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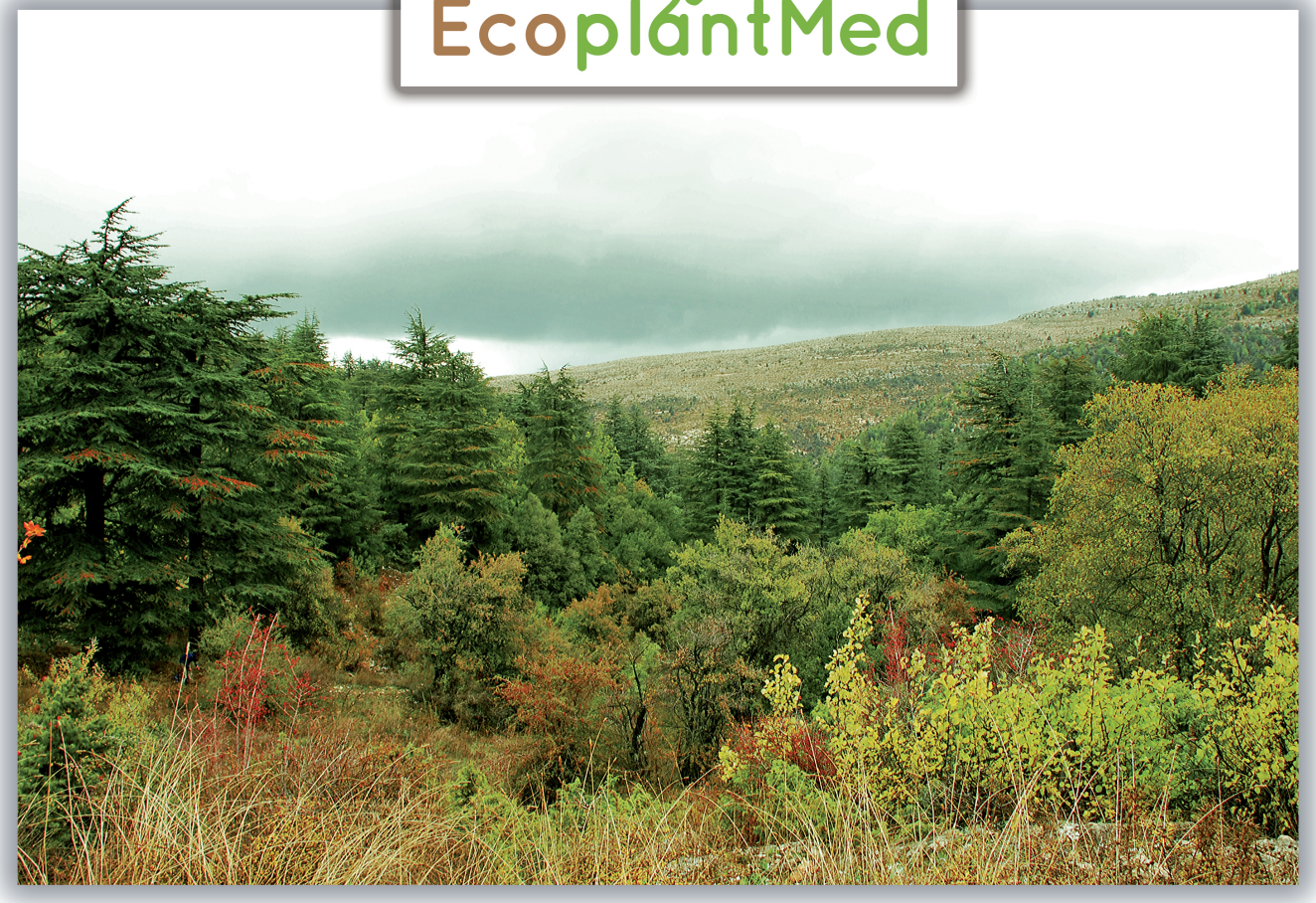

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The LIFE+ project "RES MARIS - Recovering Endangered habitatS in the Capo Carbonara MARIne area, Sardinia": first results

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Abstract
RES MARIS is an environmental protection project cofinanced by the European Union through the LIFE + Nature and Biodiversity Programme. The project aims at the conservation and recovery of marine and terrestrial ecosystems, included in the marine SCI (Site of Community Interest) "Isola dei Cavoli, Serpentara, Punta Molentis e Campulongu". The habitats selected for the implementation of the project are "*Posidonia* beds (*Posidonion oceanicae*)", "Coastal dunes with *Juniperus* spp." and "Wooded dunes with *Pinus pinea* and/or *Pinus pinaster*". They are characterized by a high biodiversity and exclusive vegetal and animal communities and can easily undergo both floristic and faunal changes. Some of the main threats to the site are landscape alteration, the introduction of invasive alien plants, and boat anchoring, which are mainly the result of human activities such as tourism and recreational activities, enhanced by a strong attendance (mostly in summer months). Sea-land integrated actions are therefore needed to achieve the following objectives: (1) to reduce/eliminate the invasive plants; (2) to reduce or to eliminate the mechanical damage from boat anchoring on *Posidonia* beds; (3) to favour the recovery of the spontaneous autochthonous vegetation; (4) to raise the awareness of the local population and stakeholders; and (5) to share conservation skills among the key decision-making bodies of the territory for the long-term protection of these habitats. Marine concrete actions consist of the positioning of mooring buoys in selected areas to ensure the conservation of *Posidonia* beds and the restoration of this habitat through naturalistic engineering techniques. Terrestrial concrete actions consist of the eradication of invasive species (*Carpobrotus* spp., *Agave* spp., and *Acacia* spp.) in the priority habitats and restoration through naturalistic engineering techniques. Communication actions use various conventional and multimedia tools including brochures, panels, a role-playing game, and an application/game for mobile phones. Environmental education and awareness-raising activities are addressed to schools and local stakeholders; a good practices manual on the integrated management of the coastal zone is devoted to key territorial players. Bathymetric and biocenotic maps were produced for 700 hectares of seabed; also, the main anthropogenic traces of disturbances were detected. The presence of the invasive alien macro algae *C. cylindracea* was also registered. The floristic analysis in the coastal dune systems led to the creation of a list with 127 native and 91 alien taxa. Among these, the most invasive species are those belonging to the genera *Carpobrotus*, *Agave*, and *Acacia*; distribution maps of these species in the SCI were created. Germplasm collections led to the acquisition of 40 seed accessions belonging to 14 structural plant species of dune habitats. It was possible to define optimal germination protocols for the selected species, and this was used to produce 30,000 plants for the restoration action.

