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Effectiveness of the “Ecological Beach” Model: Beneficial Management of Posidonia Beach Casts and *Banquette*

Alice Rotini ¹, Stefania Chiesa ^{1,*}, Loredana Manfra ^{1,2}, Patrizia Borrello ¹, Raffaella Piermarini ¹, Cecilia Silvestri ¹, Sergio Cappucci ³, Luca Parlagreco ¹, Saverio Devoti ¹, Marco Pisapia ¹, Carla Creo ³, Tiziana Mezzetti ¹, Alfonso Scarpato ¹ and Luciana Migliore ⁴

¹ Italian Institute for Environmental Protection and Research (ISPRA), via Vitaliano Brancati 48, 00144 Rome, Italy; alice.rotini@isprambiente.it (A.R.); loredana.manfra@isprambiente.it (L.M.); patrizia.borrello@isprambiente.it (P.B.); raffaella.piermarini@isprambiente.it (R.P.); cecilia.silvestri@isprambiente.it (C.S.); luca.parlagreco@isprambiente.it (L.P.); saverio.devoti@isprambiente.it (S.D.); marco.pisapia@isprambiente.it (M.P.); tiziana.mezzetti@isprambiente.it (T.M.); alfonso.scarpato@isprambiente.it (A.S.)

² Department of Marine Biotechnology, Stazione Zoologica Anton Dohrn, Villa Comunale, 80121 Naples, Italy

³ National Agency for New Technologies Energy and Sustainable Development (ENEA), via Anguillarese 301, 00123 Rome, Italy; sergio.cappucci@enea.it (S.C.); carla.creo@enea.it (C.C.)

⁴ Department of Biology, Tor Vergata University, via della Ricerca Scientifica *snc*, 00133 Rome, Italy; luciana.migliore@uniroma2.it

* Correspondence: stefania.chiesa@isprambiente.it

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Abstract: The accumulation of *Posidonia oceanica* dead leaves on the beaches of the Mediterranean shores is a natural phenomenon. They are either temporary or permanent structures (*banquettes*) and represent a valuable resource, with important ecosystem functions including coastal protection against erosion. Nevertheless, the perception of these plant accumulations by the different stakeholders (beach managers, local administrations and tourists) is often negative; they consider these deposits a malevolent waste to be removed, rather than a natural and valuable component of the coastline. We propose an integrated/beneficial management model for *posidonia* deposits, called ECOLOGICAL BEACH, firstly proposed in France, and recently implemented and applied in Italy. The model promotes the preservation of *posidonia* beach casts on site, with a balanced coexistence of natural and anthropic elements. The model fosters the several important ecosystem services of the beach casts and contributes to coastal preservation. To successfully spread the model, several activities must be implemented: a regulatory framework, the collection of data about the occurrence of beach casts, management protocols and educational programs. The most important activity is the educational one, based on the dissemination of the ecological and economic value of the beach casts, aimed at switching the perception of this phenomenon towards positive appraisal.

Keywords: *Posidonia oceanica*; seagrass; Mediterranean Sea; coastal erosion; monitoring; governance; management; sustainable tourism; awareness-raising campaigns; environmental education

1. Introduction

Posidonia oceanica (Linnaeus) Delile is a seagrass (Magnoliophyta) endemic to the Mediterranean Sea. Within the Mediterranean, it constitutes extensive underwater meadows throughout virtually the whole of this sea, with the exception of the extreme south-east (from the Nile Delta to south-east

Turkey), the northern Adriatic Sea, most of the shores of Languedoc (France) and the vicinity of the Gibraltar Straits. It dwells from the sea surface down to a 20–40 m depth (more rarely, down to 45 m), depending not only upon water transparency but also upon water movement [1].

On the beaches, the presence of *Posidonia* meadows is marked by the presence of banks mainly made of dead leaves called *banquette*, which may also include broken rhizomes with leaf bundles. *Banquette* can reach thickness of up to 2.5 m, protecting the beaches from erosion by swell and waves, particularly during winter storms. Moreover, a rich macrofauna (gastropods, crustaceans, annelids and insects) inhabits the *banquette*, especially the “aged” ones, established for some years, and the residual nutrient content of *P. oceanica* dead matter represents an important input of nitrogen and carbon, contributing to the formation of the dune and its colonization by psammophilous vegetation. The positive relationship between *posidonia* beach casts and vegetation cover has been demonstrated, especially in nearshore plant communities [2].

