Going with the flow: Facilitating seagrass rehabilitation

By Stephanie Seddon

Techniques used to-date have focused on vegetative transplants that, while reasonably successful, may impact donor meadows. Can larger areas of seagrass be restored using seedlings and other non-destructive 'recruitment facilitation' methods?

Figure 1. The restoration and rehabilitation of seagrass meadows not only involves the development of transplanting techniques but also requires diving skills. Divers here are coring seagrass from a *Posidonia* meadow at 6 m depth. At this relatively shallow depth a tank of air will last around 75 min, but each diver is limited to a maximum of 4 dives per day. Photo by Sonja Venema (SARDI Aquatic Sciences).

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Introduction

Seagrass meadows form key ecosystems that can be found growing in relatively sheltered coastal environments throughout temperate and tropical waters. In recent decades seagrass loss has become an increasing problem worldwide, owed in large to the desire for humans to live near the coast where we create extensive infrastructure and modifications to the marine environment, including discharging pollution directly into marine waters (Shepherd *et al.* 1989; Walker & McComb 1992; Short & Wyllie-Echeverria 1996).

One of the unfortunate consequences is the loss of seagrass meadows and associated communities of plants and animals. Seagrasses, like terrestrial grasses, are well known for their ability to consolidate and bind sediments (Fonseca *et al.* 1985; Walker & Woelkerling 1988; Fonseca 1996; Koch 2001), consequently their loss destabilizes the seafloor leading to sediment erosion and usually high turbidity associated with the resuspension of fine sediments,

Box 1. Seagrass restoration terminology

Seagrass restoration terminology is similar to terminology used for terrestrial restoration:

- Seagrass '**restoration**' refers to returning a seagrass meadow its pre-existing condition (i.e. same species composition, distribution, abundance and ecosystem function).
- Seagrass '**rehabilitation**' is a more general term and implies returning seagrass to an area where seagrass meadows previously existed (but not necessarily the same species, abundance or equivalent ecosystems function).
- '**Meadow creation**' is the establishment of seagrass meadow in an area that has not previously been known to support seagrass.

NB. These definitions are based on interpretations by Gordon (1996) and Lord *et al*. (1999)

contributing to overall poor water quality perpetuating further seagrass loss (Larkum & West 1983; Seddon *et al*. 2003).

In cases where the sources of seagrass loss have been removed or ameliorated, regeneration is usually notoriously slow (e.g. Kirkman 1989; Meehan & West 2000). Sometimes the loss of seagrass can lead to irreversible changes in the nature of the environment and habitat, rendering the site no longer suitable for seagrass survival (e.g. West *et al*. 1990). One of the most significant meadow-forming seagrasses in Australia is *Posidonia* (commonly known as ribbon, strap or tape weed). There is considerable evidence that *Posidonia* meadows, and similar slow-growing seagrasses elsewhere in the world, can take decades to recover after a major disturbance (Kirkman 1997; Meehan & West 2000). In contrast, seagrasses with faster-growing rhizomes, such as *Heterozostera* (Table 1), have been known to colonize bare areas within 6 months (Kirkman 1989). Even so, if the disturbance is large enough, even recovery by fast-growing species may take several decades (Olesen & Sand-Jensen 1994; Orth *et al*. 1994).

The increasing loss of seagrass habitat and its slow regeneration time are issues that have concerned people for a long time and has provided the impetus for marine researchers to direct their attention and efforts toward developing methodologies for seagrass restoration and rehabilitation, or in some cases, meadow creation (Fig. 1, Box 1).

Seagrass restoration to-date

Restoration underwater, and of seagrasses in particular, is a relatively recent endeavour when viewed against developments in habitat restoration in terrestrial environments (Box 2). Some early pioneering attempts at seagrass restoration in the United States were made by Addy (1947; cited Fonseca *et al*. 1998) and Philips (1960; cited Fonseca *et al*. 1998) who reported varying degrees of success. Over the last 20–30 years, however, there has been intense activity and developments in this area, but unfortunately a large proportion of these seagrass restoration attempts have only resulted in limited transplant survival and coverage. For instance, of the 53 restoration projects Fonseca *et al*. (1998) reviewed, only 5% of the plantings of sprigs or cores had 100% survival, whereas, the mean planting unit (PU) survival for these studies was 42%, so that many of these projects would require replanting to attain the desired coverage.

