NOVEL MARINE TECHNOLOGIES

Development of non-degrading, NOvel Marine TEChnologies (NOMATEC) for the sustainable exploitation and protection of Mediterranean marine resources

Manual on the application of the electrochemical accretion technology for the restoration and rehabilitation of *Posidonia oceanica*

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Content

1. Introduction

The oceans are subject to an increasing development and show marks of severe overexploitation and degradation with significant loss of productivity, biodiversity and aesthetics.

Posidonia oceanica sea grass plays an important role in ecosystems of shallow coastal waters of the Mediterranean Sea. But this species is suffering from mechanical damages caused by trawling and anchoring. Major damage is generated by comparably small injuries as dislodged parts of the meadows are exposed to wave action and will be lost as the slow-growing *Posidonia* is not able to reattach itself prior to the next storm.

Rehabilitation efforts undertaken so far applied strong metallic nets to secure dislodged parts or seedlings in hope of providing enough protection until the seagrass roots reattach the plants to the sea bottom. Unfortunately, these plastic coated metallic nets are subjected to corrosion and the remaining plastic spoils the marine environment with alien material. A way out could be the application of a mesh coated by EAT fulfilling the same mechanical function but serving as well as a nature- like substrate to be colonised by benthic settlers. Thereby, the strength is derived from the coating and not from the metal mesh. Beyond that, the mineral crusts are anti-corrosive as long as the structure is needed. Assuming a successful reattachment process the mineral crusts can be re-dissolved by changing the electrical polarity leaving nothing behind apart from the tiny mesh which will corrode rapidly afterwards.

In the NOMATEC research project experiments for *Posidonia* rehabilitation were conducted on selected sites of the study area and tested to compare the EAT to traditional used methods. A major deliverable has been a manual for the rehabilitation of damaged *Posidonia oceanica* meadows using carbonate coated grids. Figure 1 represents one possible application.

The following user guide presents step by step the procedure for restoration and rehabilitation of *P. oceanica* directing from the optimal selection of sites, donor beds and shoots up to the installation and features of the electrification process. Also biological characteristics have been figured out.

2. Users guide for application of EAT

The electrochemical accretion technology belongs to the key technologies for clean and environmentally compatible construction methods.

Using low voltage direct current at appropriately constructed electrodes, mineral compounds of the sea water can be precipitated on the cathode. With this technique matrixes of steel mesh (e.g. chicken wire or steel grids) can be coated and reinforced by the hard crusts of carbonate minerals. The resulting construction material derives directly from the sea and represents an ideal colonisation substrate for a variety of benthic organisms. As the matrix is easily shaped in any required design EAT structures or meshes can be applied for the attachment of *Posidonia oceanica* shoots or even entire plant cushions.

Except for the wire matrix the building material is genuine material from the ocean itself. Regarding any structure for temporarily fixation of the sea grass shoots as artefacts one of the big advantages of EAT comes into account. In contrast to other fixing methods EAT-structures can, if necessary, be re-dissolved by changing the electrical poles. It represents a key technology, which is capable to create structures of any shape as well as to take these apart again.

The usage of genuine material (minerals from ions abounding in seawater) and renewable energy makes the EAT a first choice candidate to serve as a key technology for application in scour protection, mariculture and marine engineering.
In the following we will detail the application of EAT for purposes of species protection for *Posidonia oceanica*, the characteristic shallow water phanerogam in the coastal waters of the Mediterranean.

EAT can be applied for two different strategies.

- Rehabilitation of dispatched *Posidonia oceanica* cushion.
- Restoration of *Posidonia* sea grass to denuded sand patches.

This manual presents both strategies with recommendations for practical implementation.
Technical details on the EAT can be obtained from the manual on the electrochemical accretion technology issued within the NOMATEC project.

2.1 Rehabilitation of dispatched *Posidonia oceanica* meadows

The rehabilitation strategy aims to reattach dispatched parts of *Posidonia oceanica* meadows thus enables the plants to form new roots after mechanical impacts. Beyond this target, the EAT was used to stabilize the sediment with carbonate coated grids.

Within this manuscript the relevant steps are described and illustrated.

