3.3 Seagrasses of southeastern Australia

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Abstract

The southeast portion of Australia has a high energy coastline that generally prohibits growth of seagrasses except in sheltered bays and estuaries. This is also the most densely populated portion of the country, meaning that seagrasses are subject to pressures from agriculture, industry, and urban activities. Yet the maintenance of healthy seagrass meadows is critical to the economy of these regions as it forms a critical link in the food chain of many recreational and commercial fish species as well as providing other functions. In order to generate a better understanding of these pressures and derive appropriate economic and environmental outcomes, an understanding of the biology of seagrasses and their value to the community is critical. This chapter presents an overview of the seagrass habitats of SE Australia as well as the differing management approaches in Queensland, New South Wales and Victoria. It also provides an overview of the role of community monitoring projects in providing important information for management of these critical habitats.

Introduction

The body of knowledge about seagrasses in Australia, and at the global scale is extensive (see texts in the supplementary reading list). Recent output from a National Working Group (see ACEAS (Australian Centre for Ecological Analysis and Synthesis)) has differentiated three main Australian bio-regions for seagrass: Tropical and Sub-tropical Northern Australia, Temperate SE Australia, Temperate SW Australia. This chapter focuses on the seagrasses of the temperate southeast Australian coast, defined somewhat arbitrarily based on the north-south orientation of the coast as stretching from the Noosa River (Queensland) to Corner Inlet in Victoria. The extensive meadows of seagrass in the Great Barrier Reef and those of Western Port, Port Philip Bay and western Victoria deserve mention at another time. Relative to the entire Australian coastline this represents less than 10% of the coastline, but with more than 80% of Australia's population. The distribution of seagrasses in the south-east also differs from other parts of the continent, being confined with estuaries and bays rather than forming extensive offshore meadows as occurs in southern and western Australia. Each of the states within the southeast sector recognises the value of seagrass (e.g. Queensland: AquaBAMM, Clayton *et al*. 2006) and various initiatives are in place to assess seagrass condition for protection and planning purposes (e.g. Queensland: seagrass depth range monitoring in Moreton Bay). Further, there are state-wide reviews based on extensive local literature (e.g. Victoria: Warry and Hindell 2009).

Although the importance of seagrass in protecting community values for estuaries and coastal regions was poorly understood in the past, the role seagrass plays in supporting coastal fisheries and reducing coastal erosion is becoming more understood and appreciated by the wider community. This increased awareness has been assisted by many different approaches. One that has assisted greatly is the involvement of community associations, such as Coastcare and other local groups that have become actively involved in the monitoring of these habitats and the role of seagrasses in coastal ecology. Community awareness continues to grow as a result of research efforts to understand better the biology of seagrasses and the translation of those outputs into protective legislation, policy and guidelines. This chapter provides an overview of the management of seagrasses in the southeast sector of Australia. This sector is instructive because of the ever growing population pressure to use the locations in which seagrasses live – the shallow inshore waters of bays, lagoons and estuaries.

The objectives of this chapter are to provide:

- an introduction to seagrass biology and its implications for conservation management;
- a simple comparison of the basis for management between three principal management authorities along the southeast sector of the mainland (southern Queensland, New South Wales, eastern Victoria); and
- a differentiation of the types of community monitoring that has been and might be initiated to assist in determining the well being of beds of seagrass in southeast Australia.

There are many species of seagrass, most of which have a specific shape, distribution and behaviour, and so it is more apt in scientific and management terms to refer to "seagrasses" rather than seagrass. This is particularly so in the management sense as there is a need to understand better their individual conservation needs. (The same situation also prevails with "mangroves", Chapter 3.4; and "saltmarsh", Chapter 3.5).

At the global scale there is considerable concern about the present management of seagrasses and their long term fate (Orth *et al*. 2006; Global Seagrass Trajectories Working Group 2009). Within Australia there is a recent effort to identify and synthesise current knowledge and threats to seagrasses to support management actions aimed at maintaining healthy meadows. This Seagrass Working Group (online), supported by ACEAS, has initiated two review papers. The first explores the different spatial and temporal scales at which anthropogenic and natural processes impact on seagrasses and will provide managers with an understanding of the most appropriate monitoring approaches to assess seagrass condition. The second paper will update a previous assessment of the distribution of seagrass around the Australian Coast (Mount and Bricher 2008), provide conceptual understanding of the major processes important for maintaining seagrass habitats in the different bio-regions of Australia and provide a risk assessment framework for the sustainability of seagrass along the Australian coast.

Taxonomy

"Seagrasses" are a diverse group of aquatic plants that evolved from terrestrial counterparts millions of years ago to inhabit shallow coastal and estuarine waters across the globe. All species of seagrass are flowering plants (angiosperms). They are not grasses in the true sense of the word but are distantly related to lilies and gingers. Seagrasses have leaves and rhizomes – a type of robust root that anchors the plants in sand or mud. Fine roots, with hairs, emerge from the rhizomes providing structural stability and providing for the uptake of nutrients. The leaves contain the chlorophyll necessary for the photosynthetic process, which uses light to turn carbon dioxide and water into the complex molecules of growth. Even though the flowers produce seeds, the main mechanism by which most species of seagrass sustain and expand themselves is through their rhizomes. There are many reviews of the complex anatomical and physiological features of seagrasses (e.g. Vermaat 2009).

There are nearly 70 species of seagrass worldwide, with some having restricted distributions but others occurring globally. Some species are found in nearshore oceanic waters (bays and coastal lagoons) whereas others grow in estuaries, within habitats ranging from near marine channels to brackish upstream locations.