In Australia, comparatively less effort has been directed toward studies on seagrass restoration, despite the significant declines in seagrass coverage that have occurred in Australian waters over recent decades

Table 1. Comparison of colonizing potential and rates of expansion for common Australian temperate seagrasses. Adapted from Kirkman and Kuo (1990) and Clarke and Kirkman (1989).

Species	Availability of seeds	Seedling spread	Seedling holding	Rhizome elongation (cm y^{-1})	Root penetration (cm)	Colonizing ability
P. australis *P. sinuosa* *P. angustifolia*	Dec–Jan once/year	slow	medium	0–30*	15–25	poor
A. antarctica *A. griffithii*	once/year	slow	high	20–50	10–20	some
H. tasmanica	Jan, Feb	probably fast	low	100–200	4–10	good

*Mean rhizome extension rate for *P. australis* was 21 cm y^{-1} at Jervis Bay, NSW (Meehan & West 2000).

In Oyster Harbour, Western Australia, the rhizome extension rate ranged between 8–26 cm/year for *P. australis* and 8–15 cm/year for *P. sinuosa* (Cambridge *et al*. 2000).

Box 2. Constraints of Working Underwater

From the perspective of the practical application of restoration ecology, there are several significant factors that define marine environments from terrestrial – the most obvious being working underwater. These add another layer of logistical considerations and planning that have, no doubt, hindered the progress of habitat restoration in the marine environment in general.

Water in marine systems in many ways can be seen as analogous with the *atmosphere* in terrestrial systems. For example, both wind and water can erode the substrate exposing root systems and dislodging plants, and both form a medium which transports gametes (pollen) and disperses propagules (fruits, seed and seedlings); all fundamental processes in any plant community. Particularly in exposed intertidal and shallow subtidal environments, where wave action is a constant and significant force influencing communities, perhaps more so than the wind does in most terrestrial environments.

Unlike air that we can breath, however, water constrains marine researchers in many ways. For example the amount of time SCUBA divers can work underwater on a given dive and within a 24-h period, the window of opportunity for working in intertidal environments, and, in general, any task underwater seems to take at least twice as long as it does on land (Fig. 1)! Additionally, 'bad' weather (specifically strong wind and seas) precludes safe access to sites located in the sea more often than on land.

The net result is that restoration efforts underwater require a lot of time, skilled workers, specialist equipment, and a healthy financial budget. To add yet another significant challenge, relatively little is known about the basic biology of most marine organisms, including seagrass, and a lack of knowledge about life history strategies in particular (e.g. reproduction, growth and recruitment) make it difficult to design appropriate techniques to maximize success. Nevertheless, in spite of these considerable challenges, some good progress with seagrass restoration and rehabilitation has been made.

Figure 2. Coring seagrass is a common technique used to collect donor material for transplanting to the rehabilitation site. This diver has just extracted a plug of seagrass (*Amphibolis antarctica*) using a 10-cm PVC core, from a donor meadow off Henley Beach in Adelaide, South Australia. Photo by David Miller (SARDI Aquatic Sciences).

(Walker & McComb 1992). The majority of the research has occurred over the last 10–15 years, with most of this activity centred in Western Australia – the location of highest seagrass diversity in the world (Walker 2003) and so a hotspot for seagrass research in general, although some early work on restoration methodologies was initiated by Larkum (1976) in Botany Bay (NSW). A comprehensive review by Lord *et al.* (1999) found that there had only been a total of 21 restoration projects in Australia in the 20 years prior to 2000, with over 60% based in Western Australia. As found in the United States and Europe, success has been limited, with by far the majority of failures in Australia attributed to high wave action, particularly as a result of storm activity (e.g. West *et al.* 1990; Paling 1995; Paling *et al.* 2001a).

Vegetative transplanting techniques

Many different transplanting and planting methodologies have been developed and tested over the years (Box 3 and Figs 1

Figure 3. The need to salvage large areas of seagrass as a result of sand mining operations in Western Australia led to the development of submergible machines (such as ECOSUB1 and 2) capable of transplanting large sods of seagrass. The main advantage of large sods is that they have a greater mass and a better rate of survival in high wave energy environments compared with those transplanted by hand. Clockwise from top left: (a) ECOSUB2 and accompanying sod shuttle prior to launching (photo reproduced with permission of Cockburn Cement Limited, Western Australia); (b) a diver storing a seagrass sod in the ECOSUB2 sod shuttle at Success Bank in Western Australia; and (c) commercial divers operating ECOSUB2 underwater (photos courtesy of Brian Richards, Murdoch University).

and 2), with varying degrees of success depending on factors such as species, sediment type and current speeds. Success with traditional techniques is highly variable, as discussed earlier, but even when high PU survival and good coverage are reported, there are limits to the area that can be realistically restored or rehabilitated using these techniques.

