SIGNIFICANCE OF SEAGRASS ECOSYSTEMS IN COASTAL ENVIRONMENTS

A SCIENCE SUMMARY FOR THE SOUTH-EAST MARINE PROTECTION FORUM
Seagrasses are marine flowering plants that occur in intertidal and shallow subtidal zones in tropical and temperate regions (Kaiser et al. 2005; Gillanders 2007). These marine plants form patches and extensive beds in soft-sediment environments, where seagrass meadows can span up to several square kilometres. Individual plants consist of shoots and leaves that are evident above the sediment surface, while below-ground material includes rhizomes (horizontal stems) that connect individual plants and roots that anchor the plants into the sediment. In well-established seagrass meadows, the root-rhizome matrix can be considerable, forming a thick mat within the sediment (Kuo & Den Hartog 2006).

Seagrasses are highly productive coastal habitats that provide a range of key ecosystem functions and services (Duarte & Chiscano 1999; Gillanders 2007). Seagrasses have been recognised to support one of the most valuable ecosystems worldwide, and represent a significant ecological and economical component of coastal habitats (Costanza et al. 1997).

New Zealand has only one species of seagrass, Zostera muelleri (formerly known as Z. capricorni, Z. novazelandica, or Z. mucronata), which also occurs in Australia and Papua New Guinea (Jones et al. 2008; Matheson et al. 2011). Zostera muelleri is a relatively small species, with leaf lengths of less than 30 cm (mostly about 10 cm) and leaf widths of 0.1 to 0.4 cm (Matheson et al. 2009). Although this species produces seed in Australia, flowering and seed production are rare in New Zealand (Turner & Schwarz 2006). Instead, the maintenance and expansion of Z. muelleri beds are largely dependent on vegetative reproduction by rhizomes and the dispersal of vegetative shoots. Owing to this feature, Z. muelleri has low genetic diversity in New Zealand, with limited gene flow between populations (Jones et al. 2008; Matheson et al. 2011).

Zostera muelleri occurs throughout New Zealand, where it has a wide geographical distribution from Northland to Stewart Island (Inglis 2003). This species primarily inhabits intertidal sandflats of sheltered habitats such as harbours and estuaries, and also shallow-subtidal sediments in northern regions. Areas within the south-east marine protection planning forum area, sheltered environments in Otago and Southland contain extensive seagrass areas and patches on intertidal sand and mudflats (Figure 1). Within this southern region, a number of studies provide information on different aspects of Z. muelleri in local estuaries and inlets, including Otago Harbour (e.g., Miller 1998, Berkenbusch et al. 2007, Leduc & Probert 2011). The spatial extent and cover of Z. muelleri beds and patches can vary over time, including seasonal changes such as have been noted in Otago Harbour (see Turner & Schwarz 2006). Seagrass cover in an intertidal area of Otago Harbour declined between autumn and spring, and changed little in the subsequent spring-autumn period, while low-density seagrass increased in area over the same period.

Although there is little information on the historical distribution of Z. muelleri in New Zealand, anecdotal evidence suggests that seagrass meadows were previously more widespread than their present-day distribution suggests (Inglis 2003). For example, at the end of the 19th century, seagrass was sufficiently common to be considered as an export commodity based on its potential value as a filling material for mattresses and furniture overseas.

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Figure 1. Underwater image of *Zostera muelleri* (leaf length approx. 10 cm) at Papanui Inlet, Otago Peninsula (top), and extensive *Z. muelleri* meadow at Blueskin Bay during low tide (bottom).

Source: Katrin Berkenbusch
Seagrass beds stabilise soft-sediment environments, influence hydrodynamics and nutrient regimes, oxygenate sediment, provide habitat, shelter and food for other species, and impact on the structure and functioning of associated communities (Table 1) (Gillanders 2007; Townsend et al. 2015). Other ecosystem services provided by seagrasses (documented in a European study) involve their use as feed for domestic animals (e.g., cattle), as garden material, and for construction (Terrados & Borum 2004). Direct benefits of seagrass ecosystems by humans also involve recreational activities, such as boating, fishing and walking.

