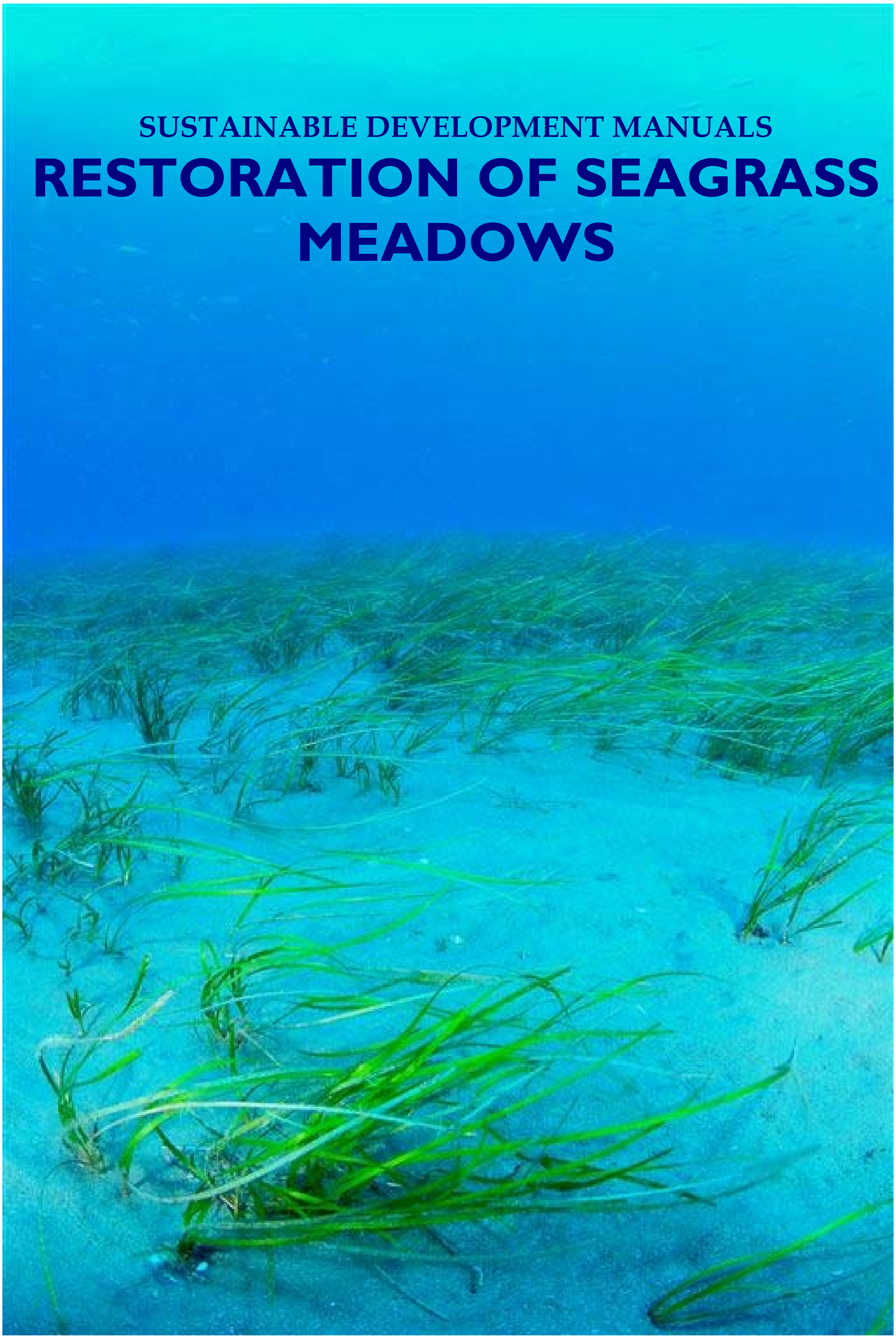
SUSTAINABLE DEVELOPMENT MANUALS

RESTORATION OF SEAGRASS MEADOWS



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Cover photo
Cymodocea nodosa meadow, known as seahorse grass, in front of Punta Entinas-Sabinar Natural Park, Almeria © OCEANA Rafael Fernández.

SEAGRASS MEADOWS

Description and distribution

Seagrasses are plants with roots, stems and leaves adapted to living in the marine environment and capable of producing flowers, fruits and seeds. These plants are more evolved and complex than seaweed, which have a more simple structure, although the two species are often confused.

Seagrass beds occur extensively in shallow waters and can reach up to depths of 40m or more, if the environmental conditions permit photosynthesis. Present in warm and temperate waters, they form "seagrass meadows". There are 60 known species of seagrasses in the world that can create meadows, although the European coasts harbour mainly four species, all of which are present on the Spanish coasts; including *Zostera marina, Zostera noltii, Cymodocea nodosa* and *Posidonia oceanica*. In addition, there is a fifth species present on the coasts of the Canary Islands, *Halophila decipiens*, which mainly occurs in African waters.

Table 1.General characteristics of seagrasses present in European waters.

Species	Distribution on European coasts	Description of the meadow	Approximate maximum depth
Zostera noltii	Atlantic, Mediterranean and Black Sea	Loose meadows, 20-25cm high, thin leaves, 1-2mm wide.	Up to 10m
Zostera marina	Atlantic (except Canary Islands) and Mediterranean	Meadows are 30-60cm in height, reaching up to 1m or over, with ribbon-like leaves, 10-12mm wide.	Up to 10m
Cymodocea nodosa	Atlantic and Mediterranean	Loose meadows, 30-40cm high, thin leaves, 2-4mm wide.	Up to 30m
Posidonia oceanica.	Mediterranean	Meadows are 40-60cm in height, reaching up to 1m or over, with thick, ribbon-like leaves, 5-12mm wide.	Up to 30-40m or over if there is enough sunlight
Halophila decipiens	Atlantic (only Canary Islands)	Short meadows, 2-3cm high, oval-shaped leaves, 3-6mm wide.	Up to 30m or over if there is enough sunlight

*Cymodocea nodos*a meadow, next to a *Posidonia oceanica* plant (left). El Calón, Almería © OCEANA Juan Cuetos.