Seagrasses should not be confused with macroalgae or "seaweeds" which are simple plants with no root system or flowers. (The excellent photos provided by Sainty *et al*. (2012) readily distinguish seagrasses from macroalgae; other estuarine plants are also identified in this valuable text.)

All seagrasses fall within the Order Alismatales, a large group of approximately 4,500 species with an aquatic lifestyle, either living underwater or in marsh habitats. Of the nearly 70 species of seagrass currently recognised worldwide, Australia has the world's highest diversity, having approximately half of the total number of species (Butler 1999).

The stretch of coast between Noosa and Corner Inlet includes sub-tropical and temperate climates. Relative to other parts of Australia the southeastern sector has relatively few species of seagrass and less extensive meadows than other sections of the coastline (Kirkman 1997). Many of the species in this sector are found elsewhere in Australia as well as globally (Table 3.3.1). The seagrasses of the southeast are usually found in estuarine and inshore waters less than 15m deep.

Five Families of seagrass occur along the southeast sector of Australia: Cymodoceaceae, Hydrocharitaceae, Posidoniaceae, Ruppiaceae and Zosteraceae (Table 3.3.1). The northern part of this region, from Noosa to the Qld/NSW border is a transition zone that includes both tropical and temperate species. However, in NSW and Victoria the seagrass meadows are dominated by temperate species. Progressively more sophisticated techniques in anatomy, biochemistry and genetics have in recent times distinguished between similar looking species within these families, but studies are underway to reduce uncertainty, for example, with regard to the distribution of species in the genus *Zostera* (Sainty *et al*. 2012, p. 127, p. 129, p. 131).

The five families contain at least 12 species with different distributions (Table 3.3.1). *Posidonia australis* is the sole species within the family Posidoniaceae to be found along the southeast coast (Other species within this genus occur along the southern and western coasts of Australia.). Three species are within the family Zosteraceae: *Zostera capricorni*, *Zostera muelleri* and *Zostera nigricaulis*. The Hydrocharitaceae family includes *Halophila australis*, *Halophila decipiens* and *Halophila ovalis*. Within the Cymodoceaceae are *Halodule tridentata* and *Halodule univerus*.

Three species belong to the Family Ruppiaceae: *Ruppia maritima*, *Ruppia megacarpa* and *Ruppia polycarpa*. These are usually found in the upper portions of estuaries where salinity is low. The plants in this family have a distinctly different life history from other seagrasses – they have emergent flowers that are pollinated in the air. For other seagrass species this reproductive function takes place under water.

Some seagrasses, such as *Posidonia australis*, the *Halodule* and *Halophila* species are found exclusively in sheltered bays and near the entrances to estuaries where tidal exchange offers clear oceanic water of high salinity. *Posidonia australis* is found no further north than Wallis Lake, NSW (West 1983), and in a few bays and permanently open estuaries south along the coast to Corner Inlet, Victoria (Warry and Hindell 2009). Other species, such as *Zostera*, are found not only near estuary entrances in Queensland, NSW and Victoria but further upstream as well and are therefore assumed to be able to tolerate variation in light regime, salinity and temperature.

Seagrass distributions can change over time. Some offshore beds migrate naturally, a phenomenon recognised off the West Australian coast where beds have leading and trailing edges that appear to respond to the movement of sand. As the wave energy off the southeast coast is extreme, no

Table 3.3.1. Characteristics of NSW seagrasses within the Order Alismatales (after Kuo *et al*. 2012).

Family	Genus and species	Common name	Characteristics	Southeast Australian distribution
Cymodoceaceae	*Halodule tridentata*	–	A short stem at each rhizome node with slender (<1.5mm) leaves to 150mm length with tridentate tip. Estuarine/marine.	Tropical Indo-Pacific extending to Wallis Lake (NSW). Estuarine/ marine.
	Halodule univerus	Shoal Weed	Narrow (<4mm) leaves at each rhizome node with leaves to 150mm length with tridentate tip having two well-developed lateral teeth.	Tropical Indo-Pacific extending to Sandon River (QLD). Estuarine/ marine.
Hydrocharitaceae	*Halophila australis*	Paddleweed	Largest leaved of the *Halophila* genus. Paired bright green or brown oval leaves 6-15mm in width to 70mm in length with smooth margins. Thin whitish surface rhizome.	Victoria. Estuarine/ marine.
	Halophila decipiens	Paddleweed	Paired bright green or brown oval leaves more elliptic than above, 5mm in width, 25mm in length with small toothed margins. Thin whitish surface rhizome.	Most widely distributed seagrass on the globe. Estuarine/marine.
	Halophila ovalis	Paddleweed	Paired green or brown oval leaves more elliptic than above, <15mm in width, <45mm in length with smooth margins. Thin whitish surface rhizome.	Indo-Pacific to Victoria Estuarine/marine.
Posidoniaceae	*Posidonia australis*	Strapweed	Long green leaves 10mm in width and 300-600mm in length, robust (20mm) rhizome. Occurs below Mean Low Tide.	Southwards from Wallis Lake in permanently open estuaries and bays to Corner Inlet. Estuary entrances/ marine.
Ruppiaceae	*Ruppia maritima*	Sea Tassel	Leaves 0.5mm in width and 150mm in length. Rivers, lakes and estuaries.	Global distribution. Rivers, lakes and estuaries.
	Ruppia megacarpa	Sea Tassel or Widgeon Grass	Leaves <1mm in width and <250mm in length. Flowers pollinate on surface of rivers, lakes and estuaries.	Southeastern Australia. Rivers, lakes and estuaries.
	Ruppia polycarpa	Sea Tassel	Leaves 0.5mm in width and 150mm in length. Flowers pollinate on surface of rivers, lakes and estuaries.	Southeastern Australia. Rivers, lakes and estuaries.