Getting enough areal coverage is a major problem. While acknowledging that failures are common, Lewis (1987) concluded that there have been successful restoration and meadow creation projects of up to 6 ha in size. This is a huge area of seagrass for divers to transplant. However, even this falls well short of the area required to rehabilitate many of the sites of significant seagrass loss in Australia and elsewhere.

Recently a team in Western Australia lead by Eric Paling developed mechanical techniques to enable large sods of seagrass to be extracted and transplanted. These sods have a much greater mass than cores and, therefore, better anchorage in high wave energy environments compared with cores and sprigs. In 1996 Ocean Industries Pty., on behalf of Cockburn Cement Ltd, constructed ECOSUB1 – a purpose built, fully submergible machine capable of transplanting large sods measuring approximately a quarter of a m^2, designed as part of an operation to salvage seagrass removed as a result of a sand mining operation (Paling *et al.* 2001a). Later in 2000, ECOSUB2 (Fig. 3 and Box 3) went into operation with a significantly improved design enabling sods of twice the area (and considerably greater mass) of ECOSUB1 to be extracted, plus the addition of an extra storage unit (shuttle), greatly increased the number of planting units that could be transplanted per day from about nine sods, to an estimated 75 sods. Average long-term survival of the mechanically transplanted sods, around 70% over 3 years for ECOSUB1, has proven to be much higher using this technique than other transplant methods (cores and sprigs) used in similar locations (Lord *et al.* 1999; Paling *et al.* 2001b).

Even still, mechanical transplantation by ECOSUB2 at the maximum predicted rate of 75 sods per day – approximately 40 m^2 of 100% seagrass cover (Paling *et al.* 2001b), which could potentially cover 227 m^2 per day at the planting site (assuming 1 m between sods), would still take 44 days to plant just 1 ha.

Need for new technologies to restore larger areas

It is clear from these studies and many more documented in the grey literature, that it is possible to successfully regenerate small-scale seagrass loss (several hectares at most). However, many of the problem locations in Australia, and indeed worldwide, have lost hundreds and even thousands of hectares of seagrass habitat (Walker & McComb 1992; Short & Wyllie-Echeverria 1996). What new techniques might be developed to address these situations?

To add a further complication, there has been considerable concern about the damage caused by traditional techniques that depend upon donor meadows (e.g. cores and sprigs) and for this reason, many believe that these vegetative techniques should not be used for large-scale projects (especially for slow-growing seagrasses such as *Posidonia* or *Thalassia*). As Lewis (1987) points out,

> 'the future of seagrass restoration and creation efforts will depend increasingly on the availability of plants obtained without damage to existing healthy seagrass meadows . . . or through salvage efforts'. (p. 154)

Evidently there is a need for inexpensive methodologies, in terms of time, labour and materials, in order to replant large areas of seagrass loss. One relatively new area of focus in Australia involves the use of seagrass seeds and seedlings to rehabilitate an area, sometimes referred to as donor meadow independent methods (Box 3 and Fig. 4), because they do not require mature seagrass to be extracted from healthy meadows – a major consideration in a region where seagrass is scarce or significant areas have been lost.

Might it be possible to achieve restoration of larger areas, and reduce impacts, by broadcasting seed or planting seedlings, thereby relying more heavily on facilitating natural regeneration?

Facilitating natural recruitment on a larger scale?

Like terrestrial grasses, seagrasses have two forms of propagation; sexual (i.e. seeds) and vegetative (i.e. rhizome extension). Many seagrasses are prolific annual fruiters, but there is evidence that some species are biannual or perhaps even sporadic fruiters depending on the location, and possibly also environment factors that we are yet to determine (Kirkman 1998; Seddon *et al.* 2004b). Regardless of mode of sexual reproduction (e.g. release of fruits, viviparity), most species spread as a result of vegetative methods rather than by recruitment of seedlings (Kuo & Kirkman 1996).

