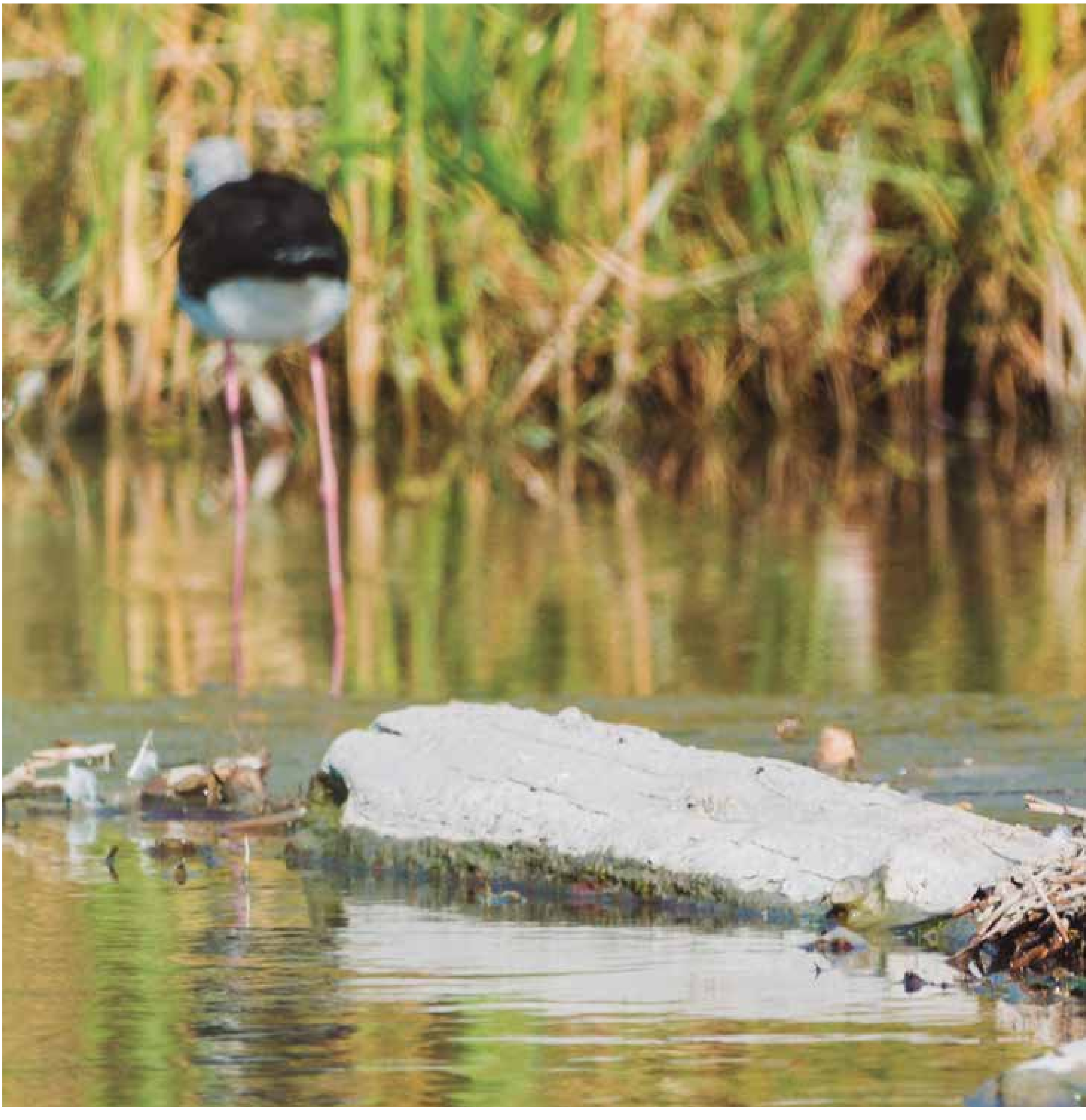
CHAPTER 8:

BLUE CARBON ECOSYSTEM RESTORATION



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BLUE CARBON ECOSYSTEM RESTORATION

Ecosystem restoration is a powerful tool to recover those ecosystems that have been lost or destroyed, together with their ecosystem services. The carbon markets provide a source of income to finance the restoration of ecosystems that, as salt marshes or seagrass meadows, would promote removal of CO_2 from the atmosphere or avoid the emission of stored CO_2.

Restoration projects focusing on blue carbon services can be financed through the voluntary carbon markets where private companies choose to buy carbon credits on a voluntary basis, most often as a tool for corporate social responsibility. It will also be important that restoration projects are integrated as part of local climate-change adaptation-planning to preserve the carbon and other ecosystem benefits of these habitats.

The given definition of restoration implies the return to a past state of the ecosystem owing to the actions of a given programme [89]. Restoration may benefit an area, however, we need to take into account that a restoration activity may improve one ecosystem parameter while deteriorating another. Therefore, the possible trade-offs coming from restoration activities need to be taken into consideration in any a given set of interventions, as well as the objective of minimising decreases in any existing ecosystem service [89].

Collaborating with local communities provides a useful source of knowledge about the previous state of the ecosystem to be restored. Following the Global Natured-based Solutions Standard[28], is important during restoration projects that the needs and aspirations of local communities are taken into account when the project is designed, as they can assist in safeguarding the restored ecosystem. This requires dialogue with the local communities before the project preparation and while it is being implemented [90].

Mitigation

Decreasing or compensating the impact of some known activity; includes a variety of management options.

Rehabilitation

Improving, augmenting or enhancing a degraded or affected area.

Restoration

Returning an ecosystem from a disturbed or totally altered condition to a previously existing natural or altered condition.

Passive restoration: refers to those actions that, by removing the environmental stressors or source of degradation, allow the natural recovery of the ecosystem. Passive restoration relies on the ecosystem's resilience, its capacity to return to a past state after the disturbance has disappeared. An example of a passive restoration would be the implementation of management regulations banning anchoring over seagrass meadows, preventing new impacts and allowing the local seagrass species to recolonise the affected areas.

Active restoration: refers to those actions that directly intervene in ecosystem management to correct the degradation state. This approach is usually utilised when the ecosystem does not have the capacity to recover by itself after the environmental stressors have disappeared or when the natural recovery is slow. Examples of active restoration would be the revegetation of a seagrass meadow, the construction of foreshore - permeable fence or the addition of sediments to elevate the soil surface in salt marshes.

Creation

Establishment of a salt marsh or seagrass meadow on a site that is documented not to have supported that ecosystem in the recent past.

[28] Criterion 5: NbS are based on inclusive, transparent and empowering governance processes. IUCN NbS Standard.

CONCEPTUALISATION AND DEVELOPMENT OF A BLUE CARBON RESTORATION PROJECT

Here, a stepwise approach to conceptualising and developing a restoration programme in salt marshes or seagrass meadows is proposed (Fig. 34), summarising previously outlined approaches to coastal ecosystem restoration [89, 91, 92].