Table 3.3.1. (cont.) Characteristics of NSW seagrasses within the Order Alismatales (after Kuo *et al*. 2012).

Family	Genus and species	Common name	Characteristics	Southeast Australian distribution
Zosteraceae	*Zostera capricorni*	Eelgrass or Ribbon Weed	Most common of NSW seagrasses. Olive green or brown leaves (<500mm) with round tip.	Eastern Australia. Estuaries and bays.
	Zostera muelleri	Dwarf Grass-wrack	Smaller than above with notched leaf tip.	Southwards from Jervis Bay to the Victorian border. Estuarine/ marine.
	Zostera nigricaulus	Eelgrass or Ribbon Weed	Leaves arise from an upright stem.	Southwards from Port Stephens to the Victorian border. Estuarine/marine.

such bed movement is seen unless in the lee of islands. However, small-scale fluctuations in the areal extent of seagrasses have been reported in sheltered waters of Queensland (Udy, unpublished data), Victoria (Blake and Ball 2001) and NSW (Williams *et al*. 2003) over the past several decades.

Another reason for change in distribution is that species migrate with changes in global temperature and sea level. At the height of the last Ice Age (18,000 years ago) the shoreline of southeastern Australia was 15 to 20km further east of where it is today with sea level 120 to 130m lower than it is at present. While knowing the distributions of seagrasses thousands of years ago is problematic, it could be hypothesised that species confined to the southern Queensland coast during the last Ice Age migrated to NSW as warming progressed and sea level rose. Shifts of distribution, possibly due to global warming, are continuing at present, with *Halodule tridentata* and *Halodule univeris* now found in estuaries of northern NSW where they had not previously been described (Sainty *et al*. 2012, p. 97, p. 99). Species present in subtropical Queensland can be expected to move further south with global warming, and temperate species, such as *Posidonia australis*, presently found along the NSW coast can be expected to retreat to cooler latitudes.

Functions of Seagrasses

Seagrass leaves capture carbon dioxide, offer a three dimensional habitat for plants and animals, and are a source of food for many animals, either directly or through detrital pathways. Leaves act as baffles, slowing down currents allowing particles to fall from suspension, in turn enhancing water clarity. The rhizome mats of seagrass bind sediments and provide protection against wave-induced erosion.

Seagrass canopies modify what would otherwise be featureless substrata to provide a high value ecosystem: canopy structure supports more diverse invertebrate assemblages and higher community primary production than bare mud or sand, facilitating numerous food web linkages to higher trophic levels, including fish, turtles and dugong. Some small plants (epiphytes) attach themselves to seagrass leaves, as do some small encrusting animals (epizoa). Species of fish graze on these attached organisms, inadvertently consuming seagrass leaf material. Seagrass beds and meadows have often been referred to as “nurseries” for many species of small fish, crustaceans and molluscs as well as the juveniles of larger species. Large fish invade seagrass beds during their hunt for food, and some juvenile fish, after being sustained in the beds for the early part of their lives will be harvested by commercial and recreational fishers.

One of the processes that sustains the nursery function of seagrass beds is the production of detritus. Leaves that are lost from the plants either due to age or are broken off during occasional storms are colonised by fungi, bacteria and other microorganisms that degrade the dead leaf material creating ever smaller particles and releasing nutrients into the water column. The fungi and bacteria in turn provide sustenance for larger organisms such as phytoplankton, and then through the food chain larger individuals of zooplankton provide food for juvenile and small adult fish, crustaceans and molluscs. In some cases seagrasses are directly consumed by herbivorous fish, and in Queensland by dugong and turtles.

Sampling of fishes in shallow estuarine waters shows a greater diversity in estuaries where seagrass is present. For example, the Hunter River, NSW has been reported to have no seagrass (Williams *et al*. 2004) and has of the order of 40-50 species of small adult and juvenile fishes, while other estuaries of the same type, with seagrass meadows (Clarence, Richmond and Shoalhaven Rivers), have between 70-80 species (Williams, unpublished data). The conservation of seagrass would seem to be of fundamental importance for the support of commercial and recreational fisheries. It has often been remarked: "No habitat means no fish!".

A conservation issue that is becoming more topical is the role seagrasses (and other marine plants) play in removing CO_2 from the atmosphere and binding it up in long-lived biomass. This has been referred to in popular texts as "blue carbon". The research in this arena is in its infancy but inroads have been made (e.g. Macreadie *et al*. 2012). If blue carbon can be utilised for this purpose it will make an even stronger case for seagrass conservation.

Threats to Seagrasses

Mechanical damage to seagrasses moorings, from dredging and reclamation, and the insults from pollutants such as herbicides are more readily recognised and dealt with in environmental studies and management plans than in the past.

Of particular importance along the southeast coast is increase in water turbidity and its effect on photosynthesis. Sunlight falling on seagrass leaves stimulates photosynthesis, whereby carbon dioxide taken from water is converted into plant tissue. The degree of photosynthesis is therefore contingent on the amount of light travelling through the water column and reaching the leaves. Different species have to contend with differing light regimes. Some species grow at much greater depths than others due to innately different physiologic characteristics (Table 3.3.1), and most can survive short term reductions in water clarity from rainfall and runoff events.

