BIBLIOGRAPHY OF INTERNATIONAL SEAGRASS PAPERS COVERING GENERA NOT FOUND IN THE UNITED STATES, 1998 - 2015

Badalamenti, F., Alagna, A., D'Anna, G., Terlizzi, A., and Di Carlo, G., 2011, The impact of dredge-fill on Posidonia oceanica seagrass meadows: Regression and patterns of recovery: Marine pollution bulletin, v. 62, p. 483-489.

Posidonia oceanica meadows can be severely damaged by dredge-fill operations. We report on the construction of gas pipelines that occurred between 1981 and 1993 in SW Sicily, Italy. A large portion of the meadow was mechanically removed, and the excavated trench was filled with a mosaic of substrates, ranging from sand to consolidated rock debris. Meadow loss and recovery were quantified over 7 years after the end of operations. We recorded an overall loss of 81.20 ha of meadow. Substrate strongly affected recovery as the percent cover by P. oceanica consistently increased on calcareous rubble, reaching values of 44.37 +/- 3.05% in shallow sites after 7 years, whereas no significant increase occurred on other substrates. As in the Mediterranean Sea exploitation of coastal areas continues to grow with consequent impacts on P. oceanica meadows, this case study illustrates how artificial rubble-like materials could be employed to support the restoration of damaged meadows. (C) 2010 Elsevier Ltd. All rights reserved.

Balestri, E., Vallerini, F., and Lardicci, C., 2011, Storm-generated fragments of the seagrass Posidonia oceanica from beach wrack - A potential source of transplants for restoration: Biological Conservation, v. 144, p. 1644-1654.

The use of fragments detached naturally from Posidonia oceanica, a threatened seagrass protected by European legislation, as non-destructive alternative to removing cuttings from donor meadows for restoration efforts has been recently proposed. A 4-year study was performed to investigate whether storm-generated fragments deposited on beaches can be salvaged and used as transplant source. Specifically, we examined in outdoor tanks (i) how long fragments survive after detachment from parents, (ii) whether fragment survival and regeneration ability are influenced by morphological characteristics, i.e., initial fragment growth form and size, and (iii) whether a single fragment can be divided artificially to obtain more transplants. Finally, we monitored the first year survival of fragments lodged between nibbles of a submersed artificial reef 3 years after storage in tanks to test for their capacity to re-establish in the field. Four months after collection, fragment survival was high (80-96%). Half of the fragments regenerated and survived as long as 3 years in tanks. Initial growth form and size were not predictors of fragment survival or regeneration probability. Division of fragments allowed doubling transplant number. One year after transplanting, 50% of the fragments on the artificial reef were still present and ca. half of them produced new shoots. This indicates that fragments retain the capacity to re-establish once reintroduced into the field and thus could represent a potentially important transplant source. The use of this material could have major advantages over traditional restoration techniques, including large availability with zero impact on existing populations and low collection efforts. (C) 2011 Elsevier Ltd. All rights reserved.

Balestri, E., and Lardicci, C., 2014, Effects of Sediment Fertilization and Burial on Cymodocea nodosa Transplants; Implications for Seagrass Restoration Under a Changing Climate: Restoration Ecology, v. 22, p. 240-247.
Sediment fertilization is recommended for improving seagrass restoration efforts, but few studies have evaluated the efficacy of such practice. Increasing storm frequency due to global change could lead to greater sediment mobilization. Understanding how this alteration will interact with fertilization to affect transplants is essential for future restoration planning. We examined the individual and combined effects of nutrients (ambient vs. repeated addition) and burial (control vs. increased frequency and intensity) on the performance and biomass partitioning of transplants of the seagrass Cymodocea nodosa at two sites within a north-western Mediterranean meadow. Fertilization stimulated the production of shoots, total biomass, and branching. Burial increased leaf sheath length in one site while reduced shoot number, leaf number, leaf sheath length, total biomass, net shoot gain, and root-to-shoot ratio in the other site. Regardless of the site, fertilization and burial interaction reduced the length of vertical internodes and horizontal rhizomes, and the net shoot gain. Our research demonstrates that sediment fertilization ensures rapid colonization of restoration sites, providing C. nodosa plants up to eight times larger than controls in one growing season. However, it also indicates that interaction of increased burial and nutrients reduced the gain in terms of vegetative expansion and depressed vertical growth, making plants more vulnerable to subsequent disturbances. Therefore, seagrass restoration practitioners should account for changes in sediment elevation at transplanting sites when planning restoration programs and carefully evaluate the opportunity of applying fertilizers in sites subjected to greater sediment accumulation to avoid failure.

Balestri, E., and Lardicci, C., 2012, Nursery-propagated plants from seed: a novel tool to improve the effectiveness and sustainability of seagrass restoration: Journal of Applied Ecology, v. 49, p. 1426-1435.
Seagrasses and the valuable ecosystem services they provide are threatened world-wide by impacts of human activity. Numerous revegetation efforts have attempted to restore seagrasses. Most restoration programmes use plants collected from the field because of limited seed availability, low seedling survival and difficulty in culturing plants. However, this practice risks damage to donor populations and has the potential to reduce genetic diversity, which may counteract the desired effects of restoration. A novel aquaculture system for producing plants (mother plants and cuttings) from a limited number of seeds was tested using Cymodocea nodosa as model species. The ability of transplanted cuttings to survive and grow in the natural habitat was also evaluated. Seed germination was high (48%) compared with field conditions, and most seedlings produced mother plants with up to 7.8 m of rhizome and 300 shoots within 4 years in culture. All cuttings from mother plants regenerated new plants. Up to 100 transplants were produced from two seeds, and most (85%) of them survived and initiated the colonization of substrate, 1 year after planting. Synthesis and applications. This study provides a robust protocol that can reduce plant and/or seed collection pressure on donor populations and produce a high number of transplants which show lower mortality rates during the early transplantation phases. This method can also help to preserve genetic diversity in restored populations, which should be one of the major goals of ecological restoration. This novel tool can be applied to other seagrass species with low or unpredictable reproductive success, therefore the development of nurseries should be incorporated in future restoration programmes. This is currently the only sustainable methodology to produce material for transplanting programmes for protected species.

Bastyan, G.R., and Cambridge, M.L., 2008, Transplantation as a method for restoring the seagrass Posidonia australis: Estuarine Coastal and Shelf Science, v. 79, p. 289-299.

Transplant trials of the seagrass Posidonia australis were carried out after loss of seagrasses following eutrophication and increased turbidity in two marine inlets on the south coast of Western Australia. A pilot study in Oyster Harbour measured survival and growth in situ for 4 years. Long-term survival rates were high (96-98%), providing plants were anchored into the sediment. All unanchored plants were lost in the first winter. Following the success of the pilot study, a more comprehensive program began 3 years later with over 500 transplant units collected from either actively growing edges of nearby patches (plagiotropic growth form) or within established meadows (orthotropic growth form). Transplant units from edges expanded at a faster rate compared to units from mid-meadow but increases in shoot numbers were similar. Growth rates in the first 2.5 years averaged 10-20 cm yr(-1) horizontal rhizome extension, depending on the source of the transplant units, and 4-12 shoots per initial shoot yr(-1), depending on the initial shoot number of the transplant unit. After 5 years, shoot numbers of individual transplants were similar to shoot densities recorded for natural meadows, >500 shoots m(-2). Approximately, 10% of transplants from mid-meadow flowered in the first year, whereas transplants from edges flowered only after 5 years. Transplant trials were also established in nearby Princess Royal Harbour at a site selected to test the effect of disturbance by bioturbation from large sand-burrowing worms or by sediment erosion. Survival was lower than in Oyster Harbour, 75-89% in areas with bioturbation but only 14% in areas where sediments were eroded. Growth was poor, <1-2 shoots per shoot yr(-1) with high shoot mortality, and low rates of increase in rhizome length, <5 cm yr(-1). In areas affected by worm bioturbation, there was almost no horizontal expansion of plants because rhizomes grew vertically to keep pace with sediment deposition. This study showed that Posidonia australis could be transplanted with a high degree of success into a protected embayment previously vegetated with seagrass meadows. After 4 years, flower and seed production had occurred, and transplants spaced 1 m apart began merging. By the fifth year, individual transplant units could no longer be distinguished and planted areas resembled a natural meadow. These findings have important implications for restoration of impaired Posidonia habitats in Australia, using conventional low-cost techniques for transplantation once the sources of injury have abated.