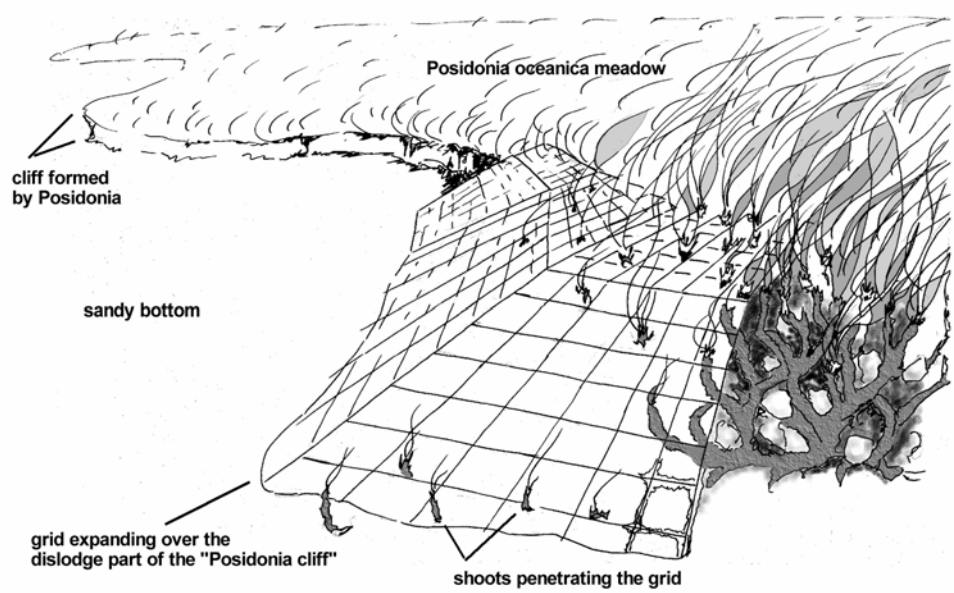


Fig. 1: Experimental design proposed to reattach dislodged *Posidonia* stands to the sea bottom.

Experiments were conducted on selected sites where *Posidonia* had been dislodged. A steel mesh spanning over the edge of a *Posidonia* meadow was installed thus attaching the dislodged parts of the meadow back to the bottom. The mesh reached out into the adjacent sandy bottom and be partly buried in the sand.

By electrically induced precipitation of carbonate minerals from the seawater the mesh was accreted with calcium carbonate and thus reinforced with regard to mechanical strength.

The protection provided by the mesh prevents the dislodged parts from being washed away and additionally intends to accumulate sediments behind the mesh. The newly formed substrate wall in front of the *Posidonia* cliff should be penetrated by the shoots of *Posidonia* thus further stabilising the whole structures (Fig. 1).

Fig. 2: *Posidonia oceanica* cliff showing a dislodged section.

Within an extended *Posidonia* stand off STARESO (Research Station near Calvi, west coast of Corsica) several cliffs had formed and the seaward sided had been subject to severe erosion. One of these sites in 15m depths was selected to serve as experimental site (Fig. 2).

A big cushion of *Posidonia* broke down from the cliff and feel to the lower level of the adjacent sand patch. The experimental target was to secure this piece of *Posidonia* meadow against further erosion.

A galvanised steel mesh was spanned over the site and fixed in the sediment by steel rods (Fig. 3). We uses industrial metal grid from the local hardware store. For construction purposes it is nearly impossible to purchase ungalvanised grid. If uncoated grid is available this should be given preference as the zinc alters the precipitation and the corrosion protection is not necessary. The grid had openings of 10 by 10 cm and the wire was 2mm in diameter, each grid came in 2 by 1 m size. 5 grids were connected underwater to cover the entire site.

Fig. 3: Installation of the EAT grids over the dislodged parts of the *Posidonia* meadow.

Fig. 4: Installation with beginning mineral accretion.

After installation of the grids (cathodes) anodes were mounted above the structure and cables connected the electrodes with the power supply. The grids were charged for 544 days by a DC current with 5.8 A at 7 V resulting in a current density of 1.4 Am^{-2} cathodic surface (for further details see manual on EAT).