Furthermore, as a physical structure, *banquette* provides refuge to detritivores and predatory species (such as sea birds), but also endemic plants in the post-germination vulnerable phase, from environmentally stressful conditions [1,2].

The presence of a thick *banquette* on the beach is a biological indication of a high-quality marine coastal environment, since it marks the presence of extensive healthy *P. oceanica* meadows [3]. Notwithstanding this, when the plant is outside the water and accumulates on the shore offering coastal protection, a trade-off occurs between regulatory and cultural services. The little knowledge about the *posidonia* beach-cast phenomenon and the lack of consolidated reference legislation for protection results in the consideration of these deposits as malevolent waste, rather than a natural and valuable component of the coastline [4,5]. Therefore, removal and disposal in landfills is a widespread approach, despite being ecologically incorrect and economically inconvenient, as it damages the integrity of the beach ecosystem and leads to a considerable increase in beach cleaning costs. The negative perception of seagrass accumulation has been reported in different areas of the Mediterranean [6,7]. Moreover, in a recent study carried out in the POSBEMED INTERREG-MED Project, the perceptions of different stakeholders (beach users, managers and local administrations) regarding the presence of *posidonia banquette* were investigated across five Mediterranean countries (Italy, France, Spain, Greece and Cyprus) [8]. Perception was negative for 41% of the people interviewed; moreover, the effects of the presence of *banquette* on tourism was negatively considered by local authorities (40%) and tourist operators (50%) [8]. Negative perception of seagrass casts has also been reported in the Indian Ocean [9] or the Baltic Sea [10–12].

The mechanical removal of the *banquette*, in Mallorca (Balearic Islands), showed a severe impact on the beach profiles, after a stormy episode, resulting in the erosion of both the “cleaned” beach and the foredune [13]. In Sardinia (Italy), it has been estimated that the removal of the *banquette*, which can retain an average of 93 kg/m³ of sediment, can lead to a loss of sediment between 0.5 and 1725 m³ [14]. Hence, the protective role of the *banquette* and the impact of its removal should be taken into consideration.

Moreover, coastal erosion also has high economic costs, related to beach nourishment activities. Botero and coauthors [15] estimated that beach nourishment costs vary from EUR 13 to 100/m³; thus, 1000 m³ of sediment lost due to *banquette* removal corresponds to economic damage ranging from EUR 20,000 to 100,000. In addition, the beach cleaning costs vary from EUR 15,000 to 130,000 per municipality per year, and the disposal of *posidonia* in landfills is a further cost, around EUR 60–80/m³ [8].

The ecological role and importance of *banquette* are extensively reported in the scientific literature, but the social perception and acceptance of this social–ecological system still need to be deepened. A gap in the social dimensions associated with seagrasses in the Mediterranean systems was recently highlighted in the latest Regional IPBES report [16], which focused on the biophysical aspect, without attention to the community knowledge or perceptions of this phenomenon. Plugging such a gap could be helpful for prioritizing management, policies or regulations aimed at the protection of these important ecosystems [12].

In claiming that Posidonia-compatible beaches are well managed and seaside tourism is eco-sustainable, the success of such a beach model requires a profound socio-cultural innovation, by changing the perception of the *banquette* from waste matter to a good water-quality indicator and strong sign of Mediterranean identity [17]. This change of mind requires awareness campaigns and educational activities to spread knowledge on the ecological role of posidonia and its *banquette* [6,18]. The perception of ecological beaches as socio-ecosystems, i.e., ecosystems including mankind, will allow positive economic fallouts in the beach management and tourism industry.

The so-called “ecological beaches” were firstly introduced in France, where any plant part of *P. oceanica* species has been protected since 1988. In French ecological beaches, the management of Posidonia *banquettes*, namely, no removal of the *banquette*, is combined with information provided to citizens by park rangers, the local press, leaflets and information boards on site [17,19–21].