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Burnell, O.W., Connell, S.D., Irving, A.D., and Russell, B.D., 2013, Asymmetric patterns of recovery in two habitat forming seagrass species following simulated overgrazing by urchins: Journal of experimental marine biology and ecology, v. 448, p. 114-120.
The persistence of seagrass meadows reflects variation in factors that influence their productivity and consumption. Sea urchins (Amblypneustes pallidus) can over-graze seagrass (Amphibolis antarctica) to create sparse meadows in South Australia, but this effect is not observed in adjacent Posidonia sinuosa meadows despite greater densities of inhabiting urchins. To test the effect of urchin grazing on seagrass biomass, we elevated the density of urchins in meadows of A. antarctica and P. sinuosa and quantified seagrass decline. Urchins removed similar amounts of biomass from both seagrass species, but the loss of leaf meristems was 11-times greater in A. antarctica than in P. sinuosa. In a second experiment to assess the recovery of seagrass, we simulated urchin grazing by clipping seagrass to mimic impacts measured in the first experiment, as well as completely removing all above ground biomass in one treatment. Following simulated grazing, P. sinuosa showed a rapid trajectory toward recovery, while A. antarctica meadows continued to decline relative to control treatments. While both A. antarctica and P. sinuosa were susceptible to heavy grazing loss, consumption of the exposed meristems of A. antarctica appears to reduce its capacity to recover, which may increase its vulnerability to long-term habitat phase-shifts and associated cascading ecosystem changes. C) 2013 Elsevier B.V. All rights reserved.

Cabaco, S., Ferreira, O., and Santos, R., 2010, Population dynamics of the seagrass Cymodocea nodosa in Ria Formosa lagoon following inlet artificial relocation: Estuarine Coastal and Shelf Science, v. 87, p. 510-516.
The population dynamics of the seagrass Cymodocea nodosa was investigated in three meadows differently affected by the artificial relocation of an inlet in the western sector of the Ria Formosa lagoon, southern Portugal. One meadow was subjected to increasing currents that caused erosion, another one was subjected to an initial episode of burial and a third meadow was undisturbed by the inlet opening. The hydrodynamic/sedimentary condition of meadows was assessed through comparative sediment analysis between the meadow and the adjacent unvegetated area. The studied C. nodosa meadows clearly reflected the resultant hydrodynamic changes and consequent sedimentary disturbances caused by the inlet opening, eleven months prior to sampling. In all meadows except the eroded one, C. nodosa promoted the accumulation and stabilization of sediments with grain-size dominated by a mode of 2.75 phi, much finer than the surrounding sediments, which grain-size was dominated by modes of 0.75-1.25 phi. Under the strong currents of the eroded meadow, the sediment was much coarser (mode of 0.75 phi), had less organic matter content and was not significantly different from the adjacent unvegetated area. A lower horizontal rhizome elongation, higher shoot mortality and lower shoot recruitment was observed at the eroded meadow indicating a strong population regression. Based on the sediment grain-size of the eroded meadow, it was inferred that the current velocity thresholds for C. nodosa decline occur at water current >60 cm s(-1). Sediment burial resulted in longer leaf sheaths, higher vertical and horizontal rhizome elongation, lower shoot age, lower total biomass and higher shoot recruitment, which suggests population recovery after disturbance. The net recruitment of all studied meadows, including the undisturbed one, was negative, even though the buried meadow was close to zero. If environmental conditions will remain the same, all studied meadows are predicted to decline to extinction. Results thus suggest that the inlet relocation may alter the landscape distribution of C. nodosa meadows in Ria Formosa, but it was not the main cause of C. nodosa decline.
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Cambridge, M.L., and Kendrick, G.A., 2009, Contrasting responses of seagrass transplants (Posidonia australis) to nitrogen, phosphorus and iron addition in an estuary and a coastal embayment: Journal of experimental marine biology and ecology, v. 371, p. 34-41.
Addition of nutrients to sediments has been proposed as a means of enhancing transplantation success in seagrasses. The effects of nutrient and iron additions to natural sediments on the growth and morphology of Posidonia australis transplants were evaluated in underwater plots in two contrasting environments: a coastal embayment (Princess Royal Harbour) with sandy sediments and little riverine input, and an estuary (Oyster Harbour) with organic-rich sediments and subject to seasonal river flow from a large rural catchment. Sixty six planting units spaced 1 m apart were transplanted in situ in each location. Nitrogen (N) and phosphorus (P) were added in a randomized factorial design using slow release fertilizer granules at the start of the experiment and repeated every 4-5 months for 2 years. In a concurrent experiment, chelated iron Fe EDTA was added to modify the sediment sulphur cycle. In Oyster Harbour, the addition of N significantly increased leaf N concentrations but reduced total biomass and biomass of leaves. Addition of P significantly increased leaf P concentrations and number of living leaves per transplant, leaf area, leaf length, length of longest rhizome axis and total rhizome length. Combined N + P addition resulted in a significant increase in leaf P concentrations and leaf area per plant only. In Princess Royal Harbour, addition of N produced significant increases in leaf variables (total and leaf biomass, number of shoots and living leaves, leaf area, and leaf length) but there were no significant differences observed in below ground plant parts (rhizomes). Addition of P had no significant effects on any growth measurements. Addition of N + P combined increased number of living leaves and leaf area significantly. delta(15)N in mature leaf tissue were significantly more negative for N and N + P treatments at both locations. Our results indicated that N limitation was occurring in the coastal embayment, Princess Royal Harbour whereas in the more estuarine Oyster Harbour, P was limiting plant growth. Addition of FeEDTA produced equivocal results at both sites and we suggest these results are confounded by the addition of N and C in the EDTA. We caution the use of nutrient addition to transplants of slow growing seagrasses such as P australis without a thorough understanding of the nutrient status of the system, estuarine or coastal embayment, in which they are to be transplanted.
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Campbell, M.L., 2002, Getting the foundation right: A scientifically based management framework to aid in the planning and implementation of seagrass transplant efforts: Bulletin of Marine Science, v. 71, p. 1405-1414.
The process of seagrass transplantation is widely recognised as complex, producing few successes. Globally, there have been many attempts to restore, revegetate and mitigate for seagrass losses yet there is still no single method that ensures success. Transplantation efforts have suffered from significant lack of a clear and consistent planning and implementation approach. Here, a decision-based framework to aid in the planning and implementation of seagrass transplant efforts is presented. The framework is based on species-specific biological considerations and comprises five steps: (1) objective setting; (2) site selection; (3) transplant unit and technique; (4) habitat enhancement; and (5) review of objectives. This framework was implemented in a transplant effort using Posidonia australis (R. Br.) Hook f., resulting in moderate success rates (42% survival and 39% growth). The framework has the potential to be applied to other bioregions and other species.