A New Zealand ranking of different coastal marine environments highlights the diverse range of ecosystem services provided by seagrass Z. muelleri beds, including primary production, the provision of habitat, regulating services (populations and communities, food webs, ecological functioning), sediment retention, nutrient regeneration, carbon (long-term) storage, gas balance (e.g., exchanges with the atmosphere), bioremediation of contaminants, storm protection, (indirect) provision of food, and spiritual and cultural well-being (Townsend et al. 2015). Although there is little information available of the cultural value of seagrass and its direct uses in New Zealand, Inglis (2003) suggested that Z. muelleri rhizomes may have been used as food by Māori, while leaves were sometimes used to decorate clothing.

**TABLE 1. OVERVIEW OF ECOSYSTEM FUNCTIONS AND SERVICES PROVIDED BY SEAGRASSES IN COASTAL ENVIRONMENTS**

<table>
<thead>
<tr>
<th>Ecosystem function and service</th>
<th>Description</th>
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<tbody>
<tr>
<td>Primary production</td>
<td>Photosynthesis (generation of biomass/plant material from solar energy).</td>
</tr>
<tr>
<td>Trapping and recycling of nutrients</td>
<td>Mitigation of coastal eutrophication.</td>
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<tr>
<td>Oxygenation of sediment</td>
<td>Release of oxygen by roots.</td>
</tr>
<tr>
<td>Stabilisation of soft sediment; baffling of current and wave action, protecting sediments and coastlines from erosion</td>
<td>Roots and rhizomes stabilise the sediment, preventing erosion; seagrass leaves baffles wave action and currents, create low-energy environment.</td>
</tr>
<tr>
<td>Sediment retention</td>
<td>Through stabilising effect and baffling of water flow (see above).</td>
</tr>
<tr>
<td>Provision of habitat, refuge, shelter, nursery grounds</td>
<td>Above- and below-ground structure and attachment surfaces; creation of low-energy environments; creation of extensive heterogenous coastal ecosystems.</td>
</tr>
<tr>
<td>Provision of food</td>
<td>Direct grazing on plant material; indirectly by providing habitat to prey species that are targeted by other members of the food web (and humans), overall increase in food availability.</td>
</tr>
<tr>
<td>Enhancing and maintaining biodiversity</td>
<td>Habitat use by fish, invertebrates (including commercial species), marine mammals, wading birds, microbial communities, single-celled plants, filamentous algae.</td>
</tr>
<tr>
<td>Filtering of the water column, sink for land-derived nutrients</td>
<td>Absorption of sediment, organic matter, excessive nutrients, and other land-derived substances and pollutants.</td>
</tr>
<tr>
<td>Export of organic matter/carbon</td>
<td>Seagrass material and detritus, algae growing on seagrass blades.</td>
</tr>
<tr>
<td>Historical and cultural values</td>
<td>Used for medicine, food, cultural life.</td>
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</table>
One important role of seagrass plants is their stabilising effects in coastal habitats (Madsen et al. 2001). The root-rhizome network of seagrass meadows stabilises sediment and reduces erosion, while shoots and leaves extend into the water column, slowing currents and buffering waves. This influence on coastal hydrodynamics has a direct impact on sediment transport, as the slowing of water currents leads to the trapping of sediment, enhanced deposition of fine particles, and a reduction in resuspended sediment. Furthermore, the creation of a low-energy environment is conducive to the retention of organic matter, including seagrass detritus. On a larger spatial scale, the stabilising effects of seagrass areas are important for the natural protection of coastal habitats and shorelines.

In addition to influencing physical properties, seagrasses also impact on chemical characteristics of coastal ecosystems through their influence on organic matter transfer (Duarte & Chiscano 1999). Compared with other marine primary producers, seagrasses are characterised by high biomass and productivity, estimated at nearly 3 times the productivity of macroalgae and 8 times that for phytoplankton. The large amounts of biomass provide high quantities of carbon to coastal ecosystems, supporting food webs and exports into other marine areas.

