 1963, pp 417-418), and especially in the USA, the slime mould hypothesis was accepted as conclusive (Renn, 1934, 1936; Young, 1938a, b, 1943; Cottam, 1939; Moffitt and Cottam, 1941; Johnson and Sparrow, 1961). However, it has turned out that both forms occur together and apparently everywhere where the *Zostera* disease has been reported, i.e., on both sides of the Atlantic. Also from New Zealand there are reports of *Zostera* decline plus the presence of *Labyrinthula* (Armiger, 1964, not *Z. marina*).

Many other theories have been proposed to explain the sudden and nearly total disappearance of the *Zostera* in 1931-33. Among the most important and most debated are, in addition to the above-mentioned: bacterial attack (Lami, 1935) and changes in the surrounding factors. Lewis (1932) and Butcher (1934) sum up the possible causes. Changes in solar activity are named by Stevens (1936, 1939) and Tutin (1938). Tutin's suggestions that the fundamental cause could be fewer hours of sunshine in 1931-32 are vigorously and convincingly opposed by Atkins (1938). Martin (1954) suggests that shifting periods of widespread drought and precipitation greater than normal are responsible for the mass death. Setchell's results (1929), where he attributes a dominating influence on growth and ordinary development to water temperature, are partly drawn into the discussion, but are strongly opposed by many (Butcher, 1934; Cottam and Munro, 1954). On the other hand, McRoy (1966), on the basis of his thorough physiological investigations of *Z. marina*, considers temperature to be the decisive factor and believes it can be responsible for the 'wasting disease'. However, he gives no real documentation."

Cottam and Addy (1947) and Young (1943) agree that the activity of *Labyrinthula* is greater in warm weather months than in cooler months.

During and after the disappearance of *Zostera marina* in the 1930's much was learnt of the dependence of estuarine fauna upon the seagrass. A direct source of food for some aquatic birds and fishes and an indirect source for many marine invertebrates disappeared. Bare areas were created and an agent in sedimentation and in the retention of shellfish was eliminated. Certain animals declined in abundance or disappeared entirely (Dexter, 1944). Later workers traced the recovery of *Zostera* (Dexter, 1950; Stevens, *et. al.*, 1950; Renn, 1937; Cottam and Munro, 1954). Changes in the invertebrate community of a lagoon before and after *Zostera marina* had disappeared were carried out by Stauffer (1937).

Nelson (1947) questions the importance given to *Zostera* by these earlier workers and suggests that the more rapid turnover of nutrients and the faster growth of macroalgae and microalgae in areas denuded of eelgrass reduced the predicted catastrophic results of losing it.

PHYSICAL DAMAGE TO SEAGRASS

Although *Labyrinthula* and the conditions leading to its epidemic have been blamed for the wasting disease of *Zostera marina*, all seagrass is subjected to extremes of conditions which cause damage to it in one form or another. Land reclamation, canal development and effluent from man's many activities have diverse and adverse effects on seagrass.

Natural conditions of storms, currents and tides cause many changes in the estuarine habitats of seagrass. Very little cooperation between biologist and geologist has occurred so that the effects of sediment transport and the effect of erosion on the biology of the area are not documented. Maxwell (1970) in his paper on the sediments of Moreton Bay was helped by the Dept. of Zoology, University of Queensland but his results are not combined with any particular zoological or botanical study. Tidal flats are generally depositional features growing at the expense of the tidal channels and in turn being engulfed by salt marsh vegetation (Redfield, 1967).

The destructive effects of hurricanes on shorelines can be briefly stated as follows: (a) erosion of the protective foreshore dunes; (b) erosion of the oceansides of the beaches; (c) opening of inlets across barrier islands; and (d) erosion of offshore shoals and redistribution of their sediments (El-Ashry, 1971; Thomas, *et. al.*, 1961). With continuous erosion of the beaches along the southeast Queensland coast and bars at the mouth of Moreton Bay there may be evidence to support the theory that some of the eroded oceanic sand is entering Moreton Bay. El-Ashry (1971) was able to show that the frequency of cyclones on the Texas coast had increased and he believed this to be the major cause of coastline erosion. Coleman (1972) has documented the frequencies, tracks and intensities of cyclones in Australia but no cyclic or year by year trends can be shown from his work. It has been known for some time now that sediment has been building up in Moreton Bay and erosion has occurred along the eastern coastline but whether the two are related has not been looked at. Coastal erosion is on the increase along the eastern Australian coast (Thom, 1974) but little is known of the effect on estuaries. Still less is known of the tolerance of species of seagrass to deposition of sand and silt.

