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OPINION ARTICLE

Changing Paradigms in Seagrass Restoration

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Abstract

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.

Key words: European seagrasses, habitat mitigation, restoration guidelines, seagrass conservation, seagrass loss, seagrass transplantation.

Introduction

Continual loss of seagrasses has resulted in research progressively focused on restoration and mitigation. The ability to successfully mitigate seagrass loss through restoration and or transplantation is environmentally and economically imperative given that seagrasses provide numerous ecosystem functions (Costanza et al. 1997; Duarte et al. 2008). Concern over decreasing trends in seagrass habitat cover and distribution in European countries as well in the rest of the world (Duarte 2009; Waycott et al. 2009; Cunha et al. 2011) triggered the development of many seagrass restoration programs around the European coast. Seagrass restoration is seen as an important means to recuperate damaged areas and so, seagrass habitat restoration has been the focus of many research groups working in Portugal (CCMAR with the LIFE Biomares in the Arrábida coast), in Spain (Oceana-Madrid; AZTI-Tecnalia, in the Basque Country; IMEDEA-CSIC in the Baleares, and ICCM Instituto Canario de Ciencias Marinas in the Canary Islands), in the Netherlands (Radboud University) and France (GIPREB Cours Mirabeau, Berre-l'Étang). The workshop with 30 participants, was held in Portinho da Arrábida, Portugal, on the 30 September and 1 October 2010, and was organized under the Biomares Project (LIFE06 NAT/P/192).

Results

The results of the workshop revealed that seagrass restoration success in all/most of the European projects presented during the workshop was very low. In general, results varied spatially and temporally at multiple scales. Within-site variability of planting success was often related to differences in physical factors (e.g. depth, exposure, and sediment texture gradients among other factors), while success rates between sites was often linked to climate/weather issues, herbivory, macroalgae, or exposure to name a few significant factors. With regard to success rates over time, it was also apparent that restoration success or failure could be linked to between-year differences in the above factors (i.e. a stressor was absent 1 year and present the next). While the species varied from one region to another, the general lack of long-term success was a common

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and re-occurring theme. Despite these discouraging results, a large body of experience and knowledge have been developed and factors related to success and failure have been generally identified. An important discussion arisen after one of the participants presented a partial review with the analysis of circa 200 publications on the results about seagrass restoration projects. It showed that most projects reporting/publishing success are flawed by the fact that most of them have had short monitoring periods (<1 year). For most of the reported cases in the scientific literature, the seagrass success has a median planting unit survival of 15%, but in 44% of experiments/actions PU survival was 0%. Most seagrass restoration experiments/actions have been conducted at scales of less than 10 m^2 (only in 30% of cases plantation size was >100 m^2), and in shallow waters (50% of them in ≤2 m depth).

Given these results it was clear that most reported cases of successful seagrass restoration correspond to projects with limited monitoring. Also, an important issue was raised when the participants recognized that the literature available is skewed by these "successful" projects as researchers and editors have the tendency to avoid publishing failed projects.

General Recommendations

The participants agreed that the workshop was a worthwhile endeavor that should be repeated in the future. The following recommendations have been considered:

(1) Increase public awareness and appreciation of seagrasses throughout Europe by means of education and outreach efforts to citizens, politicians, managers, and regulators.
   (i) Engage the public in a dialogue regarding status and trends (e.g. interview fishermen, NGOs, students).
   (ii) Make every effort to include public awareness campaigns, with the cooperation and assistance of local NGO's that involve professionals in outreach, education, and promotion.
   (iii) Publish the results of such education and outreach efforts in scientific *fora* to share results and prevent unnecessary future failures.
   (iv) Explain clearly to the public and project financers the reasons of success and failure of projects.

(2) Determine the distribution, cover, and conservation status of seagrasses in each member country to make effective protection and management possible.

(3) Given the fact that many participants identified existing/ongoing large-scale impacts to seagrass meadows (e.g. commercial fishing, marine construction, etc.), it was agreed that these issues need to be addressed within each member country.
   (i) Demand that managers, regulators, and politicians protect existing seagrass meadows to the extent that existing laws allow. There are several marine habitat regulations that can be used; get to know these!
   (ii) Identify regulations that allow identifiable impacts to take place (e.g. commercial fishing and bottom trawling). Consider recommendations to modify existing regulations that will better protect seagrasses and will additionally include "potential" seagrass habitat (i.e. historic areas plus appropriate buffer zones to allow for natural recovery and/or restoration).
   (iii) A new European regulation should be developed for the protection of the Atlantic European seagrasses facing destruction caused by aggressive fisheries, similar to the existing Council Regulation (EC) No. 1967/2006 applied to the Mediterranean Sea, to prohibit damaging fisheries above seagrass beds.

Technical Recommendations

The following actions are recommended prior the start of a restoration project submission/implementation:

(1) Establish clear goals and objectives prior to initiation restoration.

(2) Define monitoring methods and success criteria prior to beginning and make accommodations for long-term monitoring (i.e. 5–10 years) if it is not a part of the initial project.

(3) Include donor population monitoring in the project (Cunha et al. 2009).