Seagrasses also play a pivotal role in the cycling, uptake and export of nutrients, which are released through the leaching of living and dead plant material, the export of leaves and fragments, and the transfer of energy via grazing organisms (Hemminga & Duarte 2000, Turner & Schwarz 2006). As below-ground material is decomposed via microbial and chemical processes (e.g., denitrification), nitrogen contained in roots, rhizomes and detritus becomes available in the sediment and the overlying water column. In turn, as seagrass plants take up nutrients, they further contribute to the cycling of nutrients, and increase the productivity of coastal ecosystems. The direct uptake of nutrients by the plants, and through seagrass-mediated sedimentation processes also involve the effective removal of land-derived nutrients from the water column, highlighting the role of seagrasses in the mitigation of coastal eutrophication (Short 1987). In addition, seagrasses help to reduce habitat degradation by binding organic pollutants, and mitigate climate change by sequestering atmospheric carbon dioxide in photosynthetic processes. Although the latter aspect is relatively small on a global scale compared with phytoplankton, the high productivity of seagrass meadows means that their influence is disproportionate in coastal ecosystems (Green & Short 2003).

The ecological importance of seagrass landscapes has also been highlighted in a large number of studies that document higher species richness, diversity and abundance in seagrass areas compared with bare sediments (e.g., see review by Bostroem et al. 2006). Although the relative importance of seagrass may vary, depending on factors such as the location, size of the seagrass area and the position within it (for New Zealand examples see Turner et al. 1999, van Houte-Howes et al. 2004), the high value of seagrass landscapes is well-recognised at a global scale (Green & Short 2003, Orth et al. 2004). Through the provision of physical structures below and above the sediment surface, seagrasses increase the structural complexity of soft sediments, providing habitat for organisms living on and amongst seagrass plants. These organisms range from single-celled plants, filamentous algae, and sessile epifauna that are attached to shoots and leaves, to mobile animals within and above the sediment, such as crustaceans and fish species (Turner & Schwarz 2006). Furthermore, the low-energy environment provided by seagrass meadows is used as a spawning ground (e.g., by fish), encourages the settlement of larvae, and provides shelter for other species, including juveniles (Beck et al. 2001; Polte & Asmus 2006). The provision of habitat and refuge from predation by seagrasses (including in New Zealand) has been attributed to their significant role as nursery areas for juvenile fish, including species that are targeted in commercial and recreational fisheries (Jackson et al. 2001, Inglis 2003, Morrison et al. 2014a,b). In New Zealand, the reduction in water flow and higher food availability within seagrass beds has been linked to the importance of Z. muelleri as habitat for juvenile snapper (Parsons et al. 2015).
In addition, seagrass plants (and also algae growing on them) provide food for grazers (herbivores), and also for detritus-feeders (detrivores) that consume broken-down (decomposed) seagrass material (Valentine & Heck 1999, Moncreiff & Sullivan 2001, Barberá et al. 2013). These consumers in turn attract other consumers and predators, so that the seagrass habitat reflects an integral component of complex coastal food webs. Primary and secondary consumers include organisms that reside permanently in seagrass beds (e.g., macroinvertebrates such as intertidal mud crabs) or use them as feedings grounds only, such as fish and wading birds.

New Zealand studies confirm the significance of Z. muelleri meadows as “hotspots” of biodiversity and productivity, involving macroinvertebrate and fish assemblages (Battley et al. 2011; Morrison et al. 2014a). For example, subtidal seagrass meadows in northern New Zealand represent important nursery areas for juvenile snapper and trevally, while these areas in Southland support higher densities of pipefish and leatherjackets (Morrison et al. 2014a). Seagrass fragments form also part of the diet of some fish species, such as garfish (or New Zealand piper), and a number of invertebrates feed on live Z. muelleri material and detritus (e.g., mud crab Macrophthalmus hirtipes, Woods & Schiel 1997).

Studies from Otago document the importance of seagrass in coastal habitats in southeastern New Zealand, for example as a food source for resident macroinvertebrates, and as a structuring agent of resident benthic communities (Leduc et al. 2006; Berkenbusch et al. 2007). At Blueskin Bay and Harwood/Otago Harbour, seagrass material constituted a significant component of the diet of intertidal macrofauna residing in Z. muelleri beds, particularly in late winter (Leduc et al. 2006). Seagrass material contributed 24 to 99% to the diet of a diverse range of macroinvertebrates, including crustaceans (mud crab Macrophthalmus hirtipes and ghost shrimp Bifarius filholi), bivalves and gastropods (Macomona liliana, Diloma subrostrata, Amphibola crenata), and polychaetes (lugworm Abarenicola affinis).