Key words: beach system, coastal ecosystems, eradication, habitat restoration, invasive species, Mediterranean, priority habitats.

Introduction

The LIFE RES MARIS Project (LIFE13 NAT/IT/000433) has a duration of four years (2014-2018) and a total budget of € 1,510,805 (EU contribution € 1,121,479 equal to 74.23% of the total). The Province of Cagliari (PROVCA) is the Coordinating Beneficiary; in 2017 it was replaced by the Metropolitan City of Cagliari. The Associated Beneficiaries are the Municipality of Villasimius - Marine Protected Area "Capo Carbonara" (MPACC), scientific partner for interventions at sea and managing body of the project territory, the University of Cagliari - Centre for the Conservation of Biodiversity (UNICA-CCB), scientific partner for interventions on dune habitats and the Association TECLA (management and administration). The project is supported by the Sardinian Region (Environmental Department), by Federparchi - Italian Federation of Parks and Natural Reserves, and by the Consortium "Villasimius for tourism".

RES MARIS aims at the conservation and recovery of marine and terrestrial ecosystems of the emerged and submerged beach system, and in particular the priority habitats 1120* "*Posidonia* beds (*Posidonion oceanicae*)", 2250* "Coastal dunes with *Juniperus* spp." and 2270* "Wooded dunes with *Pinus pinea* and/

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or *Pinus pinaster*" (Habitats DIR. 92/43/EEC) included in the marine SCI ITB040020 "Isola dei Cavoli, Serpentara, Punta Molentis e Campulongu".

The impact caused by the presence of invasive alien species (IAS) is one of the most significant pressures (Pinna *et al*., 2012; Report PROVIDUNE, 2012) due to the widespread practice of using exotic species in gardens as ornamental plants. In particular, invasive species belonging to the genus *Carpobrotus*, [*Carpobrotus acinaciformis* (L.) L.Bolus, *Carpobrotus edulis* (L.) N.E.Br.], *Acacia* [*Acacia* saligna (Labill.) H.L. Wendl., *Acacia* karroo Hayne] and *Agave* [*Agave fourcroydes* Lem., *Agave attenuata* Salm-Dick, *Agave americana* L., *Agave ingens* Brg. var. *picta* (Salm.) Bgr.], pose a threat to the priority habitats 2250* and 2270*, determining the decrease of the surface coverage of such habitats.

During the summer season, human activities may represent important pressures on the habitat 1120*. Its deterioration, mainly due to the mechanical action of the anchors, may favour the colonization of invasive benthic algal species such as *Caulerpa cylindracea* Sonder. This species is competitive with *Posidonia oceanica* (L.) Delile and can invade the so called 'dead matte' (Klein & Verlaque, 2008) preventing the re-colonization of *P. oceanica*. Sea-land integrated actions are therefore needed to achieve the following objectives: (1) to reduce or to eliminate the IAS; (2) to reduce or to eliminate the mechanical damage from boat anchoring on the habitat 1120*; (3) to favour the recovery of the spontaneous autochthonous vegetation; (4) to raise awareness amongst the local population and stakeholders; and (5) to share conservation skills among the key decision-making bodies of the territory for the long-term protection of these habitats.

The project started with various preparatory actions (A actions) that aimed to update the state of knowledge on the emerged and submerged beach system and the related threats, leading to the identification of the areas of intervention and to the planning of conservation actions (C actions). These include the application of protocols and of low impact solutions already tested in other similar projects such as the LIFE+ PROVIDUNE project (Layman's Report, 2014). The foreseen C actions are the eradication and/or control of IAS, the restoration of priority habitats, and the installation of new mooring structures to reduce the impact of anchoring in the most sensitive areas. Monitoring actions (D actions) will assess the effectiveness of the interventions on each coastal habitat through indicators such as the long-term monitoring of the resilience of alien species; the effectiveness of the germplasm collection (seed testing and plants propagating); and of habitat restoration. The effects on marine habitat 1120* will be assessed by non-destructive methods and by the application of ecological indices useful in defining its conservation status.

Study area

The SCI Isola dei Cavoli, Serpentara, Punta Molentis and Campulongu is located in south-eastern Sardinia, in the Sarrabus sub-region, and more specifically in the municipal area of Villasimius, province of Cagliari. It stretches over 9,281 ha (of which 8,538 ha is marine and 742 terrestrial) and protects one of the most important marine and coastal sites of the Natura 2000 network in Sardinia, as demonstrated by its full overlay with the Marine Protected Area Capo Carbonara (MPACC). In addition, the SCI includes three Special Protection Areas (SPAs) designated as Isola Serpentara (ITB043026), Isola dei Cavoli (ITB043027), and Capo Carbonara e stagno di Notteri – Punta Molentis (ITB 043028) (Fig. 1).

The SCI is comprised of the islands of Cavoli and Serpentara, the pond of Notteri, and the coastal area from Campulongu to Punta Molentis, as far as Punta Is Porceddus. The island of Cavoli is an extension of the Capo Carbonara promontory, which is about 700 meters away and the island of Serpentara and is located at the northern end of the site, just over three kilometres from the coast. The area presents great variety in terms of landscape, geomorphology, flora, and fauna. Coastal environments are characterized by long beaches (Porto Giunco and Simius) separated by rocky headlands; other small beaches can be found on the rocky coast of Punta Molentis.