Collier, C.J., Lavery, P.S., Ralph, P.J., and Masini, R.J., 2009, Shade-induced response and recovery of the seagrass Posidonia sinuosa: Journal of experimental marine biology and ecology, v. 370, p. 89-103.
The effect of shading on the seagrass Posidonia sinuosa Cambridge et Kuo was investigated to identify mechanisms that prolong its survival during periods of low light and permit its subsequent recovery. We also tested whether the responses were consistent in plants growing at different depths. Shade treatments were low (LS; 70 - 100% of ambient Photosynthetic Photon Flux Density), medium (MS; 12 - 39%) and heavy (HS; 5 - 4%) at the shallow (3 - 4 m) site, whilst the deep (7 - 8 m) site had no HS treatment. HS at the shallow and MS at the deep site were below minimum light requirements (MLR) for the long-term survival of P. sinuoso. Physiological, morphological and growth attributes were repeatedly measured during 198 d of shade treatments and a subsequent 384 d recovery period at ambient PPFD. Shoot density declined by 82% within 105 d under HS treatment, though 6% of shoots remained after 198 d. We estimate that complete shoot loss in HS would have taken 2 years. Rhizome sugar concentrations declined to 32 - 52% of the controls at the end of the most severe shading treatments but after shoot loss, sugar concentrations declined more slowly or increased, suggesting a return to positive carbon balance. In the treatments below MLR, shading induced changes in physiological, morphological and growth characteristics, including reduced leaf length and width, reduced delta(13)C and photosynthetic adaptation to low light (increased alpha, reduced E(k) and ETR(max)), though not consistently. After removal of shading, photosynthetic characteristics became more typical of high light adaptation, possibly induced by greater light penetration through the thinned canopy, including reversal of the changes in alpha, E(k) and ETR(max) and induction of non-photochemical quenching. Carbohydrate concentrations increased to ambient concentrations within 115 d at ambient PPFD. Recovery of shoot density was slow, remaining significantly reduced in the MS and HS treatments after 384 d recovery. Shoot density at the end of shading is an important determinant of the rate seagrass meadows will recover and we estimated that the moderately and heavily shaded meadows would require 3.5 to 5 years to recover. (C) 2008 Elsevier B.V. All rights reserved.

Cunha, A.H., Marba, N.N., van Katwijk, M.M., Pickerell, C., Henriques, M., Bernard, G., Ferreira, M.A., Garcia, S., Garmendia, J.M., and Manent, P., 2012, Changing Paradigms in Seagrass Restoration: Restoration Ecology, v. 20, p. 427-430.
Sharing experiences and results among scientists and managers working on seagrass restoration was the main objective of the first European Seagrass Restoration Workshop that gathered researchers from around Europe. The meeting was the first forum in Europe that allowed for scientists, NGOs, and managers to interact and share their experiences relating to seagrass restoration and management. The results show that none of the seagrass restoration programs developed in Europe by the participants during the last 10 years was successful. Furthermore, an informal review of data published in seagrass restoration success, showed that the results reported were biased because they were mostly based on a very short monitoring period (i.e. <1 year). Numerous decision trees, guidelines, and restoration models have been developed to aid seagrass restoration management, but the results of this workshop point toward a new paradigm in seagrass restoration were efforts should shift to give priority to natural restoration potential, with an emphasis on the fact that restoration should never be considered the first alternative when planning for the mitigation of coastal development projects or to justify mitigation as a compensation measure for economic activities.

Han, H., Jiang, X., Pan, J., Cong, W., Sun, J., Zhang, Z., Song, S., Sheng, B., Wang, Q., and Li, X., 2012, Characteristics of seagrass seed and restoration of seagrass bed: Chinese Journal of Plant Ecology, v. 36, p. 909-917.
Reported seagrass bed losses have led to increased awareness of the need for seagrass bed restoration, and seeds have potential for this restoration. In this paper, we systematically review the research and application of seagrass seeds in recent years. The morphology, development, dispersal, dormancy and germination of seagrass seeds are summarized and compared from the viewpoint of seed biology and seed ecology. We propose that when natural seagrass seed banks are researched, it is also necessary to establish artificial seagrass seed banks based on research of seed biology and seed ecology, which will guide seed collection and preservation. Seeding method and the approach of restoration using seeds are discussed, and we also point out problems existing in current research and application. In conclusion, we project expectations of the future in the research and application of seagrass seeds, and we forecast that seagrass seed ecology research will be an emphasis in the future. In the application area, research should focus on increasing the seed germination rate and seedling rate, and the problem of low seedling survival rate must be solved if artificial seedlings grown from seeds are to be utilized to restore seagrass beds.

Kirkman, H., 1998, Pilot experiments on planting seedlings and small seagrass propagules in western Australia: Marine pollution bulletin, v. 37, p. 460-467.
The aim of this study was to investigate characteristics of some south-western Australian seagrasses that might be useful for further investigation with respect to restoration. Although seeds and fruits of seagrass species may be useful for producing propagules for planting, their collection is based on knowing when they become available. Posidonia australis, P. angustifolia and P. coriacea flower profusely annually, but P. sinuosa does not. Once collected, the fruits dehisce in a few days and are ready for planting. It was found that the best way to plant Posidonia seedlings is in clusters in Growool blocks but the rhizomes do not spread quickly. Single Posidonia seedlings, when planted out, were not successful and neither were naturally colonizing seedlings of Posidonia sinuosa in unexposed unvegetated areas. Successful planting of seedlings and sprigs of Amphibolis in matting needs months of calm weather for them to spread out from their attaching matting which must be very securely attached to the substratum. Little success was achieved in growing Amphibolis. In a search for Halophila ovalis seeds, few were found because of the patchy nature of their fruiting and small size. Germination was slow but 63% germinated within 6 months. (C) 1999 Elsevier Science Ltd. All rights reserved.

McMahon, K., and Lavery, P.S., 2014, Canopy-scale modifications of the seagrass Amphibolis griffithii in response to and recovery from light reduction: Journal of experimental marine biology and ecology, v. 455, p. 38-44.
A manipulative experiment using Amphibolis griffithii seagrass, a clonal plant with a complex canopy, tested within-canopy responses to and recovery from light reduction. There were consistent patterns in the distribution and arrangement of leaves, growth rates and resources within the seagrass canopy, and they were modified under reduced light and following recovery from this impact. Under light reduction, plants responded by: reducing leaves in the mid-canopy where the maximum biomass was located; maintaining meristems throughout the canopy; and re-allocating nitrogen to the top of the canopy. During recovery plants increased the number of leaves throughout the canopy and enhanced growth in the part of the canopy that had lost most biomass. These responses have the potential to enhance light capture and recovery of the meadow. There is a clear evolutionary advantage for these submerged plants to be able to modify traits within the canopy, which increase the chance of survival under light stress. Crown Copyright (c) 2014 Published by Elsevier B.V. All rights reserved.

McMahon, K., Lavery, P.S., and Mulligan, M., 2011, Recovery from the impact of light reduction on the seagrass Amphibolis griffithii, insights for dredging management: Marine pollution bulletin, v. 62, p. 270-283.
A large-scale, manipulative experiment was conducted to examine the extent and rate of recovery of meadows of the temperate Australian seagrass, Amphibolis griffithii to different light-reduction scenarios typical of dredging operations, and to identify potential indicators of recovery from light reduction stress. Shade cloth was used to mimic different intensities, durations and start times of light reduction, and then was removed to assess the recovery. The meadow could recover from 3 months of light stress (5-18% ambient) following 10 months re-exposure to ambient light, even when up to 72% of leaf biomass was lost, much faster recovery rates than has previously been observed for large seagrasses. However, when the meadow had been shaded for 6-9 months and more than 82% of leaf biomass was lost, no recovery was detected up to 23 months after the light stress had ceased, consistent with other studies. Five potential indicators of recovery were recommended. (C) 2010 Elsevier Ltd. All rights reserved.