Legislation

The conservation, protection and improvement of the environment, including conservation of natural habitats and species, constitute a fundamental objective for the European Union and a variety of laws and international conventions have been established to protect certain habitats and species.

Based on these laws and the establishment of regulatory procedures applicable in the Spanish Mediterranean, some species of seagrass present in Spanish coastal areas have been included in different conservation categories, proving the increasing interest in these ecosystems, which are in decline around the world.

Of the four species that occur on the Spanish coasts, *Posidonia oceanica* is the most highly protected seagrass. Native to Mediterranean waters, these meadows are considered a "priority natural habitat" by Directive 92/43/CEE of 21 May 1992 on the conservation of natural habitats and wild fauna and flora (Habitats Directive), the EU's most important environmental conservation tool. A number of studies and efforts have been carried out to ensure the good state of conservation of this essential plant and the health of the Mediterranean Sea.

Other seagrass meadows also occurring in the Mediterranean, including *Z. marina, Z. noltii* and *C. Nodosa*, are not as protected, though they are equally important and constitute essential habitats for a variety of species, as well as a source of oxygen and organic matter for our seas. Oceana and the Banco Santander Foundation carried out a joint study in 2006 called "*Praderas sumergidas*", aimed at calling upon the European Union to include all seagrass species present in Spanish waters in the Habitats Directive annexes.

All of these communities are currently significantly threatened by various factors, most importantly, human activities: illegal fishing on top of these beds according to the *Plan Integral de Gestión para la Conservación de los Recursos Pesqueros en el Mediterráneo (comprehensive plan for the conservation of fishing resources in the Mediterranean)*, uncontrolled anchoring on top of the beds by recreational boats, contamination and water turbidity due to fishing, agricultural and aquaculture activities, as well as endless construction work on the coasts that modify coastal dynamics and, as a result, the coast itself and its ecosystems.

Inhabitants

Thousands of marine species benefit directly or indirectly from these *underwater forests* that, like forests on land, are shelters, nurseries and feeding grounds and harbour high levels of biodiversity. In fact, many seagrasses around the world are named after the emblematic species that live there, for example "turtle grass" or *Thalassia testudinum*, is a tropical marine plant that provides food for the green turtle (*Chelonya midas*) whose beak is designed precisely for this type of diet. "Manatee grass" or *Syringodium filiforme* is the basic sustenance for the impressive manatee (*Trichechus manatus*), a large tropical marine mammal that can reach up to 3 metres in length and weigh 500kg, and eats up to 50kg a day of this seagrass to maintain its body heat.

On our coasts, it is a well known fact that *Posidonia oceanica* beds are essential for the biodiversity of the Mediterranean, the only sea where this seagrass occurs. Moreover, these beds guarantee the survival of a wide variety of fish, molluscs, invertebrates and other species of commercial interest, while harbouring protected species including *Pinna nobilis*, a large mollusc that is protected by various international and national laws.

Cymodocea nodosa and *Zostera* spp. beds can also harbour hundreds of different species including molluscs, crustaceans, cnidarians, fish, echinoderms, ascidians, seaweeds, etc. *Cymodocea nodosa* is capable of forming mixed ecosystems, either with other seagrasses or with seaweed, so it can harbour a wide range of species with different habits. Even sea turtles frequently visit these environments, feeding on both the seagrass and other organisms that live among or on the leaves. In addition, these beds also harbour species from the Syngnathidae family of fish, some of which are well known and protected on a national and international level, including seahorses (*Hippocampus* spp.). These species have specifically adapted to life among the *Cymodocea* leaves, also known as "seahorse grass".

The presence of seagrass beds transforms the seabed into spawning, nursery and resting grounds, while providing shelter for a variety of fish species. This, in turn, attracts predators from the pelagic environment thus increasing the ecosystem's biodiversity. A wide variety and abundance of invertebrates are also an important part of this ecosystem, including bivalves, crustaceans, small invertebrates and microalgae distributed among the leaves and rhizomes, providing food for many other species.

Seahorse *(Hippocampus ramulosus),* perfectly adapted to living among *Cymodocea nodosa* leaves © OCEANA Carlos Suárez.

Ecological and economic importance

The loss of seagrass meadows involves a decline in marine productivity and biodiversity, alteration of coastal dynamics, decreased quality of the water, lack of oxygen, instability of the substrate, loss of beach sand and a decline in fishing resources, all of which directly or indirectly affect humans. The disappearance of seagrass meadows negatively affects the ecological and economic value of coastal ecosystems.

The presence of these beds is an indicator of the quality of the coastal environment. Moreover, biodiversity has significantly declined in marine areas where seagrass beds have declined, turbidity has increased and nearby beaches have become unstable because they are no longer protected from the waves by the seagrass beds. All of this affects the human activities developed in adjacent areas.

Activities such as tourism, recreational, artisanal, underwater and industrial fishing or recreational diving suffer the consequences of a loss of marine biodiversity that the presence of healthy seagrass beds guarantees in coastal zones. A decline in biodiversity directly leads to significant economic losses due to various factors, including the disappearance of attractive areas for diving, a decline in available fishing resources, partial or total loss of beach sand with the subsequent loss of tourism, etc. Indirectly, it can adversely affect the economy because costly activities must be developed to mitigate these negative effects, including restoring beaches, which has important economic and environmental impacts, and searching for fish and other species that become more and more scarce.

Because it is a colonizing and pioneer species that is highly resistant to variations in temperature and salinity, *C. nodosa* allows for the development of *Posidonia oceanica* beds in areas that would otherwise be inaccessible to this species. The ecological role played by both seagrasses as nursery, spawning and resting grounds for commercially valuable coastal species turns them into feeding grounds for other commercial marine species. As such, these environments are essential for the future health and productivity of coastal zones and this fact should be taken into account when developing coastal management plans.