The lithologies are essentially referred to the ercinic batolite of Sarrabus emerged at the end of the ercinic orogenesis in the Middle Carboniferous. They are composed mainly of granites and granodiorites subjected, during the alpine orogenesis, to tectonic move-

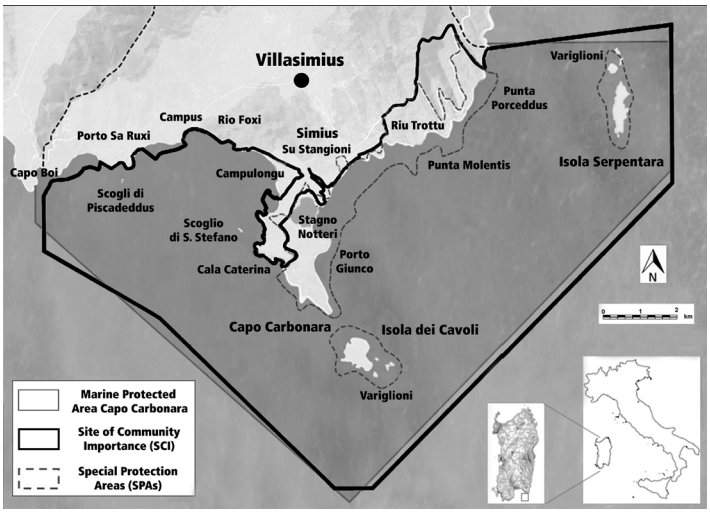

Fig. 1 - Project implementation area.

ments that deformed them according to the prevalent northwest-southeast direction (Orrù *et al*., 1994). The veins present the same orientation and are mainly of a basic nature, dominated by lamprophiric and spessartitic lithologies that assume a particular relief in the determination of the coastal and submarine landscape. In fact, the coastline is formed by promontories with the same orientation of those of Capo Carbonara (Orrù *et al*., 1994) and the sea areas are characterized by the continuity of the granite forms with emerging areas. In the surrounding landscape, ancient shapes of smoothing, such as inselberg and tor, ornament the ridges and the plateaux at an elevation of around 400 and 500 m (Orrù *et al*., 1994).

There are a great number of endemic plants or species with a limited spreading distributed prevalently on Cavoli and Serpentara islands. *Brassica insularis* Moris (All. II and IV Habitat, DIR. 92/43/EEC) can be found only in the Cavoli island, where it represents one of the most important populations, while Serpentara island is considered to be the locus classicus for two narrow endemic (Bocchieri, 1988): *Ferula arrigonii* Bocchieri, a Sardinian-Corsican endemism that can be found in a few coastal and insular areas; and *Silene valsecchiae* Bocchieri, an endemism of eastern Sardinia. Also, *Limonium retirameum* Greuter et Burdet, distributed in all the coastal area, is limited to this sector of the island. Along the same coast, other important endemisms can be found such as *Verbascum conocarpum* Moris; *Helicodiceros muscivorus* (L.f.) Engler; *Bryonia marmorata* Petit; *Aristolochia tyrrhena* E.Nardi et Arrigoni; *Helichrysum microphyllum* (Willd.) Camb. subsp. *tyrrhenicum* Bacch., Brullo et Giusso.

The SCI hosts the priority habitats 1120* "*Posidonia* beds (*Posidonion oceanicae*), 2250* "Coastal dunes with *Juniperus* spp." and 2270* "Wooded dunes with *Pinus pinea* and/or *Pinus pinaster*". The habitat 2250* consisting of the dune systems is extremely rare and only present in Italy, Portugal, Spain, France, and Greece. Habitat 2270* has remarkable value for its biodiversity (even if of artificial origin), by promoting the development of the forest vegetation of habitat 2250*. Habitat 1120* consists of *Posidonia oceanica*, an endemic vascular species in the Mediterranean Sea. This habitat is widely extended in the area (22% of the total area of the SCI), presenting an ecological role (the protection of the submerged beach and of the marine biodiversity) and a major economic role (fishing, diving, etc.). The habitats mentioned above are currently subjected to various pressures derived from the presence of IAS and from anthropic activities. For these reasons, the protection of these habitats in the project area is a priority not only at regional level but also at a national and community level, and it is fundamental to realize urgent conservation actions.

Material and methods

The project includes four preparatory actions (A1-A4), divided in marine and terrestrial.

Marine preparatory actions

In the first two actions (A1 and A2), an updated version of the distribution of *P. oceanica* and of the algal alien species was carried out based on existing data (mainly grey literature, and Marine Protected Area technical reports and bionomic maps).

A1: During the period April-June, 2015, *P. oceanica* meadows were surveyed using different methods (acoustic surveys and visual observations by towed video camera and scuba diving). The morphological and bathymetric surveys of the seabed were carried out along transects parallel to the coastline using both multibeam (Reson Seabat 8125 at a frequency of 455 kHz) and single beam (Simrad at a frequency of 200 kHz) sonar. A side-scan sonar (Klein 3000 at frequencies between 100 and 500 kHz) was used to identify the main biological and geomorphological evidence on the seabed. Visual observations by scientific divers and/or by towed video camera were carried out to avoid errors due to uncertain interpretations of the sonograms obtained.

A2: The presence and abundance of algal alien species was investigated in four areas (Punta Molentis, Porto Sa Ruxi, Cala Is Cascias and Campulongu) through the Point Intercept Transect method (Bianchi *et al*., 2003). The frequency and percentage cover of the target species was measured according to a hierarchical sampling design at three different depths (shallow: 5-8 m; intermediate: 12-15 m; deep: 19-22 m).

Terrestrial preparatory actions

The purpose of these actions was to acquire an updated knowledge of the native and non-native vascular flora and vegetation in the SCI.

A3: Action aimed at characterizing the coastal dune habitats and the structural species present in the intervention areas, in order to acquire the information needed to correctly plan the concrete conservation actions C3 and C5. Flora and vegetation data were collected based on bibliographical research (Camarda & Ballero, 1981; Mossa *et al*., 2000; Bacchetta *et al*., 2006a, 2007; Report PROVIDUNE, 2012) and on herbarium specimens found at the Herbarium CAG. This data was combined with the observations performed during field excursions and harvests that took place between June 2014 and February 2015.

During the fieldwork, the flora and vegetation of priority habitats, and of those related to them in catenal succession, were analysed in order to identify the structural species of each habitat and assess the state of conservation. Floristic, phytosociological, and phe-

nological surveys were made by means of the standard sheets internationally adopted according to Bacchetta *et al*. (2006b, 2008). The relevés of vegetation were made according to the phytosociological method of the school of Zurich-Montpellier (Braun Blanquet, 1951).

The surveys were carried out in the SCI areas where dunes and psammophilous ecosystems occur. The measurements were carried out mainly within the psammophilous geosigmetum, detecting the different types of vegetation. Nomenclature of plant species and subspecies is in line with Conti *et al*. (2005, 2007), while, as recommended by the International Code of Botanical Nomenclature (Greuter *et al*., 2000), the authors of plant names are abbreviated according to 'Authors of plant names' (Brummitt & Powell, 1992). Life forms were checked in the field according to the Raunkiaer's classification (Raunkiaer, 1934), using the abbreviations of Pignatti (1982). For the chorological types we used Pignatti's classification (Pignatti, 1982), modified by Brullo *et al*. (1996) for Mediterranean types. In order to ascribe the endemic taxa to the chorological types, the ranks proposed by Arrigoni & Di Tommaso (1991) were adopted, as modified by Bacchetta & Pontecorvo (2005).