For seagrasses that do produce seeds, there are two significant processes that influence whether an area of seagrass loss is able to regenerate naturally and where recruitment facilitation could play an important role; fruiting and recruitment. For instance, circumstances can occur where there is an overall lack of recruitment success owing to extremely low (or absent) fruiting for a given year. This could happen when there is very little of the original meadow left, or perhaps existing meadows are under metabolic stress and unable to sustain the energy reserves required for fruiting. Second, circumstances can occur where fruiting occurs in high numbers but there is a lack of recruitment success. This could happen if seedlings are unable to attach or remain attached as a result of storms and strong currents, or if the seafloor is unconsolidated, or in some cases if the seeds/seedlings just don't make it to the location of seagrass loss. Tidal and wind driven currents may represent a barrier to recruitment if the prevailing currents at the time of fruiting simply do not carry the propagules to areas of seagrass loss (e.g. Box 4). Furthermore, even if there has been good recruitment, seedlings may not survive due to factors such as poor water quality and associated factors such as smothering and shading due to excessive algal growth.

Trials involving broadcast seed

Assuming that poor water quality is not an issue, an important consideration for all restoration programs (e.g. Fonseca *et al.* 1998; Meehan & West 2002), one of the simplest ways to maximize the success of any given recruitment event may be to collect the fruits and disperse the seed or seedlings at desired locations to enhance recruitment. For example in Chesapeake Bay (USA) good results have been achieved by broadcasting eelgrass (*Zostera marina*) seeds over large areas. In this case around 15% of viable seeds became established, improving to 41–56% when protective burlap bags were used (Orth *et al.* 1994; Harwell & Orth 1999).

There are a couple of prerequisites that make the seed broadcast method possible with regard to large-scale seagrass rehabilitation in the US. First, *Z. marina* is a prolific annual fruiter and, therefore, a reliable source of abundant propagules (Granger *et al.* 2000), and second, the prevailing hydrodynamic conditions in Chesapeake Bay are relatively calm, that is, low swell. Although Orth *et al.* (1994) state that the current speed is 'quite high', up to 1.2 cm s^{-1} (0.5 m s^{-1} is considered too strong for most restoration attempts; Fonseca *et al.* 1998), they postulate that this is not a problem because the small-scale topography shields the tiny seeds from strong currents. In Australia, there are several relatively small, fast-growing endemic species (e.g. *Z. mucronata*, *Z. muelleri* and *Heterozostera tasmanica*) that are likely to be amenable to reseeding via the broadcast method. Unfortunately the second prerequisite rules out most sites in temperate Australia as candidates for the seed broadcast method, as most sites are subject to high current speeds and more importantly, strong swell.

Regeneration niche improvements

Recruitment facilitation is a method researchers are starting to seriously consider with a view to large-scale seagrass rehabilitation in Metropolitan Adelaide (South Australia), where over 5200 ha of seagrass has been lost over the last 50 years (Seddon 2002). In particular, those of us involved with seagrass rehabilitation in South Australia believe that we should be working with natural life history processes, such as reproduction and recruitment, by enhancing the success of recruitment events (through the capture of seedlings) and facilitating seedling survival and subsequent spread via lateral expansion. To this end, we recently started investigating methods of trapping seedlings using biodegradable hessian matting (a material previously used in dune revegetation projects and a good substitute for remnant seagrass fibre mat) and encouraging the seedlings to attach and grow (Fig. 5). Preliminary results show that *Amphibolis* seedlings do effectively attach to the hessian strips, with initial numbers up to 18 seedlings per linear meter (Seddon *et al.* 2004b).

Fast-tracking recovery

Recolonization and succession are both key processes driving seagrass dynamics, and in this respect, manipulations of these processes could be utilized to augment or accelerate recovery. Like any habitat dominated by a long-lived plant community, seagrasses also tend to form vast meadows of slow growing, high biomass species; climax species. In the situation where a major disturbance has removed the climax species, the resulting bare substrate is usually colonized by fast growing, low biomass, colonizing species (e.g. Box 4). These species quickly cover space, stabilize sediments, and create a microclimate more conducive for the survival of the seedlings of climax species.

Much of the recent thinking in seagrass rehabilitation relates to methodologies to 'fast-track' the natural process of succession – also referred to as 'compressed succession' (Fonseca *et al.* 2000), by encouraging the growth of colonizing species, then in-planting with climax species either

Box 3. Methods used in Seagrass Rehabilitation

***Revegetation** techniques can be broadly divided into (a) vegetative methods (e.g. cores, sods and sprigs etc.) used where mature plants need to be extracted directly from a donor meadow and (b) seed-based methods (e.g. fruits/seeds and seedlings) used where seagrass material is not sourced directly from a donor meadow. A brief description of these methods is given below, but for a more comprehensive description see Fonseca* et al. *(1998).*

(a) Vegetative

CORES or PLUGS of seagrass are usually removed from the donor bed using a metal or PVC corer and transported to the planting site in the corer (Fig. 2), then extruded into a previously excavated hole in the sediments. While cores keep disruption of roots and rhizomes to a minimum, the inclusion of sediments requires more time for collection and transport etc., and is, therefore, more costly in relation to other methods (Fonseca *et al*. 1994; Gordon 1996).