Seagrass beds also play an important role as indicators of coastal ecosystem health. Because they are highly sensitive to changes in environmental, physical, chemical and biological conditions, seagrass health is used as a sensitive index of the impact of the activities developed in the area. This is because even slight changes in light, temperature or salinity, among other factors, significantly affect the normal development of seagrasses. Such changes can be identified in practically all European coastal zones and are caused by a variety of human activities carried out irresponsibly and without any type of control. These activities often go unpunished because the corresponding legal sanctions are not applied.

Many studies attempt to estimate the economic value of the services provided by certain ecosystems, including seagrass beds. Because is it difficult to calculate the value and scope of these services, a specific figure cannot be established and any estimate is always too low. Taking this fact into account, seagrass beds are usually assigned an annual economic value between €12,000 and €16,000 per hectare, which is 10 times more than the value assigned to tropical forests and up to 3 times more than coral reefs. However, many estimates exceed the ones mentioned above, as is the case with the Indian River Lagoon seagrass beds in Florida, where annual value has been estimated at €25,000 per hectare, taking into account profits from fishing only.

Global threats

Seagrass meadows are declining around the world and the causes are clear: most human activities developed at sea or in coastal zones, including inland areas, negatively affect marine ecosystems. Seagrass beds are highly affected by these activities because they are extremely fragile and sensitive and also because they are usually found close to the coast, an area where a myriad of human activities are developed. The impact human activities have on these environments should be evaluated and minimised before they are carried out.

There are two types of human activities that threaten marine ecosystems, and especially seagrass beds: activities that cause a direct impact on the beds and activities that generate an indirect, although equally dangerous, impact.

Human activities that directly affect seagrass beds: these activities are carried out in areas where seagrass beds are present, causing immediate degradation. This category includes:

- Underwater pipelines and cables.
- Trawling.
- Anchoring over seagrass beds.
- Oil extraction.
- Mining.
- Sand extraction.
- Beach regeneration.
- Mass seasonal tourism in coastal zones.
- Other fisheries.
- Direct discharge and runoff.
- Coastal construction, including ports, marinas, breakwaters, etc.
- Aquaculture farms.

Some of these activities allow for a certain degree of natural recovery once the work or activity ceases, as is the case with the installation of underwater pipelines or cables. Other activities prevent recovery because they involve occupying the entire space or permanently altering the physical or chemical conditions necessary for the development of new beds.

Human activities that indirectly affect seagrass beds: these activities are not directly developed on the seagrass beds but they may affect the surrounding marine environment, significantly altering water quality (increased turbidity, changes in chemical composition) and preventing the normal development of the plants, inhibiting the survival of the beds. The most common activities include:

- Hydrocarbon spills or routine dumping of pollutants by merchant, fishing or recreational vessels, both in port and on the high seas, increasing the presence of pollutants in the water.
- Large amounts of chemical products and other materials and sediments are dumped into the seas from agricultural, construction and industrial activities, through pipelines or rivers and streams, polluting the waters and seabeds.
- Strong human presence in coastal areas usually involves deficient treatment of waste waters that eventually reach the seas; this fact is worsened by mass occupation of the coastal areas, especially in countries where tourism is concentrated on the coasts.
- Construction work in coastal zones can modify the area's natural marine currents and coastal sedimentation processes, subsequently affecting littoral land and marine ecosystems. In addition, runoff of sediments from inland construction work, transported by rivers and rain directly into the sea, can bury or completely destroy entire seagrass beds.
- Overfishing can also negatively impact seagrass beds and other habitats. Overfishing of certain species of commercial value can lead to their disappearance or decline, causing a domino affect along the entire food chain.
- Brine discharge from desalination plants via underwater pipelines can cause local changes in water salinity, modifying the optimum conditions for the presence and growth of seagrass beds.
- Lastly, the myriad of human activities that generate greenhouse gases should also be taken into account. These gases are causing global temperatures to rise (climate change), including sea and ocean water temperatures, seriously threatening life on our planet, and negatively impacting both land and marine environments.

Bottom trawler fishing in waters of the Alboran Sea © OCEANA Juan Carlos Calvín.

SEAGRASS RESTORATION TECHNIQUES

The number and variety of seagrass restoration projects has increased in recent years due to the growing interest of the scientific community, including marine environment managers, the media and even some fishermen and politicians, as well as other groups. As such, the search for solutions that began some decades ago to mitigate the proven decline of these valuable ecosystems has been reinforced.

Most widely used methods

In recent years, seagrass beds have been restored around the world using a variety of techniques that may be divided into two basic groups; activities focused on collecting and transplanting plants, and activities focused on obtaining and planting seeds:

- **Transplanting adult plants** Traditionally, this is the most widely used method, probably because habitats are immediately created. This technique focuses on collecting core plugs, or adult plants, from healthy beds, mature plants with rhizomes and adhered substrate, or shoots without adhered substrate, for subsequent transplant into degraded areas. After storms, the shoots may also be collected directly on the beach, in great numbers.

  The core plugs are either inserted directly into the substrate or planted by means of a biodegradable "pot". The shoots may be weaved on to grids or frames, preferably made of a biodegradable material, or attached directly to the substrate. This type of transplant is characterised by high rates of mortality of transplanted plants recorded in practically all the experiments carried out to date. It also involves high economic and logistics costs, both for manual and machine transplanting. Furthermore, it can seriously damage or degrade the donor beds. To date, no transplant project has been proven to be completely effective.

- **Planting seeds** In recent years, researchers have been focusing their attention on this method because of its reduced costs. Also, the relevance of seed planting compared to clonal reproduction is currently being corroborated, both in the extension and natural recovery of seagrass beds.