With time the mineral crust form on the mesh. While the P*osidonia* leaves were surprisingly not effected by the shift of the pH values around the crusts.

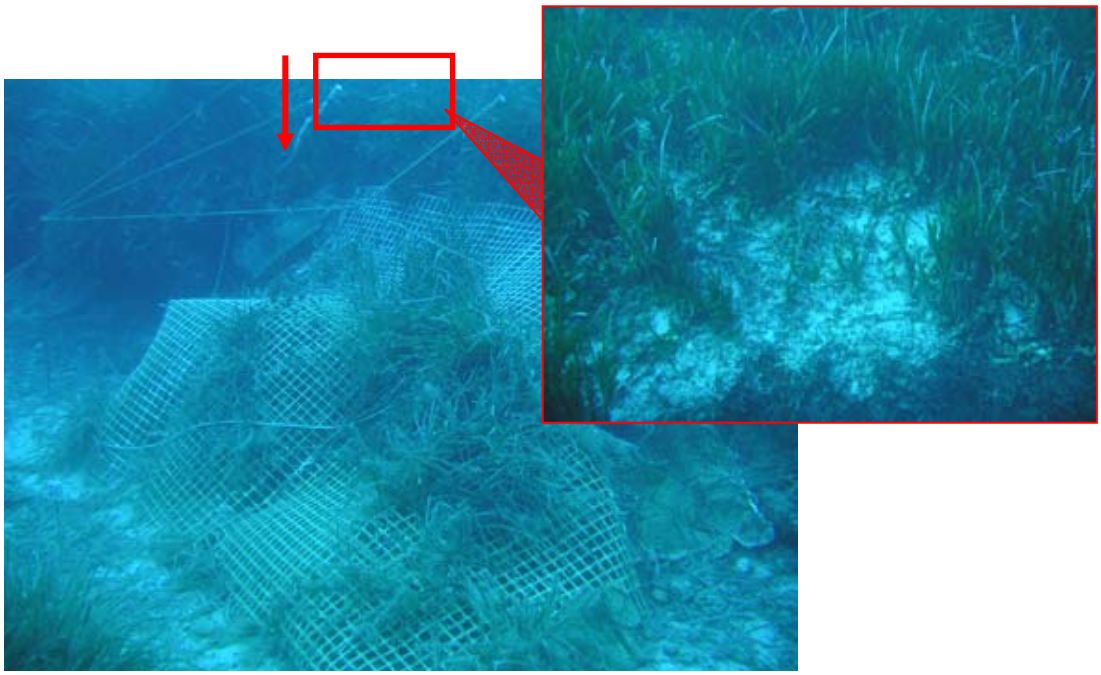


Fig. 5: *Posidonia* damaged on the top of the cliff by the movements of the electric cable.

Caution has to be paid on the out-laying of the cables to prevent subsequent damages of the meadow by moving cables (see Fig. 5). During our study, the P*osidonia* meadow just under the cliff was damaged by the repetitive movements of the electric cables due to strong swells.

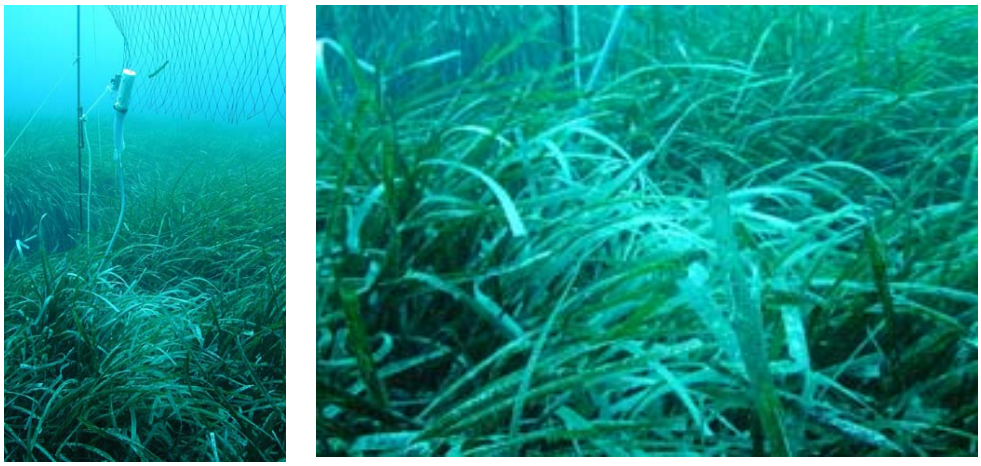


Fig. 6: *Posidonia* leaves showing necrosis due to installation of anode in the ultimate vicinity.