A4: Action to update the knowledge of the IAS that threaten the priority coastal habitats. For this reason, a mapping tool was created in order to properly plan the control and/or eradication measures of the subsequent action C4 (eradication of IAS). The basis for the current analysis was represented by the latest checklist produced by the PROVIDUNE project (Report PROVIDUNE, 2012), updated through data collected in field surveys. The distribution maps of the invasive species were created on orthophotos at a scale between 1: 2,000 and 1: 10,000; the orthophoto cartographic base at a scale of 1: 25,000 (flight 2006) was used, overlapping with the Natura 2000 network habitats maps. Two different types of software, ArcMap 10.2 and gvSIG 1.12.0, were used. The population census was performed by taking into consideration the most powerful invasive species such as those belonging to *Carpobrotus*, *Agave*, and *Acacia* genera. This will lead to the production of maps of the area of influence or extent of occurrence (EOO) inside habitats 2250* and 2270*. These areas, calculated for each population as corresponding to the largest polygon covered, are georeferenced according to the UTM and Gauss Boaga coordinates; based on the percentage of coverage, it was also possible to estimate the real occupied area. In the SCI area, 17 localities were sampled; field data related to the identification of the IAS and population (habitat, locality, and geographic coordinates) was collected. The status of alien species was determined and ordered on the basis of the criteria proposed by Richardson *et al*. (2000), elaborated by Pyšek *et al*. (2004), and reviewed according to Richardson *et al*. (2011). Archaeophyte and neophyte taxa were differentiated depending on their introduction before or after years 1492/1500, respectively.

The project includes five concrete conservation actions: C1-C5.

Marine concrete conservation actions

These actions are planned to apply to a series of interventions aimed at the protection of habitat 1120* through low-impact solutions and the best techniques already used in similar projects.

C1: Action to reduce the anchorage threat to the priority habitat *Posidonia* beds (*Posidonion oceanicae*), by positioning mooring buoys that reduce the impact of anchoring in the selected areas identified in the preparatory action (A1).

C2: Action to restore the priority habitat *Posidonia* beds (*Posidonion oceanicae*) by applying naturalistic engineering techniques and reducing the threat due to the presence of invasive algal species through the manual and experimental elimination of *C. cylindracea*.

Terrestrial concrete conservation actions

These actions aim at the complete restoration of the terrestrial priority habitats, through the eradication of IAS, the plantation of native plants, and the use of naturalistic engineering techniques.

C3: The outputs of the action A3 was employed to select the species to be used in the restoration actions. We selected 14 taxa of both structural and functional importance. All activities concerning the collection and management of the germplasm were executed in accordance with standard procedures (Bacchetta *et al*., 2006b, 2008; Ballesteros *et al*., 2015). Seed collections were carried out in order to obtain a sufficient quantity of material that was representative, from the genetic point of view, of the diversity present in the SCI while avoiding an excessive collection that could damage the populations.

Germplasm was harvested from June 2014 to February 2016 and deposited in the Sardinian Germplasm Bank (BG-SAR). It was stored for a post-ripening period at 20°C and 40% relative humidity (RH), to achieve uniformity in the degree of maturation of the seeds. Afterwards they were subjected to manual and/or mechanical cleaning and to quantitative-qualitative monitoring.

The selected taxa are: *Juniperus macrocarpa* Sibth. & Sm.; *Juniperus phoenicea* L. subsp. *turbinata* (Guss.) Nyman; *Pistacia lentiscus* L.; *Pancratium maritimum* L.; *Eryngium maritimum* L.; *Elytrigia juncea* (L.) Nevski; *Cistus salviifolius* L.; *Achillea maritima* (L.) Ehrend. & Y.P.Guo subsp. *maritima*; *Pycnocomon rutifolium* (Vahl) Hoffmanns. & Link.; *Glaucium flavum* Crantz; *Rhamnus alaternus* L.; *Helicrysum microphyllum* (Willd.) Camb. subsp. *tyrrhenicum* Bacch., Brullo

& Giusso; *Crucianella maritima* L.; and *Ammophila arenaria* subsp. *arundinacea* H.Lindb.

Some germination tests were carried out to identify the optimal protocol for large scale germination and multiplication. The species selected for testing, for which there was no published germination protocol, were: *J. macrocarpa*; *G. flavum*; *R. alaternus*; *H. microphyllum* subsp. *tyrrhenicum*; *P. rutifolium*; *A. maritima* subsp. *maritima*. For each of these species, germination tests were carried out at constant temperatures of 5, 10, 15, 20, 25, and 30° C and alternating 25/10° C in growth chambers (Sanyo MLR 351) in the facilities of BG-SAR. For each temperature tested, four replicates were arranged with a 12/12 photoperiod (12 hours light and 12 hours darkness) and five replicates with a 0/24 photoperiod (24 hours darkness). Seeds were sown on 1% water agar substrate, which provided a solid, non-sterile medium for germination, in 90 mm diameter plastic Petri-dishes, with 25 seeds each. Darkness was achieved by wrapping dishes with two layers of aluminium foil. The tests were monitored daily in sterile conditions under a laminar flow cabinet. Seeds incubated in the light were scored daily; germinated seeds were discarded, whereas seeds incubated in the dark were scored only at the end of the test, to avoid any exposure to irradiance (Baskin *et al*., 2006). When no additional germination occurred in the light for two consecutive weeks, tests were stopped both in the light and in the dark and the viability of any remaining seeds was checked by a cut test.

All the rest of the collected germplasm were delivered to the Forestas Agency (AF), which is responsible for the germplasm multiplication. This activity will be carried out as indicated in the germination protocols developed by UNICA-CCB, which will also provide technical and scientific support to the AF. For the renaturation interventions of priority habitats, 30,000 plants will be produced.

C4: The following interventions are planned in order to eradicate/control the IAS:

(1) The eradication of *Carpobrotus* sp. pl.: by the manual removal of the plants. The intervention must be carried out with particular care in order not to damage the native vegetation present in the area. In addition, it will be necessary to restrict removal of the sand by shaking the removed plants before their transfer.