Meehan, A.J., and West, R.J., 2002, Experimental transplanting of Posidonia australis seagrass in Port Hacking, Australia, to assess the feasibility of restoration: Marine pollution bulletin, v. 44, p. 25-31.
Over the last 50 years, about one-third of the original area of the seagrass Posidonia austrailis has been lost from Port Hacking (Australia) due to anthropogenic impacts. To assess the feasibility of restoring these seagrass meadows, healthy Posidonia rhizomes were transplanted to four impact sites and one control site. Survival rates of transplanted shoots were monitored in situ bi-monthly for 16 months and, at the end of the experiment, rhizome growth, shoot growth, shoot production and growth architecture were assessed by harvesting tagged rhizomes. A total of 575 shoots were transplanted and after 16 months 650 shoots were present. Four of the five sites exhibited high survival rates in the short term (less than six months) but only two impact sites, Burraneer Bay (BB) and Red Jacks Point (RJP), and the control site (CS) survived to the end of the experiment. Total number of shoots increased by 61% at CS, tripled at BB, but decreased by 22% at RJP. Rhizome growth varied significantly between site, from 22.3 +/- 1.4 cm yr(-1) at BB to 9.1 +/- 1.0 cm yr(-1) at RJP. Shoot growth did not vary significantly between sites and was approximately 2-3 cm yr(-1). At BB and CS there was substantial colonisation of the surrounding substrate, with new rhizomes, orthotropic shoots and transitional shoots produced. Survival of transplants appeared to depend on whether the factors that had caused the original loss of Posidonia were still operating in the study area.
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Meehan, A.J., West, R.J., University, o.W., Ocean and Coastal, R.C., and Fisheries Research, &.D.C., 2002, Seagrasses in southern NSW Estuaries: their ecology, conservation, restoration and management: Wollongong NSW], University of Wollongong

Paling, E.I., and Van Keulen, M., 2003, Pilot seagrass transplantation trials in Forsters Bay, Narooma, NSW:, 10 p., http://researchrepository.murdoch.edu.au/10942/1/Narooma_report.pdf
The last reported extent of seagrass coverage in the Wagonga Inlet, Narooma was given as 148 ha, although estimates of seagrass coverage vary considerably. The channel area consists of approximately 4 ha or 2.7% of this total coverage. The bare sand flats adjacent to the channel are naturally colonising at a reasonably rapid rate (c.a. 1 m y-1). That seagrasses are healthy in the inlet is illustrated by the fact that they are growing successfully underneath jetties, boardwalks and oyster leases. Additionally, in the quite turbid environment of the upper reaches of the inlet, Zostera sp. is growing well. Any factor that would increase this turbidity such as runoff from land clearing would be expected to impact upon these communities and possibly reduce their range. However sediments in the channel between Mill and Forsters Bay are more coarse and turbidity caused by dredging would be expected to be short-lived; and, if carried out at the appropriate time of year would be expected to have minimal impact upon adjacent seagrasses. After more than a year pilot seagrass transplantation trials on the sand flats adjacent to the channel have shown 92% survival. In addition there has been natural colonisation in this area by both seedlings and seagrass fragments within and around the transplant area. Recent data on transplantation trials in another NSW estuary have also shown good survival. This indicates that the seagrasses in the Narooma Inlet may neither be under stress nor are they decreasing in area and that seagrass transplantation may be a viable method to increase meadow area. Dredging a channel would remove approximately 2.7 % of the seagrasses in the inlet adjacent to a seagrass meadow that is naturally colonising and of a greater size. The bare sand flat area is approximately 40 ha and might be expected to support at least half of this as seagrass meadows in the future. It would be possible to augment the colonisation by further transplantation of the appr.

Paling, E.I., van Keulen, M., Wheeler, K., Phillips, J., and Dyhrberg, R., 2001, Mechanical seagrass transplantation in Western Australia: Ecological Engineering, v. 16, p. 331-339.
An underwater seagrass harvesting and planting machine ('ECOSUB1') was designed with the specific parameters that a large seagrass 'sod' (0.25 m(2) in area and 0.5 m deep) could be extracted and planted with minimal disturbance to the leaves, roots and rhizomes contained within it. A prototype was developed and tested by the end of September 1996 and transplantation commenced in November 1996. Over 1500 sods have been planted up to March 1999. Survival appears dependent on the species being transplanted; Posidonia species have shown good survival to date, with Posidonia sinuosa and Posidonia coriacea plants showing 76.8 and 75.8% survival, respectively, 2 years after transplantation. Amphibolis griffithii plants have not done as well (44.3%), although this appears to be largely dependent on planting technique and winter storm damage to the plants at the time of transplanting. (C) 2001 Elsevier Science B.V. All rights reserved.

Paling, E.I., van Keulen, M., Wheeler, K.D., Phillips, J., Dyhrberg, R., and Lord, D.A., 2001, Improving mechanical seagrass transplantation: Ecological Engineering, v. 18, p. 107-113.
Until recently seagrass transplantation efforts have met with limited success in areas with high wave energies. Survival in Western Australia has been markedly improved by the deployment of large, mechanically transplanted units which provide sufficient anchorage to overcome water motion. ECOSUB1 was an underwater seagrass harvesting and planting machine designed to extract and plant large seagrass units with minimal disturbance. Over 2000 sods have been planted, with an average survival of approximately 70% over 3 years. New machines (ECOSUB2) have now been constructed to improve efficiency; these are located semi-permanently on the seafloor and allow for concurrent seagrass harvesting and planting. (C) 2001 Elsevier Science B.V. All rights reserved.

Paling, E.I., van Keulen, M., and Tunbridge, D.J., 2007, Seagrass transplanting in Cockburn Sound, Western Australia: A comparison of manual transplantation methodology using Posidonia sinuosa Cambridge et Kuo: Restoration Ecology, v. 15, p. 240-249.
Seagrass transplants (plant units PUs]) were established to examine the feasibility of seagrass rehabilitation in Cockburn Sound, Western Australia. Five hundred and twenty plant units (plugs and sprigs) of Posidonia sinuosa Cambridge et Kuo were placed at seven locations at depths of 3, 5, and 9 m and monitored to determine the influence of transplant method, location, and depth upon survival and growth over 2 years. Depending on the site, more plugs had survived at the completion of the trial (mean survival 41%) than sprigs (mean survival 15%). Plug and sprig survival differed significantly with transplant depth, decreasing overall with increasing depth. Forty-five percent of surviving plugs and 50% of sprigs exhibited horizontal rhizome extension. Mean rhizome extension after 2 years was 9.5 cm/plug (1-23 cm) and 18.3 cm/sprig (0.5-31 cm). Declines in PU survival and variable growth correlate with site-specific variability in light climate. Plug transplantation was deemed the most suitable method for further manual seagrass rehabilitation, exhibiting higher survival across all sites and conditions; however, they are costly to deploy. Sprig PUs have greatest potential in shallow water with fine sands, moderate water movement, and maximum light availability. The low cost of deploying sprigs may outweigh their lower survival compared to plugs; further efforts should be directed to enhancing survival of sprig PUs under a wider range of conditions. Suitable locations for future rehabilitation efforts in Cockburn Sound were the Eastern and Western Banks and shallow areas off Woodman Point and Mangles Bay.