During the accretion process chlorine gas evolves from the anode grid. Seawater is an excellent buffered system and shifts in the pH values could not be measured in distances bigger than 10 cm. However, under very adverse weather condition without water movement this chlorine might lead to comparable high HCL concentrations and thus low pH values in the vicinity of the anode (Fig. 6). This can be avoided if the anode is hung at least 30 cm above the *Posidonia* leaves.

A successful rehabilitation critically depends on an efficient scour protection. In our first approach the movement of the dispatched parts could be avoided, the erosion behind this part, however could not be stopped (Fig. 7). The mesh width was oversized to accumulate the sediment thus, the open ends of the installation had to be closed.

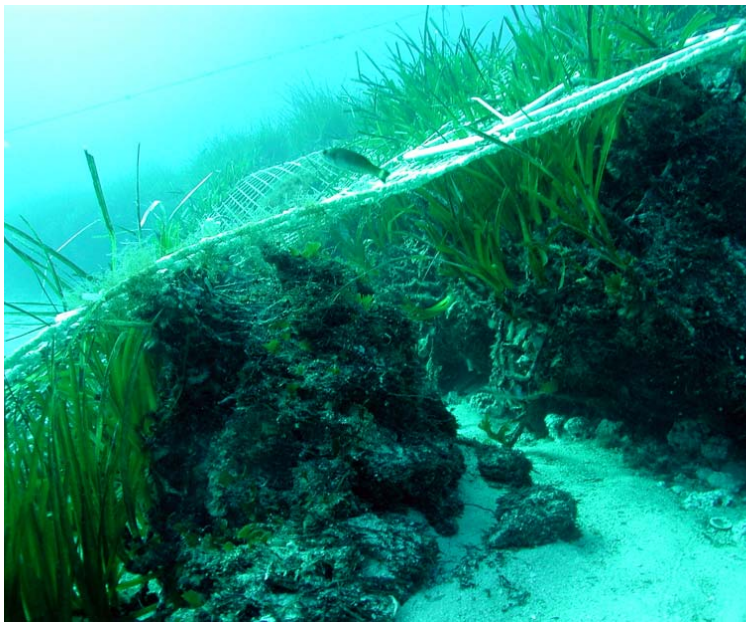


Fig. 7: *Posidonia* Rehabilitation site after severe storm event. Sour protection was missing and erosion is evident.

Fig. 8: Site supplemented with scour protection at the edges.

Ungalvanised chicken wire was used to close the openings and gave the desired results (Fig. 8 and 9). Even after strong hydraulic impacts such as winter storms with wave heights over 6 m the structure was stable and behind the fine mesh sediment starts to accumulate.

Each application has to consider the local sediment dynamic right from the very beginning. Mesh width must be adjusted to the respective conditions and all moving parts need to be secured firmly to avoid damage as described for the cables.

Fig. 9: Scour protection at the edges with visible mineral crusts.

2.2 Restoration of *Posidonia oceanica* meadows using plagiotrophic shoots

Beside the rehabilitation of damaged Posidonia oceanica meadows the EAT can also be applied for the de novo formation of *Posidonia* stands. Shoots of the plant can be used to seed bare substrates with *Posidonia* if suitable fixation can be provided until the plant has developed enough foothold by own new roots.

2.2.1 Selection of suitable sites for restoration

The selection of the site will influence the results of the transplantation (e.g. mortality, shoot loss, rooting speed). A similarity of environmental conditions of donor and recipient beds must exist (temperature, salinity) with respect to ecological requirements of *P. oceanica*.
To increase the efficiency of the transplantation, it is essential to take into account the substrate-energy regime (i.e. waves, current) of the site.
Avoid rocky and muddy sediment and avoid the sites with high hydrodynamic pressure. Substrates with mean granulometry higher than 1 cm (Fig. 10) are generally zones where hydrodynamic pressures are too high to permit the transplantation.
Ideal conditions are small sandy areas (50 to 100 m²) on surfaces where recently *P. oceanica* meadows were installed or sandy patches (50 to 100 m²) in natural *Posidonia* meadows.