(4) Make every effort to ensure that local threats (e.g. bioturbation, herbivory, hydrology, sediment movements, human impacts, etc.) to seagrasses are well known prior to initiating restoration projects. Consider every possible impact based on a review of the literature, measurements of physical conditions, evaluation of the general ecosystem condition (Fonseca 2011) and start only when all threats causing the regression had been eliminated.

(5) Initiate with small-scale or pilot restoration trials, prior to engaging in large-scale restoration projects, although in some cases, a large scale might be necessary because a critical mass of plants/area planted is often required (van Katwijk et al. 2009).

(6) Additional devices to anchor plants or protect them against storms, sediment dynamics or herbivory should be avoided. In most cases they either disappear due to dynamics, or do more harm than good, by adding to the dynamics rather than combating them (they move in the sediment, uprooting the transplants directly or via scouring; van Katwijk et al. 2009), damage leaves, or grow more epiphytes. Both in the (intertidal) Wadden Sea and (subtidal) Arrábida, there are extensive negative experiences with this (Cunha & Serrão 2011).

(7) Covering the transplant rhizomes with a local stone (or sand bag to improve the technique) seems to be a positive exception and may be applicable at several locations, provided sites are selected carefully, such as where a certain density of stones already present, otherwise

scouring around the stones damages the plants (Pickerell, unpublished data).

(8) The application of a shell layer on top of the sediment to stabilize sediments is another positive exception that worked in the Wadden Sea (van Katwijk & Hermus 2000; it also improved success in Eastern Scheldt, because of bioturbation prevention). There may be more exceptions, but the general guideline is not to add devices (but see *Posidonia* transplants Meinesz et al. 1990; Molenaar & Meinesz 1995; Balestri et al. 1998).

(9) To improve success and efficiency of restorations, Traditional Ecological Knowledge (e.g. stakeholders with experience with manipulations in the area, like fishermen or shellfish/ bait collectors, Johnson 2008) can give a big help. Spread the trials throughout different sites and use different methods. In the face of unusual threats, learn and be willing to change plans based on the experienced results. Even consider moving to another site in the face of difficulties. In other words Adaptive Management should be the base of a seagrass restoration project ("Adaptive Restoration," Fonseca 2011).

(10) Strive to learn from the experience of others and use the information to improve methods at specific sites. It seems that it may take more than 5–10 years to start becoming successful although instant lucky successes occur (C. Pickerell, Cornell University, U.S.A., personal communication).

(11) Publication of the results and increased sharing of experiences, particularly when starting new projects is essential. It would be good to also interview the restoration scientists and experts that worked on transplantation in the 1970s and 1980s, like Meinesz (France), Thorhaug (Florida, Caribbean), and/or study their work.

(12) Almost all participants expressed frustration about natural beds being disturbed and/or natural recovery being prevented (trawling, shellfish/bait collection, tourist activities…). This is partly due to the absence of law enforcement, and partly due to limited regulation or protection status, or modification of protection status if economics prevail. Make sure you have identified all these constraints and their magnitude and frequency before starting a restoration effort.

Important Recommendations for Seagrass Conservation

(1) Efforts on conservation of existing meadows should be an European priority.

(2) In no case should restoration be considered the first alternative when planning for the mitigation of coastal development projects. Managers should follow an appropriate mitigation sequence when working in areas that support seagrass. Avoid damage to existing meadows through site selection (i.e. move the project to an area that will not damage seagrass). When it is impossible to move to another area, reduce the footprint of the impact to minimize disturbance to seagrasses. Finally, where the first two alternatives are not possible, consider restoration efforts to mitigate the impact. As a last resort, restoration should be considered in the following order: On Site In-Kind, Off Site In-Kind, and Off Site Out of Kind.

(3) Restoration success is generally too low to justify mitigation as a compensation measure for economic activities. Mitigation in case of overriding interests (like safety) should be employed but with additional aiming at knowledge development. Restoration successes should never be used as a compensation measure for economic activities. Every meadow is unique itself and the conservation of all existing seagrass beds is crucial to maintain and restore the oceans.

(4) Give priority to natural restoration potential. Acknowledge patch dynamics as a natural phenomena and look at the landscape perspective and connectivity between populations.

(5) Press governments to catalog seagrass species as priority/protected species. Furthermore, it is a priority that coastal managers/fisheries, start to re-evaluating trawler's operation areas to avoid damage to seagrass beds or/and historical seagrass areas to allow for recovery. The 2008 European Marine Strategy Framework Directive EC (Directive 2008/56/EC of the European Parliament and of The Council of 17 June 2008. Official Journal of the European Union. 25 June 2008. 164/19-40) states that Member States has the obligation to achieve a "good environmental status" by 2020. So all human activities that have an impact on the marine ecosystems have to be addressed with the aim of the preservation of biodiversity.

(6) All participants agreed on the low level of investment on public communication actions and education by most entities working on the implementation of seagrass conservation projects (research institutes, government bodies, or NGOs). It was recommended that the entities developing a seagrass conservation or restoration project should consider the hiring of a public relations or marketing specialists to help in the outreach communication.

(7) Include local or national NGOs in the projects.