Define goals and objectives

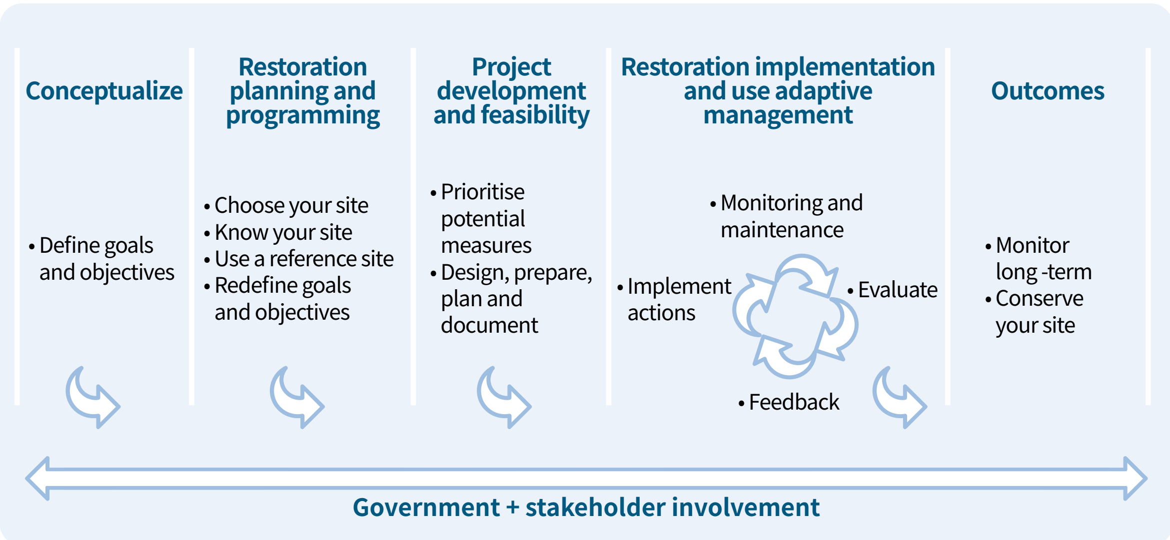
This would require the identification of the biological target (species or community) to be restored and familiarisation with its general biology and ecology. Also in scope here is the need to define the type of interventions and the ecosystem service that will be the focus. In the case of a blue carbon project, this should state and define which type of project it would be (see section above), including the objectives, long- and short-term goals and the success criteria.

Choose the restoration site

In some cases, the restoration location would already be known; in other cases, a landscape study would be needed to identify the best location to maximise success. Gathering information about the environmental conditions that affect the ecosystem service targeted in the proposed project is essential to find the most suitable location. Those areas where the cause of the ecosystem regression has disappeared, but no natural recuperation or a very slow recuperation has occurred, constitute interesting areas for active restoration projects, as the cause of the ecosystem's decline must be removed if the project is to be successful.

In seagrass meadow restoration, an ideal site to maximise restoration success would be a sheltered area with sufficient light, close to and at a similar depth to the donor meadow [93]. The bigger the area in which the project's intervention takes place, the higher the rate of success, as any negative effect of local variability would only partially affect the project [93, 94]. Poor site selection is often mentioned as a cause for restoration failure [95].

Figure 34: Schematic timeline for planning, implementing and conducting restoration project activities.



Know the project site

In this step, information about the current and past states of the chosen site is gathered. The key stakeholders need to be identified as well as legal requirements and responsibilities.

Use a reference site

A reference site is a less-degraded seagrass meadow or salt marsh in the same area, with similar environmental conditions, that can function as an indicator of how the ecosystem would be without or with less disturbance. This would allow for a better definition of the goals, project targets and tasks.

Redefine goals and objectives

The information gathered should be used to re-evaluate the viability of the project´s goals and to provide specific targets and tasks derived from its objectives.

Use adaptive management

No matter how detailed the initial information collection is, there will always be unforeseen events and consequences or new information available. Adaptive management means the continuous re-evaluation of the project to incorporate any new information or events.

Prioritisation of potential measures

When several techniques can be implemented, the following prioritisation is recommended: passive restoration > restoration with soft materials (soft engineering) > restoration with hard materials (hard engineering).

Accordingly, ecosystem-friendly alternatives that rely on some combination of natural or living materials, less common than traditional engineering approaches (i.e. hard-built infrastructure for coastal defence structures), can have high potential for private investment and work towards an approach of nature-based infrastructure or hybrid infrastructure.

Design, prepare, plan and document

This step integrates the information collected in the previous steps and ends with the preparation of an activity plan, including which techniques are suitable for the site, success indicators, a monitoring plan, and the required documentation. A cost-benefit analysis of the results would provide a realistic estimate of the funding needed, including the cost of a monitoring programme to test restoration success. A peer review of the project is recommended to ensure that the design matches scientific requirements, decreasing the probability of failure [95].

Involve stakeholders and licensing authorities

Collaboration with stakeholders and local authorities facilitates the obtaining of legal permission. Moreover, the more involved they are, the higher the probability of success in implementing the project. Local communities can provide invaluable information for the project as well as help to manage the restored ecosystem.

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Abandoned saltpans are potential sites for wetland restoration.

Restoration implementation and use adaptive management

Implement

This is the phase were the restoration actions are executed. All measurements of previous states of the ecosystem would be performed before the implementation. It is important to know what monitoring tasks are to be performed so that any necessary structure or task can be implemented during this phase.

Monitor long-term

The monitoring phase allows the impact and success of the project to be tested. It is possible that, after the implementation phase, corrections need to be done, like replanting seeds or digging new channels, as the goals of the project have not been reached. The monitoring programme would allow such a need to be identified. Monitoring programmes, for example every 5-10 years, are mandatory in blue carbon projects to be able to prove additionality.

Conserve the project site

Long-term that can also include new or updating existing regulations or legal frameworks (e.g. MPAs), is often needed to ensure that the site is functioning properly and that it does not return to a degraded state once the restoration activity has finished.

Evaluate measure of success

Clear restoration objectives allow for a measure of restoration success, as well as informs how to adaptively manage restoration to improve outcomes. Monitoring is used to determine whether the restoration activities are having the desired habitat response where the success might beyond the initial restoration objectives.

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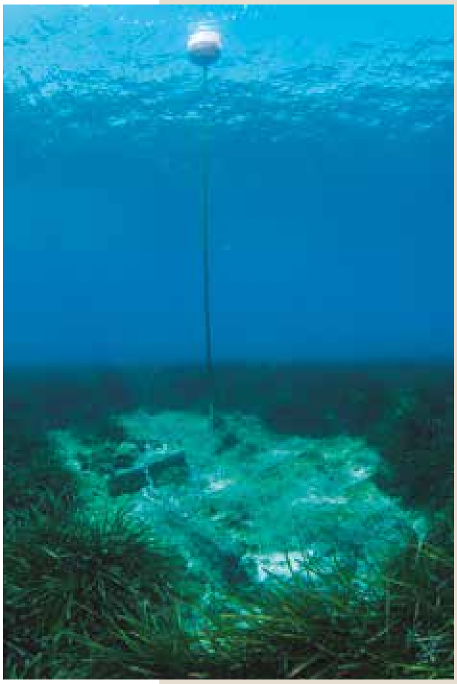

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Evaluation of a blue carbon restoration project in Agua Amarga, Cabo de Gata Nijar Natural Park, Andalusia, Spain

This protected area hosts one of the largest seagrass meadows in the Andalusia region. It is often visited by recreational small boats, particularly during the summer season.

Major damage to seagrasses seems to be caused by the use of homemade concrete block anchors with chains that break easily, as well as by the dragging of anchors and scraping of anchor chains along the bottom, as boats swing back and forth. This generates degradation of the seagrass and GHG emissions that increase over time. The study involved looking at:

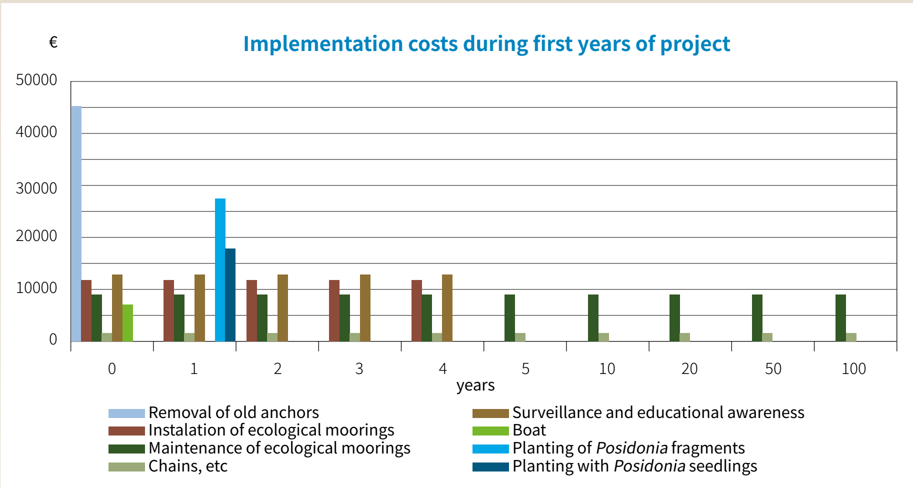
- Costs associated with the initial restoration activity (removal of concrete block anchors, installation of ecological moorings, replanting Posidonia with cuttings and seeds);
- Costs associated with carbon crediting and verification; and
- Costs associated with long-term management (maintenance and surveillance of ecological moorings, awareness education).