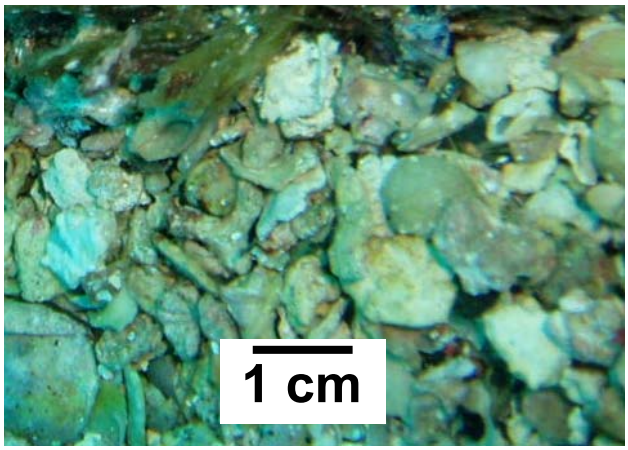


Fig. 10: Maximum grain size of sediment to obtain good results in *P. oceanica* transplantation.

Planting in high wave energy areas will require planting in denser groups to avoid disruption (see selection of the number of shoots on the transplanted area).
The sites highly impacted by seawage discharges are unsuitable for seagrass restoration plans, until the installation of efficient waste water treatment.

2.1.2 Selection of donor beds

The seeds are often rare in some areas and seedlings show low survival rates. The use of naturally uprooted shoots due to waves, storms or after a breaking down of a cliff, limits the impact on the healthy meadow (Fig. 11). The gathering of shoots in the vicinity of the transplanted area will ensure better results.
P. oceanica cuttings from deeper zones, adapted to low light and transplanted at higher light intensity in shallow water are more resistant.

Fig. 11: Dislodged *Posidonia* as source for shoots.

2.1.3 Selection of shoots used for the restoration

Choose pieces of horizontal (plagiotropic) rhizomes (10 cm long) bearing a maximum of 3 shoots (Fig. 12). On longer rhizomes, the mortality of shoots is more frequent and the rhizome has a tendency to deterioration. Cut the long roots (they are often altered during the installation of the rhizomes on the grids and they go rotten during the first months after the transplantation); cuttings with root bud are preferable.

Fig. 12: Plagiotrophic *Posidonia oceanica* rhizome bearing 3 shoots.

2.1.4 Installation of the grids

The grids (mesh size: 10x10 or 5x5 cm) of one square meter must be fixed on the sediment underwater (Fig. 13)