Paling, E.I., van Keulen, M., Wheeler, K., and Walker, C., 2000, Effects of depth on manual transplantation of the seagrass Amphibolis griffithii (J. M. Black) den Hartog on Success Bank, Western Australia: Pacific Conservation Biology, v. 5, p. 314-320.
Transplants were established in February and December 1997 to supplement and provide feedback for a mechanical seagrass transplantation programme. A total of 580, 15 cm diameter plugs of Amphibolis griffithii were transplanted to depths of 5, 6, 8 and 10 m with similar energy conditions, and their survival monitored. There was a significant decline in plug survival over the subsequent 14 months. This appears to correlate with the onset of the winter storms in May 1997; the control plugs (seagrass excavated and replanted in the same location) also declined during this period. There was a seasonal decline in stem density in all plugs, with some recovery in the following spring and summer. The decline of plug survival corresponded to large-scale fluctuations in sediment levels across Success Bank. This suggests that, provided the transplants survive hydrodynamic disturbances resulting in sediment level fluctuations, the light climate (up to 10 m depth) does not prevent the survival and growth of seagrass transplants.

Paling, E.I., Van Keulen, M., Wheeler, K.D., Phillips, J., and Dyhrberg, R., 2003, Influence of Spacing on Mechanically Transplanted Seagrass Survival in a High Wave Energy Regime: Restoration Ecology, v. 11, no. 1, p. 56-61.

Abstract The wave-exposed nature of much of the southwestern Australian coastline considerably reduces the protective influence of seagrasses, and sediment movement appears to be relatively unaffected by their presence. Present seagrass restoration efforts focus on the deployment of large mechanically transplanted â€œsodsâ€ of seagrass as a means of combating the negative effects of water motion on transplant survival. The aim of this study was to investigate the combined role of wave energy and transplant spacing on sediment movement and transplant survival to provide guidance for seagrass transplantation in areas of high wave energy. One hundred sixty sods (0.25 m2) of seagrass were mechanically extracted from a mixed meadow consisting of Amphibolis griffithii (Cymodoceaceae) and Posidonia coriacea (Posidoniaceae) and planted in a high wave energy site with the treatments configured as three replicates of 16 sods placed in 4 Ã— 4â€“meter squares at distances of 0.5, 1.0, and 2.0 meters apart. An additional 16 single sods were planted randomly throughout the site. Monitoring was conducted at two monthly intervals and consisted of counting the number of sods surviving and measuring the shoot density of seagrass species within each surviving sod. Sediment height was monitored using a series of sediment plates and an electronic sediment level sensor. Sod spacing had no significant effect upon transplant survival, which remained above 90% for 4 months after transplantation and then declined with the onset of winter (June to August). After 14 months individual sod survival was between 9% and 40%. Initial shoot densities were 200 to 500 shoots/m2 and declined to less than 50 shoots/m2. Sediment fluctuations up to 35 cm were noted, occasionally taking place over a matter of hours, and storms during winter caused significantly increased sediment movement. This probably curtailed rhizome extension and prevented the expansion of the transplants. This study indicates that the ability of seagrasses to influence sediment would appear to vary with the prevailing hydrodynamic regime and that a reappraisal of the notion that all seagrass communities trap sediment is necessary.

Pan, J., Jiang, X., Sai, S., Zhou, W., Wu, J., Li, X., and Yang, G., 2012, Seagrass meadow ecosystem and its restoration: a review: Shengtai Xuebao/Acta Ecologica Sinica, v. 32, no. 19, p. 6223-6232. Seagrass meadows have long been recognized for the important ecosystem services they provide. Seagrass meadows not only play critical roles in near shore primary production and nutrient cycling, but also provide feeding, refuge and nursery habitat for a diverse array of marine organisms, and increase the stability of the seafloor. However, seagrass meadows have suffered great declines in the last century from anthropogenic effects, which in turn stimulated studies of seagrass ecosystems as well as development of restoration techniques. More recently, China has initiated restoration work on seagrass ecosystems in direct response to observed and anticipated loss of seagrass habitat. Here, four topics are reviewed that form the basis of the Chinese restoration effort: (1) Seagrass meadow ecosystem analysis, (2) Declines of seagrass meadows and its reasons, (3) Progress of seagrass restoration techniques abroad and in China, and (4) Actionable guidance. Under (1), seagrass species and their distribution, functions and ecosystem services will be inventoried. Although seagrasses globally have comparatively (to terrestrial systems) low taxonomic diversity they still have discernible niches whose ecological limits must be understood in order to forecast their response and resiliency when faced with local stressors. Because seagrasses have successfully colonized all but the most polar seas and thus have occupied wider latitudinal ranges as compared with the other major coastal marine habitats (mangroves and coral reefs in tropical regions, salt marshes in temperate regions), defining their ecological limits is a significant challenge. Moreover, although seagrasses indisputably provide important and extensive natural resource services, specifically identifying those services in the context of the near shore ecology and human needs are fundamental to establishing effective protection. Under (2), identification and mitigation of human stressors that impair or eliminate seagrasses in coastal waters is a fundamental step to creating a sustainable resource base. The impact of local, anthropogenic stressors (eutrophication, dredging and near shore engineering) needs also to be separated from far-field effects such as global warming, sea level change, natural diseases, and disturbance events such as typhoons in order to understand that which is manageable and that which is natural or beyond local boundaries and thus not practicable for intervention. Under (3), seagrass restoration has been practiced for decades, with the first documented attempt at seagrass restoration being carried out in the USA in 1947. However, it was not until the mid-1970s that development of seagrass restoration techniques began to move beyond the experimental stage. In the past 40 years there has been considerable development of restoration methodologies and techniques, and a significant increase in the number of locations and species involved. Nonetheless, because seagrass restoration typically takes place in open (uncontrolled or non-engineered) settings, the restoration process is widely recognized as being complex and expensive. The most common method has involved the transplantation of adult plants, because they result in an immediate presence of the seagrass community. Some of these methods have involved transplantation of seagrass and associated sediments, whilst with other methods only the seagrass plant is utilized. But in recent years, new seeding techniques for a few species have been developed and successfully employed. Regardless of the method, the general success of previous restoration attempts have been variable and unfortunately in many cases, have resulted in limited survival and coverage (average success has been 50%). In most cases the transplantation of seagrasses relies on harvest from otherwise healthy meadows, which for some species (but not many in China) have extremely slow recovery rates, making donor bed impacts a concern for those species. Nonetheless, there remains an urgent need for better understanding of the limiting factors for seagrass in a restoration context and to employ new advances in applied research and methodology to conduct seagrass restoration in a

cost-effective manner over large spatial extents. Finally, under (4) we propose to provide actionable guidance for seagrass conservation and restoration efforts in China. China covers two geographic bioregions and has a vast (but poorly inventoried) expanse of seagrass meadows along its coast. But China has not yet developed a comprehensive study of seagrass meadow ecosystems and applied practices in restoration. As a consequence of limited studies and popular understanding of the importance of seagrass resources, seagrass meadows in China are widely vulnerable and threatened. Consequently, seagrass meadows in China have, like many other under-managed seagrass ecosystems worldwide, suffered great declines from excessive emission of nutrients and pollution of coastal waters. Although there have been some limited studies that have been highly focused on seagrass restoration, China's ability to incorporate restoration into a management strategy has been severely limited by knowledge gaps identified in the four topic areas defined here. Without a balance of studies involving inventories, functions and services, population ecology and disturbance responses in which to place seagrass restoration in context, it is likely that (as occurred in the U. S. during the 1960's and 1970's) seagrass restoration could be perceived as an inappropriate solution to many coastal development problems, resulting in failed projects and continued seagrass losses. We conclude that conservation and restoration of seagrass meadows should be integrated with coastal planning in China for sustainable seagrass ecosystem services.

Pranovi, F., Curiel, D., Rismondo, A., Marzocchi, M., and Scattolin, M., 2000, Variations of the macrobenthic community in a seagrass transplanted area of the Lagoon of Venice: Scientia Marina, v. 64, p. 303-310.