(2) The eradication of *Acacia* sp. pl.: some features of *A. saligna* make its eradication and/or control problematic. In fact, this species is particularly difficult to control in sandy habitats by mechanical methods, such as the removal of adults, because of the danger of drastically altering the dune ecosystem structure. According to Meloni *et al*. (2015), manual control is the safest method for the management of *A. saligna* in coastal Mediterranean habitats, with the destruction of adults in combination with the manual removal of seedlings. Therefore, our strategy will be to proceed with two different methods depending on the size of individuals; for small ones, the eradication will be carried out manually; for adults, the cutting of the plant at the base of the stem with mechanical means will be made (with a chainsaw and handsaw).

(3) The eradication of *Agave* sp. pl. In this case two different methods will also be applied, based on the size of the individuals—manual eradication of seedlings and young individuals through the extraction of the root systems, and repeated cuts and the use of mechanical means for the adult ones. Priority will be given to the elimination of the individuals of reproductive age, avoiding the fall of fruits to the ground and the subsequent dispersal of seeds. All plant remains will be removed. In the years subsequent to the intervention, all sites will be checked for the possible regrowth of seedlings. Also, the sucker sprouts from *Acacia* roots must be managed through repeated cuttings, leading to the weakening of the tree, which will not re-grow and will die off.

C5: This action focus on the restoration of the dune vegetation habitats 2250* and 2270*, using bioengineering techniques and planting with autochthonous plants. Similar measures had already been carried out in the LIFE PROVIDUNE project, but were limited to small areas; in the framework of RES MARIS, this action will cover an area of about 14,500 square meters. The actions to be implemented are the following: (1) the positioning of cane structures for sand retention and the consequent recovery of the dune profile; (2) the positioning of coconut fibre bionets to avoid erosion, particularly after the eradication; and (3) sowing with germplasm collected in action C3, and planting 30,000 native plants multiplied in nurseries by the EFS from the germplasm collected in the SCI.

Monitoring actions

The project involves several monitoring actions (D).

D1: Monitoring action D1 *ante operam* of the conservation action C1 consisted of assessing the status of *P. oceanica* through the study of its phenology and of the structure of the meadows (density; percentage cover with elaboration of some ecological index; description of the upper and lower limits of distribution). In addition, the count of pleasure boats anchored in the areas of study was elaborated by distinguishing the size and type (sailing/motor) and by using a remote video system recording, was also part of monitoring action D1.

D2: Monitoring action D2 *ante operam* of the conservation action C2 consisted of updating the knowledge of the presence of *C. cylindracea* and the percentage cover in the selected areas.

D3: The action D3, which concerns the action C3, included the monitoring of parameters such as the effectiveness of the germplasm collections, germination,

and large-scale multiplication protocols.

Communication actions

The project involves ten communication actions: E1-E10.

E1: The communication plan provides guidance for all dissemination tools, actions and products, thus guaranteeing an efficient and active involvement of key territorial players and local population.

E2: A web portal and social networking are the containers for all project deliverables, as well as the primary source of information for key stakeholders.

E3: Bilingual information panels provide essential information on the area such as the presentation of the SCI, of its territory, habitats and species, general information about the Natura 2000 network, and the rules of behaviour.

E4: The school educational project differs according to the schools' needs. It involves the construction of a path of knowledge in stages, with both individual work and playful moments in group activities. Each stage will end with a guided tour to the different beaches of the SCI.

E5: This territorial animation action is scheduled throughout the project duration and provides both public presentation events and technical workshops. One of the events is addressed to local actors and involves the use of a participatory methodology known as Open Space Technology (OST). The main stakeholders will be involved in the project's dissemination activities through membership in the RES MARIS club. The members of the club will offer services to tourists in line with the objectives of the project and will be asked to host information points during the summer and to distribute dissemination products.

E6: This Layman's report is written in two languages (Italian and English). It focuses on the project's methodology, objectives, actions, and achievements and highlights the aspects of its reproducibility.

E7: This action calls for the involvement of private citizens through enlistment to the RES MARIS club and for their cooperation through the eradication of invasive plants and their replacement with native ones.

E8: This action foresees the making of documentary videos and a video channel where each documentary addresses a specific phase and project activity, from the ex ante situation to the synthesis of the results.

E9: This action provides guidelines for the proper use and management of the beach system. It represents a necessary tool for sustainable and integrated coastal zone management by all territories dealing with marine and/or coastal SCI areas.

E10: This awareness-raising action includes beach activities along with specific recreational and educational activities for children, as well as information and awareness-raising activities for tourists, by setting up movable information points and guided tours along a nature trail.

Results and discussion

Marine preparatory actions

A1: From sonar surveys, 700 hectares of seabed were characterized, distinguishing between rocks, sands and *P. oceanica* beds settled on matte, sand or rock. Bathymetric and biocenotic maps were produced and the main anthropogenic traces of disturbances on the bottom of each area were identified. In this way, the sites for the conservation action C1 (positioning of mooring buoys) were selected at Campulongu, Punta Molentis and Cavoli Island (Fig. 2).

A2: In all four areas investigated (Punta Molentis, Porto Sa Ruxi, Cala Is Cascias and Campulongu) the presence of the invasive alien macro algae *C. cylindracea* was registered, showing greater abundance at intermediate and deep depths than at shallow depths (Fig. 3). The Campulongu and Punta Molentis areas were selected for the conservation action C2 (the intervention for the recovery of the habitat 1120*). At Campulongu, evidence of anchors and/or trawling disturbances were observed on the *P. oceanica* bed (Figs. 4-5). This area was therefore selected for restoration activities.