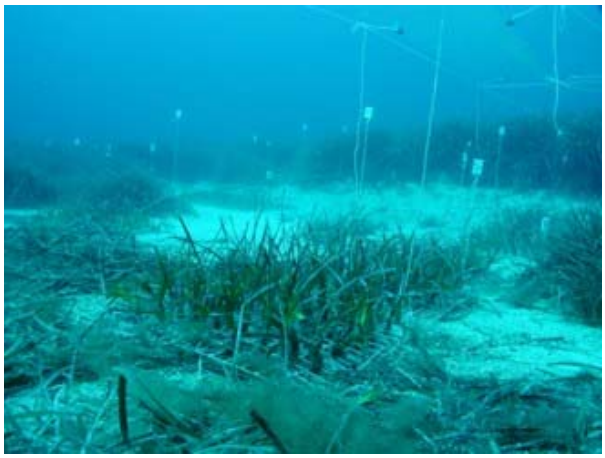
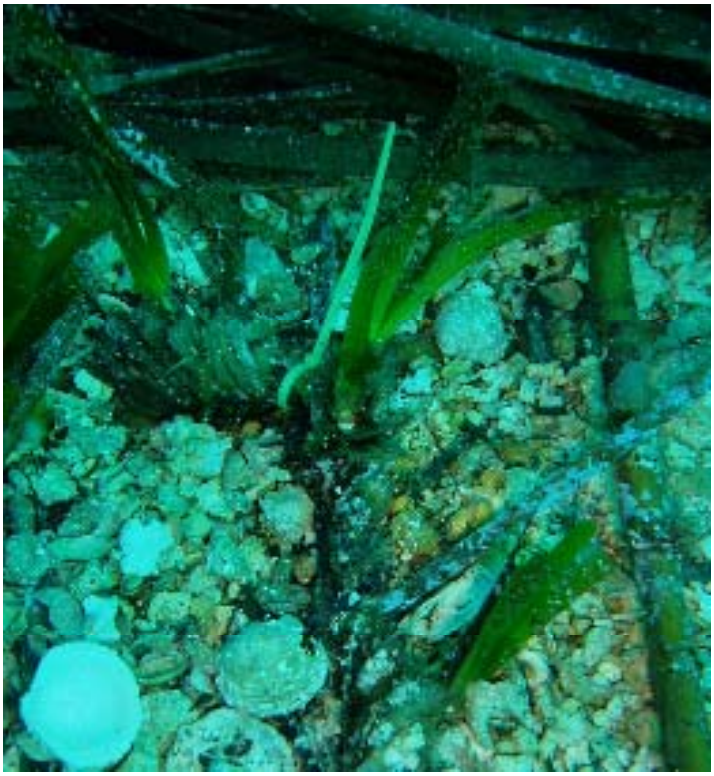


Fig. 13: Installation of EAT grids with *P. oceanica* shoots in the Bay of Calvi/Corsica.

2.1.5 Selection of the link type to attach the shoots on the grids

In calm areas, it is possible to use organic link (sisal rope), the rooting of shoots go faster than the disintegration of the organic link. In high hydrodynamic pressure areas, the rooting is more difficult (slower), use metallic or plastic links (Fig. 14) which



will attach the rhizome until a solid rooting occurs (one year). The link ensures the stability of the unrooted rhizome on the transplantation grid during the storms, it also protects the shoots against the effect of the fauna (grazers and sediment burrowers).

Fig. 14: Rhizome attached with a plastic link on a grid serving for the transplantation of *P. oceanica*, after one year the sediment has covered the grid.

The link has to stabilize the rhizome bearing the shoots without crushing it. In the case of electrification and the use of metallic link, the link has to be placed as far as possible from the meristematic zones.

2.1.6 Selection of the number of shoots on the transplanted area

A density of twenty to thirty pieces of rhizomes/m² (each with one to three shoots) provides a good barrier effect by the leaves and promotes the rooting. In choppy areas, the increase of transplanted rhizomes (fifty) increases the barrier effect of leaves against the water currents and avoids a sediment deficit.