SODS or TURFS of seagrass are similar to cores only larger in size (e.g. 0.25–1 m^2), though generally not as deep as cores and are removed with a shovel or mechanical device (e.g. Figure 3). Sods are planted into a previously excavated hole, sometimes they are washed free of sediments during collection and sediments from the planting site are added again during installation. Major advantages of this method are that a large volume of the rhizosphere remains undisrupted and they are of sufficient mass to withstand high wave energy.

Figure 4. Developing techniques for the successful growth of seagrass seedlings on a large-scale is a relatively new and ongoing endeavour. This year-old *Posidonia* seedling is part of a trail where seedlings were grown in biodegradable Jiffy pots at the South Australian Aquatic Sciences Centre (from Seddon *et al*. 2004b).

SPRIGS are sections of seagrass rhizome with shoots and leaves attached that are dug out from a bed and washed free of sediments. Sprigs can be planted directly into the substrate or secured by tying to a wooden or metal anchor which is pushed into the sediments, or they can be 'stapled' into place using U- or V-shaped metal or wooden staples (Davis & Short

1997). Sprigs have also been sewn into biodegradable mesh which is then anchored into the substrate (Homziak *et al*. 1982; Fonseca *et al*. 1998; Kirkman 1998; Seddon *et al*. 2004b). It is easy to check for apical meristems using sprigs (important for rhizome extension) and they are relatively cheap and have a low impact on the donor bed.

(b) Seed-based

***Seeds and seedlings* can easily be collected from mature plants or when washed-up on shore. In some locations seeds can be sown directly into the sediments (Orth *et al*. 1994) or grown and held as seedlings in aquaria to be planted at an optimal time (Balestri *et al*. 1998; Kirkman 1998). Good results have been achieved when seeds were grown in small biodegradable peat blocks, which provide both protection and anchorage (Phillips 1990) and when *Posidonia* spp. seedlings were planted into Growool blocks (Kirkman 1998). At present we are trialing biodegradable Jiffy pots for growing *Posidonia* spp. seedlings (Fig. 4; Seddon *et al*. 2004b). There are several advantages for using seedlings, including ease of transport and minimal donor bed damage. They are far easier to plant compared with other methods subtidally (i.e. by SCUBA divers) and do not require any cutting of rhizomes (which disrupts gaseous transport and potentially introduces fungus and other diseases into the plant) and, therefore, may be a more suitable method for slow-growing species with large rhizomes (e.g. *Posidonia* and *Thalassia*).**

Figure 5. A diver adding a final layer of sediment along a biodegradable strip of hessian matting which is partially buried and secured into the seafloor with steel pegs, leaving an edge free and exposed to initially trap seedlings (particularly *Amphibolis*) drifting past with the current. Once the seedlings are captured, the matting provides a point of anchorage for the seedlings to attach their roots to in what would otherwise be a bare substrate (from Seddon *et al*. 2004b).

collected as seedlings or cultured seedlings. Certainly results by van Keulen *et al.* (2003) indicate that cores of *Posidonia* fair much better when planted into a bed of *Heterozostera* compared with bare sand or even bare sand with mesh protection. Nevertheless, using colonizing species to cover ground, then in-planting with seedlings, still remains largely untested in the context restoration or rehabilitation methodologies.

In South Australia we have started a program of collecting the fruits of the climax species *Posidonia* spp., germinating the seeds and culturing the subsequent seedlings for future planing into areas of seagrass loss (Fig. 5).The advantages of this technique are that seedlings can be held in culture until the conditions are optimal for planting (usually spring, when the photoperiod is increasing and the winter storms are over), thereby maximizing chances of success. Previous results with aquarium grown *Posidonia oceanica* seedlings by Balestri *et al.* (1998) in the Mediterranean are very encouraging as approximately 70% of the cultivated seedlings survived for 3 years when planted-out, compared with 66% survival over the same period for naturally recruited seedlings, whereas survival of surf grass (*Phyllospadix torreyi*) seedlings planted-out in California (USA) was much lower, but still approximated naturally recruited seedlings at 30% (Holbrook *et al.* 2002).

