## Advances in approaches to seagrass restoration in Australia

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### Abstract:
Seagrass restoration in Australia has made significant advances to overcome some of the challenges associated with ecosystem restoration in the marine environment. These advances involve targeted collaborations and the use of seeds, seedlings and transplants to overcome project specific challenges, enabling an increase in the speed and spatial scale of restoration of degraded seagrass meadows. We use three case studies from two temperate Australian species, *Ruppia tuberosa* and *Posidonia australis*, to highlight different approaches taken to establish new ‘Blue Restoration’ projects at relevant scales. The first case study describes a mechanical seed harvesting method to recover *Ruppia tuberosa* seeds and disperse them widely. This collaboration involved working with Traditional Owners in the Coorong Region. A second case study, ‘Seeds for Snapper’, combined the collection of *Posidonia australis* fruit, and seed dispersal through collaboration with local recreational fishers, to increase seagrass habitat for a targeted fish species. Thirdly, the ‘Operation Posidonia’ assessed local community perceptions around seagrass to gain support from a wide range of beach and water users to source *P. australis* rhizomes to recover boat mooring scars. These new case studies show that including Traditional Owners and local stakeholders in project planning and implementation leads to new approaches to seagrass restoration, thus increasing the likelihood of successful restoration outcomes.
Ecological Management & Restoration: Feature

Advances in approaches to seagrass restoration in Australia

Three case studies involving two temperate Australian seagrass species - Pondweed (Ruppia tuberosa) and Ribbon Weed (Posidonia australis) - highlight different approaches to their restoration. Seeds and rhizomes were used in three collaborative programs to promote new approaches to scale up restoration outcomes.

Keywords
Blue Restoration, citizen science, marine restoration, stakeholder engagement, Traditional Owners

Introduction
Some of our most important and threatened natural ecosystems are those along the coastal fringes. One billion people live within 50 kilometres of the coast globally (Lotze et al. 2006; Halpern et al. 2008), including 85 per cent of Australians (Clarke & Johnston 2017). Valuable ecosystems, such as coral reefs, macroalgae, mangrove forests, saltmarshes, and seagrass meadows (Figure 1), are in the precarious position of being a buffer between the terrestrial and marine environments. They will continue to be under increasing pressure from anthropogenic activities through coastal development, pollution, and climate change (Lotze et al. 2006; Duarte et al. 2015). The planet has lost one quarter of its seagrasses globally (Waycott et al. 2009) with widespread and accelerating losses continuing (Statton et al. 2018; Evans et al. 2019).

Declining fisheries around the world are linked to the loss of seagrasses which also
play a critical role in supporting a diverse range of marine life (Unsworth et al. 2018).

Seagrass meadows represent globally significant carbon sinks (‘Blue Carbon’, McLeod et al. 2011), contribute to water quality (Barbier et al. 2011; Lamb et al. 2017) and stabilize sediments (Orth et al. 2006a). Losing seagrasses, particularly the larger species that support critical habitat provision and ecological functions, will lead to further reduction in an ability of seagrass habitats to resist climate impacts through carbon sequestration (Arias-Ortiz et al. 2018) and shoreline stabilization (Donatelli et al. 2019). This increased understanding of the value of ecosystem services is laying the foundation to improve conservation of our remaining seagrass meadows, as well as expand restoration activities to recover damaged meadows.

Restoration efforts using transplantation methods have largely been small in scale and costly compared to other marine habitats (van Katwijk et al. 2016; Bayraktarov et al. 2016). We argue that in the long term it is too costly not to restore them. Given the massive scale of seagrass losses, both nationally and globally, development of scalable techniques is necessary. Terrestrial seed-based restoration approaches have been successful at spatial scales of 10s - 100s of ha, and seagrass restoration practitioners and scientists have embraced this wealth of knowledge. The application of seed-based restoration is a relatively new concept in marine restoration (Marion & Orth 2010; Orth et al. 2012). Seeds add versatility to current transplant practices, emerging as an alternative, genetically-diverse, less damaging, cost-effective approach to restoring larger areas.