REVEGETATION

Experiments in seagrass sometimes require laboratory material to be grown in tanks under controlled conditions. A number of workers have attempted this (McRoy, personal communication; Koch, *et. al.*, 1974; Fuss and Kelly, 1969). Success has been related to the species, e.g. Fuss and Kelly (1969) were successful with *Thalassia testudinum* but not with *Halodule wrightii*. Growth hormones assisted plants to strike (Kelly, *et. al.*, 1971) as did algal culture medium (Koch, *et. al.*, 1974) and, in both cases, growth was quicker.

The earliest record of transplanting was by Addy (1947) who attempted to replace diseased *Zostera marina*. His transplants were of limited success but natural recovery exceeded the rate at which transplants augmented growth. Transplanting seagrass has a number of uses:

(1) to replenish stocks in areas damaged by pollution, disease or excessive sand movement;

(2) to compensate for seagrass areas lost (or to be lost) to reclamation programmes; and

(3) to commence resettlement of areas at which some event has prevented or destroyed seagrass and that event has now ceased.

Fuss and Kelly (1969) initiated present work in transplants with some success. A number of methods were tried. This is well reviewed by Phillips (1974b) who also transplanted and grew *Zostera marina* L. He suggests that using transplanting techniques there is much more information concerning seagrasses that can be gained than merely the procedures to maintain or create a meadow. Information on phenotypic plasticity, validity or varietal distinctions, the presence of local physiological races, an assessment of the extent of pollution damage on seagrass and finally insight into the dynamic relations such as inter-specific competition and succession of seagrasses as well as compensation point may be determined.

Ranwell, *et. al.*, (1974) in Great Britain have had considerable success in transplanting *Zostera noltii* and *Z. marina* var. *angustfolia* and they submit an estimate of cost for stabilising areas of mud flat.

Unfortunately none of this work relates to Australian seagrass and it is evident from these overseas attempts that success varies with the particular species involved. Problems in Australian estuaries such as transplanted plots being cropped by garfish or turtles do not seem to have arisen overseas. The marine angiosperms have quite varied modes of growth and morphology so transplanting depends on size of rhizomes or root and ability to produce more subsurface areas to improve attachment.

## REFERENCES

Addy, C.E. (1947). Eel grass planting guide. *Md. Conserv.*

Aleem, A.A. (1955). Structure and evolution of the seagrass communities *Posidonia* and *Cymodocea* in the south eastern Mediterranean. *In* Essays in the Natural Sciences in Honour of Capt. Alan Hancock, 279-298.

Armiger, L.C. (1964). An occurrence of *Labyrinthula* in New Zealand *Zostera*. *N.Z. Jl. Bot.* 2: 3-9.

Atkins, W.R.G. (1938). The disappearance of *Zostera marina*. *J. mar. biol. Ass. U.K.* 23: 207-210.

Bernatowicz, A.J. (1952). Marine monocotyledonous plants of Bermuda. *Bull. mar. Sci. Gulf Caribb.* 2(1): 338-345.

Blaber, S.J.M. (1974). Field studies of the diet of *Rhabdosargus holubi* (Pisces: Teleostei: Sparidae). *J. Zool.* 173: 407-417.

Blake, S.T. (1964). Queensland Sea Grasses. *Qd Nat.* 17 (3 & 4): 70-73.

Butcher, R.W. (1934). *Zostera.* Report on the present condition of eelgrass on the coasts of England, based on a survey during August to October, 1933. *J. Cons. perm. int. Explor. Mer.* 9: 49-65.