Information available for the area included data on sediment accretion rates, coverage, carbon stocks and carbon sequestration in the first metre of sediment in seagrass areas, with depth, as well as stocks and sequestration in other areas under degradation by mechanical action.

The exercise concluded with the assessment of the use of carbon markets. While the implementation of this type of project provides climate mitigation benefits, these interventions are better suited to non-carbon market incentives where private companies and funding mechanisms could invest in their restoration.

Reference: IUCN (2021). Viability study, Life Bluenatura

Figure 35: Assessment of implementation costs of a blue carbon restoration project in 2020, Almeria, Spain. Source: IUCN.



SEAGRASS MEADOW RESTORATION

Seagrass restoration is a rapidly maturing discipline, and despite the major gaps that still remain, a variety of tools and techniques have recently been developed that will improve the efficiency, cost-effectiveness, and scalability of restoration programmes, including those that could be part of blue carbon-financed projects [90].

Passive seagrass restoration is usually related to the restriction of damaging activities like high impact fisheries, anchoring of boats, or improvement of water quality through removal of sewage outfalls and agricultural run-off to tackle eutrophication or sand aggregate extractions. Therefore, stopping the cause of the impact and allowing the ecosystem to recover by itself via blue carbon projects could be valuable activities [10]. Introduction of legislation to protect ecologically important carbon sink habitats can also have potential as blue carbon projects.

The capacity of seagrass ecosystem restoration is high in fast-growing species, and for those with significant seed banks, but scarce in slow-growing species.

Unlike passive restoration, which ultimately relies on natural recolonisation, the most common efforts for **active seagrass restoration** are the revegetation of degraded or bare areas that could take place alongside other restoration actions focused on the management of threats and pressures in an ecosystem. This might include efforts such as the physical planting of seagrasses, distribution or planting of seagrass seeds, or coastal engineering to modify sediment and/or hydrodynamic regimes.

Revegetation projects proposing physical planting of seagrasses as one of these alternatives for restoration efforts have often been discarded due to high implementation costs and the failure of past restorations. However, recent attempts and methodologies had yielded positive results that allow us to more effectively identify opportunities for blue carbon projects that could facilitate the recovery of seagrass meadows today [4]. A revegetation project would involve using diverse techniques such as the transplant of seagrass shoots, seedlings or rhizome fragments (known as transplanting units), the dispersal of seeds to promote the development of a new seagrass meadow or coastal sediment, or hydrodynamic modifications to enhance the settlement of seagrass seeds, propagules or fragments.

Restoration project planting rhizome fragments of seagrass *Posidonia oceanica* at Pollenca Bay, Mallorca. Marine forest project funded by Red Electrica, Spain.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Cymodocea nodosa seedlings.


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Posidonia oceanica seedlings.

Fast-Growing VS Slow-Growing Seagrass Species

Seagrasses represent a second colonisation of marine environments by terrestrial plants. Although they have developed a similar adaptation to marine life, there is a wide variability in life and reproductive strategies among them. From an ecosystem-management point of view, two groups can be identified, slow- and fast-growing species [97].

FAST-GROWING SPECIES are also known as colonising or opportunistic species. They quickly colonise areas where the environmental setting is favourable for seagrass growth and are the first seagrasses to appear after a degradation. They produce large quantities of seeds compared to slow-growing seagrasses. These are the species that benefit most from passive restoration strategies. Revegetation efforts with fast-growing seagrasses usually rely on seed dispersion. In Europe, the most extensive fast-growing genera is *Zostera,* distributed along the Atlantic coast and the Baltic Sea, followed by *Cymodocea*, very abundant in the Mediterranean Sea.

SLOW-GROWING SPECIES are those that form the most persistent meadows, have the highest productivity, and hold the largest carbon stocks. These species have a very low growth rate and a very small or no seedbank. The passive restoration of slow-growing meadows is difficult due to the low colonisation rate of these species. Usually, passive and active restoration techniques need to be combined. Revegetation projects with these species are usually based on the transplant of shoots, rhizomes or seedlings. The most common species in Europe is *Posidonia oceanica,* known as the seagrass species with the highest carbon stocks [38].

ACTIVE RESTORATION: COLLECTION OF TRANSPLANT UNITS

Seagrass restoration experiences have developed from small-scale pilot studies to large-scale transplantation trials, using a variety of techniques involving both manual and mechanical planting and a wide range of anchoring methods [90].

Transplant units can be seagrass seedlings, shoots or rhizome fragments. Commonly, they are obtained from an existing seagrass meadow known as the donor meadow. The choosing of the donor meadow is an important consideration, as this may influence the survival rate of the transplant units. The more similar the environmental characteristics of the donor meadow to the area to be restored, the higher the survival expectations, as the local seagrasses would be adapted to those conditions. For this reason, it is recommended to obtain the transplanting units from a nearby meadow at the same depth range [93]. This also minimises the need to handle the transplanting units as well as the time between collecting and transplanting, increasing the survival rate of transplants.

However, transplant unit collection has an impact on the donor meadow, which in the case of slow-growing species may offset the benefits of the restoration project.

Recently, both indoor and in situ small aquaculture systems have been tested to germinate and grow seagrass plants to a size where transplanting was possible, suppressing the need to collect transplanting units from an existing meadow [90, 98]. Only a few attempts have been undertaken so far, but the results obtained are promising.

Other source of transplanting units can be using seagrass wrack, often accumulated on beaches or in the marine waters of the shoreline. Both seeds obtained from wrack and storm-generated rhizome fragments have been successfully used as transplanting units [90], the latter being particularly interesting for *Posidonia oceanica* revegetation [98].

Here, the distribution of the transplant units in the area to be restored also influences success probability. Restoration plots with a higher seagrass density have higher survival rates due to the beneficial positive feedback among plants from the same area. On the other hand, the higher the number of restoration plots, the higher the chance of success as the risk of localised disturbances affecting a high number of the plots is minimised [93]. Thus, a high density within the plot and a high number of plots would always be advisable, aiming for a balance between the number of available transplanting units and the size of the area to be restored.

Manual collection of *Posidonia oceanica* adrift fragments.

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Production of *Posidonia oceanica* seedlings from beach-cast fruits.