**Seeding for ecosystem recovery**

Large-scale restoration of seagrasses is now possible with recent advances helping to reverse declines and return the benefits of healthy seagrasses to coastal communities.
Large expanses of Eelgrass (*Zostera marina*) have been restored to Virginia’s coastal lagoons in the United States, enabled through the development of an efficient seed collection, processing, and delivery program (Orth *et al.* 2012). The reintroduced seeds have grown, flowered, and produced seeds themselves that have spread naturally to new areas, such that by 2018 almost 3,600 ha of seagrass has been restored. This recovery has been followed by an increase in abundance of fish and invertebrate species (Reynolds *et al.* 2016; Lefcheck *et al.* 2017). Decades of pioneering and foundational seagrass restoration research has brought us to this point. We now have the science to begin tackling restoration at ecologically-meaningful scales to restore our coastal ecosystems.

We note that reintroduction on its own will not be the ‘silver bullet’ to reversing the long history of seagrass decline. Indeed, resilience-based restoration and management will form an integral part in enhancing the ability of seagrasses to withstand the effects of anthropogenic stressors, and to recover naturally (recruitment, growth, survival) after major impacts or climate events. Managing anthropogenic stresses to re-build ecosystem resilience has been linked to successful restoration of nearshore seagrass habitats over large spatial and temporal scales (Orth & McGlathery 2012). Thirty consecutive years of watershed modelling, biogeochemical data, and comprehensive aerial surveys of Chesapeake Bay, in the north-eastern United States, was used to quantify the cascading effects of anthropogenic impacts on submersed aquatic vegetation (including seagrasses and other underwater vascular plants; Lefcheck *et al.* 2018). Models linked land use change to higher nutrient loads, which reduce submersed aquatic vegetation cover through multiple, independent pathways. The submersed aquatic vegetation has regained 17,000 ha to achieve its highest cover in almost half a century, due to
sustained management actions that reduced nitrogen concentrations in Chesapeake Bay by 23% (Lefcheck et al. 2018). This success required long term investment by multiple stakeholder agencies and communities.

A comprehensive review of seagrass restoration across Australia and New Zealand (Tan et al. 2020) highlights emerging tools, techniques and approaches needed to restore seagrass meadows and associated ecosystem services. Here, we use three case studies from temperate Australia (Figure 2) to demonstrate how these approaches are improving the success of restoration activities. These align with practical strategies proposed by Aronson et al. (2020) in support of the United Nation's Decade on Ecosystem Restoration (2021-2030).

THREE SEAGRASS RESTORATION CASE STUDIES

Case study 1: Seeding life back into the Coorong, South Australia, supported by a partnership with Traditional Owners