Coleman, F. (1972). Frequencies, tracks and intensities of tropical cyclones in the Australian region 1909 to 1967. *Met. Summ. mon. clim. Bull. Aust.*

Cottam, C. (1939). The eelgrass situation on the American Pacific coast. *Rhodora* 41: 257-260.

Cottam, C. and C.E. Addy. (1947). Present eelgrass conditions and problems on the Atlantic coast of North America. *Proc. N. Am. Wildl. Conf.* 12: 387-398.

Cottam, C. and D.A. Munro. (1954). Eelgrass status and environmental relations. *J. Wildl. Mngmt* 18 (4): 449-460.

Dexter, R.W. (1944). Ecological significance of the disappearance of eelgrass at Cape Ann, Massachusetts. *J. Wildl. Mngmt* 8(3): 173-176.

Dexter, R.W. (1950). Restoration of the *Zostera* fasciation at Cape Ann, Massachusetts. *Ecology.* 31 (2): 286-288.

El-Ashry, M.T. (1971). Causes of recent increased erosion along United States shorelines. *Bull. geol. Soc. Am.* 82: 2033-2038.

Fenchel, T. (1970). Studies on the decomposition of organic detritus derived from the turtle grass *Thalassia testudinum*. *Limnol. Oceanogr.* 15 (1) 14-20.

Fosberg, C. (1959). Quantitative sampling of subaquatic vegetation. *Oikos* 10 (11): 233-240.

Fuss, C. Jr. and J.A. Kelly, Jr. (1969). Survival and growth of sea grasses transplanted under artificial conditions. *Bull. mar. Sci.* 19: 351-365.

Gillham, M.E. (1965). Fisher Island Field Station. IV. Vegetation: additions and changes. *Pap. Proc. R. Soc. Tasm.* 99: 71-80.

Ginsberg, R.M. and H.A. Lowenstam. (1958). The influence of marine bottom communities on the depositional environment of sediments. *J. Geol.* 66: 310-318.

den Hartog, C. (1970). The Sea Grasses of the World. (North-Holland: Amsterdam).

den Hartog, C. (1971). The dynamic aspects in the ecology of sea grass communities. *Thalassia jugosl.* 7 (1): 101-112.

Hirth, H.F., L.G. Klikoff and K.T. Harper. (1973). Seagrasses at Khar Umaira, People's Democratic Republic of Yemen with reference to their role in the diet of the green turtle, *Chelonia mydas*. *Fishery Bull. Fish. Wildl. Serv. U.S.* 71 (4): 1093-1097.

Hopkins, S.M. (1963). Parasitism. *In:* J. Hedgpeth (ed.): Treatise on Marine Ecology and Paleoecology. *Mem. geol. Soc. Am.* 63 (1): 417-418.

Humm, H.J. (1964). Epiphytes of the sea grass, *Thalassia testudinum*, in Florida. *Bull. mar. Sci. Gulf Caribb.* 14 (2): 306-341.

Johnson, T.W. Jr. and F.K. Sparrow. (1961). Fungi in oceans and estuaries (J. Cramer: Weinheim) 668 pp.

Kelly, J.A. Jr., C.M. Fuss, Jr. and J.R. Hall. (1971). The transplanting and survival of turtle grass *(Thalassia testudinum)* in Boca Ciega Bay, Florida. *Fishery Bull. Fish Wildl. Serv. U.S.* 69 (2): 273-280.

Koch, S.J., R.W. Elias and B.M. Smith. (1974). Influence of light intensity and nutrients on the laboratory culture of seagrasses. *Contr. mar. Sci.* 18: 221-227.

Lami, R. (1935). Travaus verents sur la maladie des Zosteres. *Revue Bot. appl. Agric. trop.* 15: 263-266.

Lewis, H.F. (1932). The eelgrass situation on the Atlantic coast. *Trans. Am. Game Conf.* 19: 411-423.

Marsh, G.A. (1973). The *Zostera* epifaunal community in the York River, Virginia. *Chesapeake Sci.* 14 (2): 87-97.

Marshall, N. and K. Lucas (1970). Preliminary observations on the properties of bottom sediments with and without eelgrass. *Zostera marina* cover. *Proc. natn. Shellfish Ass.* 60: 107-111.