  The collection, maintenance, transportation and planting processes are easier and more cost-effective. The mature seeds are collected directly from the bed. Eventually, large quantities of seeds may reach the beach, where they may be collected, although this type of collection cannot be predicted.

  Once the seeds have been collected, they may be planted directly in the area to be restored or maintained and treated in a laboratory to promote or even induce germination (by means of temperature and salinity variations) before being taken to sea. In recent years, mechanical planting methods have been developed to make the process faster and reduce costs. As such, this method clearly presents more advantages than transplanting adult plants.

Risks involved in each case

Restoration work involves a series of risks that should be carefully addressed to avoid the failure of the transplant or planting work:

- Transplanting adult plants:
    1. During the collection phase, the donor bed will suffer damages and the configuration of shoots and rhizomes will be altered. When extracting the core plugs or shoots, gases will escape though leaves and surrounding roots, compromising the strength of the healthy bed. This problem does not occur when core plugs are collected while drifting or on the beach.
    2. The process of transplanting adult plants involves significant expenses, including high labour costs. Collection at sea, transportation to the chosen area – with or without holding the plants in tanks to maintain optimum conditions - as well as the planting process itself, are very complex operations that require specialised personnel. All of these tasks should be carefully completed and must be supported by extensive preparation work, because the plants are extremely sensitive.
- Using seeds:
    1. If the donor bed's rhizomes are unearthed when the seeds of the plants are collected during the seed collection phase, this may alter the anchoring of the donor bed to the substrate. This is not a problem if the seeds are collected on the beach.
    2. The planting process may involve maintaining the seeds in a laboratory. This phase is very delicate because many factors are involved (water oxygenation, light levels, temperature, salinity) and must taken into account to ensure the viability of the seeds.

Some transplant efforts have obtained significant survival rates, but these results are not predictable. Furthermore, these efforts are not economically viable and are usually experimental.

Cymodocea nodosa rhizomes, frequently exposed by currents © OCEANA Sergio Gosálvez.

Evaluation of the different methodologies

Many environmental factors affect the development of seagrass beds. Knowledge about the physiology of these plants and its relevance for colonising new areas is still lacking, especially concerning colonisation by seed reproduction. Restoring a degraded marine ecosystem and its natural balance is an extremely complex task, not only because of the complexity of the ecosystem itself, but also because the work must be carried out in the marine environment.

In terms of expenses and logistics, there is no ideal restoration method for restoring large degraded areas, and no method can be considered the most important in terms of restoring the altered ecosystem to its original state.

Table 2. Evaluation of the different restoration techniques.

Method		Donor	Environmental impact	Economic cost	Logistics cost	Recommendation
Plant transplant	**Core plugs**	Healthy bed	⇧	⇧	⇧	☒
	Shoots	Healthy bed	⇗	⇗	⇧	☒
		Beach	⇘	⇩	⇨	☑
Seed planting	**Laboratory**	Healthy bed	⇘	⇨	⇘	☑
		Beach	⇩	⇨	⇘	☑
	On-site	Healthy bed	⇘	⇘	⇘	☑
		Beach	⇩	⇘	⇘	☑

Legend: ⇧ high; ⇗ medium-high; ⇨ medium; ⇘ medium-low; ⇩ low; ☒ not recommended; ☑ recommended; ☑ highly recommended

The success of the different methods depends on a series of key factors:

1. Species of seagrass.
2. Location of the donor bed (oceanographic and climate conditions, type of substrate, etc.).
3. Future location of the adult plants, shoots or seeds.
4. Manual or mechanical method used during the entire process.
5. Magnitude of the project.
6. Time of year.
7. Other factors (experience of the personnel involved, unpredictable weather conditions, etc.).

These variable factors make is difficult to evaluate a restoration project and the possible rates of survival. Furthermore, studies have not yet proven the full recovery of the ecological functions and natural balance of the transplanted beds.

All of the methods used are constantly being researched, developed and improved, focusing on efforts that have achieved the highest survival rates. The mortality rate of transplanted adult specimens is very high. When successful, the costs of even small-scale transplants prevent these techniques from being applied to real restoration work.

Research and new methodologies

The main problem related to seagrass restoration is cost-effectiveness. To date, no transplant or planting method has been proven adequate for large-scale restoration. Research into new methods is focused on optimising the effectiveness of the techniques, paying special attention to the use of seeds because they are easier to handle and are more resistant, and the techniques employed are less aggressive for the donor bed. Thus, the use of seeds for large-scale restoration seems to be the most effective method and worldwide research is focusing on this technique.

In addition, research is also focusing on the factors that condition the growth and propagation of seagrass beds, including light conditions, nutrients in the water, type of sediment and salinity, among others. These factors determine whether or not an area is adequate for future restoration and the success of the restoration project itself.

Protection instead of restoration

Seagrass restoration, mainly experimental efforts, is currently being used to justify aggressive actions on the coast. Restoration techniques –often involving the transplant of entire beds- are being used as an excuse to compensate for aggressive human actions in the marine environment. Moreover, the viability of these techniques has yet to be proven.

Obviously, transplanting entire beds to different areas where they did not exist cannot be considered a restoration or regeneration technique, because the existing beds disappear. In addition, the beds are often transplanted in areas where they do not occur and, in many cases, have never occurred. This may indicate that the area does not present the optimum conditions for the development of the species or that human activities are developed that prevent its growth, and these activities must be addressed before the transplant is carried out.

Unfortunately, there are two "famous" cases of seagrass bed transplant projects carried out due to construction work on the Spanish coast:

First, the large-scale transplant of an extensive posidonia bed (*Posidonia oceanica*) was carried out to make room for the expansion of a recreational port in waters of the Region of Valencia. Because these beds are nationally and internationally protected, solutions to prevent the destruction of this important ecosystem had to be implemented. As such, a large-scale project to transplant the entire bed to another location, far from the construction work, was developed. The failure of the project was categorical. Practically all of the transplanted plants died and the construction work was halted. Currently, a lawsuit for the definitive cancellation of the construction work is now in court, endorsed by studies carried out by universities and research institutes.