The Coorong, Lake Alexandrina and Lake Albert Wetland in South Australia, were listed as a Wetland of International Importance under the Ramsar Convention in 1985. The Coorong supports a high abundance and diversity of wetland fauna, particularly migratory shorebirds (Phillips & Muller 2006; Paton 2010). Pondweed (Ruppia tuberosa) is the most commonly found seagrass species providing important food resources and habitat for birds (Paton et al. 2017). Pondweed is tolerant of the extreme range of salinities common in the estuary, from near freshwater to salinities over four times oceanic levels (Collier et al. 2017). It was once widespread in the Coorong South Lagoon, with meadows occupying more than 1500 Ha (DEWNR 2014). The millennium
drought of 2002-2010 had a devastating impact on the ecological health of the Coorong (Paton et al. 2017), with reduced water levels and increased salinities resulting in the rapid decline of Pondweed (Paton 2010). Its expected recovery did not occur despite the return of a moderate level of water at the end of the drought (Paton et al. 2018). The lack of recovery is attributed to the loss of the seed bank over the drought period as this species is essentially an annual species that flowers, produces seed (which remains in the sediment) and then dies off (Box 1). This means that extended periods of unfavourable drought conditions resulted in the loss of the seed bank through seed bank depletion and the ability of meadows to return once favourable conditions return (Paton et al. 2017). Intervention through a large-scale seed-bearing sediment transfer program was undertaken in 2013, in partnership with Traditional Owners from the Ngarrindjeri community (DEWNR 2014). Pondweed seeds, about 1 mm in size, black and tear-dropped shaped, can be found in many of the region’s lake bed sediments which dry out over summer. Lake Cantara, an ephemeral lake immediately south of the Coorong, was one of the few sites where seed densities were still high in surface layers of sediment. A thin surface layer containing Pondweed seed bank was removed mechanically using a small excavator along the edge of Lake Cantara during late summer and early autumn when the lake was dry (Figure 3a, b). Track mats were used to reduce the impact of the excavator in the donor site. A total of 730 tonnes of sediment containing seeds was bagged and translocated to five restoration sites (Figure 3c). Supplementary planting of seedlings of Pondweed was carried out when mudflats around the edge of the Coorong South Lagoon were exposed. The sites were chosen based on water level predictions, as Pondweed grows best in water depths between 30 - 100 cm.
Pondweed established across translocation sites within three months of the sediment transfer, totalling approximately 61 Ha across three sites in two years. All sites showed an emergence of Pondweed seedlings with abundant patches established in following years. For example at one site, referred to as Policeman’s Point, there were zero shoots in sampling cores in annual monitoring of the site prior to translocation in 2011 and by 2015 37.5% of cores had shoots (Table 1; Figure 3d; Paton et al. 2018). However, long term persistence of Pondweed is dependent on a regular water supply and annual seed production (Collier et al. 2017). Subsequent to this recovery, declining water levels during spring, when Pondweed flowers and sets seeds, led to seed banks not being adequately recharged and overall recovery rates slowing (Paton et al. 2018). This observed reduction in recovery rates exemplifies how essential it is to remove the causes of seagrass loss, in this case reduced annual water levels enabling completion of the Pondweed life cycle and as a result the depletion of the seed bank preventing natural recovery. Thus, to prevent future occurrences, water levels would need to be maintained to achieve minimum ecological requirements for success in achieving long term sustainability of restoration actions.

Subsequent to the initial post-transfer actions, increased average water levels have occurred, resulting in an increase in the extent of Pondweed across the Coorong (Paton et al. 2019). However, water quality conditions continue to prevent the formation of dense Pondweed meadows in the southern Coorong. A new management initiative, under the banner ‘Project Coorong’ (www.projectcoorong.sa.gov.au) has been announced to improve the ecological
condition and hydrological regime of the Coorong including the conditions for enhancing Pondweed productivity.

**Case study 2: Recreational fishers support ‘Seeds for Snapper’ in Cockburn Sound, Western Australia**

Cockburn Sound in Western Australia has lost ~77% of seagrass cover since the 1960s, with little evidence of natural recovery, despite significant improvements in water quality (Kendrick *et al*. 2002). The main impacted genus, *Posidonia*, is characterised by slow horizontal growth and decadal timeframes to naturally recolonize adjacent degraded areas). Traditional approaches to restore *Posidonia* spp. have often focused on transplantation of adult shoots which, although successful, can be labour-intensive, costly and often employ cumbersome and technically difficult methodologies not readily accessible or easily replicated by members of a local community (Paling *et al*. 2001; Paling *et al*. 2007; Bastyan & Cambridge 2008). Ecological and genetic data have highlighted the extent to which sexual reproduction plays a vital role in population persistence, expansion and regeneration of many seagrass populations including *Posidonia* (Kendrick *et al*. 2012, 2017). Therefore, there has been increasing interest in potential for the use of seeds or seedlings in conservation and restoration strategies to underpin effective large-scale management of this species (Kilminster *et al*. 2015).

More than a decade of research on Ribbon Weed (*Posidonia australis*) has improved our understanding of the influence of sexually produced propagules on meadow maintenance and genetic diversity (see Box 2 for life cycle; Kendrick *et al*. 2012, 2017; Sinclair *et al*. 2014), physiological and growth requirements (Statton *et al*. 2013, 2104; Borum *et al*. 2016; Fraser *et al*. 2016; Strydom *et al*.
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2018; Cambridge et al. 2019) and bottlenecks to seedling establishment (Orth et al. 2006b; Statton et al. 2017; Johnson et al. 2018). This has given rise to exploring seeds (or ‘seedlings’ as they are direct developing seeds) as an alternative approach to restoring Ribbon Weed. Methods have been developed and improved upon each year to harvest, process, and remotely deliver increasingly larger quantities of local mature Ribbon Weed seed to the seafloor (Figure 4). These simple but effective technologies have the capacity to increase the scale of seed deployment, significantly reduce the costs of getting plants in the ground and improve our ability to restore locations that are difficult to access (deep, turbid, or diver-restricted locations). More importantly, these approaches are developed specifically with community participation in mind whereby community members can contribute to all areas of the restoration including fruit and seed collection, processing, and delivery to the seafloor.