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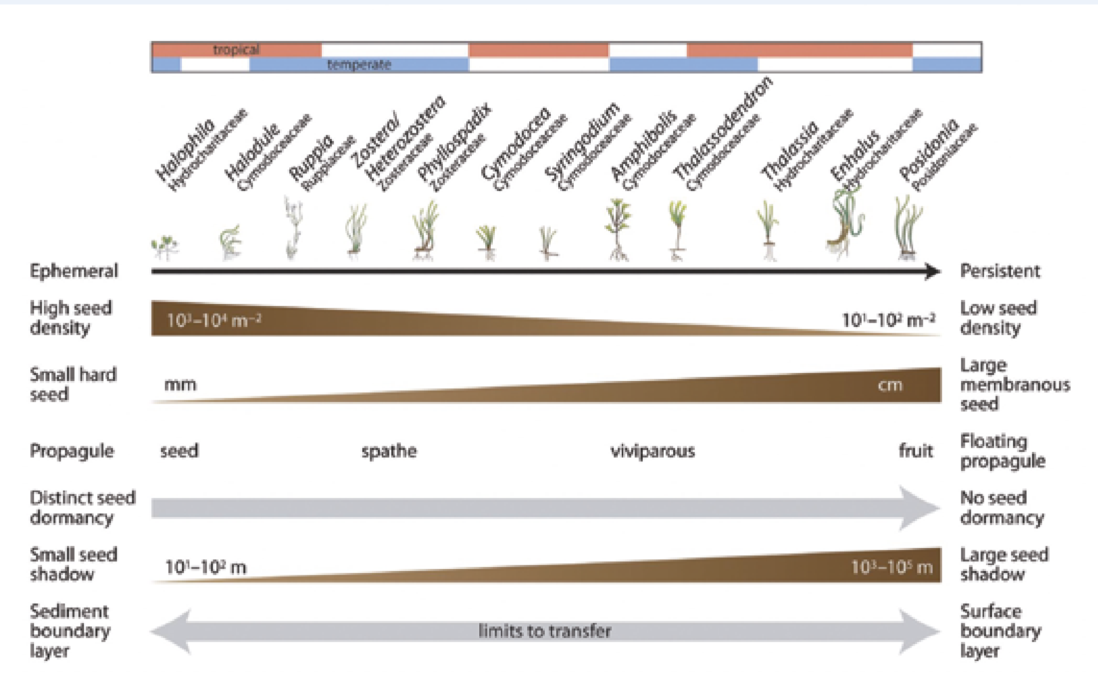
Revegetation techniques

Seagrass revegetation of an empty or degraded area can be done using seeds, fragments of living rhizomes or seedlings, however, there is evidence that seedlings are less effective as a transplanting unit [8]. There is no technique that would work in every project and the use of one or another would depend on the biological target and the selected site. Seed-based techniques are recommended in restoration of fast-growing species [97]. Their use in slow-growing species is less efficient, due to the low number of seeds produced by those species and the long time needed for the seedlings to grow. Nevertheless, the combination of transplanting and seed-based techniques has been reported to achieve good results in slow-growing species [99].

The main advantage of seed-based techniques is that they improve the genetic diversity of the population, increasing the resilience of the restored ecosystem [100].

Posidonia oceanica fruits.

Reproductive characteristics of tropical and temperate seagrasses. Gary *et al.*, 2012 [108]



Seed-based techniques:

- **Fall broadcast seeding:** this methods consists of the free dispersion of seeds by hand or with mechanical dispersion methods [17].

- **Buoy-deployed seeding:** collection of mature reproductive shoots that are suspended in a mesh above the restoration area using buoys. This method can be deployed over large areas, ensures high genetic diversity, and facilitates the participation of citizens in the programme, thus also promoting environmental awareness and restoration efforts [102]. However, the suspended seagrasses are susceptible to grazing, lowering the available number of seeds. The recruitment effectiveness of this method is low and has only been tested for *Zostera marina* [90, 101].

- **Dispenser injection seeding:** with this technique, seeds are mixed with sediments and injected into the substratum with a modified sealant gun. The sediment is collected near the restoration area and sieved to obtain a fine-grained substrate. This method is especially useful for areas with strong currents, however, it has only been tested for *Zostera marina* seeds and is more labour-intensive than other techniques [90].

Buoy-deployed seeding.

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Dispenser injection seeding.

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Posidonia oceanica seedling plantings within “Bosque marino de Red Eléctrica project” Mallorca, Spain

2018
4 plots: 40x40 cm
16 seedlings
in each plot

SURVIVORSHIP:
2019, 55 ± 14 %
2020, 55 ± 14%

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2019 and 2020
9 plots: 40x40 cm
1/32/64 seedlings
in each plot

SURVIVORSHIP:
2020, 42 ± 23 %

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Transplant techniques:

A wide range of anchoring methods, including the use of staples, frames, iron nails or weights have been used. These experiences, particularly from those that revolved around restoration efforts of *Posidonia oceanica,* with low seed production, indicate that rhizome fragments showed a higher survival rate than seedlings. They are many variables that can play an important role in the rooting process and in the performance of a transplant (e.g. substrate, techniques, water dynamics, etc.). This also can be explained by the movement of tools used due to water dynamics, which may destabilise the rooting process. [93].

Despite significant losses of transplanted areas, concrete frames as weights have given positive results on large scales and in the long run on sand seabeds [114]. Other methods investigated with *Posidonia oceanica* on matte are giving encouraging results but they were used on smaller surfaces or monitored so far over a short time span and are still being evaluated. Furthermore, spontaneous colonization of *Posidonia oceanica* on seabed consolidated with stones in some sites monitored over the long term have shown positive results.

The use of rhizome fragments generated by the storm is a possibility but gives less guarantees[29].

Artificial seagrasses, biodegradable matte (or matrix) and biodegradable pots have also been used in seagrass restoration to increase the survival rates of planted meadows, especially in exposed sites, by lowering the hydrodynamic forces, stabilising the sediment grain size or preventing grazing [90].

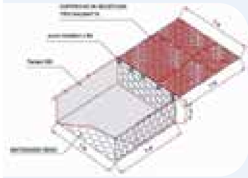
[29] http://www.lifeseposso.eu

Transplant techniques
(project Life SEPOSSO)

Spontaneous colonization
SUBSTRATE: rock

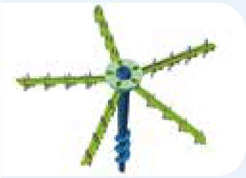
Cement frames
SUBSTRATE: sand

Mattresses
SUBSTRATE: sand



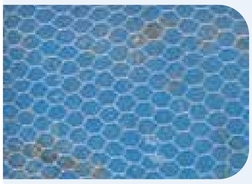
Mats
SUBSTRATE: matte

Degradable modules (star)
SUBSTRATE: matte

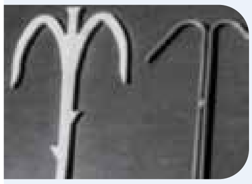


Clods
SUBSTRATE: sand

Metal mesh
SUBSTRATE: matte



Pickets
SUBSTRATE: matte



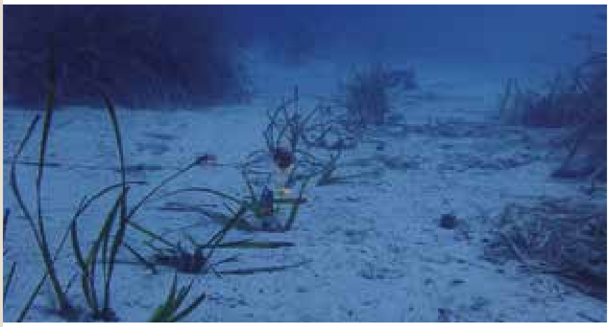
Seagrass restoration experiences

Revegetation of a *Posidonia oceanica* meadow disturbed by the laying of power lines

The installation of power lines between two main islands of the Balearic archipelago, Spain, disturbed a *Posidonia oceanica* meadow, leaving long trails of uncovered seabed. The promoting company financed a test planting to asess the feasibility of restoring the affected area.

The transplanting units were rhizome fragments naturally detached from the meadow and beach-cast fruits cultured in seawater tanks. Thus, the collection of transplanting units did not have a negative impact on donor meadows. Rhizome fragments and seedlings were anchored to the sediment. This approach obtained high survival rates, in the short-term (<1 year) [98].

Source: Red Eléctrica de España, Instituto Mediterráneo de Estudios Avanzados, (CSIC-UIB).