In the Canary Islands, construction work to expand an industrial port is being rejected by the public, the scientific community, ecologists and finally the High Court of Justice of the Canary Islands, because of the damage it would cause to the area's seagrass bed. In this case, it is a *Cymodocea nodosa* bed or *sebadal*, as these beds are known in the Canary Islands. As in the other example, the company involved proposed to transplant the entire bed to another area in compensation for the construction of the port, although this never occurred because the viability of the transplant was consistently under question, taking into account the low success rate of large-scale transplants. Currently, the courts have halted the construction of the port pending a ruling. If the ruling allows construction work to continue, this unique ecosystem would completely disappear.

It is a well known fact that human activities constitute the main threat to these ecosystems. As mentioned above, the construction of industrial and recreational ports, breakwaters, artificial beaches and underwater pipelines; waster water dumping, brine discharge from desalination plants; and even certain fishing gear –like bottom trawling- and seafarming activities, have caused the deterioration of some seagrass beds and the disappearance of others. In some cases, natural causes must also be taken into account, like wave action or winter storms, capable of seriously damaging seagrass beds.

The approval and implementation of measures and tools to conserve and restore underwater ecosystems is an essential and urgent objective, taking into account the accelerated loss of marine biodiversity due to the degradation of water quality. The conservation of seagrass meadows may be achieved by combining measures to protect the existing beds (designating marine protected areas, regulations focused on preventing pollution and eliminating destructive fishing practices like trawling, applying sanctions, etc...) and measures that allow the degraded areas to recover, like replanting.

The joint application of effective protection and restoration strategies is the only way to stop the accelerated regression of seagrass meadows and recover lost biodiversity.

Cymodocea nodosa seeds exposed by currents. These appear in pairs at the base of the leaves © OCEANA Sergio Gosálvez.

SEAGRASS RESTORATION PROJECTS IN SPANISH WATERS

Restoration of *Cymodocea nodosa* beds in Punta Entinas-Sabinar Natural Park (Almeria)

A project to plant *Cymodocea nodosa* seeds in Roquetas de Mar, Almeria, was carried out within the line of action that the Banco Santander Foundation established for the recovery of natural spaces and in line with Oceana's objectives to conserve the marine environment. Following is a description of the activities completed in July and August 2008.

Description of the study area

The most important seagrass beds in Almeria are located around Cape Gata and surrounding areas (Vera Gulf and the Bay of Almeria). *Cymodocea* beds in different states of degradation and with different densities were identified during a research project developed by Oceana and Banco Santander Foundation in the summer of 2006. Subsequently, the data was analysed and the restoration stages were identified and characterised.

The study area, comprised of *Cymodocea nodosa, Posidonia oceanica* and *Zostera marina* beds in open seas subjected to wave action, was similar to the areas identified on the Cantabrian coast and Spanish Atlantic, so the work experience obtained during this intervention may be applied to other areas. This provides important resources to address the conservation and recovery of seagrass meadows, not only in Spain, but anywhere these plants are distributed.

Main threat: human activity

In Andalucia, the coastal zone is subjected to pressure from population centres, intensive agricultural activities (greenhouses) and mass tourism that generates significant urban pressure. These factors have significant environmental consequences, in terms of the degradation and deterioration of the coastal landscape, quality of water, coastal dynamics and coastline. More specifically, the Mediterranean coast of Almeria is one of the most affected by aggressive human activities, which degrade both land and marine ecosystems.

The study area, the marine area between Punta Sabinar and Punta Elena –this last located east of the Natural Park- is only a few miles from two spots exerting strong anthropogenic pressure: the residential zones of Roquetas de Mar and the Almerimar recreational port.

In 2006, the Banco Santander Foundation and Oceana carried out this research project in Spanish waters of the Mediterranean and South Atlantic and identified trawling marks on seagrass beds and high rates of sedimentation caused by the burying of beds in some areas.

Protection measures applicable to the study area

The restoration areas are located near Punta Entinas-Sabinar Natural Park, between El Ejido and Roquetas de Mar. This Natural Park, which covers 1,960 hectares, includes the 785-hectare Natural Reserve and was designated a protected area by Law 2/89 of the Regional Government of Andalucia. Subsequently, the EU designated it a Special Protection Area for Birds (SPA). In addition, the wetland is included in the Ramsar Convention on Wetlands of International Importance.

In the case of the Bern Convention on the Conservation of European Wildlife and Natural Habitats, adopted in 1979 by the majority of countries in the Mediterranean basin under the auspices of the Council of Europe, the annexes did not initially include any species of marine flora, although these were modified in 1996 to include three of the five species of seagrasses found in the Mediterranean (*Cymodocea nodosa, Posidonia oceanica, Zostera marina*). More specifically, of the European countries in the Mediterranean basin, only France, Croatia and Spain have legislations established to protect *C. nodosa*.

Apart from these direct protection measures, the establishment of regulatory procedures focused on controlling contaminating discharge (i.e. application of the Barcelona Convention protocols), ensuring the treatment of urban wastewater (i.e. application of Directive 91/271/CEE), fighting against eutrophication (i.e. application of Directive 91/676/CEE), prohibiting certain fishing gear (i.e. application of Council Regulation (CE) 1967/2006 of 21 December 2006) and fighting against the introduction of invasive species (i.e. application of Directive 92/43 CEE), constitute important instruments to indirectly protect seagrass beds. In addition, according to Habitat Directive Annex I that lists the natural habitats that should be protected through the designation of special areas of conservation, *Cymodocea nodosa* beds would be indirectly included because they form part of habitat 1110 *Sandbanks which are slightly covered by sea water all the time*.