In an Australian first, over 200,000 viable Ribbon Weed seeds were collected, processed and delivered to 1,000 m² of sea-floor in Cockburn Sound, Western Australia, in both 2018 and 2019. This program, conducted in partnership with OzFish Unlimited, The University of Western Australia and community members from the Cockburn Power Boat Club, became ‘Seeds for Snapper’. Boat users collected floating fruits while travelling to/from fishing locations and recreational divers used purpose-built nets to harvest mature fruit directly from parent plants (Figure 5a). Collected fruits were held within a bucket or esky containing seawater. Once fishers and divers returned to the Cockburn Sound Boat Club, fruit containing seeds were placed into large aquaculture tanks (Figure 5b). The warm and stable temperature combined with agitation from the water movement inside the tanks promoted rapid splitting or dehiscence of fruit.
This technique simulates floating fruit at the ocean surface exposed to warm sunlight and being agitated by waves. After splitting, the seeds rapidly sank to the bottom of the tank where they were collected (Figure 5c). Seeds were then transported to restoration sites by fishers on their way to their fishing grounds. Restoration sites were marked by buoys and ranged in area from 200 – 400 m². The process of delivering 40,000 seeds, broadcast by hand over the side of the vessel, took less than 10 minutes. The seeds naturally spread out as they descend, resulting in a relatively even coverage on the seafloor (Figure 5d).

Seedling establishment across the restoration plots using this approach was ~10%, amounting to ~20 seedlings m⁻² after one year. Surviving seedlings tended to aggregate, produce multiple shoots by the second year (Figure 5e) and show coalescence by 2.5 to 3 years (Figure 5f). An assessment of ‘return to ecosystem function’ will be conducted in the future, as part of ongoing monitoring of the restoration. The most recent cost-benefit analysis indicates that by using this approach, 1 ha of seagrass can be re-seeded for $AUD13,000 – 32,000 depending on the use of community or professional labour, respectively (Rogers et al. 2019). These innovations are being applied to other larger scale restoration activities locally and in Corner Inlet, Victoria. The future includes larger restoration efforts covering 10s to 100s of ha with a focus on community-driven activities.

Case study 3: ‘Out of sight, out of mind”? - Changing perceptions within a local community to restore boat mooring scars, Port Stephens, New South Wales
Changes to underwater ecosystems are not visible to most people and large-scale degradation can go unnoticed (Coleman et al. 2008). Marine ecosystems such as seagrass meadows receive substantially less attention from the media than coral reefs, and they also tend to receive less funding in research, which can result in lower conservation outcomes (Duarte et al. 2008). A general lack of public awareness about the importance of seagrasses has been put forward as one of the key global challenges for seagrass conservation (Unsworth et al. 2019). This points towards a need to develop appropriate science communication campaigns to accompany and facilitate seagrass conservation and restoration actions.

‘Operation Posidonia’ (www.OperationPosidonia.com) aims to restore threatened Ribbon Weed in Port Stephens, New South Wales (NSW), while also raising awareness about this important ecosystem. Before embarking on the actual restoration, social researchers engaged with local communities including boat owners and fishers, local government, private industry and coast care groups. The overall aim was to canvas voices across a range of stakeholder groups to uncover the broad knowledge, perceptions, experiences and uses of marine and coastal spaces where seagrasses occur. This public consultation subsequently informed a science communication campaign designed to enhance awareness about the importance of seagrass and recruit citizen scientists to take part in the restoration project.