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Planted fragments of *Posidonia oceanica* rhizomes.

© RED ELÉCTRICA DE ESPAÑA E IMEDEA (CSIC-UIB)

Revegetation of 2 ha of a degraded *Posidonia oceanica* meadow

Two hectares of degraded *Posidonia oceanica* meadow were revegetated in the Pollença Bay (Mallorca), the first attempt of a *Posidonia oceanica* revegetation of that size.

The transplanting units were rhizome fragments naturally detached from the meadow that were anchored to the substrate. Two years after planting the survival rate was higher than 90%. The sheltered conditions of the area enable the meadow to survive storm events. However, the long-term success of the restoration has not yet been tested [98, 99].

Source: Red Eléctrica de España, Instituto Mediterráneo de Estudios Avanzados, Conselleria de Medi Ambient I Territori (Illes Balears) and Aeródromo Militar de Pollença.

COASTAL WETLAND RESTORATION

Restoration efforts for coastal wetlands in general may include proper management of existing marshes, introduction of legislation to protect ecologically important habitats, reduction of intense development along the coast, and restoration of damaged marshes. Preserving adjacent lowlands will also allow for salt marshes to adapt and migrate landward to survive rising seas.

Today, restoration techniques for coastal wetlands that include salt marshes and mudflats are more advanced than for other marine or estuarine habitat types. As previously mentioned, it is important to carefully consider in the preparation of blue carbon projects how to prioritise the selection of salt marsh restoration sites (e.g. ownership, hydrologic restrictions, presence of invasive plant species, history of dredged material or other fill placement, adjacent land use, local communities' concerns) as well as to evaluate the alternatives that offer the best chance of achieving the greatest outputs.

Solutions to restore these ecosystems can be directed towards passive restoration of degraded wetlands by targeting the source of the degradation, like preventing over-grazing or reducing the influx of nutrients from sewage, agricultural run-off and industrial waste. This would in turn restore the environmental conditions needed for salt marsh vegetation to settle. In atlantic marshes, grazing (at low density) can enhance carbon stocks because of vegetation set backs. In other cases, a passive restoration may not be possible, or the natural recovery capacity of the ecosystem may be very low, so more active restoration efforts would be needed.

Some management techniques have proved successful in maintaining or enhancing habitat use by wildlife in several cases. The water quality, salinity and hydrology requirements of different fish and wildlife species vary, and therefore management techniques applied to coastal wetlands to increase or enhance habitat for one species may have adverse impacts on others.

Additional actions to restore erosion at coastal marshes.

Placement of permeable wooden dams to increase sedimentation or prevent erosion. Case study estuarine marsh Wadden Sea, The Netherlands.

Active restoration

A range of coastal wetland restoration and creation activities can provide net GHG benefits as well as helping to stabilise shorelines, mitigate damage to natural marshes and mudflats, and revegetate destroyed salt marshes and biodiversity. Best practices for salt marsh restoration include [89, 92, 103, 104].

Restoring natural hydrology and tidal morphology (elevation, slope and substrate)

As many marshes and mudflats have been drained, the reestablishment of tidal hydrodynamics is a critical first step in the restoration process. Drained organic soils continue to emit CO_2 until either the water table rises to near the surface of the soil or the stock of carbon is depleted. Removal of manmade barriers, such as dykes, dams and tide gates, or the development of new tidal channels are solutions used to restore the influence of the sea and freshwater in an area, increasing the water table and marsh surface elevation.

This will support a diversity of native salt marsh plants and animals and allow the natural flushing of nutrients across the marshland as well as the increase of carbon sequestration.

However, restoring the tidal influence in areas that have suffered subsidence effects may result in too much flooding time and can transform high marsh areas into mid or low marsh areas, and even to unvegetated tidal flats [92]. Therefore, it is recommended that restoration of the hydrologic conditions of an area should be preceded by evaluation of whether any substrate elevation or installation of water-level controls is required.

In other areas, where the degree of tidal flooding is sufficient, or where removal of water control structures or dykes is not feasible, restoration may focus primarily on replanting with native vegetation to accelerate natural recovery.

Restoring salinity conditions (reducing CH_4 emissions)

Salinity influences methane emissions from salt marshes: in dyked, impounded, drained and tidally-restricted salt marshes, substantial methane (CH_4) and CO_2 emission reductions can be achieved through the restoration of disconnected saline tidal flows.

Some coastal wetlands have blockage or restriction of tidal flows, through installation of dykes or tide gates, as a common method to protect coastal infrastructure; having been drained in the past for farming, mosquito control or development; or having had their water table raised or managed to reduce salinity, for aquaculture, roads or rice production, for example. As a result, they have become freshened and flooded due to retention of freshwater drainage from the watershed.

Increasing influence of the sea through tidal restoration in salt marshes, by removing tide gates and other flow restriction devices, will result in avoided methane emissions, providing further complementarities relative to enhanced CO_2 sequestration in other land-use-based climate change interventions, due to key aspects that result in rapid, substantial, and sustained reduction.

Improving wastewater and stormwater management

The management of stormwater can reduce the nutrients entering salt marshes from urban development (e.g. sewer systems) and rainwater runoff that contributes to unwanted algal blooms and pollution. This can be achieved by reducing the volume and frequency of stormwater runoff and increasing the quality of stormwater before it is discharged to downstream waterways and coastal wetlands. This can in turn improve water quality for salt marshes and seagrass meadows.

Removal of dredged material from salt marshes and restoration of soils

Drainage of salt marshes promotes the compaction of their soils, and if the tidal influence is later restored, the area may be flooded as the soil elevation is lower than before the drainage took place. Therefore, the direct addition of sediments or the promotion of their natural arrival is needed. On the other hand, the quality of the soil may not be adequate to sustain the vegetal community and nutrients or organic matter may need to be added.

Increasing sediment supply by removing dams or raising soil surface with dredged material in some other areas are potential activities to enhance carbon sequestration.

Planting/revegetation

If restoration does not result in natural revegetation, it may be necessary to plant propagules and plants to facilitate recovery, establishing local vegetal communities after restoring hydrology and soil condition. It is important to consider that revegetation not only recovers biodiversity but also influences the restoration of ecosystem services. Plants will generate changes in topography, sedimentation, oxygen or gas exchange carbon storage that ultimately will support the recovery of provisioning services (e.g. hydrological dynamics), regulating services (e.g. climate regulation, soil fertility and erosion) or supporting services (e.g. provision of terrestrial habitat).

To ensure a successful plant colonisation it may be necessary to control erosion, add nutrients, or establish fast growing species as 'foundation species or ecosystem engineers' while the slow growing species colonise the area. Furthermore, it is necessary to monitor the development of the vegetal community in the restored area to remove any invasive species, ensure diversity of salt marsh species and help sustain a healthy marsh, and to control the impact of grazing animals.

Recent advances in transplant designs draws on engineering knowledge [106, 107], as awareness and representation of local conditions can increase success in restoration programmes at landscape level. The use for example of biodegradable structures can for specific conditions assist the establishment of vegetation patches for transplanting, ameliorate hydrodynamic energy from waves and flow, and stabilize and accumulate sediment, resulting to enhance the survival and growth of small salt marsh grass and enable a faster restoration programme.

Carbon stock enhancement by maintaining a salt marsh at an intermediate state

Grazers can have a large impact on carbon sequestration in a salt marsh. They can alter carbon storage a) through above-ground biomass removal, (b) through alteration of biomass distribution towards the roots and/or (c) by changing soil abiotic conditions that affect decomposition and thereby carbon sequestration [105]. Managing livestock grazing can manage and enhance carbon stocks in mature marshes, particularly on marshes with fine-grained soils.

In the Netherlands, to keep coastal marshes in an intermediate state, grazers are being kept on the marsh system, including sheep, cattle, horses, and natural small grazers like geese. Grazing alone, and especially in old marshes, increased carbon content up to a kilogram of carbon per square metre.