Furthermore, the governments of some autonomous regions, like Catalonia, Valencia and the Balearic Islands, have established regulations that are applicable in the Spanish Mediterranean effectively protecting marine magnoliophyta (the plant phylum to which seagrasses belong). In Catalonia's case, an Order dated 31 July 1991 includes the protection of *Posidonia oceanica*, *Cymodocea nodosa* and *Zostera noltii*. In the Region of Valencia, an Order dated 23 January 1992 prohibits the destruction of seagrass meadows because these are areas of fishing importance. The government of the Balearic Islands, through an Order dated 21 September 2991, regulates fishing, shellfishing and aquaculture on top of seagrass meadows.

Previous work and preparation

In 2006, Oceana developed a joint research project in collaboration with the Banco Santander Foundation on board the *Oceana Ranger* focused on researching *Cymodocea nodosa* and *Zostera* sp. beds on the Mediterranean coast. Most of the work was focused on Almeria because of its characteristics as a transition area between the Mediterranean and Atlantic, including high rates and diversity of endemism and characteristic species of both biogeographical regions. Unlike the beds in other areas like the Mar Menor, the *Cymodocea nodosa* and *Zostera sp,.* beds on the Almeria coast are exposed to wave action, and are similar to those found in other Spanish Atlantic coastal areas.

The objective of the research was to lay the foundations for the design of an ecological restoration programme for degraded seagrass meadows. The results of the collaboration were presented in the report "Praderas sumergidas". During the campaign, the seagrass beds around Roquetas de Mar, Punta Entinas-Punta Sabinar-Punta Elena, Balerma and Balanegra were documented, among others. Due to its unique ecological conditions, this area was chosen to develop an experimental planting project to be carried out during the summer of 2008. This was, once again, a joint project between the Banco Santander Foundation and Oceana.

A few months before the planting began, the organisations consulted various scientists and technicians experienced in the field and collected as much data as possible about the results obtained in previous seagrass restoration projects. Once the methodology was designed and the necessary material was prepared -dive equipment, personnel and equipment for collecting and planting seeds-, the necessary permits to carry out the manipulation of a wild species of flora (*Cymodocea nodosa*) were obtained from the Directorate-General of the Environment of the Regional Government of Andalucia.

Cymodocea nodosa beds present a strong seasonality, in terms of reproduction, growth and production of biomass. This plant's reproductive phenology has been the subject of in-depth studies. Flowering occurs during the spring –between March and June-, when water temperature begins to rise after reaching minimum temperatures during the winter months. Seed production takes two or three weeks and the optimum dispersion time is between July and August.

In areas where seed production is high, rates of viability and germination have also proven to be high, and more than half the seeds can grow into new plants. Nevertheless, the mortality rates of new plants and clones is also significant, as well as predation of seeds by invertebrates and fish, limiting the seagrass' possibility of expansion. On average, it is estimated that *Cymodocea* beds produce between 200 and 600 seeds/m2, although in some areas, both in the Mediterranean (Italy) and the Atlantic (Canary Islands), more than 1000 or even up to 2000 seeds have been collected annually per m^2. After analysing this data, we estimated the number of seeds required to carry out the project.

Seed harvesting and planting

1st Phase: Examination of areas and search for seeds.

In order to document and determine the state of health of the meadows in the area, we examined the seabeds in front of Balanegra and Balerma, an area of roughly 400 ha, in order to locate the best spots for seed harvesting. The seagrass beds identified as possible seed donors were further examined by divers, in order to immediately plant the seeds after harvesting.

A number of search transects were run parallel to the coast via GPS, bathiscope, ROV and satellite images in an area with high density of shoots, with a coverage of more than 80% especially between 9 and 13m depth, previously documented by Oceana. After various dives on these seabeds in front Balanegra and Balerma, only a few thin and dispersed plants were identified in what used to be a dense and healthy seagrass bed. The dense seabed documented only two years before had almost completely disappeared, torn out or buried under the sand, apparently due to the winter storms and trawlers fishing illegally in the area. At least in this case, the high growth rate of *C. nodosa* shoots, which also makes this plant highly resistant to adverse conditions, was not enough to save it from the natural and human disruptions in the area.

2nd Phase: Seed harvesting and planting.

C. nodosa seeds were harvested and planted around the Roquetas de Mar area from on board the Oceana Ranger during August. Two locations were chosen, in front of Roquetas de Mar and in front of the Punta Entinas-Sabinar Natural Park, characterised by different levels of degradation or alteration of their seagrass beds (*Table 3*).

During the first dive in front of the residential area of Roquetas de Mar, south of the Natural *Posidonia oceanica* Barrier Reef Monument, it was verified that the seagrass bed had barely produced any seeds that year. In front of Punta Elena, after various dives at depths between 8 and 15m, areas with sufficient seeds were identified, thus considered apt for harvesting (*Table* 3). A total of 813 seeds were harvested. These were slightly buried, only 1 or 2cm under the sand in most cases, making it easier to harvest them without disturbing the rhizomes. Even so, all the divers had cloth bags with them to collect sand from nearby areas in case it was necessary to cover exposed rhizomes. The seeds, which were semicircular and flat, measuring an average of 9.98mm width and 12.82mm length, were harvested by the divers and placed in small mesh bags. They were stored on board the ship in jars filled with seawater and protected from direct sunlight until it was time for planting -only a few hours.

The seeds were subsequently planted (*Table* 4). Based on the information obtained from the videos previously filmed by Oceana and with the help of a bathiscope, the ideal areas for planting were identified, without extensive growth of *C. nodosa*, but close enough to other beds to ensure that the environment's conditions were favourable for the development of the seeds.

In both areas, the seeds were planted at two different depths, for a total of 4 planting points, in order to compare the success of the germination of the seeds and their degree of adaptation to the different conditions of degradation and depth. Thus, at each one of the four points, 10 plastic seed plots were anchored to the substrate, separated roughly 50cm from each other, in two columns of 5 seed plots each.