Persistent reduction in water clarity will result in seagrass loss. Turbidity is increased when the concentration of inert sediments in the water column increases (for example by dredge operation) or where sediments are kept in suspension (e.g. vessel movement). Turbidity levels are especially of concern in estuaries and semi-enclosed bays where land use practices can cause erosion of sediments or deliver nutrients that enhance algal densities in the water column or epiphyte growth on seagrass leaves. In either case the amount of light reaching seagrasses is diminished and the depth at which seagrasses can survive is reduced (Dennison *et al*. 1993).

Direct damage arises from dredging, reclamation, mooring blocks and chains, anchors, keels, propellers, bait digging and shading from structures like jetties and berthing areas. Indirect damage comes about via changes in catchment landuse as well as agricultural, industrial and urban pollutants. An invasive algae, *Caulerpa taxifolia*, has appeared in a number of NSW estuaries and may pose a threat to the survival of seagrasses (NSW Department of Primary Industries 2009), and another invader, the algae *Codium fragile* ssp. *fragile* also occurs in seagrass beds in Corner Inlet and Port Phillip Bay (S. Howe, pers. comm., 2013). The rise of sea level will alter the distribution and extent of beds of seagrass, with the lower margins receiving reduced sunlight and possibly dying off and the upper margins moving further upslope as water depth increases if suitable habitat exists.

Seagrasses in South East Australia

Australia has extensive areas of seagrass with the largest meadows in Western Australia, followed by the Torres Strait (e.g. Kirkman 1997). Nevertheless, there are ecologically important areas of seagrass along the southeast coast, a high energy, geomorphically complex environment. As a consequence, meadows are smaller than in other parts of Australia, being found almost exclusively in bays and estuaries where protection is afforded from storms and currents. This pattern of distribution puts the southeast seagrasses at particular threat because agricultural, industrial and urban pressures on coastal habitats are greatest in estuaries.

In NSW, at least one species of seagrass is found in about 110 of the 184 recognised estuaries (NSW DPI unpublished data; West *et al*. 1985). The distribution of seagrass is, however, not consistent among different types of estuary in the south-east. Some seagrass is found in every large embayment (e.g. Moreton Bay, Botany Bay, Jervis Bay, Twofold Bay, Corner Inlet) or drowned river valley (e.g. Hawkesbury River, Clyde River) along the southeast Australian coast. Seagrass is also found in over 85% of coastal plain rivers and large coastal lagoons that

Additional Information

Sydney Olympic Park, situated in the upper portion of the estuary of the Parramatta River, will never host species such as *P. australis* or those in the *Halodule* and *Halophila* genera as these plants, found in sheltered bays and near the entrances of estuaries (e.g. Sydney Harbour), occur in water of high clarity. In contrast, species of the genus *Zostera*, while commonly found at entrances of estuaries, are also found in upper estuarine locations. Decades ago, Tarban Creek (Hunters Hill) was the most upstream location of *Zostera* in the Parramatta River (West *et al*. 1985) but more recently *Zostera* has been found further upstream (West *et al*. 2004). Upstream migration may have occurred between the two surveys as water pollution controls became more and more stringent in the Parramatta River through the 1980s and 1990s. Alternatively, there may have been small patches of *Zostera* not identified in the earlier survey.

There is no record of *Zostera* in Sydney Olympic Park precincts, either along the Parramatta River or in Homebush Bay, and this may relate to sediment movement and high turbidity levels brought about by vessel traffic.

Ruppia megacarpa (hereafter Ruppia) has been located intermittently in Sydney Olympic Park (S. Paul, pers. comm., 2013). It was identified in 1997 in an estuarine but almost detached lagoon (known as Waterbird Refuge) at Bicentennial Park, Homebush Bay. It occurred in the shallower parts of the Refuge but was sparsely established due to dense coverage of filamentous algae. The lagoon had been artificially constructed in early 1950s using dredge spoil from Homebush Bay. Tidal exchange was enhanced in 2006 by installing an automated tidal gate, and Ruppia quickly disappeared and has not been detected since. Nevertheless, the primary aims of restoration at the Waterbird Refuge were fully realised.

In 2001, Ruppia was identified at another semi-detached estuarine lagoon, the Newington Nature Reserve Wetland. As this lagoon is separated by a walkway from the adjacent Parramatta River's only tides over 1.6m can enter the wetland. Ruppia was detected in a few disturbed pockets of the wetland, and appears to have thrived at those sites to the present day.

In 2010, *Ruppia maritima* was identified in a totally unexpected water body within Sydney Olympic Park – a leachate treatment pond in Wilson Park (S. Paul, pers. comm., 2013). This pond, also adjacent to Parramatta River and separated from it by a walkway, was constructed in 1999 to assist in bioremediation of tar seeps. The pond has a water impermeable liner, and, to enhance treatment of leachate, water is always in motion inside the pond. *Ruppia maritima* was detected along the shallower edges of the approximately 2.0m deep pond, and appeared healthy with relatively long stems, perhaps due to the continuous movement of water.

are mostly open to the sea. In these estuaries, the area covered by seagrass is less than 10-15% of the water surface area.

In contrast, only 30 to 50% of intermittently open estuaries and coastal lagoons have any seagrass (OEH, DPI Fisheries unpublished data). This is thought to be due to extremes of temperature and/or salinity that come about when a berm prevents tidal flushing and/or evaporation creates hypersaline conditions, particularly during droughts. Sometimes *Ruppia* species are seen to survive in these fluctuating conditions.