Source: Community and Conservation Ecology Group, University of Groningen; Ecosystem Management Research Group, University of Antwerp; and The Spatial Ecology Group, Royal Netherlands Institute For Sea Research.

Improvement of the hydrological connection of the salt marshes from the Ebro Delta

In the framework of a larger project to restore a coastal lagoon in the Ebro Delta, connectivity between dyke-isolated patches of salt marsh was restored, improving the resilience of the ecosystem to sea-level rise.

Source: Institut de Recerca i Tecnologia Agroalimentàries.

Evaluation of a blue carbon restoration project in Bay of Cadiz, Andalusia, Spain.

This area of 216 ha borders the Bay of Cádiz Natural Park. The proposed project area has a high state of degradation and altered tidal regime, arising from previous works to modify the terrain profile and land-use changes for the development of agriculture crops.

The actions envisaged in the project were aimed at improving the environmental conditions and optimising the conditions for carbon sequestration and reducing emissions of other GHG by restoring natural hydrology and tidal morphology of the area. This would promote the natural restoration of salt marsh plants and animals, and allow the natural flushing of nutrients across the marshland accompanied by an increase in carbon sequestration. GHG emissions and sequestration were assessed in terms of CO_2, CH_4 and N_2O taking into account also the above-ground biomass.

Here we show the evolution of the estimated emissions accumulated over time for the base scenario, the project scenario, derived from the execution of the actions, and the corresponding reduction in emissions.

Source: IUCN (2021). Viability Study, Life Bluenatura.

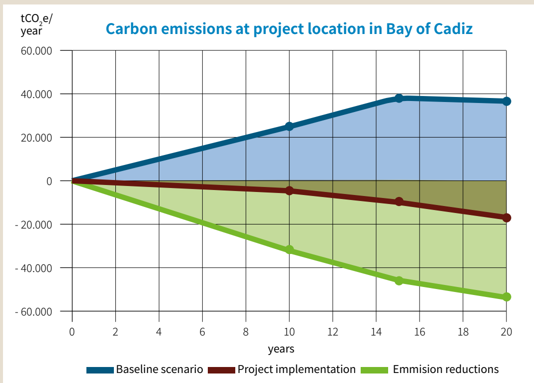
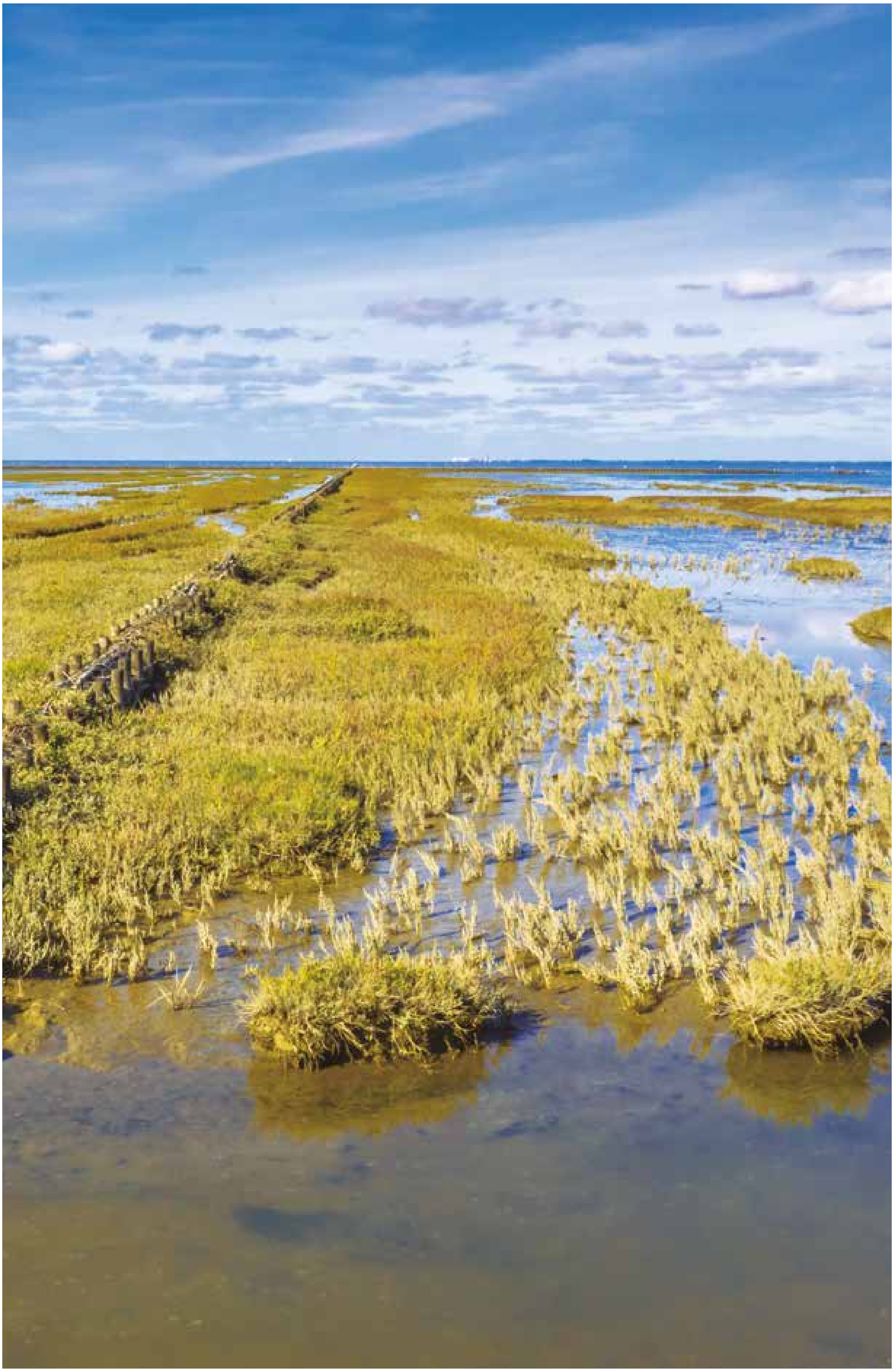


Figure 36: Blue Carbon potential is determined by the difference between the baseline scenario (when doing nothing) and the blue carbon project scenario (protection/enhancement).