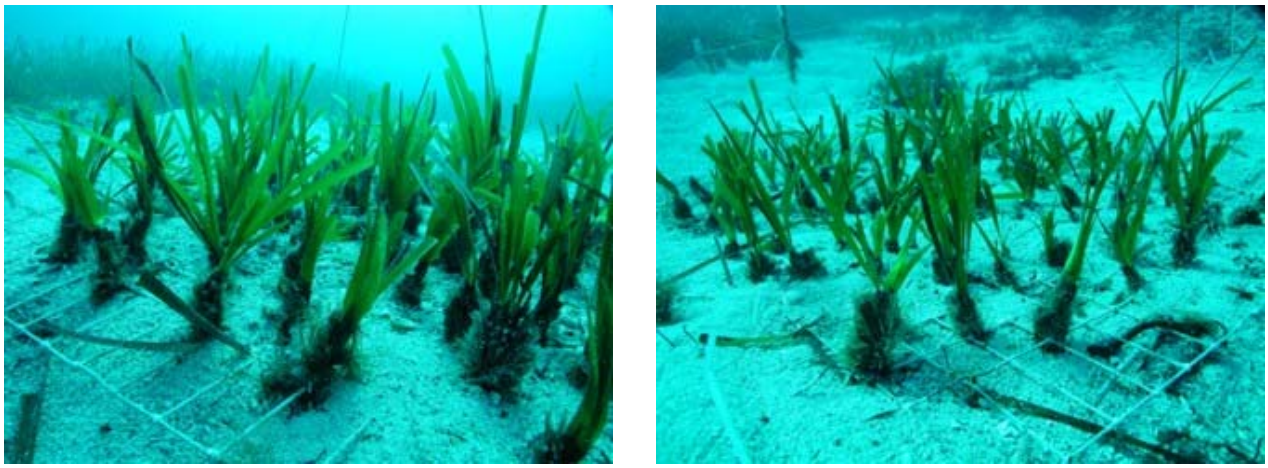


Fig. 15: EAT grids with transplanted *P. oceanica* shoots in 17 m depths.

2.1.7 Arrangement and installation of the shoots on the grids

The alignment of rhizomes must be avoided to reduce the possibility of erosion, place the rhizomes in all direction. A fixation of the rhizome on the grid must be used.

Fig. 16: Preparation of the *P. oceanica* shoots for transplantation on the EAT grids.

2.1.8 Selection of the time of the year for planting

The transplantation shows good results during all the year, but before and after the storm periods the marine gardeners must ascertain the fixation of the shoots on the grids.

2.1.9 Survey of the work

During the first year after the shoots were installed, the gardeners must moonitore the attachment of the rhizomes on the grid. The shoots need more than one year to be enrooted and the loss of cuttings is one of the most important factors of failure in the transplantation.

Fig. 17: Underwater monitoring of the *P. oceanica* transplants.

3. Estimation of costs

Table 1:

	material			labour costs									TOTAL			
				on land					under water							
	total costs / photovoltaic [€] 0,76€ / Kwh	total amount material [€]	contribution to the costs for reusable parts [€]	working hours (help) [h]	working hours shoots [h]	total cost for fabrication [€] (for cathode)	installation of cable [€] (one set, 2 persons, 0,5 h each)	total for fabrication	working hours under water [h] (80€ each)	working hours under water shoots [h] (40€)	total costs [€] for installation		Material costs [€] (without working hours)	total costs [€] (with working hours)	total costs [€] incl. line power	total costs [€] incl. photovoltaic power
Posidonia rehab	402,86	20	351,0	0,5		5	50	55	4		320		371,0	746,0	894,4	1148,8
Posidonia resto	53,47	14,5	154,5	0,5	1	5	50	70	2	4	320		169,0	384,0	578,7	612,5

The analysis of the cost for the *Posidonia* experiments is summarized in Table 1.

The main cost categories considered are:

- Costs for electricity (net power or photovoltaic)
- Costs for consumables (mainly for cathode material, steel etc.)
- Share of costs for the controlling and transforming units and parts to be used longer than the period required to produce the structure
- Working hours, specified in onshore and underwater

Taking all categories into consideration the prices for the application of the EAT technology for *Posidonia* rehabilitation amounts to 1.148,80 € if photovoltaic is used as source of electricity and approx. 900 € if line power is used. The calculation covers the entire costs for our experiments thus significant reduction can be expected for applications beyond the research. The very long electrification time during our experiments is clearly oversized and is not necessary to achieve the

desired effects. After 3 months the electrical current can be turned off thus the costs can be reduced. 351 € are allocated to finance the usage of reusable parts which is a high guess high as well. These costs can be reduced if the costs considered and shared are not for a prototype system but a series model. As an estimate the rehabilitation trials can be financed with about 500- 700 €. In this range the method is competitive to other methods.

In comparison the costs for the restoration of *Posidonia oceanica* using plagiotrophic shoots sum up to approx. 612,50 € for all EAT experiments done within the project, including working hours on land and underwater for the selection of a site and shoot material, preparation of shoots, installation and survey of the experimental sites. Again the working hours are most significant and the “expensive” source of electricity is responsible for comparably high prices. (The high costs for development and pre-testing of the different methods are not considered)
Taking the entire experiments as prototypes the cost are very reasonable.
For medium scale applications prices per m² will amount to approximately 50 – 100 €. Taking these assumptions as given, the fixation / transplantation of each shoot costs about 1 €.

4. Related literature

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