Large losses of seagrass have been documented for some estuaries. The cover of seagrass in Port Hacking, NSW was consistently of the order of 180ha between 1930 and 1950, but declined in the 1960s and 1970s to 90ha (Williams and Meehan 2001). The most recent estimate (Creese *et al*. 2009) indicates cover in Port Hacking has stabilised at 90-100ha. There are distinct management implications for these large variations in cover that will be discussed below. Large losses of seagrass have also been seen in the Parramatta River (West and Williams 2008) and in other NSW estuaries (Williams *et al*. 2003).

Management

The relatively small cover of seagrasses in southeast Australia (compared to other parts of Australia), coupled with the important functions seagrasses contribute, mean that protection of meadows should be the first priority in management. This priority is reinforced by the fact that restoration techniques such as seagrass transplanting are in their infancy (see below). All Australian states have expressed concern for the conservation of seagrasses but some states are more explicit with their legislative and policy initiatives.

Queensland and New South Wales have legislation specifically designed to protect seagrass (Table 3.3.2). The primary difference between the two states is that the *Queensland Fisheries Act* 1994 protects all marine plants in all waterways, public and private, whereas in NSW the *Fisheries Management Act* 1994 deals principally with seagrass, mangrove, saltmarsh and macroalgae (seaweeds) in all public waters. In Queensland, New South Wales and Victoria seagrasses are also managed within marine protected areas and aquatic reserves. Under the terms of the NSW *Fisheries Management Act* 1994, *P. australis* has been declared as having "Endangered Populations" in the Sydney metropolitan and Central Coast regions (NSW Fisheries Scientific Committee 2009). Except for the proposal to list *P. australis* under the Commonwealth's *Environment Protection and Biodiversity Conservation Act* 1999, no other use of that act has been applied to protect and manage seagrasses in a national context.

It is the aim of legislation, policies and guidelines to safeguard beds of seagrass from direct and/or indirect damage.

Monitoring

The monitoring of seagrasses is a complex issue that is sometimes best approached with a series of questions: is there a perceived problem? What are the needs of management (e.g. early indicators of impact vs. long-term meadow scale effects)? What resources are available? Monitoring to detect early indications of impact necessarily occurs at the time scale of hours, weeks or months, and at the spatial scale of individual plants or patches of plants, taking the form of measuring rates of photosynthesis or changes in carbohydrate stores, actions that in the past have been the domain of professional scientists. Similarly, if a series of yearly status reports of the cover of seagrass in one or more estuaries was desired such that a decadal trend of gain or loss could be produced, airphoto imagery, appropriate hardware and software, and skilled operators to assemble and interpret the data would be needed. In contrast, monitoring to detect natural variability in cover and/or density (months, seasons, years) at a local scale (individual beds), is readily undertaken by community volunteers.

The ambit of a monitoring program is directly influenced by extent of disturbance and the scale of impact on seagrasses.

In circumstances where funds for conservation managers and researchers are diminishing, new models for natural resource monitoring are required. One new model is to establish partnerships between professional seagrass biologists and community volunteers, a model that can be mutually beneficial as it brings sophisticated skills and equipment to a site(s), as well as enhances the labour pool.

In situations where no professional expertise is available there still are standard measurements that volunteers can use to contribute to local or even regional understanding of the ecological processes of seagrasses. A localised loss (or gain) of seagrass can be monitored with simple equipment: measuring tape, GPS, permanent marking fixtures. The Sea Search Manual (Browne *et al*. 2013) provides a set of criteria for selecting the best indicators for monitoring programs. These range from 'easy' to "difficult" to provide for volunteers with different skill levels and interests and to help ensure data are of sufficient quality to inform management.

Major factors to consider in the planning phase include:

- objective of the project;
- geographic extent of a project;
- number of persons available;
- skill base of the persons involved: professional scientists or community volunteers;
- type of equipment available;
- logistic constraints;
- data quality;
- data management;
- framework to implement management response;
- feedback to volunteers; and
- budget.

These factors might need to be iterated several times to match the objective with the capacity to execute the project, and the final objective must be made explicit to all participants. One logical starting point is to determine whether a project is strategic or tactical in nature. The former may

Table 3.3.2. State legislation relevant to seagrass management in southeast Australia.

State	Queensland	NSW	Victoria
Legislation	*Fisheries Act* 1994	*Fisheries Management Act* 1994 Fisheries Management (General) Regulation 2010	*National Parks Act* 1975 *Fisheries Act* 1995
Objective	The destruction, damage or disturbance to seagrass (and other marine plants: mangrove, saltcouch, algae, sampfire, melaleuca and coastal she-oak on all coastal lands whether alive or dead)	Prevent "harm" to seagrass (and mangrove, saltmarsh and seaweed whether alive or dead)	*National Parks Act*: "for the protection and preservation of the natural environment . . . " *Fisheries Act*: "protection and conservation of fisheries resources, habitats and ecosystems including the maintenance of aquatic ecological processes and genetic diversity"
Jurisdiction	Private, leasehold or public land	Public land	Public land
Provisions for	"cut, trim or remove seagrass"	"Harm" is defined as "gather, cut, pull up, destroy, poison, dig up, remove, injure, prevent light from reaching or otherwise harm the marine vegetation or any part of it."	"Preserve and protect indigenous flora"
Permit required to "harm"	Yes	Yes	*National Parks Act*: Yes *Fisheries Act*: Yes
Corporate penalties	Yes	Yes	Yes
Individual penalties	Yes	Yes	Yes
Policies and guidelines available	Yes	Yes	Yes
Associated legislation	*Sustainable Planning Act* 2009	*Threatened Species Conservation Act* 1995 *Environmental Planning and Assessment Act* 1979	*Environment Protection Act* 1970 *Water Act* 1989 *Flora and Fauna Guarantee Act* 1988 *Planning and Environment Act* 1987 *Land Act* 1958 *Conservation, Forests and Lands Act* 1987