Considering the positive externalities of this management strategy in France [21], this “Ecological Beach” model has been adopted and further developed in Italy within the project BARGAIN (POR-ERDF Lazio “Research Group Projects” L.R. 13/2008) in the Lazio Region, during the years 2018–2020 [5].

Therefore, starting from the success of the BARGAIN project, and taking into account the previous experiences at local or regional scale, the aim of this paper is to describe this innovative and integrated model for the management of posidonia *banquette*, highlighting its effectiveness and replicability at the Mediterranean basin scale. The Ecological Beach model herein described includes (i) the assessment of the legal, geographical and ecological framework; (ii) the selection of eco-sustainable management options; (iii) the main communication, awareness raising and education activities for local stakeholders.

2. Preliminary Assessment

2.1. Legislation Framework

The decision-making process for the management of seagrass must be distinguished between alive and dead seagrasses. Moreover, the management also depends on geographical and administrative scales.

Alive seagrasses. The preservation of the species may fall under National, Regional or European regulation. In Italy, for instance, *P. oceanica* falls under both local national/regional jurisdiction and European Directives (and their transposition at the national level). The Habitat Directive [22] aims to preserve biodiversity, through the conservation of natural habitats, flora and fauna. It establishes a series of conservation measures to protect specific habitats and species listed in the annexes: *P. oceanica* is listed as a priority habitat type, “Posidonia meadows” (code 1120). The Water Framework Directive [23], implemented in Italy by a Legislative Decree [24], aims to protect aquatic environments by making it compulsory to achieve a good environmental status for the coastal waters. In Italy, *P. oceanica* is listed as a bioindicator species and used to establish the ecological status of marine systems [25]. The Marine Strategy Framework Directive [26], implemented in Italy by a specific Legislative Decree [27], is an innovative tool for sea protection, being the first regulatory context with a systemic view of marine environments. The Directive requires Member States to maintain or achieve a good environmental status for marine waters, based on eleven descriptors. Among these descriptors, #1 is biodiversity, and includes the monitoring of *P. oceanica* habitats, by using different protocols according to the extension and condition of the meadows.

Dead seagrasses. At the international level, the London Dumping Protocol [28] listed a category in which the accumulation of beached Posidonia can be assimilated. The Protocol provides exceptions to the general prohibition of dumping at sea, which includes dredging sediments, residues from fishing activities, ships and offshore platforms, aggregates and geological material, organic materials of natural origin and raw materials, and bulk raw materials including iron and steel (Annex 1, Point 1, Paragraph 6). In this context, the posidonia residues could be similar to “organic materials of natural origin”, and the aforementioned Protocol applies to regulating the immersion in the sea of both waste and other substances (including posidonia residues), through specific authorization by the

competent authority following a scheme for assessing and identifying the potential impacts deriving from deliberate immersion in the sea, for the purpose of safeguarding the marine environment.

At the regional level, the Barcelona Convention [29] is a regulatory instrument within the framework of the Mediterranean Action Plan [30], for the countries bordering the Mediterranean Sea. The Convention is divided into seven protocols, one of which is the SPA/BIO Protocol (“Protocol on Protected Areas of Particular Interest and Biodiversity in the Mediterranean”, “Specially Protected Areas and Biodiversity Protocol”), ratified with a national law in 1999 [31]. *Posidonia* dead leaves and/or other macrophytes accumulated on any kind of substrate (biogenic and non-biogenic rock, coarse sediment, sand, etc.) are included among the priority habitats of the SPA/BIO protocol under mandatory preservation and protection.