According to the results of actions A1 and A2, the Campulongu area was the only area that was clearly degraded by human activities; this is probably due to the large flow of tourists concentrated in this area during the summer months. Other areas are also crowded but are characterized by *P. oceanica* beds located very distant from the coastline and are of little or no interest for boat anchoring. The presence of *C. cylindracea* has been recorded on several substrates (rock, sand and

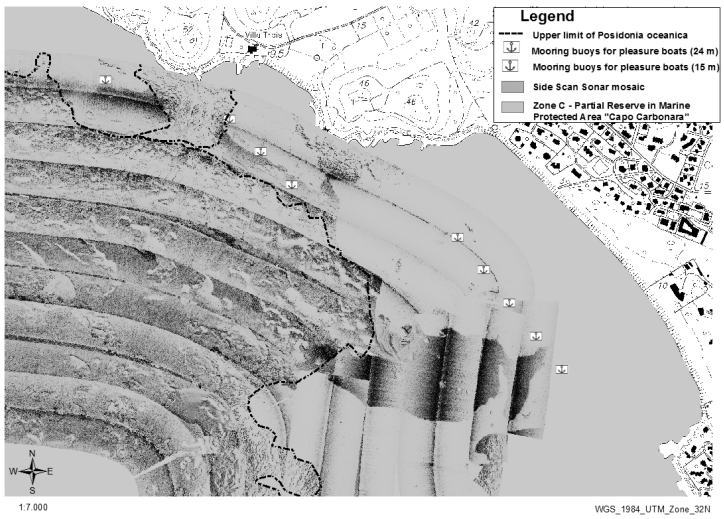

Fig. 2 - The positioning of mooring buoys in Campulongu area.

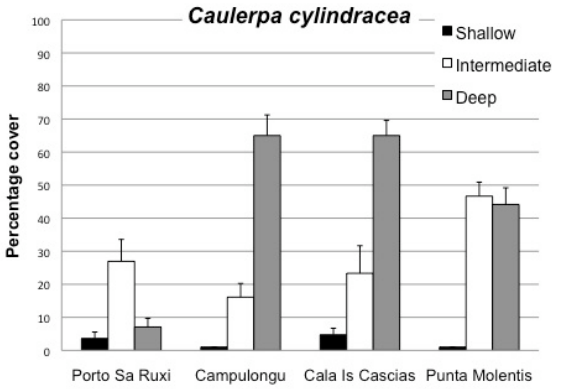

Fig. 3 - Abudance (mean + Standard Error; n = 6) of *Caulerpa cylindracea* within the four areas investigated at three different depths (Shallow: 5-8 m; Intermediate: 12-15 m; Deep: 19-22 m).

dead matte) and on the rhizomes of *P. oceanica*, preferentially at the margins of the beds. In our study, according to Piazzi *et al*. (2001), *C. cylindracea* was found mainly where *P. oceanica* meadows are fragmented, with a predilection for the dead matte and the lower limit where the plant development is naturally less vigorous. The abundance of *C. cylindracea* was generally low within shallow areas, but has been probably underestimated in this study due to the sampling period. In fact, this invasive alga is characterized by a marked seasonal pattern that shows a higher development, in terms of coverage and biomass, between June and November rather than between December and May.

Terrestrial preparatory actions

A3: Based on the analysis of the surveys in the coastal dune systems, natural vegetation includes different habitats, of which the most representative are 2250* "Coastal dunes with *Juniperus* spp." and 2270* "Wooded dunes with *Pinus pinea* and/or *Pinus pinaster*)". They are both part of the psammophilous phanerophytic vegetation represented by heaths and thickets, with *J. macrocarpa* related to the association *Pistacio-Juniperetum macrocarpae* Caneva, De Marco et Mossa 1981. Habitat 2270* is dominated by *Pinus halepensis* Mill. and *Pinus pinea* L.; *P. lentiscus*, *R. alaternus* and *J. phoenicea* subsp. *turbinata* accompany them. Directly related to these formations in catenal succession, chamaephytic retrodunal formations of *Crucianelletum maritimae* Br.-Bl. (1921) 1933 can be found (habitat 2210*, *Crucianellion maritimae* Rivas Goday et Rivas-Martínez 1963 fixed beach dunes), characterized by *C. maritima*, *H. microphyllum* subsp. *tyrrhenicum*, *Lotus cytisoides* subsp. *conradiae* Gamisans, and *P. maritimum*. Occasionally, in the clearings and often mixed up with previous formations, some terophytic formations characterized by annual species like *Malcolmia ramosissima* (Desf.) Gennari were detected, including in the habitat 2230* (*Malcolmietalia* dune grasslands). The surveys carried out in the mobile dunes revealed the presence of perennial formations belonging to the association *Sileno-Corsicae-Elytrigetum junceae* (Malcuit 1926) Bartolo *et al*., 1992 *corr*., mainly with *E. juncea* and *A. maritima*. Further back, there is the association *Echinophoro spinosae-Ammophiletum arundinaceae* (Br.-Bl. 1933) Géhu, Rivas-Martínez, Tüxen 1972, characterized by the locally rare *A. arenaria* subsp. *arundinacea*. These two vegetation types characterized by rhizomatous grasses are attributable to the habitats 2110 "Embryonic shifting dunes" and 2120 "Shifting dunes along the shoreline with *Ammophila arenaria* (white dunes)". In front of these formations, pioneer terophytic communities were detected, represented by the association *Salsolo kali-Cakiletum maritimae* Costa *et* Manz. 1981 *corr*. (habitat 1210 "Annual vegetation of drift lines").

The floristic analysis led to the creation of a list with 127 native taxa, of which there were 89 of spe-

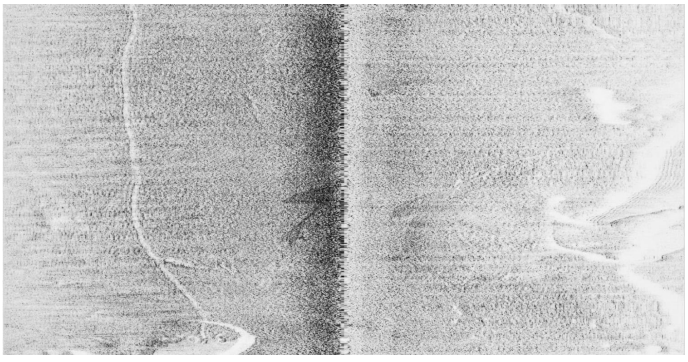

Fig. 4 - Example of the sonograms obtained with the Side Scan Sonar: on the left side, a furrow in the bed caused by human activities, probably trawling or boat anchoring. On the right side, evidence of a dense *Posidonia oceanica* bed on matte, with semicircular sandy depressions.