be to assess natural variation in bed or meadow dynamics and will certainly be long term. A tactical study might attempt to investigate impacts of a perceived disturbance. In the latter case, monitoring will ideally be initiated before change (e.g. dredging) occurs at a specific location, and have an appropriate experimental design, including such features as multiple control or reference sites (e.g. Underwood *et al*. 2000) so that change can unequivocally be attributed to the disturbance.

Seagrasses can change their characteristics naturally over time, with some changes occurring on a predictable cycle, as for example with the loss of leaves during winter months. Other natural changes occur intermittently, such as storm erosion of seagrass beds, but beds can be expected to regrow, although more quickly for some species than others. However, other types of stressors such as land clearance that alters the runoff of sediments and nutrients, thereby increasing turbidity, will reduce photosynthetic capacity of seagrass. Discharge of pollutants into estuarine or nearshore waters can produce immediate and persistent disturbance. Of critical interest to conservation scientists and managers is being able to differentiate between change brought about naturally and that brought about by human disturbance. Such discrimination is difficult given that seagrass ecology is complex, and a matter of interest to professional scientists is “effect size”, which asks the question “How much effort must be used to differentiate a real change (which may be small but critical) from natural variation? One way to envision the issue is to contemplate the number of quadrats needed to determine average % cover. How many quadrats should be used at a site? How many sites should be used to describe a location (large bed or meadow)? Resolving questions such as these to determine effect size is a statistical matter that requires appropriate skills. Unless a mentor is available to resolve statistical issues such as these it would be more appropriate for volunteers to deal with matters such as presence/absence of species, number of beds in a meadow, and depth of the deepest seagrass margin.

The use of community volunteers in monitoring projects has wide-ranging outcomes which are highly beneficial to natural resource managers. However, how these programs are integrated into Natural Resource Management (NRM) across the southeast sector of Australia can be highly variable. As local programs can differ in its scale and purpose, it is a challenge for natural resource managers to determine the best ways to plan and execute projects where the ultimate goal is to integrate various data sets into decision-making framework. Some assistance on this issue will come from an Australia-wide study to determine the applications of “citizen science” by identifying the major factors which influence the provision and use of data collected by volunteers (C. Sbrocchi, pers. comm., 2013).

All monitoring programs, whether conducted by scientific professionals or by members of the community, require clear objectives that lead to appropriate field methods. Community projects need to be framed in the first instance by objective, and then by the resources at hand. It may be necessary to scale down what is proposed in a project so that it can actually be done. When the objective is clear the hard but important question needs to be asked – is it still worthwhile to proceed (the effect size issue) or is some other objective more appropriate? In some cases an over-exuberant launch of a community project has wound down over time due to inadequate person-power or other logistic difficulties. Projects that require regular field sampling are often derailed in the winter months or during inclement weather when volunteers become less than willing to expose themselves to the elements.

Other issues that can prove troublesome are the degree of quality control exercised during data collection. If collection techniques are flawed, appropriate management action cannot be demanded or expected due to uncertainty about conclusions. A dedicated budget is needed to consolidate, archive and summarise data for managers and volunteers. Endless data sets without archival facilities or without resources to provide summary statements have limited value. Volunteers need feedback to sustain interest and engagement.

Nevertheless, there are means by which higher order monitoring can be undertaken by the community, and some well established methods are being used along the southeast Australian coast (Table 3.3.3). These methods include determination of total area, species abundance, per cent ground cover, shoot density, growth rate (e.g. above-ground biomass), or, available seed bank. Sediment composition, as it is readily determined, is often added to field observations.

“Seagrass Watch”, operating since 1988, initially in tropical Queensland but then expanding to other states, has promulgated manuals that identify objectives and procedures for community involvement in seagrass monitoring (McKenzie *et al*. 2003). A number of scientific reports have been produced from Seagrass Watch.

"Sea Search", sponsored by Parks Victoria with commercial partners, university and community volunteers, monitors seagrass and other coastal resources in that State (Koss *et al*. 2005; Browne *et al*. 2013). One of its objectives is to engage the community and this is done via fieldwork to determine the condition of seagrass beds in marine national parks and sanctuaries. A technical manual for field procedures and data entry protocols was developed in 2005 (Koss *et al*. 2005, Table 4). The program was updated in 2012 to include a broader range of methods with varying levels of difficulty to provide opportunities for a range of volunteers with different skill levels and interest, and to help ensure data quality is sufficient to help inform management (Browne *et al*. 2013). Parks Victoria rangers oversee each project and are responsible for data quality and continuity. A number of scientific reports have been produced from Sea Search.

A community project being run by Great Lakes Council is using recreational divers to collect and deploy artificial seagrass to monitor the overgrowth by algae (I. Strachan, pers. comm., 2013). Data from this exercise have been analysed and are the basis for a longer term project.

Along the southeast coast the location of the largest of seagrass meadows have been identified albeit at a coarse scale (West *et al*. 1985; Mount and Bricher 2008; Creese *et al*. 2009). One type of community monitoring could take the form of locating smaller units, i.e., the beds and patches. As an adjunct operation, species can be differentiated

Table 3.3.3. Differential approaches to seagrass monitoring projects.