In Italy, legislation on *posidonia* beach casts is still lacking. The issue has been traced back to waste regulation, since beach-cleaning operations are generally carried out with no separation of waste from seagrass casts. However, a dedicated national circular letter n. 8838/2019 by the Italian Ministry of the Environment [32] implemented the previous circular letter n. 8123/2006 by the Italian Ministry of the Environment, issued in 2006 [33], and now offers several options for the management of *posidonia* beach casts. Beached plant materials are now considered “waste if there is the need to dispose of it” or “resources if they are used to protect the beach and its ecosystems”. The Circular confirms that in situ preservation is the best option, particularly for beaches under regression. It underlines the important role of the beach casts in the conservation of coastal areas/ecosystems and emphasizes the need for “ecological beach” diffusion by highlighting that removal compromises the integrity of coastal habitats.

The Circular suggests that administrations favor the development of such a model of an “ecological beach” by carrying out awareness and communication activities for beach users on the importance/role of plant biomass for shores and beach-dune systems. The municipal administrations or the concessionaire/managers of the beach have the obligation to remove any anthropogenic waste present above and/or inside the accumulations (manually or through the use of light vehicles by sieving; the use of tracked vehicles is prohibited).

Seaweed and marine plants (*posidonia* beach casts) can be used as compostable waste, after separating any sediment, but cannot exceed 20% (in weight) of the initial mixture (Ministry of Agricultural, Food and Forestry Policies) [34,35].

Domestic regulations include Marine Protected Areas indications about *P. oceanica* beach-cast management. Moreover, specific national regulations exist in some Mediterranean countries. In France, the removal of *banquettes* is theoretically banned, as *P. oceanica* is a species strictly protected by a national law, since 1988 (*Arrêté du 19 juillet 1988 relatif à la liste des espèces végétales protégées*); the strict protection is extended to both dead and alive specimens; therefore, complete individuals or fragments of individuals cannot be collected, transported, purchased or sold [21]. Nevertheless, ref. [21] reported how local agencies of the French Ministry of the Environment (*DREAL: Direction Régionale de l’Environnement, de l’Aménagement et du Logement*) systematically release exemptions to local authorities (municipalities). In Spain, *P. oceanica* is included in a List of Wild Species under a Special Protection Regime [36], for which a series of generic prohibitions are established (live or dead specimen collection, damaging, transport, sale/exchange, import/export, etc.); in the case of activities controlled by local authorities (*Law on Natural Heritage and Biodiversity* [37]), any beach-cast removal must be carried out under administrative authorization [8].

2.2. Geographical and Ecological Framework

2.2.1. Identification of the Sites of Seagrass Heaps

Several approaches may help to identify the coastal stretch where seagrass heaps. The available bibliographic and cartographic sources or information collected by research projects may be a first source (see, for instance, [38]). Information questionnaires, addressed to coastal municipalities, can be another source [4]: the questionnaires must address specific questions such as the presence and

localization of beach casts and/or banquettes, amount of beached biomass, management methods and removal procedures, removed amounts, recovery of trapped sand and cost of removal activities [4]. In addition, in the last decade, methodologies were implemented to monitor the spatial and temporal evolution of seagrass beach casts, by using the same systems to evaluate beach morphology [39]. Therefore, according to the spatial resolution, it is possible to use direct (DGPS topographic survey) and/or indirect measurements, such as the sophisticated Terrestrial Laser Scanner techniques [40] or Unmanned Aerial Vehicle (UAV) instruments (e.g., drone photography [41,42]). Furthermore, remote-sensing techniques can be applied [43–45] to observe the phenomenon from an hourly (video monitoring) to weekly (satellite image) frequency. Finally, citizen science may help to localize and monitor the temporal evolution of seagrass beach casts by using apps for smartphones and social media [46].

2.2.2. Characterization of Seagrass Beach Cast

Field surveys aimed at collecting data on *Posidonia* beach casts are better carried out during Spring and Autumn, and should include the main characteristics of the heap, such as the foliar size and degradation rate, presence of rhizomes and other plant remains, and presence of waste. An example of the survey form developed during the BARGAIN project is provided as Supplementary Material (File S1). These data may help to classify the deposits into different typologies. During the BARGAIN project, the following classification was adopted [5] (Figure 1):

- **Well-structured deposits**, mainly composed of intact leaves and rhizomes, often characterized by leaf/sand stratification, with distinctive inclined lying and landward immersion; the stratification may reach up to meters, as in the areas not exposed to the strength of waves;
- **Unstructured deposits**, mainly composed of senescent/decayed leaves and rhizome residues (advanced maturation stage);
- **Unstructured mixed deposits**, composed of a minor fraction of senescent leaves and rhizome residues (highly fragmented) and a major presence of other plant material, including waste.