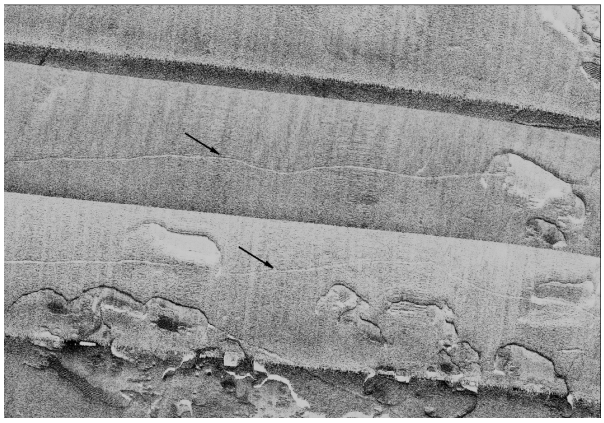

Fig. 5 - A zoomed detail in the sonogram of Campulongu area: the black arrows indicate the furrows of planting interventions.

cific rank, 37 subspecies, and 1 variety, belonging to 43 families and 104 genera. The *phylum Pinophyta*, represented by four taxa, constitutes 3% of the total flora, while *Polypodiophyta* is represented by a single taxon. Among the *Angiospermae*, the most numerous are the *Eudicotyledones*, which represent 74% of the total, with 94 taxa belonging to 31 families and 78 genera. The *Monocotyledones* instead constitute 22% of the flora with 28 taxa belonging to 9 families and 28 genera. The families with the highest number of entities are: *Asteraceae* (20 taxa, 16% of the total), followed by *Poaceae* (15 taxa, 12%), *Fabaceae* (10 taxa, 8%), *Apiaceae* (8 taxa, 6%) and *Caryophyllaceae* (7 taxa, 6%) (Fig. 6). The analysis of the biological spectrum shows a preponderance of therophytes (45 taxa, 35%), followed by hemicryptophytes (26 taxa, 21%), phanerophytes (23 taxa, 18%), camaephytes (17 taxa, 13%), and geophytes (16 taxa, 13%). The analysis of the chorological spectrum presents a predominance of the Mediterranean chorological component (100 taxa, 79%), followed by the cosmopolitan (6 taxa, 5%) and sub-cosmopolitan (5 taxa, 4%), circumboreal (4 taxa, 3%) and palaeotemperate (3 taxa, 2%). The spectrum of Mediterranean chorological forms shows a prevalence of species with circum-Mediterranean distribution (51 taxa, 40%), followed by the euro-Mediterranean (18 taxa, 14%), W-Mediterranean (10 taxa, 8%), Mediterranean Atlantic (9 taxa, 7%), and endemic (8 taxa, 6%) (Tab. 1). The analysis of the endemic component highlights the predominance of the elements belonging to the biogeographic Sardinian-Corsican province (4 taxa, 50%). No plant species of community interest are present in the identified areas, while 9 taxa of phytogeographical interest were detected (Tab. 2).

A4: among the alien flora of the SCI, 65% are represented by neophytes (59 taxa), while 35% are archaeophytes (32 taxa), making a total of 91 alien taxa. Of these taxa, 36% (42) are naturalized, 36% (33) are casual, and 18% (16) are invasive. Among the 16 invasive taxa, 13 are present in the monitored coastal dune habitats and 12 in the priority habitats 2250* and 2270*. The most invasive species—those occupying the greatest surface in the habitats—are confirmed to belong to the genera *Carpobrotus*, *Agave*, and *Acacia* followed by *Oxalis pes-caprae* L. (*Oxalidaceae*), *Malephora crocea* Schwantes, and *Aptenia cordifolia* (L. fil.) Schwantes, both belonging to the same family of *Carpobrotus* (*Aizoaceae*) and *Opuntia ficus-indica* (L.) Mill. (*Cactaceae*).

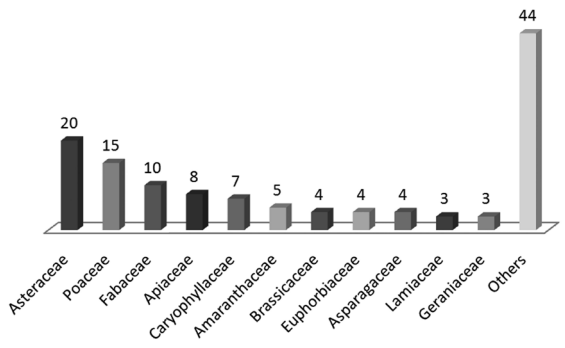

Fig. 6 - Number of taxa of the most represented families.

Tab. 1 - List of endemic species detected in the flora.

Family	Species	Chorological type
Araceae	*Arum pictum* L.fil. ssp. *pictum*	Endem. SA-CO
Asteraceae	*Helicrysum microphyllum* (Willd.) Camb. ssp. *tyrrhenicum* Bacch., Brullo et Giusso	Endem. SA-CO-BL
Plumbaginaceae	*Limonium dubium* (Guss.) R.Litard	Endem. SA-CO-SI
Plumbaginaceae	*Limonium retirameum* Greuter et Burdet	Endem. SA
Fabaceae	*Lotus cytisoides* L. ssp. *conradiae* Gamisans	Endem. SA-CO
Rubiaceae	*Rubia peregrina* L. ssp. *requienii* (Duby) Cardona et Sierra-Ràfols	Endem. SA-CO-ITM-BL
Asteraceae	*Senecio transiens* (Rouy) Jeanm.	Endem. SA-CO
Caryophyllaceae	*Silene succulenta* Forssk. ssp. *corsica* (DC.) Nymann	Endem. SA-CO

Tab. 2 - List of phytogeographical interest species detected in the flora.

Family	Species	Chorological type
Amaranthaceae	*Achyranthes sicula* (L.) All.	W-Medit.
Asteraceae	*Achillea maritima* (L.) Ehrend. & Y.P.Guo ssp. *maritima*	Medit.-Atl.
Brassicaceae	*Malcolmia ramosissima* (Desf.) Gennari	W-Medit.
Fagaceae	*Quercus calliprinos* Webb	E-Medit
Iridaceae	*Romulea rollii* Parl.	W-Medit.
Plantaginaceae	*Plantago macrorrhiza* Poir.	W-Medit.
Poaceae	*Imperata cylindrica* (L.) Raeusch.	Cosmop.
Thesiaceae	*Thesium humile* Vahl.	Medit.-Atl.