OPERATOR (Who)	SCALE (Where)	OBJECTIVE (What)	WHEN	HOW	COMMENTS
Individuals or community groups (e.g. NGO)	Patch or meadow	Locate new patches and/or meadows	Once off	GPS: surface and underwater surveys	Quality Assurance/ Quality Control (QA/ QC); Data repository needed
	Patch or meadow	Determine change in perimeter, depth or location	Quarterly/ annually (as resources allow)	GPS	QA/QC; Data repository needed
Mentored groups (e.g. university diving club, recreational fishers, commercial fishers)	Patch or meadow	Locate new patches and/or meadows	Once off	GPS: surface and underwater surveys	QA/QC; Data repository needed
	Patch or meadow	Determine change in perimeter, depth or location	Quarterly/ annually (as resources allow)	GPS	QA/QC; Data repository needed
		Determine change in species composition, density, abundance		Transects, quadrats, lab samples	Can be for macroalgae as well as seagrass

Table 3.3.3. (cont.) Differential approaches to seagrass monitoring projects.

OPERATOR (Who)	SCALE (Where)	OBJECTIVE (What)	WHEN	HOW	COMMENTS
Professional scientists (university, federal, state, local government)	Cell, leaf, or plant	Enhance understanding of seagrass function	At appropriate temporal scales	Various genetic and biochemical techniques	As funding allows
	Patch or meadow	Locate new sites and determine change in perimeter, depth or location at known sites		Quadrats, Photo quadrats, transects	For macroalgae, epiphytes and epizoa as appropriate
	Ecosystem (lagoon, bay, estuary)			Remote sensing via satellite and/or air photo images	Ascertain degree of dieoff
	Ecoregion			Remote sensing via satellite and/or air photo images	Ascertain degree of dieoff

via texts that facilitate field identification (e.g. Sainty *et al*. 2012). A second step, contingent on strategic or tactical needs, is determining the centroid and/or the extent of individual patches, beds and small meadows. As seagrasses occur in irregular distributions that can change over time, and as the time necessary to fix the location of all patches or beds within a meadow may be lengthy, a minimum size of the seagrass area of interest might need to be adopted. Alternatively, in the face of a forecast disturbance, it might be crucial to generate location and extent measurements for even the smallest of patches/beds, particularly where a meadow is already under stress and might be fracturing into smaller and smaller beds.

Direct measurement of change in area or shape of seagrass beds can, where water is clear and where appropriate facilities are at hand, can be readily assessed by the inspection of aerial photographs (Williams *et al*. 2003). Deakin University and Parks Victoria are comparing aerial photography (with near infrared) and satellite imagery (plus LiDAR) for mapping seagrass beds in marine national parks in Victoria. Recent advances in satellite sensors and software capacity mean that routine monitoring of the extent and condition of seagrass beds is becoming more feasible (Dekker *et al*. 2005; Anstee *et al*. 2009). In other locations, such as Moreton Bay where water clarity is reduced, boat and/or shore-based surveys of bed location and extent are undertaken. It was recognised some time ago (Kirkman 1997) that offshore beds of seagrass beds can be constantly moving but maintain their overall mass and therefore any measurements of extent need to be carried out over lengthy time intervals.

For a community project that aims to determine whether the outer margin of a seagrass bed(s) is changing due to:

- turbidity increase/decrease in light,
- erosion due to a change in current direction or velocity, or
- health stressors

regular distance measurements either from fixed shore stations or by the application of a GPS can be used. As a small change over a short time interval might reflect a natural disturbance, management intervention might not be needed in the first instance and repeated measurements would be required. A question arises that in some ways is difficult to answer: what is the degree of change that should stimulate management intervention? If a bed were to contract shoreward by half its width this would almost certainly be an intervention trigger, but what about a relatively small change? Further, if a bed were to maintain its size but shift its location would this be important? These issues

Table 3.3.4. Differences between seagrass monitoring projects in southeast Australia.

Program	NSW DPI	Seagrass Watch	Sea Search
Ambit	NSW	Australia wide - selected locations only	Victorian marine parks and sanctuaries
Objective	Whole-of-state trend	Regional and local trends	Regional and local trends
Coordinator	NSW DPI (Fisheries)		Parks Victoria
Operator	NSW DPI (Fisheries)	Community groups	Community groups
Reference	Creese *et al*. (2009)	McKenzie *et al*. (2003)	Browne *et al*. (2013)
Site visit details	X	X	X
Photographs	(Air photo images)	X	X
Substratum		X	X
Seagrass cover	X	X	X
Species composition	X	X	X
Leaf length		X	X
Shoot density			X
Macroalgal cover		X	X
Epiphyte cover			X
Animals		X	X
Voucher specimen		X	
Data repository	NSW DPI	Seagrass Watch Coordinator	Parks Victoria
Data outputs	NSW DPI	Seagrass Watch Coordinator	Parks Victoria

must be examined within the site-specific context (e.g. occurrence of recent bottom scour due to flooding, or modification of run-off due to a change in land use) and may require outside advice.

An initiative underway in NSW (Office of Environment & Heritage) is the derivation of conceptual models of the consequences of stresses on seagrasses (Figure 3.3.1). OEH is also developing predictive models that can be applied to anticipate the likely occurrence of seagrass at any location in large estuaries such as Lake Macquarie and Tuggerah Lakes; other models under development deal with seagrass growth and seagrass health. Each of these models recognises the primary importance of light regime, bottom stress (erosion/sedimentation due to wind and tidal currents) and sediment chemistry and provides an ability to understand the effects of changes to these variables. The models are subject to revision as more data about ecological processes are acquired.