Figure 1. Seagrass beach cast classification adopted in BARGAIN project. (a) Type 1: well-structured deposits; (b) Type 2: unstructured deposits; (c) Type 3: unstructured mixed deposit.

Other important parameters for deposit classification are water and sand contents, which significantly affect the density and compactness of the beach cast. The accessibility of the site, recreational use and occurrence of litter should also be addressed.

3. Integrated Strategy for the Ecological Beach Model

The “Ecological Beach” model promotes the sustainable management of posidonia beach casts, which includes two management options: (i) undisturbed on-site preservation; (ii) temporal/partial displacements of the deposits (Figure 2). Correct management should include different and integrated solutions, in agreement with the local specificity and socio-economic context. Good practices should minimize the disposal of posidonia beach casts, to protect the posidonia beach-dune systems and their ecosystem services. Concurrently, the ecological beaches must be tourist compatible and attractive: the presence of posidonia deposits should be managed by flexible approaches, beach tourism promoted, and economic saving achieved. Two main activities are pivotal for the success of this model: (i) awareness-raising campaigns about the important role of posidonia beach casts and the significance of their presence on the beach; (ii) providing dedicated support to local administrations and beach managers, including training courses, guidelines and regulations, for their activities.

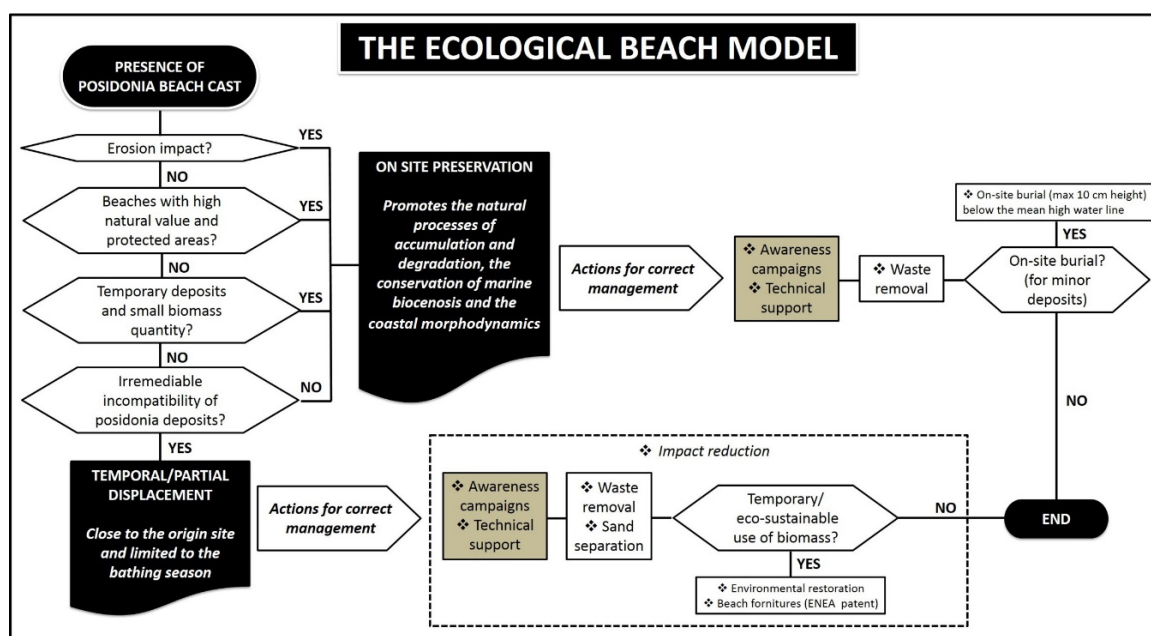


Figure 2. Flowchart of the sustainable management of posidonia beach-casts according to the Ecological Beach model (modified from [5]).