The seed plots are plastic boxes turned upside town, transformed into tops, in order to allow for the periodic revision of the seedlings and to protect the shoots from predators. Twenty seeds were placed manually in each one of the seed plots at 2-3cm depth, by making holes in the substrate. A label was placed on each seed plot indicating the date, depth and planting station. Once the plants develop and are correctly anchored, the seed plots will be removed.

Table 3. Seed identification and harvesting areas.

LOCATION	COORDINATES	No. seeds	DEPTH	CHARACTERISTICS
Roquetas de Mar	N 36° 46.000 W 002° 36.000	0	15m	*C. nodosa* and *P. oceanica* bed. Low density. Muddy seabed. Low degradation.
Punta Elena	N 36° 40.881 W 002° 39.665	273	13m	*C. nodosa* bed. Medium density. Sandy seabed with gravel. Low degradation.
Punta Elena	*N 36° 40.853 W 002° 39.723	540	13-15m	*C. nodosa* bed. High density. Sandy seabed. Low degradation.

** Dive spots. The seeds were found in a radius of 25m from these points.*

Table 4. Seed planting areas.

LOCATION	COORDINATES	DEPTH	CHARACTERISTICS
Punta Elena	N 36° 41.566 W 002° 39.307	8.8m	Medium degradation. Mixed bed (*C. nodosa, P. oceanica*). Mixed seabeds (sand, maerl, *Mesophyllum* sp. reefs). Old trawling marks.
Punta Elena	N 36° 40.645 W 002° 39.347	17.3m	Medium degradation. Mixed bed (*C. nodosa, P. oceanica*). Mixed seabeds (sand, maerl, *Mesophyllum* sp. reefs)
Roquetas de Mar	N 36° 44.112 W 02° 36.287	10.7m	High degradation. Sandy-muddy seabeds.
Roquetas de Mar	N 36° 43.987 W 002° 36.290	14.5m	High degradation. Sandy-muddy seabeds.

Supervision plan for seed planting and harvesting areas

The supervision of the seed planting and harvesting areas is carried out periodically starting the spring of 2009, coinciding with the germination of the seeds. The evolution of the cultivation will be documented –rates of germination and development of the young plants- and the evolution of the donor bed will be monitored in order to evaluate possible disturbances to growth by sexual reproduction after seeds were harvested and possible damage to the shoots from altering the substrate during the extraction of these.

The success patterns and indicators resulting from this project will be established based on the data obtained with respect to the cultivation areas, location and rates of germination and survival.

Cymodocea nodosa seed planting station in waters of Roquetas de Mar, Almería © OCEANA Sergio Gosálve

Conclusions and proposals

According to the data obtained in the seed search transects, the *C. nodosa* beds of the Almeria coast show significant variations in extension and biomass, due to both the characteristic coastal dynamics of this coastline and the trawlers that fish illegally on these beds, directly destroying them and causing persistent turbidity in the water column, which also hinders the normal development of the seagrasses in adjacent areas.

During this project, 800 *C. nodosa* seeds were planted directly after harvesting, in four areas of the Almeria coastline, taking into account the different variables including depth and health of nearby seagrass beds. Locating, harvesting and planting the *C. nodosa* seeds were straightforward and simple processes compared to other methods of seagrass restoration.

The restoration of *C. nodosa* beds by harvesting and planting the seeds directly in degraded areas is easier and more cost-effective than other methods used for seagrass recovery, for example laboratory germination of seeds and planting shoots collected directly from the plant, and is also less harmful for the donor bed. In addition, this is an ideal method for large-scale restoration once the most adequate methodology has been established.

Because large-scale seagrass restoration projects are rare, decisive conclusions cannot be drawn, irrespective of the methodology used and, as such, seagrass restoration cannot currently be considered a solution to the regression these ecosystems are now experiencing, especially when the human activities that are causing this regression are not being halted. There is also a significant lack of knowledge about the real status of *C. nodosa* beds, both on the Almeria coasts and in the rest of the areas of distribution. This lack of knowledge also extends to the importance of sexual reproduction in the proliferation of these plants, hindering the efforts focused on their conservation and recovery.

The need to ensure the persistence and recovery of *C. nodosa* beds, given their proven importance for the maintenance of marine biodiversity and the quality of coastal environments, is enough reason to protect these ecosystems. The consideration of *Cymodocea nodosa* beds as priority habitat in Annex I of the Habitats Directive is justified.

The conservation and protection of the marine environment in general, and many of its ecosystems in particular, is currently deficient due to the notorious lack of knowledge about this environment. In the case of *C. nodosa* meadows, information is lacking in many respects including actual state of conservation, distribution, degree of threat and regression, biology and opportunities for recovery. More information is necessary for the correct management and recovery of the species.

The relative success of some pilot experiences in transplanting *C. no*dosa beds in Portugal, Canary Islands and Italy is only applicable to small areas because of the significant investment needed to complete these projects. It is essential to increase the effectiveness of the transplant techniques and to develop methodologies that are more cost-effective and less aggressive and present higher success ratios. This type of research should be considered a priority as a means to halt activities that damage the coastal environment. Furthermore, seagrass transplants that have not been proven viable and are thus rejected by the scientific community, are used as an excuse to carry out these aggressive activities. However, the best way to conserve existing seagrass meadows continues to be the establishment of protection measures that prevent the factors that degrade them.

According to data obtained from previous research, restoration by means of seed planting is the most effective way to restore seagrass meadows and causes the least damage to donor beds. There is not much information available concerning how seeds contribute to the maintenance and creation of *C. nodosa* beds. In addition, this lack of information makes it difficult to predict the possible negative effects that harvesting seeds for large-scale restoration may have on established populations. Thus, the progress of this type of methodology is limited and research in this field is essential and should be fostered.

The designation of marine protected areas wherever this species is present is one way to halt the aggressions that cause its regression, -trawling, anchoring on beds, contamination, etc.- and to promote the natural recovery of degraded seagrass meadows. This type of protection involves monitoring the area and applying sanctions as necessary. If these actions are not carried out, then the designation of marine protected areas is useless.