As indicated, water clarity is an important feature for the sustainability of seagrass beds, with long periods of high turbidity a threat to survival of meadows, and it is the deeper parts of the meadows that are most at risk. In Queensland the monitoring of turbidity is an important part of the government's Healthy Waterways Ecosystem Health Monitoring Program. In NSW the monitoring of turbidity levels in estuaries is a primary indicator in the state's Monitoring Evaluation and Reporting framework (Roper *et al*. 2011).

More complex measurements such as the determination of growth rate, tissue composition, turbidity and incident light (photosynthetically active radiation - PAR) are employed by seagrass scientists to assess changes in seagrass distribution and abundance. The time periods over which these techniques are applied have to be sufficiently long to determine natural and human-induced variation.

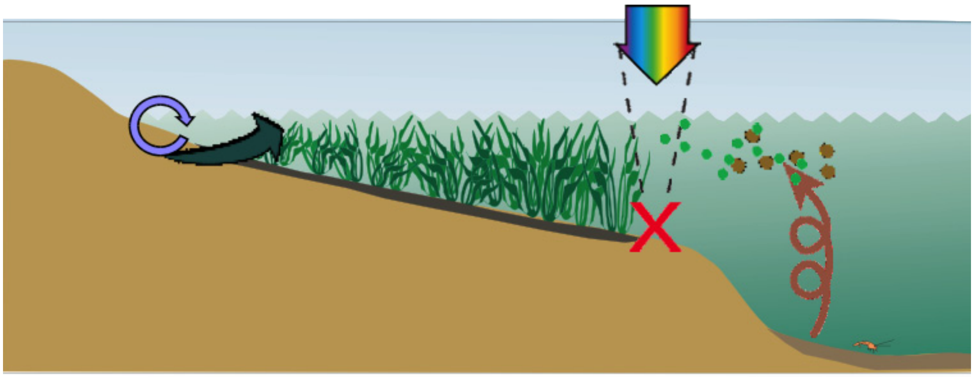

Figure 3.3.1. At its deeper margin (X) the distribution of seagrass is mainly affected by light. The amount of light can be changed by turbidity of the water from external sources **(brown dots)**, or due to re-suspension of sediments **(brown arrow)**, algal growth **(green dots)** or shading. At its upper margin **(purple arrow)**, chemical factors such as concentration of sulphides and oxygen, as well as exposure and desiccation, are important. Physical removal **(dark green arrow)** by waves and currents can also strongly affect seagrass distribution.

In NSW, as part of the NRM monitoring program, a regular census of area of macrophytes is carried out in 15 estuaries on a five yearly basis. Estuaries were prioritised on the basis of previous mapping exercises (Roper *et al*. 2011) and a range of techniques are used to identify and confirm the location of seagrass (and mangrove and saltmarsh). On the basis of comparative imagery studies in Victoria (mentioned above) similar assessments of area are expected to begin on meadows of seagrass in marine parks (S. Howe, pers. comm., 2013).

Hence, "monitoring" as a facet of management can be complex, requiring sophisticated skills and equipment. Alternatively, if an appropriate objective is formed and a suitable understanding of the need for, and type of, monitoring is achieved, monitoring can successfully be done by community volunteers. Any type of monitoring, whether strategic or tactical, whether done by professional scientists or community volunteers, is all too often made irrelevant by the failure to address the questions of what is to be monitored and why the monitoring is to take place, as well as associated matters dealing with the logistics of field sampling, data storage and data summary. Community projects that have scientific mentors or co-ordinators have shown themselves to be capable of deriving considerable scientific data on the extent and health of seagrass beds.

Rehabilitation

The transplantation of seagrass is sometimes invoked as a means by which to rehabilitate denuded areas or create new meadows as offsets in coastal projects that pose threats to existing beds. There appears to have been no projects in southeastern Australia which have successfully engaged this approach. This is in part because of cost as well as the limited Australian success of seagrass transplant projects (Ganassin and Gibbs 2003). However, one apparent success comes from a multi-party exercise in Western Australia that ranks itself as the world's most successful transplant operation. Cockburn Sound and several locations near Albany have seen over 3.1ha and 1ha, respectively, transplanted with high survival rates four years after planting (Oceanica 2011). The techniques used in Western Australia may have merit elsewhere in Australia, but until such time as transplantation and its associated issues (e.g. impact on the donor bed) are resolved it is far better to conserve seagrass in the first instance.

Conclusions

The seagrasses of southeast Australia:

- are limited in their distribution mostly to bays and permanently open estuaries.
- are susceptible to an increasing population density from Melbourne to Brisbane and need careful management to maintain the services they provide such as foreshore protection and provision of habitat.
- occasionally are damaged by storms but can generally be expected to regrow.
- are susceptible to direct damage such as dredging and/or reclamation.
- are also susceptible to indirect damage occasioned by reductions in light due to increased turbidity from inert particles.

- are susceptible to indirect damage occasioned by reductions in light due to increased turbidity from enhanced nutrient concentrations.
- are susceptible to climate change: sea level rise, increased sea surface temperature, increased air temperature (especially for intertidal species).
- can benefit from community monitoring projects provided well-reasoned objectives can be obtained from appropriate field techniques.
- may benefit from transplantation techniques developed elsewhere, but the first priority should be to conserve these species wherever they occur.

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