Modifications in a benthic community, induced by an experimental transplant of seagrass (Cymodocea nodosa Ucria), were studied in an area located in the southern basin of the Lagoon of Venice. Two surveys, carried out in March and September 1996, indicated that species composition and numerical dominants changed with season, with increasing dissimilarity between the transplanted meadow and the surrounding area. The latter was used as a control area and was characterised by the presence of pleustophytic algae (Ulva rigida, Gracilaria verrucosa, Chaetomorpha linum). Comparison with a natural C. nodosa bed showed that, only two vegetative seasons after transplant, seagrass performance and the structure of the macrobenthic community were quite similar to those recorded in a natural meadow. The experiment demonstrated the importance of C. nodosa transplant in the Lagoon of Venice and the changes induced in the whole benthic community by the introduction of seagrass in an area previously lacking it.

Procaccini, G., and Piazzi, L., 2001, Genetic polymorphism and transplantation success in the mediterranean seagrass Posidonia oceanica: Restoration Ecology, v. 9, p. 332-338.
We studied the role of genetic variability of donor beds in establishing transplantation criteria for the Mediterranean seagrass Posidonia oceanica. Horizontal rhizomes, collected from three geographically distinct populations, were transplanted into a common bed at a highly human-impacted locality. The transplantation site was located near one of the donor populations. After three years, the shoots collected in the population adjacent to the transplanting site showed the lowest growth performance. Genetic variability, assessed through the analysis of hypervariable microsatellite regions, and growth performance followed a similar trend. The shoots growing and branching at the highest rate were those collected from populations with the highest heterozygosity values, despite greater geographic distance. No genetic differences were found between the transplanted shoots and shoots from donor meadows, as expected due to the low rate of sexual reproduction in P. oceanica and the short time that had passed since the transplants. The problem of affecting the local gene pool by the introduction of foreign genotypes could arise, but introduction of new alleles could balance the degradation of genetic variability caused by human impact. In general our study suggests that the genetic variability of source material is an important aspect to consider in the development of seagrass restoration strategies.

Renton, M., Airey, M., Cambridge, M.L., and Kendrick, G.A., 2011, Modelling seagrass growth and development to evaluate transplanting strategies for restoration: Annals of Botany, v. 108, p. 1213-1223.
Background and Aims Seagrasses are important marine plants that are under threat globally. Restoration by transplanting vegetative fragments or seedlings into areas where seagrasses have been lost is possible, but long-term trial data are limited. The goal of this study is to use available short-term data to predict long-term outcomes of transplanting seagrass. Methods A functional-structural plant model of seagrass growth that integrates data collected from short-term trials and experiments is presented. The model was parameterized for the species Posidonia australis, a limited validation of the model against independent data and a sensitivity analysis were conducted and the model was used to conduct a preliminary evaluation of different transplanting strategies. Key Results The limited validation was successful, and reasonable long-term outcomes could be predicted, based only on short-term data. Conclusions This approach for modelling seagrass growth and development enables long-term predictions of the outcomes to be made from different strategies for transplanting seagrass, even when empirical long-term data are difficult or impossible to collect. More validation is required to improve confidence in the model's predictions, and inclusion of more mechanism will extend the model's usefulness. Marine restoration represents a novel application of functional-structural plant modelling.

Reuter, M., and Piller, W.E., 2011, Volcaniclastic events in coral reef and seagrass environments: evidence for disturbance and recovery (Middle Miocene, Styrian Basin, Austria): Coral Reefs, v. 30, no. 4, p. 889-899.
Volcanic disturbances and ecosystem recovery at sites of neritic carbonate production are rarely documented, neither in the recent nor past geological record. Herein, we present a Middle Miocene (ca 14.5 Ma) shallow-marine carbonate record from the Styrian Basin (Austria) that shows recurrent breakdowns of the carbonate producers (i.e., coralline red algae and zooxanthellate corals) in response to ashfalls from nearby volcanic island sources. These volcanic events are preserved as distinct marl layers with idiomorphic biotite crystals and volcaniclasts that mantle the former seafloor topography. The pyroclastic sediments suffocated the carbonate producers in coral reef and seagrass environments. A subsequent turbid, eutrophic phase caused by the redistribution, suspension, and dissolution of volcaniclastics is characterized by the spreading of suspension-feeding biota, coralline algae, and the larger benthic foraminifer Planostegina. During this stage, rapidly consolidated pyroclastic deposits acted as hard grounds for attached-living bivalves. The fact that the facies below and above the studied ashbeds are almost identical suggests that volcaniclastic events had no long-lasting effects on the structure of the carbonate-producing benthic communities. Although Miocene shallow-water carbonate systems of the circum-Mediterranean region are well known and situated in one of the geodynamically most active regions worldwide, this study is the first that exams the impact of volcanic sedimentation events on shallow marine ecosystems. PUBLICATION ABSTRACT].

Roca, G., Romero, J., Columbu, S., Farina, S., Pages, J.F., Gera, A., Inglis, G., and Alcoverro, T., 2014, Detecting the impacts of harbour construction on a seagrass habitat and its subsequent recovery: Ecological Indicators, v. 45, p. 9-17.
Managing coastal development requires a set of tools to adequately detect ecosystem and water column degradation, but it also demands tools to detect any post-disturbance improvement. Structural seagrass indicators (such as shoot density or cover) are often used to detect or assess disturbances, but while they may be very sensitive to the impact itself, it is unclear if those indicators on their own can effectively reflect recovery at time scales relevant to managers. We used the construction of a harbour affecting a nearby Posidonia oceanica seagrass community to test the ability of a set of indicators (structural and others) to detect alterations and to evaluate their sensitivity to recovery of environmental quality after harbour construction was complete and the disturbance ceased. We used a Beyond Before After Control Impact (BBACI) design to evaluate effects on one impacted and three control meadows where we used structural, morphological, community and physiological indicators (26 in total) to asses disturbance impacts. Additionally, we measured some of the potential environmental factors that could be altered during and after the construction of the harbour and are critical to the survival of the seagrass meadow (light, sediment organic matter, sediment accrual). Harbour construction caused a clear increase in sediment organic matter and in sediment deposition rates, especially fine sand. Light availability was also reduced due to suspended sediments. Sediment and light conditions returned to normal levels 5 and 15 months after the construction began. As expected, seagrass structural indicators responded unequivocally to these environmental changes, with clear reductions in shoot density. Additionally, reduced light conditions quickly resulted in a decline in carbohydrate content in affected meadows. Unexpectedly, we also recorded a significant increase in metal content in plant tissues. No response was detected in the physiological indicators related to eutrophication (e.g. N and P content in tissues) and in morphological (shoot biomass) and community (epiphyte biomass) indicators. More than three years after the completion of the harbour, structural indicators did not show any sign of recovery. In contrast, physiological indicators, mainly heavy metal and carbohydrates content, were much better in detecting the improvement of the environmental conditions over the fairly short period of this study. These results indicate that while structural indicators are critical to evaluate the immediate effect of disturbances and the recovery on impacted systems, specific physiological indicators may be much better suited to determining the timing of environmental quality recovery. The design of impact and monitoring protocols in the wake of coastal developmental projects need to consider the differential effectiveness and time-response of measured indicators carefully. (C) 2014 Elsevier Ltd. All rights reserved.

SÃnchez-Lizaso, J.L., FernÃndez-Torquemada Yolanda, and GonzÃlez-Correa, J.M., 2009, Evaluation of the viability of Posidonia oceanica transplants associated with a marina expansion: Botanica Marina, v. 52, p. 471-476.