Martin, A.C. (1954). A clue to the eelgrass mystery. *Trans. N. Am. Wildl. Conf.* 19: 441-449.

Maxwell, W.G.H. (1970). The sedimentary framework of Moreton Bay, Queensland. *Aust. J. mar. Freshwat. Res.* 21: 71-88.

McRoy, C.P. (1966). The standing stock and ecology of eelgrass (*Zostera marina* L.) in Izembek Lagoon, Alaska. M.Sc. Thesis. Univ. Wash., Seattle; 138 pp.

McRoy, C.P. (1973). Seagrass Ecosystems. Proc. Int. Seagrass Workshop Leiden, The Netherlands. 22-26 Oct, 1973.

McRoy, C.P. and K.W. Bridges. (1974). Dynamics of seagrass ecosystems. Proc. First International Congress of Ecology (unpublished).

Milne, L.J. and M.J. Milne. (1951). The eelgrass catastrophe. *Scient. Am.* 184 (1): 52-55.

Moffitt, J. and C. Cottam. (1941). Eelgrass depletion on the Pacific coast and its effect upon black brant. *Wildl. Res. Mngmt Leafl.* 204.

Mounce, I. and W.W. Diehl. (1934). A new *Ophibolus* on eel grass. *Can. J. Res.* 11: 242-246.

Nelson, T.C. (1947). Some contributions from the land in determining conditions of life in the sea. *Ecol. Monogr.* 17 (3): 327-346.

Odum, H.T. (1957). Primary production measurements in eleven Florida springs and in a marine turtle grass community. *Limnol. Oceanogr.* 2: 88-95.

Ostenfeld, C.H. (1915). On the geographical distribution of the sea-grasses. *Proc. R. Soc. Vict.* 27 (N.S.) part 2.

Ostenfeld, C.H. (1916). Contributions to West Australian Botany I. The seagrasses of Western Australia. *Dansk bot. Ark.* 2 (6).

Ostenfeld, C.H. (1929). A list of Australian sea-grasses. *Proc. R. Soc. Vict.* 42 (N.S.) Part 1: 1-3.

Petersen, H.E. (1933). Wasting disease of eelgrass *(Zostera marina)*. *Nature, Lond.* 132: 1004.

Petersen, H.E. (1934a). Wasting disease of eelgrass *(Zostera marina)*. *Nature, Lond.* 134: 143.

Petersen, H.E. (1934b). Studies on a parasitic fungus in the eelgrass *Zostera marine* L. *Tidsskr. Bot.* 43 (1): 1-9.

Petersen, H.E. (1935). Preliminary report on the disease of the eelgrass *(Zostera marina* L.) *Rep. Dan. biol. Stn* 40: 3-8.

Phillips, R.C. (1974a). Preliminary observations on transplanting and a phenological index of seagrass communities. Proc. First International Congress of Ecology (unpublished).

Phillips, R.C. (1974b). Transplantation of sea grasses, with special emphasis on Eelgrass *Zostera marina* L. *Aquaculture* 4: 161-176.

Pomeroy, L.R. (1960). Primary productivity in Boca Ciega Bay, Florida. *Bull. mar. Sci. Gulf Caribb.* 10 (1): 1-9.

Randall, J.E. (1965). Grazing effect on seagrasses by herbivorous reef fishes in the West Indies. *Ecology*. 46 (3): 255-260.

Ranwell, D.S., D.W. Wyer, L.A. Boorman, J.M. Pizzey and R.J. Waters. (1974). *Zostera* transplants in Norfolk and Suffolk, Great Britain. *Aquaculture* 4: 185-198.

Rasmussen, E. (1973). Systematics and ecology of the Isefjord marine fauna (Denmark). *Ophelia* 11: 404-414.

Redfield, A.C. (1967). Ontogeny of a salt marsh estuary. *In:* G.H. Lauff (ed.) Estuaries. *Publs Am. Ass. Advmt. Sci.* 83: 108-114.