(8) Evaluate the interest of developing an INTERREG project (European Interregional Cooperation Program) for restoration pilot/essay studies or/and, a LIFE project [European funding under Regulation (EC) No. 614/2007] on Communication for European Seagrass with emphasis on the evaluation of historical distribution based on local knowledge, conservation regulations, etc.

(9) Seek alternative sources of funding for research/conservation and restoration projects, namely, private funds from companies/institutions interested in the areas where those projects will take place (involvement of stakeholders in funding).

(10) Numerous decision trees, guidelines, and restoration models have been developed to aid seagrass restoration management (Fonseca et al. 1998; Campbell 2002; van Katwijk et al. 2009; Fonseca 2011). These have a number

of general steps, including objective setting, site characterizing and selection of transplant units and methods. In light of the outcomes of the European experience, these guidelines should be re-evaluated and expanded.

(11) To ascertain the real magnitude of seagrass restoration effort, success and progress, it is important to encourage researchers to provide this information as well as editors to publish it. Recently, some editors are paying more attention and are willing to publish unfortunate surprises (Hobbs 2009).

(12) A thorough review of global seagrass restoration projects, published and unpublished, with a special reference to monitoring period and species is urgent to be done and published.

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LITERATURE CITED

Balestri, E., L. Piazzi, and F. Cinelli. 1998. Survival and growth of transplanted and natural seedlings of *Posidonia oceanica* (L.) Delile in a damaged coastal area. Journal of Experimental Marine Biology **228:**209–225.

Campbell, M. L. 2002. Getting the foundation right: 556 A scientifically based management framework to aid in the planning and implementation of seagrass transplant efforts. Bulletin of Marine Science **71:**1405–1414.

Costanza, R., R. d Arge, R. de Groot, S. Farber, M. Grasso, B. Hannon, et al. 1997. The value of the worlds ecosystem services and natural capital. Nature **387:**253–260.

Cunha, A. H., and E. A Serrão. 2011. Tools for seagrass conservation and management in Portugal. Ecologi@ **3:**23–36, Journal from the Portuguese Society of Ecology (available from: http://speco.fc.ul.pt/revistaecologia.html).

Cunha, A. H., J. Assis, and E. Serrão. 2009. Estimation of available seagrass meadow area in Portugal for transplanting purposes. Journal of Coastal Research **SI 56:**1100–1104.

Cunha, A. H., J. Assis, and E. A. Serrão. 2011. Seagrasses in Portugal: a most endangered marine habitat. Aquatic Botany (available from 10.1016/j.aquabot.2011.08.007)

Duarte, C. M., J. Borum, F. Short, and D. Walker. 2008. Seagrass ecosystems: their global status and prospects. Pages 281–294 in N. Poluin, editor. Aquatic ecosystems. Cambridge University Press, Cambridge, UK. Foundation for Environmental Conservation.

Duarte, C. M., editor. 2009. Global loss of coastal habitats: rates, causes and consequences. FBBVA, Madrid, Spain. 181 p. ISBN: 978-84-96515-84-0.

Fonseca, M. S. 2011. Addy revisited: what has changed with seagrass restoration in the last 64 years? Restoration Ecology **29:**73–81.

Fonseca, M. S., W. J. Kenworthy, and G. W. Thayer. 1998. Guidelines for the Conservation and Restoration of Seagrasses in the United States and Adjacent Waters. National Marine Fisheries Service, NOAA Coastal Ocean Program, Decision Analysis Series.

Hobbs, R. J. 2009. Looking for the silver lining: making the most of failure. Restoration Ecology **17:**1–3.

Johnson, T. R. 2008. Fishers' knowledge in fisheries science and management. Fish and Fisheries **9:**118.

Meinesz, A., G. Caye, F. Locques, and S. Macaux. 1990. Analyse bibliographique sur la culture des phanerogames marines. Posidonia Newsletter **3:**1–67.

Molenaar, H., and A. Meinesz. 1995. Vegetative reproduction in *Posidonia oceanica*: survival and development of transplanted cuttings according to different spacings, arrangements and substrates. Botanica Marina **38:**313–322.

van Katwijk, M. M., and D. C. R. Hermus. 2000. Effects of water dynamics on *Zostera marina*: transplantation experiments in the intertidal Dutch Wadden Sea. Marine Ecological Progress Series **208:**107–118.

van Katwijk, M. M., A. R. Bos, V. N. de Jonge, L. S. A. Hanssen, D. C. R Hermus, and J. de Jong. 2009. Guidelines for seagrass restoration: importance of habitat selection and donor population, spreading of risks, and ecosystem engineering effects. Marine Pollution Bulletin **58:**179–188.

Waycott, M., C. M. Duarte, T. J. B. Carruthers, R. J. Orth, W. C. Dennison, S. Olyarnik, A. Calladine, J. W. Fourqurean, K. L. Heck, Jr., A. R. Hughes, G. A. Kendrick, W. J. Kenworthy, F. T. Short, and S. L. Williams. 2009. Accelerating loss of seagrasses across the globe threatens coastal ecosystems. Proceedings of the National Academy of Sciences of the USA (PNAS) **106:**12377–12381.