Informing and engaging the local community
Initial consultation involved 60 community members via semi-structured interviews, which allowed participants the flexibility to direct the conversation yet also address specific questions to optimise engagement with the restoration project. These interviews highlighted that many people within government, environmental groups
and private industry had a high level of knowledge about the importance of seagrass, with one respondent from industry expressing, ‘seagrasses are the backbone of our Port Stephens’ economy’. These groups also recognised the importance of Posidonia specifically as a key species. In contrast, fewer in the general boating public knew about Posidonia, referring to it as ‘weed’ or simply ‘seagrass’. The general public’s dislike for swimming or boating in seagrass and seeing it onshore as wrack was raised as an issue that the ‘Operation Posidonia’ awareness campaign then aimed to address. One of the strategies used to change negative associations was to draw on the positive connections of Ribbon Weed with charismatic marine fauna associated with seagrasses (Figure 6).

Restoration is typically perceived as an uncontested ‘good’ activity, however, the initial consultation raised unexpected concerns, particularly among coast care groups who queried the scale of the restoration and project funding. Researchers were able to explain that small scale experiments were necessary to adapt methods to local conditions – and if successful, offered potential to restore at a larger scale. The project funding was explained to which one member responded with, ‘actually that’s ridiculously good value then’. The engagement with local school students met with broad social acceptance with one member asserting, ‘there’s a tremendous amount of good with your research right there’. Conducting a listening exercise at the project outset brought researchers and stakeholders toward a shared understanding.

Citizen science in action

Finding suitable donor shoots for restoration was a major challenge because Ribbon Weed meadows have been declining rapidly in NSW in the last few decades (Glasby & West 2018; Evans et al. 2019), despite State and National protection. Further,
Ribbon Weed meadows rarely flower in NSW, and overall fruit and seed production are highly variable (Inglis & Lincoln Smith 1998), factors which limit their use in restoration. Operation Posidonia asked citizen scientists to collect rhizome fragments that become naturally detached after large storms and wash up as ‘beach wrack’ on local beaches. These fragments were subsequently replanted and used to restore meadows that have been damaged by boat moorings (Ferretto et al. 2019). This approach avoids additional damage to existing meadows, while also engaging local communities in the restoration program.

The science communication campaign was critical for the recruitment of citizen scientists to collect storm-detached shoots. The campaign materials included a website, social media presence and series of short films that communicated the importance of seagrass and mechanics behind the proposed restoration. The team also connected with local communities via a launch event, school visits, and guided seagrass collection walks (Figure 6). The overall approach was highly successful, with over 1,200 shoots being collected by local volunteers in the first 14 months of the project. One community group was particularly effective, creating their own coordinated local solution: days were colour coded according to predicted storms when Ribbon Weed shoots and rhizome were most likely dislodged. A ‘green for go’ day meant members were mobilised via email to comb the beaches for dislodged shoots and rhizome among the beach wrack. This group alone collected 750 shoots.

The restoration outcomes for Operation Posidonia are very encouraging, so far. Research to date shows that Ribbon Weed fragments collected by citizen scientists provide an effective, non-destructive source of plants for restoration, with survival rates of > 50% in restored plots (Ferretto et al. 2019).
These three case studies each highlight the need for coordination, collaboration and on-going commitment for restoration projects to be successful. These ‘Blue Restoration’ projects demonstrate examples of successfully overcoming environmental, technical, and social barriers (Stewart-Sinclair et al. 2020).

Most management of coastal environments in Australia is done by local councils, and state and territory governments, and for most environmental issues, levels of government are not coordinated (Clark & Johnson 2017). The Environmental Protection and Biodiversity Conservation Act (EPBC Act 1999) allows the Australian Federal Government to join the states and territories in managing coastal ecosystems when they fall under Matters of National Environmental Significance (MNES). A recent review outlined how seagrass meadows fall within MNES because they are important components of World Heritage Sites and Ramsar wetlands, support many species listed as threatened or endangered under the EPBC Act, and support migratory species protected through international treaties (McLeod et al. 2018).