Renn, C.E. (1934). Wasting disease of *Zostera* in American waters. *Nature, Lond.* 134: 416.

Renn, C.E. (1936). The wasting disease of *Zostera marina*. 1. A phytological investigation of the diseased plant. *Biol. Bull. mar. biol. Lab., Woods Hole*. 70: 148-158.

Renn, C.E. (1937). The eelgrass situation along the middle Atlantic coast. *Ecology*. 18 (2): 323-325.

Setchell, W.A. (1929). Morphological and phenological notes on *Zostera marina* L. *Univ. Calif. Publs Bot.* 14: 289-452.

Stauffer, R.C. (1937). Changes in the invertebrate community of a lagoon after the disappearance of the eelgrass. *Ecology*. 18 (3): 427-431.

Stevens, N.E. (1936). Environmental conditions and the wasting disease of eelgrass. *Science, N.Y.* 84: 87-89.

Stevens, N.E. (1939). Environmental factors and the wasting disease of eelgrass. *Rhodora* 41: 260-262.

Stevens, N.E., H.R. Ellis and R.B. Stevens. (1950). Wasting and recovery of *Zostera marina* on the Atlantic coast of the United States. *Pl. Dis. Reptr* 34 (12): 357-362.

Taylor, J.L. and C.H. Saloman. (1968). Some effects of hydraulic dredging and coastal development in Boca Ciega Bay, Flordia. *Fishery Bull. Fish. Wildl. Serv. U.S.* 67 (2): 213-241.

Taylor, J.L., C.H. Saloman and K.W. Prest Jr. (1973). Harvest and regrowth of turtle grass *(Thalassia testudinum)* in Tampa Bay, Florida. *Fishery Bull. Fish. Wildl. Serv. U.S.* 71 (1): 145-147.

Thom, B.G. (1974). Coastal erosion in eastern Australia. *Search.* 5 (5): 198-209.

Thomas, L.P., D.R. Moore and R.C. Work. (1961). Effects of Hurricane Donna on the turtle grass beds of Biscayne Bay, Florida. *Bull. mar. Sci. Gulf Caribb.* 11 (2) 191-197.

Tutin, T.C. (1934). The fungus on *Zostera marina. Nature, Lond.* 134: 574.

Tutin, T.C. (1938). The autecology of *Zostera marina* in relation to its wasting disease. *New Phytol.* 37: 50-71.

Westlake, D.F. (1965). Basic data on aquatic macrophytes. *Memorie Ist. ital. Idrobiol.* 18 Suppl.

Wetzel, R.G. (1964). A comparative study of the primary productivity of higher aquatic plants, periphyton, and phytoplankton in a large shallow lake. *Int. Revue ges. Hydrobiol. Hydrogr.* 49: 1-61.

Wetzel, R.G. (1965). Productivity in higher aquatic plants and periphyton. *Memorie Ist. ital. Idrobiol.* 18 Suppl.: 251-267.

Wood, E.J. Ferguson. (1953). Reducing substances in *Zostera, Nature, Lond.* 172: 916.

Wood, E.J. Ferguson. (1959). Some east Australian seagrass communities. *Proc. Linn. Soc. N.S.W.* 84: 218-226.

Wood, E.J. Ferguson, W.E. Odum and J.C. Zieman. (1969). Influence of Sea Grass on the Productivity of Coastal Lagoons. Lagunas Costeras, un Simposio. Mem.Simp. Intern. Lagunas Costeras, UNAM-UNESCO, Nov. 28-30 1967 Mexico, D.F.: 495-502.

Young, E.C. (1938a). Recent investigations on the eelgrass problem; preliminary report. *Bull. Mt Desert Isl. biol. Lab.* 26-28.

Young, E.C. (1938b). *Labyrinthula* on Pacific coast eelgrass. *Can. J. Res.* 16: 115-117.

Young, E.C. (1943). Studies on *Labyrinthula,* the etiologic agent of the wasting disease of eelgrass. *Am. J. Bot.* 30: 586-593.

Zieman, J.C. (1968). A study of the growth and decomposition of the seagrass *Thalassia testudinum.* Thesis. Univ. Miami.