More specifically, these activities have been carried out in front of the coast of Punta Entinas-Sabinar Natural Park. Taking into account that the existence of seagrass beds has often been decisive when declaring protected zones, this fact should promote the protection of waters in front of the Natural Park, and the boundaries of the natural space should include depths of at least 50m in order to ensure all the seagrass meadows in the area are protected.

Experimental transplants of seagrass beds (*Cymodocea nodosa*) in waters of the Canary Islands.

In February 2005, the Canary Island Institute of Marine Sciences (ICCM) implemented a small-scale pilot project to transplant healthy *Cymodocea nodosa* –using the core plug method- that was being affected by the construction work to expand a port in Gran Tarajal, Fuerteventura. Less than half (40%) of the plants survived the transplant after a few months and this technique was dismissed as a useful tool to prevent the loss of these habitats, according to the evaluation of the project presented by scientists during the *XIV Iberian Symposium on Marine Biology Studies*. Shortly after, the survival rate was practically null, even 0% in some areas, as explained during the *1st Conservation Workshop on Cymodocea nodosa and restoration of its habitat in the Canary Islands*.

Another series of experimental transplants of the same species were carried out in waters of the archipelago. *Cymodocea nodosa* is protected under Canary Island legislation, catalogued as “sensitive to habitat alteration” by Decree 151/2001, of 23 July, by which the Canary Island Catalogue of Threatened Species was created. In compliance with this Decree, seagrass beds were relocated and transplanted, their habitat was restored and a Conservation Plan was drafted. This research, completed by the ICCM, was relatively successful in some seagrass beds in Gran Canaria and Lanzarote, although it is estimated that the techniques used for large-scale applications must be optimised.

Other experimental transplants affected by coastal construction work were also carried out in Gran Canaria and Tenerife. None of these projects have proven the viability of transplant processes to create a habitat similar to the one destroyed by construction work.

Restoration of *Posidonia oceanica* beds in waters of the Maro-Cerro Gordo Cliffs (Malaga-Granada).

The Environmental Office of Malaga implemented a project that preceded other restoration activities in Andalucia: "*Priority actions to restore coastal ecosystems in the province of Malaga*" was focused on regenerating a hectare of *Posidonia oceanica* and *Zostera marina* beds in the Maro-Cerro Gordo Cliff area. The restoration project aimed to connect remnants of an original meadow after it was partially destroyed by illegal trawling activities in shallow waters and marine contamination, two of the most serious threats to the survival of seagrass meadows and activities that are common in the area. The results of this experience are pending publication.

Transplanting *Posidonia oceanica* due to the expansion of the Port of Roquetas de Mar (Almeria).

After it was announced that the port of Roquetas de Mar would be expanded, the Regional Government of Andalucia implemented a plan to transplant a small posidonia bed that was destined to disappear due to the construction work. In this case, the project was focused on two objectives: to test the viability/inviability of the transplant process at sea and to use these plants as indicators of the quality of the water that had been previously subjected to industrial contamination. Unfortunately, the area's difficult oceanographic conditions, with strong currents and frequent storms, made it impossible to complete the project.

ERPO Project: Structures for the Regeneration of *Posidonia oceanica*

Recently, a restoration project was implemented, funded by the Ministry of the Environment, Rural and Marine Areas. The project was focused on designing and building a prototype of a biodegradable seed plot that could be installed directly on the seabed. Posidonia seeds collected on the beach or directly floating on the water will be planted in these recipients. For this, studies are being carried out on the flowering process of posidonia and how the seeds drift with the currents.

The structure should be strong enough to withstand extreme climate conditions like winter storms, strong wave action and currents. The objective of the research is to increase the possibilities of seagrass restoration while reducing the elevated costs, the two factors that most affect the viability of the methods currently used.

Eight academic and scientific institutions are participating in the project: the Mediterranean Institute of Advanced Studies, the Polytechnic University of Catalunya, the University of Murcia, the International Centre for Research of Coastal Resources, the International Centre for Numerical Methods in Engineering, the Centre for Advanced Studies of Eivissa and Formentera, the Interpretation Centre of Sant Antoni and Active Generation. Research has already begun and the parameters of the effectiveness of the structures should be ready in 2010. The structures will then be installed in the marine environment.

INTERNATIONAL SEAGRASS RESTORATION PROJECTS

The United States was the first country to implement seagrass restoration projects in the 40s. But the most important projects have been carried out in the last decades and the list of restoration experiences is extensive. As a result, specialised equipment has been designed to reduce costs during the different stages of the process. Most of these projects have been completed in the calm waters of Florida and Virginia, for example, and most have involved *Zostera sp*. In particular, some restoration projects with *Zostera sp.* seeds in Virginia have been exceptionally successful.

In Australia, where seagrass beds have significantly regressed due to aggressive industrial activity, strong efforts are being made to recover lost biodiversity, using both *Zostera* sp. and *Posidonia* sp. Various manual and mechanical methods are being developed and tested, but satisfactory results have not yet been obtained.

Japan and Korea have focused efforts mainly on *Zostera marina*, which is common in those areas, researching the different factors that affect the development of the transplanted plants, including type of sediment, type of anchoring, time of year, etc. Manual and mechanical methods have also been tested with increased survival rates using the manual methods, although the problems related to high costs and damage to donor beds have yet to be resolved.

In Europe, research has been focused on *Zostera* sp., *Cymodocea nodosa* and particularly *Posidonia oceanica*, which is endemic to the Mediterranean and forms dense meadows that are in drastic regression. Some transplant experiences have been carried out in Italian, French and Portuguese waters. Experiments with seeds are still rare, although the LIFE BIOMARES project in Portugal is now focusing on germinating *Cymodocea nodosa* seeds in laboratories and transplanting the shoots to the marine environment in order to increase the genetic diversity of the threatened seagrass beds in the area.

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