Generally, management has focused on reducing harm from development activities and through protected areas (McLeod et al. 2018). However, despite protection through the EPBC Act, many seagrass communities are continuing to decline due to changing climate and on-going anthropogenic activities. We suggest that (1) seagrass recovery needs a more proactive approach to enable restoration, (2) there is positive value of national coordination and collaboration through organisations like the Seagrass Restoration Network (Box 3), and (3) funding should be directed towards creating a framework and good practice guidelines for seagrass restoration in Australia.
The involvement of local citizen scientists has become an important aspect of restoration. Hands-on engagement with local communities is a powerful tool that not only raises awareness about the importance of seagrass ecosystems, but also offers a positive view of how science can be used to help solve environmental problems. Restoration projects that enhance community engagement can inspire a sense of optimism that motivates further action and have been linked with positive conservation outcomes (McAfee et al. 2019).

**Box 1. Life cycle of Pondweed (Ruppia tuberosa)**

Pondweed, an ephemeral seagrass species, has developed a complex life history strategy enabling survival under hypervariable and hypersaline conditions. Pondweed can persist through summer dry periods as dormant turions (underground buds) or seeds within the sediment, or as adult plants in deeper water. Strong, seasonally adapted growth strategies are responsible for the high degree of resilience to hypersaline conditions (greater than 100 ppt salinity) which result from fluctuations in water level and salinity due to reduced water levels from declining annual flows and increased evaporation (Brick 1982). Pondweed seeds germinate and turions sprout in autumn. The plants grow through rhizome extension to form dense patches. Ideally reproduction occurs prior to senescence in late spring to early summer, either sexually through flowering and seed bank production, or asexually through turion formation. Turions and seeds remain dormant to survive through summer in shallower water. Seeds are considered critical to annual regrowth on ephemeral mud flats (Paton & Bailey 2014).

Five life stages are recognisable (see Collier et al. 2017). Initiation of growth with the onset of cooler weather and rising water levels covering summer-dry flats, breaking
seed dormancy and inundating the areas where turions have survived, or remnant plants in deeper water (1). Rapid shoot growth and colonisation occurs on the large areas of available habitat created by rising water levels (2). Sexual reproduction through flowering and seed production occurs in moderate salinities. Turion formation is favoured in hypersaline, warming, waters in late spring to early summer (3). Completion of seed production or turion formation enables persistence when water levels drop (4). Seeds and turions remain dormant in exposed environments or within the sediment (5). Plants can continue growing in deeper, hypersaline water over summer.

Box 2. Life cycle of Ribbon Weed or broadleaf seagrass (*Posidonia australis*)

Ribbon Weed forms large dense single and multispecies meadows. The meadows begin to establish via seedling recruitment (1). Dense expansive meadows take years to establish as plants grow through rhizome expansion (or vegetative growth) (2). Mature plants start flowering after about four years (3). Flowers emerge through the leaf canopy during winter. Pollen is released over a 6-week period (Smith & Walker 2002), with fruit ripening during the austral spring (Kuo & McComb 1989). The flowers are monoecious and hermaphroditic, containing male (anthers) and female (stigma) on the same flower. Multiple, protandrous flowers (anthers mature before the stigma is receptive) occur on each inflorescence stem. Mature positively buoyant fruit are released from the parent plant in late spring to early summer and rapidly float to the water surface (4), where they are subjected to local surface currents and direct wind forces (‘windage’, Ruiz-Montoya & Lowe 2014). Each fruit contains a single continuously growing seed or seedling that germinates and bears a plumule and radical (while still contained within the fruit). The mature fruit splits open within
minutes to several days, releasing the negatively buoyant seed which rapidly sinks to
the sea floor. The seedling will grow, nourished by its large endosperm, and if
conditions are suitable, will establish. Reproductive stages are locally synchronized.
Fruit production is highly variable across the species range, although prolific in the
south-west of Western Australian. The approximate timing of life history events is in
the centre wheel, although these can vary considerably with latitude. For example,
fruit ripen in low latitude meadows in Shark Bay, Western Australia, from late
October while fruit in Corner Inlet, Victoria ripen in January.