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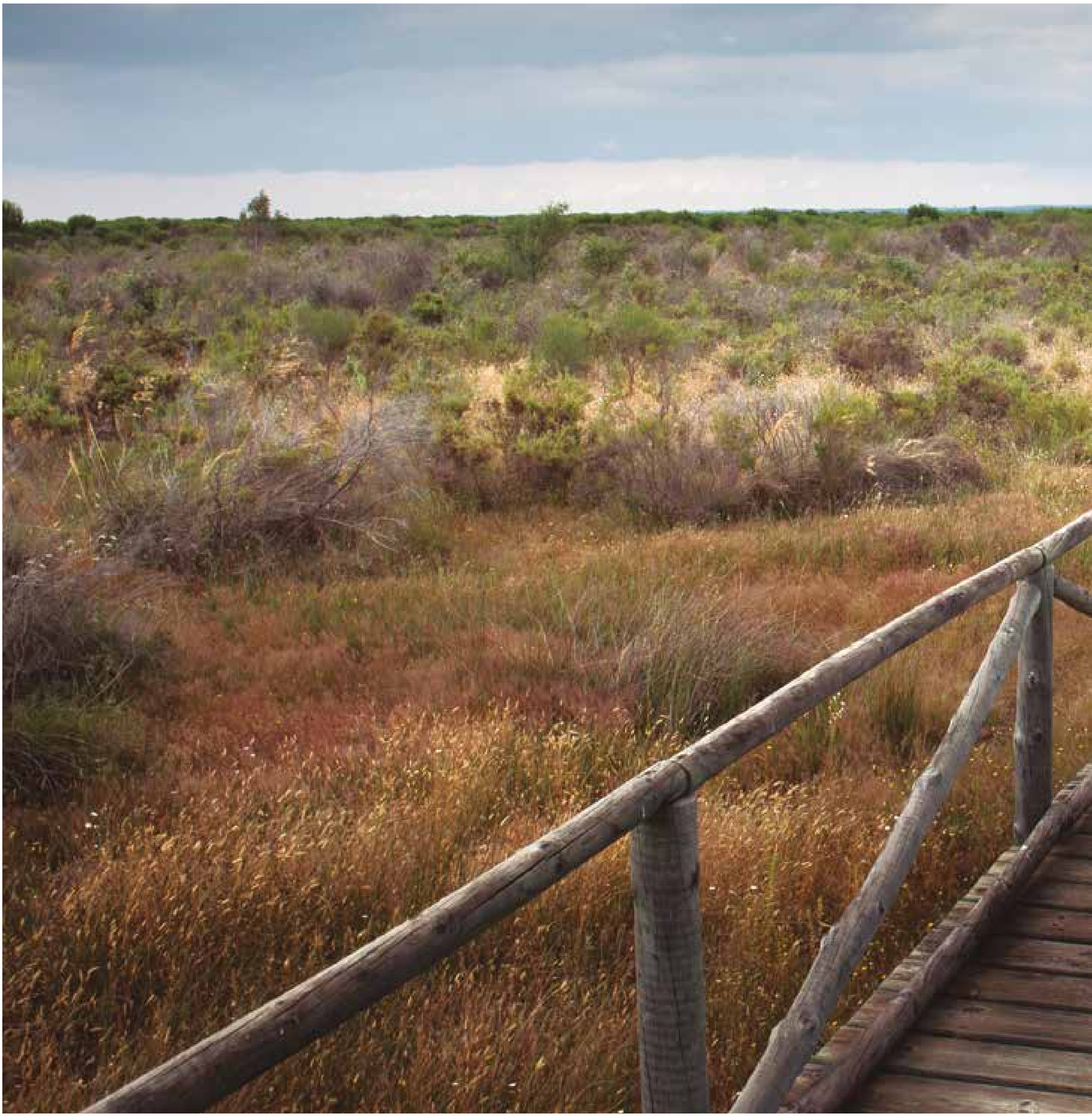
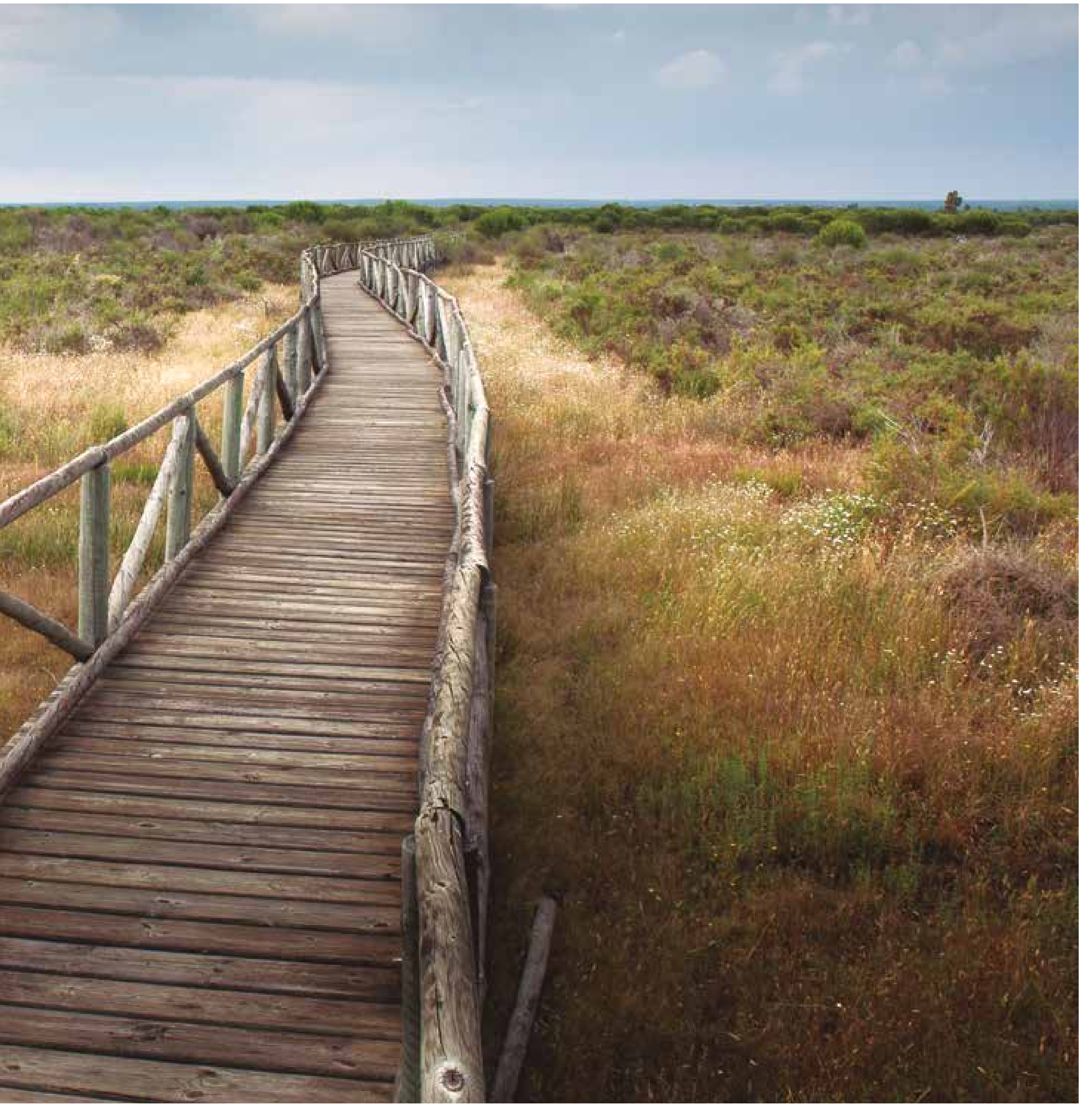
Protection of marsh habitat can be done (with high technical feasibility) by placing wooden dams along the eroding edge. The wooden dams will provide protection against wave energy and cause retention of sediment.This active restoration can prevent further erosion of the salt marsh.

CHAPTER 9:

FUTURE BLUE CARBON EFFORTS IN EUROPE AND THE MEDITERRANEAN





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FUTURE BLUE CARBON EFFORTS IN EUROPE AND THE MEDITERRANEAN

Nature-based Solutions, such as those that could be implemented in coastal blue carbon ecosystems, offer a way to build resilience to the consequences of warmer temperatures while helping to limit further temperature rises by acting as carbon sinks. Achieving the full potential of blue carbon ecosystems, however, requires improved protection measures and restoration, actions that will not only mitigate climate change but also increase other ecosystem services while delivering adaptation benefits. These works will contribute to the Paris Agreement and to the achievement of other international objectives in the 2030 Sustainable Development Agenda, such as the Sustainable Development Goals of Life Below Water (SDG14) and of course, Climate Action (SDG13).

Filling gaps in the knowledge would aid in developing effective policies and plans for protection and rehabilitation of blue carbon ecosystems. The enhancement of conservation and restoration efforts is very necessary to prevent further degradation, as ecosystems such as coastal wetlands and *Posidonia* seagrass meadows hold large standing carbon pools (previously sequestered and stored) that could be released to the atmosphere (e.g. in the form of CO_2 and CH_4), exacerbating the climate problem. Such efforts will avoid further emissions and mitigate the risks of future climate-related impacts.