In March 2005, a preliminary *Posidonia oceanica* transplantation was carried out as a restoration measure prior to enlargement of a marina. Seagrass sods of approximately 1 m^2 surface area and 40 cm depth (including rhizome and sediment) were cut free from the area expected to be impacted by harbor expansion. These fragments were transferred to nearby areas lacking *P. oceanica*, viz. in bare areas within the nearest meadows and at the same depth as the donor site (~10 m). The present work was carried out with the aim of evaluating the feasibility of this technique through estimating the vitality of transferred plants (measured as density and cover) for comparison with plants from a nearby meadow with similar conditions. There was a high level of mortality among transplants and a considerable degradation of the shoots that remained alive at the time of the sampling. When results were expressed in terms of global density, the rate of survival of transplanted shoots decreased to 15% (50 vs. 361 shoots m^{-2} of meadow in transplant and control plots, respectively). These results indicate that transplant techniques for *P. oceanica* on a large scale are not feasible.

Sinclair, E.A., Verduin, J., Krauss, S.L., Hardinge, J., Anthony, J., and Kendrick, G.A., 2013, A genetic assessment of a successful seagrass meadow (Posidonia australis) restoration trial: Ecological Management & Restoration, v. 14, p. 68-71.

Seagrass meadows are in decline globally. Although numerous experimental methods have been implemented to restore meadows, few have been successful in the long term. Poor decisions on the sourcing of transplants from donor sites, including poor genetic integration and/or low genetic diversity, may impact on restoration success. However, despite evidence to suggest a positive association between genetic diversity and ecological resilience, there is usually little or no input from genetic data to inform on the genetic management of ecological restoration. Cockburn Sound has seen a 77% decline in seagrass cover since 1967. A transplant trial was conducted between 2004 and 2008 with sprigs of Posidonia australis being planted into a bare sand area. Survival was monitored annually, and in 2012, we compared genetic diversity in this transplant area with the original donor site. Genetic diversity in the restored meadow was very high and comparable to the donor site, with no genetic differentiation detected. The high level of genetic diversity and choice of site may have played an important role in the success of this restoration trial. The observed natural recruits around the site after establishment of transplants suggest that local restoration efforts may improve seafloor habitat and facilitate natural expansion of the meadow.

Statton, J., Kendrick, G.A., Dixon, K.W., and Cambridge, M.L., 2014, Inorganic Nutrient Supplements Constrain Restoration Potential of Seedlings of the Seagrass, Posidonia australis: Restoration Ecology, v. 22, p. 196-203.

Seed represents a potentially ecologically sustainable source of planting units for restoring seagrasses, particularly for seagrasses where transplanting negatively impacts donor beds. However, newly germinated seeds may be nutrient limited as their underdeveloped root systems may constrain capacity to access sediment-based resources. We conducted a study in land-based aquaculture tanks to determine whether early growth of newly germinated Posidonia australis seedlings could be enhanced by adding inorganic nutrients to the sediment. Sediments were supplemented with nitrogen and phosphorus in a factorial design (no nutrients, N, P, N+P). Shoot survival, whole shoot biomass, root morphology, root architecture, and nutrient concentration of seedlings were assessed monthly for the first 4months after germination. More than 90% of seedlings survived during the 4months of the experiment, irrespective of nutrient treatment. Growth of P. australis seedlings was not enhanced by addition of N or P to the sediment despite nutrient uptake occurring. Seedling growth was found to be more dependent on seed nutrient reserves rather than external nutrient sources for at least the first 4months after germination. Adding inorganic nutrients to the sediment also significantly reduced the development of the seedling root system in terms of biomass, length, and density of lateral root branches. This study demonstrated that inorganic nutrient supplements constrain root development and therefore capacity for successful anchorage of seagrass seedlings, and pose a significant limitation on seedling establishment when transferred to the field, as well as potentially limiting natural and transplanted seedling establishment in eutrophic sediments.

Stratton, J., 2011, Restoration potential of seagrass Posidonia australis Hook f. seedlings is enhanced through aquaculture. University of Western Australia, Ph.D. thesis. 178 pp. http://research-repository.uwa.edu.au/en/publications/restoration-potential-of-seagrass-posidonia-australis-hook-f-seedlings-is-enhanced-through-aquaculture%289d2cdd84-a120-4b9b-86b8-a1835e4fbb95%29.html Accessed May 18, 2015.
Seeds are potentially an ecologically sustainable source of planting units for restoring seagrasses. However, seeds of the temperate Australian seagrass Posidonia australis Hook f. germinate before shedding (vivipary), and this lack of dormancy means that seeds cannot be banked for later use in restoration. To extend the timeline for seed-based restoration, this study investigated conditions for culturing seedlings in land-based aquaculture facilities, examining approaches to preconditioning seedlings with the aim of optimizing their vigour before transplanting into the field. Growth conditions in culture were tested in four separate experiments. In addition, a series of pilot-scale studies investigated strategies to establish seedlings in the field. Growth responses were examined firstly for three sediment types (unsorted carbonate, unsorted silicate and well-sorted silicate), with and without addition of organic matter. Seedling leaf, root, rhizome and total biomass increased when organic matter was added to unsorted carbonate and unsorted silicate sediment but not well-sorted silicate sediment. Root length and number of lateral root branches was also greatest in unsorted sediments, and when organic matter was added. A second component examined whether growth of seedlings could be enhanced by adding inorganic nutrients to the sediment. Sediments were supplemented with inorganic nitrogen (N) and phosphorus (P) in a factorial design (no nutrient addition, +N, +P, +N+P). Growth of seedlings was not enhanced by addition of N or P to the sediment despite nutrient uptake. Leaf mass, leaf area and leaf production were unchanged by nutrient additions whereas the size of the seedling root system, in terms of biomass, length and the density of lateral root branches was significantly reduced.

Terrados, J., Marin, A., and Celdran, D., 2013, Use of Posidonia oceanica seedlings from beach-cast fruits for seagrass planting: Botanica Marina, v. 56, p. 185-195.
Posidonia oceanica seedlings produced from beach-cast fruits were planted in an area where this Mediterranean seagrass was lost as a consequence of fish-farming. The effects of substratum type (dead matte vs. meadow) and planting level (above vs. below bottom surface) on seedling survivorship and leaf development were evaluated after 3 years. Seedling capacity to resist uprooting was also tested by comparing survivorship and leaf development after 2 years in seedlings firmly anchored in dead matte by artificial means (mesh-pot) with those planted without any anchoring other than their roots. Survivorship in dead matte was 44% after 3 years and was not affected by planting level. Seedling planting inside the meadow led to complete mortality after 3 years. Seedlings planted below the bottom surface branched during the second year and 50% had produced from one to five additional shoots after 3 years. After 2 years, survivorship and leaf development of seedlings planted with mesh-pot anchoring was similar to that of seedlings planted without anchoring. Current environmental conditions in the impacted area allow P. oceanica seedlings to survive, but natural recovery might be limited by propagule availability. Planting of seedlings in dead matte without anchoring does not affect survivorship and leaf development and might be a feasible technique for restoration of P. oceanica meadows.