It is by exploring and testing these relatively new methods of recruitment facilitation and fast-tracking succession that we are hoping to develop cost-effective tools to restore and rehabilitate large-scale seagrass loss that has otherwise previously been intractable both logistically and financially. Its much easier to find a way to go with the flow than fighting against it!

Box 4. Alternating States: Seagrass Loss and Regeneration

Most cases of seagrass loss, where regeneration is possible, involve a series of intermediate states before the return of the dominant meadow-forming climax species. It is accelerating the transitions between these alternate habitat states that is the main focus for facilitating seagrass regeneration.

The Model of seagrass loss and regeneration presented in Fig. 6, for example, illustrates the processes associated with the loss of shallow seagrasses in the Spencer Gulf, South Australia (Seddon *et al*. 2000) and subsequent habitat transitions involving both observed and predicted processes of colonization, recolon-ization and succession.

This model deals with four major habitat states:

Shallow-subtidal seagrass meadows – dominated by either *Amphibolis* or *Posidonia.*

Intertidal seagrass beds – dominated by *Zostera*, but may also include other shallow water seagrasses such as *Heterozostera*, *Lepilaena* and *Ruppia*.

Dieback habitat – which expressly includes dead and decaying seagrass remnants such as rhizome mat, fibrous leaf sheathes, and woody stems.

Bare substrate – which is generally sand, but may be fine sediments or silt in some areas.

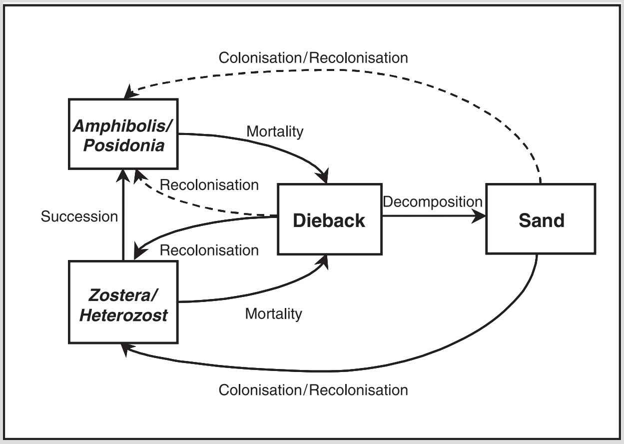

Figure 6. Processes affecting the transition between habitat states for intertidal and shallow subtidal seagrass meadows in the eastern Spencer Gulf, South Australia. Dashed lines indicate less likely transitions. Schema modified from Seddon (2000).

In the instance where seagrass dieback has occurred, a variety of scenarios are possible that generally involve either the re/colonization of areas of dieback by various species of seagrass, or the continued weathering and decomposition of seagrass remnants (i.e. dieback) until eventually the substrate is bare. It is due, in large part, to the stabilizing presence of seagrass remnants that assists the establishment of either intertidal or shallow-subtidal seagrass. Recolonization can occur by the recruitment of seedlings and/or vegetative growth, but success will depend on many factors. In particular, the extent of dieback and proximity to suitable species of surviving seagrass will influence the availability of plants for propagules or vegetative extension (Orth *et al*. 1994). Nevertheless, successful recolonization is more likely by the fast-growing intertidal seagrasses (such as *Zostera*, *Lepilaena* and *Ruppia*) rather than slower-growing *Amphibolis* and *Posidonia*.

Observed patterns of recolonization in areas of the dieback conform to this model as *Zostera* (plus *Lepilaena* and *Ruppia*) has recolonized patches along the intertidal region of dieback, whereas, virtually no *Amphibolis* or *Posidonia* have recolonized the seaward edge of the dieback, even though immediately adjacent to slightly deeper, healthy seagrass meadows of both species. Bob Orth and I visited one of the Spencer Gulf sites in May 2001, 8 years after the dieback, and we were impressed to see extensive areas re/colonized by a variety of intertidal species, but were surprised that, after all this time, we rarely spotted *Amphibolis* or *Posidonia* seedlings amongst all this new luxuriant growth.

One of the significant features about this seagrass loss and rate of regeneration is the apparent bottleneck at the transitions between *Zostera* and the climax species, which due to the shear size of loss, will depend largely on the successful recruitment of *Amphibolis* and *Posidonia* seedlings. One way to facilitate recovery in this instance, would be to focus on fast-tracking succession by in-planting seedlings of *Amphibolis* and *Posidonia* seedlings that have either been collected from the healthy meadows nearby, or in the case of *Posidonia*, perhaps cultivated from fruits, and then 'seed' these areas with the new seedlings at a time for optimal growth and survival.

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