On a regional scale, Z. muelleri consistently determined the structure of associated macroinvertebrate communities across different-sized inlets in Otago, where seagrass areas were characterised by distinct community patterns that persisted in summer and winter (Berkenbusch & Rowden 2007). The two environmental factors that best explained these patterns were proportion of sediment fines and the amount of seagrass debris, confirming the functional role of Z. muelleri in these habitats. Similarly, the establishment of Z. muelleri patches in previously unvegetated areas (via transplantation) resulted in a distinct shift in macrofaunal community composition within an Otago inlet (Papanui Inlet), including higher relative abundances of distinguishing taxa (Berkenbusch et al. 2007).

The observed patterns in community structure were correlated with a number of variables directly and indirectly linked to seagrass (e.g., number of shoots, above- and below-ground biomass, percentage of sediment fines), further highlighting the ecological significance of this seagrass species.

In a global comparison, seagrasses have been identified as one of the most valuable ecosystems based on their net primary productivity alone (Costanza et al. 1997, 1998). Although placing a monetary value on ecosystems services and functions is inherently difficult, these global studies attempt an economical assessment of different ecological systems and “natural capital stocks”. These studies clearly show that seagrasses (combined with algal beds) are top-ranking, with their value (at a minimum) estimated at USD 19,004 per ha (10,000 m²) per year, following closely behind the highest-ranking ecosystems estuaries, and swamps/floodplains. For New Zealand, this value was estimated at NZD 40,130 per ha per year (van den Belt & Cole 2014).
THREATS TO SEAGRASS HABITATS

Throughout its distribution in New Zealand, Z. muelleri is vulnerable to a wide range of impacts, particularly through its occurrence in coastal environments. While a general lack of distributional data makes it difficult to assess changes in the spatial extent of this species, information that is available indicates that seagrass beds were considerably more widespread (and extensive) than their present-day distribution suggests (Turner & Schwarz 2006). Large-scale losses of seagrass habitat have been documented in a number of estuaries and inlets, including Kaipara Harbour (Northland), Manukau and Waitemata harbours (Auckland) and Avon-Heathcote Estuary (Christchurch), although there has been regeneration of seagrass in some areas (Matheson et al. 2011; Morrison et al. 2014b,c).

In New Zealand and elsewhere, seagrasses are exposed to a range of natural and anthropogenic threats, including direct physical damage, increased sedimentation, and declining water quality (Table 2)(Short & Wyllie-Echeverria 1996; Duarte 2002; Inglis 2003; Orth et al. 2006; Turner & Schwarz 2006; Bjoerk et al. 2008). Human activities that damage and destroy seagrass plants include direct physical impacts such as trampling, horse riding, four-wheel drive vehicles, and boat moorings (Walker et al. 1989; Hastings et al. 1995; Inglis 2003). For example, Inglis (2003) noted the impact of horse riding and off-road motorbikes on seagrass patches in Otago Harbour, where the associated physical disturbance led to large unvegetated patches that took considerable time (more than one year) to be re-colonised by seagrass. While these impacts may be localised, they can result in the fragmentation of extensive seagrass beds, affecting the physical integrity and quality of these habitats, with flow-on effects for associated communities (Frost et al. 1999; Bell et al. 2001; Bostroem et al. 2006).

Adverse effects on coastal seagrasses also arise from changes in land use and coastal development, such as deforestation, the construction of causeways, and dredging (Green & Short 2003; Efremjejer & Lewis 2006). Repercussions from these activities generally occur over a large spatial scale, and include the smothering of seagrass plants by increased sediment runoff, increased sediment accretion, and changes to bottom sediments that make the habitat unsuitable for seagrass plants. Furthermore, elevated concentrations of suspended sediment (increased turbidity) can reduce light levels in the water column, negatively impacting on photosynthetic processes that are essential for seagrasses (and other plants) to produce chemical energy and build biomass. Overall, changes to sediment dynamics have been identified as one of the most significant threats to coastal ecosystems, including seagrass habitats in New Zealand (Green & Short 2003; Inglis 2003; Morrison et al. 2009).