The distribution maps of *Carpobrotus* sp. pl., *Acacia* sp. pl., and *Agave* sp. pl. were produced at a scale between 1: 2,000 and 1: 10,000. In the priority habitats 2250* and 2270* they occupy the following areas:

(1) *Carpobrotus* sp. pl.: real area 7,275 m^2, area of influence 28,297 m^2. Campulongu is the most invaded location.

(2) *Acacia* sp. pl.: real area 2,642 m^2, area of influence 3,685 m^2. Approximately, there are 600 adult individuals and 600 young individuals and Simius is the most invaded location.

(3) *Agave* sp. pl.: real area 432 m^2, area of influence 954 m^2. There are approximately 210 adult individuals and 245 young individuals. Timi Ama is the most invaded location.

According to the results of actions A3 and A4, the SCI presents a psammouphilous vegetation with high floristic diversity and is characterized by endemic species and of phytogeographical interest. It is established primarily on consolidated dunes and is part of the priority habitat 2250* "Coastal dunes with *Juniperus* spp." and is well represented especially on the beaches of Campulongu, Porto Giunco, Simius, and Is Traias (in the latter it has not been previously reported). On the

beach of Campulongu it is mixed with the priority habitat 2270* "Wooded dunes with *Pinus pinea* and/or *Pinus pinaster*" and dominated by the two termophilous Mediterranean pinus and by shrub species typical of habitat 2250*. The floristic component presents a preponderance of therophytes due to the xericity of these habitats. The distribution maps of the priority habitats and of the IAS, highlight the threat they represent, leading to a deconstruction of the vegetation of the habitats.

C3: Germplasm collections carried out in the period between July 2014 and February 2016 led to the acquisition of 40 seed accessions belonging to 14 structural taxa of dune habitats, far beyond the expected target (20 accessions of 10 species). It was possible to define optimal germination protocols for the six species that were tested (*J. macrocarpa*, *G. flavum*, *R. alaternus*, *H. microphyllum* subsp. *tyrrhenicum*, *P. rutifolium*, and *A. maritima* subsp. *maritima*). Moreover, those protocols were delivered jointly with those elaborated in the LIFE PROVIDUNE project to the EFS for large scale multiplication (approximatively 30,000 plants for the C5 action).

Communication actions

In the framework of action E1, the communication plan and the project logo were produced, together with the project slogan: Res Maris - A sea of respect. Various informative materials were produced such as flyers on the habitats and an informative brochure. In the context of action E2, a website (www.resmaris.eu) was produced in two versions, Italian and English. Project pages have also been set up on different social platforms. In the framework of action E4, environmental education activities have begun with the aim of involving 500 students over a period of three years. For action E5 a presentation event of the project was held along with the first technical meeting dedicated to key stakeholders. The first part of action E10 was implemented in the summer 2015 and involved about 1,000 people through a travelling information point and a weekly guided tour.

Expected results

Marine concrete conservation actions

C1: Twenty mooring buoys will be placed to decrease the anchoring of medium size boats in areas previously identified by the preparatory action A1.

C2: In the Campulongu area, plantations on geomats will be made; at Punta Molentis removal operations will be carried out. In both areas these will be performed by qualified personnel (scientific divers).

From these actions, we expect to achieve the main aim of the restoration of *P. oceanica* bed in the Campulongu area and indications of the effectiveness of the measures adopted for the reduction of the diffusion and presence of *C. cylindracea*.

Terrestrial concrete conservation actions

Actions C4 and C5 have not yet started; all interventions aiming at the restoration of the dune vegetation habitats are determined and reported on a cartographic instrument (Fig. 7).

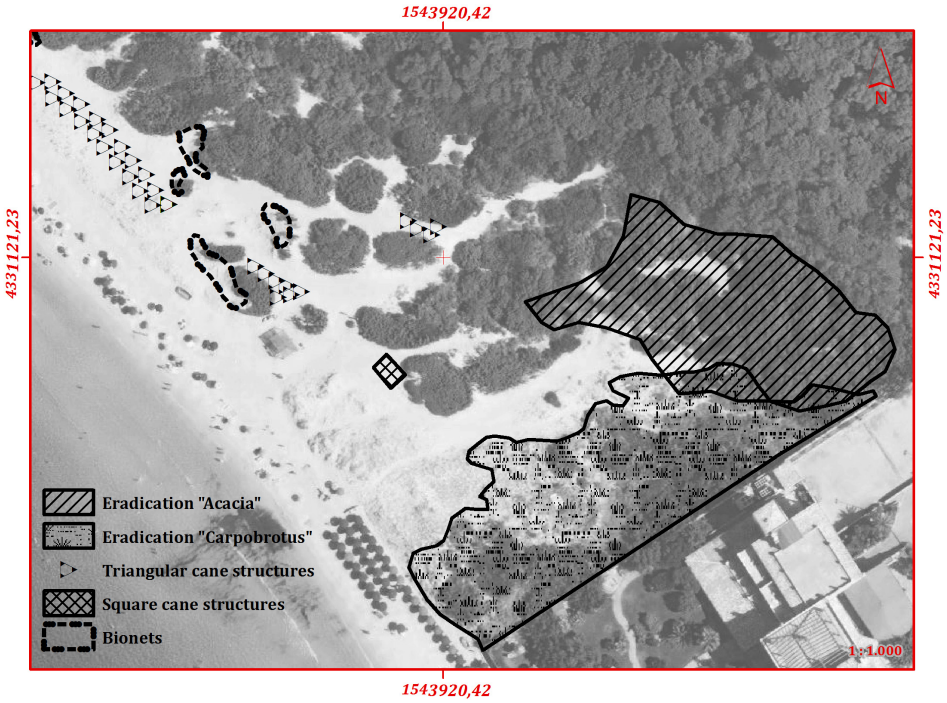

Fig. 7 - Planned interventions in the Campulongu site.

From the conservation actions C4 (eradication) and C5 (dune restoration), we expect to achieve the complete removal of the IAS and the dune vegetation reconstruction in the priority habitats located in public areas, while through the action E7 the same actions are applied to the private areas.

Communication actions

At this stage, it is still too early to objectively assess the results achieved, in terms of both numbers and results achieved. Only at the end of the project, but especially over time, it will be possible to appreciate the impact. The hope is that the local community, by increasing its awareness of the huge potential of its territory, may adopt a more sustainable and environmentally friendly approach. All this will certainly have a positive impact on the tourism sector and will generate economic growth, which will have a concrete effect on the local population.

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