**Box 3. The Seagrass Restoration Network**

The Seagrass Restoration Network (http://seagrassrestoration.net) was established in
2016. It is a network of scientists and restoration practitioners in partnership with The
Nature Conservancy Australia and with funding support by the National
Environmental Science Program Marine Biodiversity Hub. The Network continues to
support the growing number of grassroots restoration programs being established
around Australia and New Zealand. Involvement and commitment from industry
partners, Traditional Owners, local communities, NGOs, and local, State and Federal
government agencies is required to establish multi-year to decadal nationally funded
restoration projects in order to achieve large scale restoration. The Network is
developing a national framework to enable local communities and small business to
take on the challenge of restoring seagrasses and develop the business of ‘Blue
Restoration’. Coordination and collaboration at multi-institutional levels has been
achieved over decades in two of the longest running successful seagrass restoration
projects – Oyster Harbour in Western Australia (Bastyan & Cambridge 2008) and
Chesapeake Bay in North America (Lefcheck *et al.* 2018). Yet we need to
continue promoting these successes, including advances with seed-based
restoration to move restoration into our common societal language and procedures.

References


Heritage, South Australia.


Figure legends

Figure 1 A healthy *Posidonia australis* meadow in Port Stephens, New South Wales, but movement of the boat mooring chain is beginning to thin the meadow. (Photo by Adriana Vergès)

Alternative Figure 1 caption

A healthy *Posidonia australis* meadow in Port Stephens, New South Wales. (Photo by Harriet Spark)

Figure 2 Map of Australia showing the location of three case studies.

Figure 3 Project Coorong (a) Mechanical scraping of the upper surface of dried sediment containing the previous seasons’ seeds was achieved to less than 10 cm depth; (b) Large scale seed harvesting at Lake Cantara (seed donor site) located to the south of the Coorong; (c) Translocated bags of scraped sediment Pondweed seeds were moved to the restoration site by lightweight vehicle then emptied onto the sediment surface before being inundated by rising water; (d) Germinated Pondweed seedling patch growing in the shallow waters of a translocation site during winter. (Photos by Kat Ryan)

Figure 4 Number of Ribbon Weed seeds collected between 2006 to 2019, as collection, processing and delivery techniques improved in efficiency. Direct seeding to the seafloor began in 2013. Broadcast seeding trials began in 2014 with an improved capacity to collect and process more seed. The ‘Seeds for Snapper’ project began in 2018.
Figure 5 ‘Seeds for Snapper’ (a) Mature fruit of Ribbon Weed prior to harvest; (b) processing harvested fruit by agitation in 2,500 litre flow-through tanks; (c) harvested seeds are delivered to site via broadcast seeding; (d) degraded restoration site re-seeded with Ribbon Weed seeds at a rate of 200 seeds m$^{-2}$; (e) tagged 2 year old seedling with three shoots; (f) 2.5 year old seedlings coalescing to create a sparse meadow. (Photos by John Statton)

Figure 6 ‘Operation Posidonia’ engages with the local community to collect storm-detached shoots washed up as beach wrack for replanting into boat mooring scars. The communication campaign developed logos which associated the project with a local charismatic animal that relies on healthy seagrass meadows (seahorse); the ‘Storm squad’ logo on beanies and hats developed a community of beach collectors.

(Logos by catfish creative, Photos by Harriet Spark)

Table 1. Change in abundance of Pondweed shoots at long term monitoring locations in the southern Coorong, South Australia, based on the percentage (%) of 200 cores (75 mm diam x 40 mm deep) sampled at each site (data from Paton et al. 2017).

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<td>(2012 restoration site)</td>
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Figure 1 A healthy Posidonia australis meadow in Port Stephens, New South Wales, but movement of the boat mooring chain is beginning to thin the meadow.  
(Photo by Adriana Vergés)

323x242mm (300 x 300 DPI)
Figure 4 Number of Posidonia australis seeds collected between 2006 to 2019, as collection, processing and delivery techniques improved in efficiency. Direct seeding to the seafloor began in 2013. Broadcast seeding trials began in 2014 with an improved capacity to collect and process more seed. The ‘Seeds for Snapper’ project began in 2018.
Alternative Figure 1 caption
A healthy Posidonia australis meadow in Port Stephens, New South Wales. (Photo by Harriet Spark)
[Note this is an alternative photo for Fig 1 if the other one is not clear enough]

1828x1371mm (72 x 72 DPI)