In addition to sediments, other impacts on water quality such as excessive nutrients, discharge of untreated sewage, and pollutants have been also been linked to the deterioration and loss of seagrass habitats (Walker & McComb 1992; Burkholder et al. 2007). High nutrient loads (eutrophication) support the proliferation of fast-growing algae that may smother or outcompete seagrasses. Examples of seagrass losses in New Zealand involve the early discharge of untreated sewage and effluent into Avon-Heathcote Estuary, and the release of limestone washings from a cement plant into Whangarei Harbour (Inglis 2003). In Tauranga Harbour, a 34% decrease in the spatial extent of seagrass beds over a 40-year period (1959 to 1996) was largely attributed to sediment and nutrient runoff (Park 1999). Other compounds that have been identified as potentially harmful to seagrasses include heavy metals, organic pollutants, bio- and herbicides, antifouling agents, and oil and chemical oil dispersants, but information regarding these pollutants and the decline of seagrass is scarce (see Turner & Schwarz 2006, Bjoerl et al. 2008).

Similarly, introduced species have the potential to negatively affect seagrasses, but there have been no New Zealand records to date. Nevertheless, direct and indirect adverse effects of non-indigenous species on native seagrasses have been documented elsewhere, with some reports involving organisms (or related species) that have been introduced to New Zealand (Turner & Schwarz 2008; Creese et al. 1997; Reusch & Williams 1998, De Villèle & Verlaque 1995).

Potential threats to seagrasses also include repercussions from climate change, such as the loss of habitat by rising levels, an increase in the frequency of severe storms, and increases in sea water temperature (Short & Neckles 1999; Bjoerk et al. 2008). Although the exact nature of these impacts is difficult to predict, they have the potential to profoundly affect the distribution of seagrasses, including Z. muelleri.
Recognition of the overall importance of seagrasses has resulted in a call for their effective management and conservation. In spite of this understanding, seagrasses have generally received little protection on a global scale (Green & Short 2003; Orth et al. 2006). Effective protection measures would need to focus on sustaining the health and function of seagrass plants, and also the wider conservation of coastal ecosystems that contain seagrass landscapes (Turner & Schwarz 2008).

For Z. muelleri, awareness of on-going threats, and the decline of seagrass beds in some areas of New Zealand has prompted scientists to question the International Union for Conservation of Nature overall ranking of “Least Concern” for this species in New Zealand (Matheson et al. 2011). Based on the limited genetic variability and reproductive potential (i.e., largely vegetative reproduction) in this country, these authors suggested that the re-assignment to the Red List category “Endangered” is warranted.

**TABLE 2. SUMMARY OF THREATS TO SEAGRASS ECOSYSTEMS IN COASTAL ENVIRONMENTS, INCLUDING NEW ZEALAND**

<table>
<thead>
<tr>
<th>Threat</th>
<th>Impact</th>
<th>Repercussion</th>
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<tbody>
<tr>
<td>Physical damage</td>
<td>Grazing, storms, sediment disturbance, coastal construction, human activities in seagrass habitat (e.g., trampling, horse-riding, boat moorings and anchors, four-wheel drive vehicles).</td>
<td>Removal, damage and dislodging of seagrass plants, compaction of sediment, fragmentation of seagrass beds, loss of seagrass habitat.</td>
</tr>
<tr>
<td>Deteriorating water quality</td>
<td>Excessive nutrient and sediment loading, pollutants from diffuse and point sources.</td>
<td>Reduced photosynthesis and primary production, reduced plant health, competition with algae, including smothering.</td>
</tr>
<tr>
<td>Increased sedimentation</td>
<td>Changes to sediment properties so habitat becomes unsuitable, increased sediment levels in the water column, decreasing light levels, turbidity.</td>
<td>Smothering of seagrass plants, inability to anchor within the sediment, reduced photosynthesis and primary production, reduced plant health.</td>
</tr>
<tr>
<td>Introduced species</td>
<td>Competition, prevention of vegetative seagrass growth, displacement.</td>
<td>Reduction in density or abundance, loss or replacement.</td>
</tr>
<tr>
<td>Disease</td>
<td>Slime mould disease.</td>
<td>Die-back of individual plants and loss of seagrass plants across large areas.</td>
</tr>
<tr>
<td>Sea level rise, climate change</td>
<td>Increased temperature, reduction in habitat through sedimentation and changes from intertidal area to wetland.</td>
<td>Increased susceptibility to disease, reduced primary production, decrease in abundance or density, loss of seagrass.</td>
</tr>
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</table>

**MANAGEMENT CONSIDERATIONS**

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REFERENCES