Van Keulen, M., Paling, E.I., and Walker, C.J., 2003, Effect of Planting Unit Size and Sediment Stabilization on Seagrass Transplants in Western Australia: Restoration Ecology, v. 11, no. 1, p. 50-55.
The effect of increasing planting unit size and stabilizing sediment was examined for two seagrass planting methods at Carnac Island, Western Australia in 1993. The staple method (sprigs) was used to transplant Amphibolis griffithii (J. M. Black) den Hartog and the plug method was used to transplant A. griffithii and Posidonia sinuosa Cambridge and Kuo. Transplant size was varied by increasing the number of rhizomes incorporated into a staple and increasing the diameter of plugs. Planting units were transplanted into bare sand, back into the original donor seagrass bed, or into a meadow of Heterozostera tasmanica, which is an important colonizing species. Sprigs of A. griffithii were extracted from a monospecific meadow; tied into bundles of 1, 2, 5, and 10 rhizomes; and planted into unvegetated areas. Half the units were surrounded by plastic mesh and the remainder were unmeshed. All treatments were lost within 99 days after transplanting, and although larger bundles survived better than smaller ones, no significant differences could be attributed to the effects of mesh or sprig size. Plugs of P. sinuosa and A. griffithii were extracted from monospecific meadows using polyvinyl chloride pipe of three diameters, 5, 10, and 15 cm, and planted into unvegetated areas nearby. Half the units were surrounded by plastic mesh and the remainder were unmeshed. Posidonia sinuosa plugs were also placed within a meadow of H. tasmanica (Martens ex Aschers.) den Hartog. Only 60% of A. griffithii plug sizes survived 350 days after transplanting back into the donor bed; however, survival of transplants at unvegetated areas varied considerably, and analysis of variance indicated a significant two-way interaction between treatment and plug size. Transplants survived better when meshed (90% survived) and survival improved with increasing plug size. Posidonia sinuosa transplants survived poorly (no plugs survived beyond 220 days in bare or meshed treatments) regardless of size. Survival of 10- and 15-cm plugs was markedly better than the 5-cm plugs in vegetated areas, including the H. tasmanica meadow. The use of large seagrass plugs may be appropriate for transplantation in high-energy wave environments.

Verduin, J.J., Paling, E.I., van Keulen, M., and Rivers, L.E., 2012, Recovery of Donor Meadows of Posidonia sinuosa and Posidonia australis Contributes to Sustainable Seagrass Transplantation: International Journal of Ecology Article ID 837317
Donor meadow recovery is important in deciding whether removal of material from natural seagrass meadows is a sustainable activity. Thus an investigation into meadow regrowth was undertaken as part of a large-scale seagrass rehabilitation effort in Cockburn Sound, Western Australia. Several plug extraction configurations were examined in Posidonia sinuosa and Posidonia australis meadows to monitor shoot growth into plug scars. No significant differences in shoot growth between extraction configurations were observed, and both species increased their shoot numbers over two years, with P. sinuosa showing a significantly better recovery rate than P. australis. P. sinuosa shoot recovery into extracted areas was 2.2Ã‚Â±0.1 shoots over 24 months, similar to shoot changes in controls (2.3 shoots over the same period). P. australis shoot recovery for each configuration was 0.8 Ã‚Â± 0.3 shoots in 24 months compared with 1.5 shoots in the controls. Based on the number of regrowing shoots, the predicted recovery time of a meadow is estimated at 4 years for P. sinuosa and three years for P. australis. Different plug extraction configurations do not appear to affect meadow recovery, and it can be concluded that established meadows of both species are sustainable providers of planting units for rehabilitation measures.

Westera, M.B., Babcock, R., Western Australia., Geraldton, P.A., and CSIRO Marine and, A.R., 2008, Post-dredging recovery of seagrasses in the Geraldton Region : year 3 report : a report to the Geraldton Port Authority. Vol. I, Recovery and impact. September 2007: Floreat Park, W.A., CSIRO Marine and Atmospheric Research. 72 pp.
Seagrass sampling was undertaken for the Geraldton Port Authority (GPA) in February 2005, 2006 and 2007 to monitor the port area following dredging activities during 2002-2003, that resulted in a persistent plume of suspended sediment. A total of 25 sites were sampled in the Geraldton region, and at Greenough, Port Denison and Jurien. Some of these coincided with sites sampled by the GPA in February 2004 and others were established as reference sites. These sites formed the basis for ongoing assessment of potential ecological changes in seagrass condition in the Geraldton Harbour region. Sites were grouped by regions, as defined by distance from the dredging operation, for statistical analyses. These Regions were Point Moore to Chapman River (PMCR), North of Chapman River (PMCR), Greenough (GRE) and Port Dennison (PD). Reference sites, at PD and GRE were all either up-current from the dredging operations. The dominant seagrass species varied between sites and regions and included Amphibolis antarctica, Amphibolis griffithii and Posidonia sinuosa. All seagrass monitoring data collected by the GPA, URS Australia Pty Ltd and CSIRO Marine Research, as part of the Geraldton Port Enhancement Project, was reviewed and comparisons made where sufficient data were available. The basis for the monitoring was that in the absence of adequate control sites and other samples from prior to dredging significant increases of seagrass condition in the area affected by dredging impact, relative to those areas upstream from the dredging (Time x Region or Time × Site interactions), would constitute evidence of the extent and magnitude of dredging effects.

Zarranz, M.E., Gonzalez-Henriquez, N., Garcia-Jimenez, P., and Robaina, R.R., 2010, Restoration of Cymodocea nodosa (Uchria) Ascherson seagrass meadows through seed propagation: seed storage and influences of plant hormones and mineral nutrients on seedling growth in vitro: Botanica Marina, v. 53, p. 439-448.
We evaluated seed storage and effects of plant growth regulators and fertilizers on in vitro germinated seedlings with a view to optimizing restoration of Cymodocea nodosa. Storage of seeds in seawater at room temperature (22 +/- 28 degrees C) and 188 degrees C retarded germination potential for up to one year, though the best results were seen within the first six months. Seeds stored in water at 4 degrees C or under dry conditions lost their germination potential immediately. Neither plant growth regulators (PGRs) nor fertilization had anatomical effects in seedlings that would have indicated increased robustness. Gibberellic acid (10(-3) M) promoted leaf growth in seedlings, but most treatments with other auxins and cytokinins were ineffective or even inhibitory in achieving the desired hardening effect on the seedling. Seedlings appeared to be well nourished and most likely grew by utilizing their abundant nutrient reserves.

Zarranz, M.E., Gonzalez-Henriquez, N., Garcia-Jimenez, P., and Robaina, R.R., 2010, Restoration of Cymodocea nodosa seagrass meadows through seed propagation: germination in vitro, seedling culture and field transplants: Botanica Marina, v. 53, p. 173-181.
Cymodocea nodosa, a marine angiosperm, an ecosystem engineer in the Mediterranean Sea and the Northwest Atlantic Ocean; however, as in other seagrasses meadows worldwide, the swards are actually declining due to increasing human pressures. Hence, we have developed an effective propagation methodology that provides C. nodosa seedlings for seagrass meadow restoration and conservation. This method consists of: i) germination of wild-collected seeds under hyposaline conditions, ii) acclimation of germinated seedling in tanks (1.6 m(3)) until there are two shoots per seedling (similar to 30 days), and iii) transplantation of acclimated seedlings to the field in dense groups. Our field outplants withstood herbivore activity and physical disturbance during the winter season, and propagated vegetatively, resulting in the spread and establishment of a new patch that has persisted for nine months.

Zipperle, A.M., Coyer, J.A., Reise, K., Stam, W.T., and Olsen, J.L., 2010, Waterfowl grazing in autumn enhances spring seedling recruitment of intertidal Zostera noltii: Aquatic Botany, v. 93, p. 202-205.
Feeding pits dug by waterfowl in Zostera noltii meadows are thought to promote seedling recruitment by accumulating seeds and enhancing germination. We tested the latter hypothesis by creating a series of "treatment pits" (resembling natural feeding pits) in the center and at the edge of two meadows near the Island of Sylt (Germany). Seedling density was monitored from the autumn seed set until the following spring. Seedling density (mean, SE) in treatment pits was significantly higher (4.4, 5.3) than in manipulated (2.4, 1.9) and unmanipulated controls (1.4, 0.4), as well as significantly higher in center (2.8, 0.5) relative to edge (2.5, 1.1) locations. Results confirm a facilitating effect of waterfowl grazing on seedling recruitment in spring due to seed accumulation in feeding pits in autumn. The mechanism could provide a valuable tool for the conservation of intertidal Z. noltii meadows in the Wadden Sea. (C) 2010 Elsevier B.V. All rights reserved.