Robust and efficient voluntary carbon markets can enable financing of these efforts and engage the private sector to take more ambitious steps towards compensating for its contribution to climate risk. So far, voluntary carbon offsets are more known outside Europe but they have the potential to be equally useful in the Mediterranean and European regions to upscale restoration and conservation efforts.

The range and diversity of organisations active on the voluntary carbon markets internationally is reflected in the diversity of motivations when buying carbon offsets. Organisations active on the voluntary carbon markets are looking for carbon offsets that fit their priorities, match their budget, and offer social and environmental benefits beyond the emission reductions (e.g. poverty alleviation, biodiversity conservation, etc.)[30]. Each carbon-offset buyer may have very specific requirements related to the type of impact that their own businesses generate.

As blue carbon ecosystems lie in the public domain in most countries, ownership of the schemes requires consultation with local stakeholders and government right from the start of project development to ensure that their interests are considered and that there is long-term commitment.

From a private investor perspective, the first demand of voluntary carbon-offset buyers is to be certain of the quantity and in some way the quality of the carbon credits they are acquiring. Convincing a company to pay for a product that seems to be intangible is certainly a challenge, which to date has only been overcome with the use of robust carbon quantification methods. In addition to verified carbon credits, companies frequently seek other types of social and environmental impact, such as the protection of biodiversity or the improvement in the quality of life of the communities in the area impacted by the projects.

The demand for voluntary carbon projects is still not particularly high but it is expected to grow (subject to the trajectory of the COVID-19 pandemic[31]) with the increased demand for Nature-based Solutions and Natural Climate

[30] Source: State of Voluntary Carbon Market 2016 (Forest Trends, 2016)
[31] https://www.environmental-finance.com/content/analysis/strong-growth-predicted-for-voluntary-carbon-market.html

Solutions projects. Prices for blue carbon projects will need to be adjusted based on a project costs so as to ensure project sustainability, and perhaps also quantifying the beyond-carbon benefits. This is particularly important given the additional costs associated with working in the marine environment.

In some cases, blue carbon projects will have substantial climate change mitigation benefits and therefore be strong candidates for entering volunteer carbon markets. But not all the projects could be financed by the carbon markets and some will be better suited to use non-carbon market incentives, uncertified schemes, or subsidies to change practices.

The recognition of the climate change mitigation and co-benefits impacts of coastal blue carbon ecosystems is timely; the challenge now is to build on these early successes and stimulate an increase in the scale and pace of their conservation and restoration.

GLOSSARY OF TERMS

Allowances:
Allowances are freely tradable units that are allocated to the regulated participants in an emissions trading system. Each participant in the emissions trading system must surrender an allowance for each tonne of CO_2e emitted.

Allochthonous carbon:
Carbon produced in one location, transported and deposited in another.

Autochthonous carbon:
Carbon produced and deposed in the same location. In the context of blue carbon systems, this type of carbon results from vegetation uptake of CO_2 from the ocean and/or the atmosphere that is converted for use by plant tissues and decomposes into ambient soil.

Brokers:
Brokers are matchmakers between buyers and sellers of carbon credits (they do not buy the credits themselves).

Coastal blue carbon:
The carbon stored in mangroves, salt marshes and seagrass meadows, within soil, living biomass and non-living biomass carbon pools. Coastal blue carbon is a subset of blue carbon that also includes *ocean blue carbon* that represents carbon stored in open ocean carbon pools.

Carbon Offset:
One carbon offset represents a quantity of greenhouse gas (GHG) emissions reductions, measured in units (metric tons) of carbon dioxide equivalent (CO_2e) that occur as a result of a discrete project. The emissions reductions from that project can be sold to enable the purchaser/owner to claim those GHG reductions as their own. These reductions can then be used to reduce, or offset, any GHG emissions for which the purchaser is responsible.

Carbon offset standard:
A standard that helps to ensure that carbon offset projects meet certain quality requirements, such as additionality and third party verification. Several offset standards exist within the voluntary and compliance carbon markets and each has a different set of requirements depending on its focus and scope.

Carbon sink or Carbon pool:
A reservoir of carbon. A system which has the capacity to absorb and stores more carbon from the atmosphere than it releases as carbon dioxides. Carbon pools include aboveground biomass, belowground biomass, litter, dead material and soils.

Carbon stock:
The absolute quantity of carbon held within a pool (e.g. wetland) at a specific time. The units of measurement are mass (e.g. tCO_2/ha).

Carbon sequestration:
The process of removing carbon from the atmosphere and depositing it in a reservoir.

Carbon sequestration rate (or flux:)
The transfer of carbon from one carbon pool (e.g. atmosphere) to another (e.g. wetland) in units of measurement of mass per unit area and time (e.g. $t\ C\ ha^{-1}\ yr^{-1}$).

Crediting Mechanism:
A crediting mechanism allows the remuneration of emission reductions by issuing tradable offset credits for emission reductions actually achieved.

Emission reductions (carbon credits):
Represent the prevention of one tonne of carbon dioxide equivalent (tCO_2e) from entering the atmosphere, also known as carbon credits, which are used for carbon offsetting. They can include:

— Verified Emission Reductions (VERs) for voluntary climate action
— Labels for Certified Emission Reductions (CERs) for meeting compliance targets.

GHG inventory:
An accounting of GHG emitted to, or removed from, the atmosphere over a period of time.

Greenhouse gases (GHGs):
The atmospheric gases responsible for causing global warming and climate change. The major GHGs are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_20). Less prevalent —but very powerful— greenhouse gases are hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6).

Mitigation:
In the context of climate change, a human intervention to reduce the sources or enhance the sinks of greenhouse gases.

Nationally Determined Contributions (NDCs):
A term used under the United Nations Framework Convention on Climate Change (UNFCCC) whereby a country that has joined the Paris Agreement outlines its plans for reducing its emissions. Some countries' NDCs also address how they will adapt to climate change impacts, and what support they need from, or will provide to, other countries to adopt low-carbon pathways and to build climate resilience. According to Article 4 paragraph 2 of the Paris Agreement, each Party shall prepare, communicate and maintain successive NDCs that it intends to achieve.

Registries:
Most offsets transacted in voluntary markets are tracked by registries. Registries provide an extra level of accountability and assurance regarding issuance, holding, and acquisition of credits. Registries do not actively market offset credits, but buyers may become aware of credits available for sale through a registry.

Soil organic carbon:
The carbon component of soil organic matter. The amount of soil organic matter depends upon soil texture, drainage, climate, vegetation and historical and current land use.

Verified emission reductions (VERs):
A Verified Emissions Reduction is a single unit (one tonne) of CO_2 equivalent reduction captured as a carbon credit for use as a commodity within the voluntary carbon market.

Voluntary Carbon Market:
The voluntary carbon market is a market for the voluntary compensation of greenhouse gas emissions. It enables companies and individuals to voluntarily offset their carbon footprint.

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IUCN is working with many partners and members on sustainable coastal management around the world. Some of the key initiatives that have helped propel international action on blue carbon are below:

The Blue Carbon Initiative (BCI) is leading technical and policy analysis to inform adequate methodological and policy development.

The International Partnership on Blue Carbon (IPBC) is bringing together various governments and stakeholders to share lessons learned on national carbon accounting and leveraging project implementation.

The Blue Natural Capital Financing Facility (BNCFF) is working with project developers, businesses and investors to advance bankable blue endeavours with clearer conservation and climate impacts.

Save our mangroves now! (SOMN!) is conducting carbon assessments and enhancing awareness and political action to conserve mangroves.

The Blue Solutions Initiative is developing and establishing a global platform to collate, share and generate knowledge as well as to build capacity for sustainable management and equitable governance of our blue planet, including climate adaptation and mitigation measures and projects.

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