3.1. Management Options

3.1.1. On-Site Preservation

From an ecological point of view, the best management option is to maintain in place the posidonia beach casts and/or *banquette* in the coastal environment, particularly in the case of exposed beaches. In beaches with high heritage value and in protected areas, this management option must be the favorite. It is worth mentioning that there is no scientific evidence for critical issues regarding hygienic-sanitary aspects for humans due to the presence of posidonia deposits on beaches. This option requires adequate communication with beach users including, but not limited to, providing information boards (see Section 3.3). Within the preservation options, on-site burial represents a possible strategy for minor accumulations (max. 10 cm height). Burial in the sand should be in the same spot where the posidonia beach casts are found, and, in any case, it should not alter the morphological profile of the beach (accumulation areas, shoreline variations, etc.).

3.1.2. Displacement

Posidonia beach casts can be partially or temporarily moved off to one side of the beach, or onto neighboring beaches subjected to erosion. In this case, local regulations should be taken into account and the necessary authorization to move the beach casts acquired from local authorities, in the case of protected areas. The displacement of posidonia beach casts should be carried out after waste removal and limited to the bathing season. Therefore, at the end of the tourist season, vegetal biomasses can be brought back on the shoreline to restore their ecological functions and to protect beaches from erosion during the winter season. This temporal/partial displacement should be carried out in the coastal areas with no impact on natural vegetation. The displaced material should be delimited by appropriate containment structures, preferably made with natural materials (e.g., stakes fixed in the sand and connected by a close meshed net). Furthermore, to avoid putrefaction, the displaced material must be organized in well-ventilated heaps (with reduced dispersion of the fine fraction). The specific technical measures should be assessed case by case.

The displaced material may be used for dune restoration actions. In this eco-sustainable use of posidonia beach casts, biomass can sustain the core and the base of the dune and/or its crest, avoiding damage to dune vegetation. This option may help the protection and strengthening of the dunes by promoting the engraftment of pioneer species and the consequent development of dune vegetation, essential for dune stability and conservation. Moreover, posidonia beach casts can be used for the realization of multifunctional structures or outdoor beach furniture. This technology is patented by ENEA (patent no. 1424765, "Sidonia-by-ENEA" trademark [6]) and offers a co-beneficial approach that favors tourist fruition while improving consciousness on posidonia residues. Even in this case, the displaced biomass can be brought back to the beach at the end of the bathing season in order to counteract erosion during winter and avoid the exploitation of natural resources.

In addition, for minor accumulations, the return to the sea of posidonia beach casts can be considered when wind/tide conditions are favorable. After separating the sand and wastes, the re-introduction into the sea simulates the natural action of waves/tides promoting the natural cycle of plant biomass. However, this management solution currently requires more technical and legal insights due to the risks connected to the possible release of contaminants into the sea, such as, for example, plastics [47].

3.2. Waste Removal and Impact Reduction

The correct management of posidonia beach casts, in the case of either their on-site preservation (including burial) or displacement, requires the regular removal of human waste. Waste removal should be carried out manually, especially in small beaches. In cases of beach stretches longer than 100 m or for beach casts exceeding 5 m³ in volume, the authors suggest the use of small mechanical vehicles equipped with grids (weight < 2 tonnes [5]). The waste collected from the beach casts must be treated as ordinary solid urban waste and, where possible, sorted/separated into the different materials (metal, plastic, paper, etc.). Additional precautions are also necessary to reduce the impact of beach-cast handlings on the heap itself: they must be limited in time and restricted to specific sites; the temporary/partial removal must proceed step by step, by firstly removing the most superficial layers of the heap and leaving wet sand residues on site to dry off. Particular attention should be paid to the use of mechanical vehicles (small weight and size) to avoid their direct negative impacts (e.g., prolonged stays on the beach, oil leaks, etc.).

3.3. Building the Knowledge of Local Stakeholders

The new management approach requires a socio-cultural innovation aimed at changing the perception of *banquette* by beach users: from "annoying seaweed" to a natural resource and good environmental-quality indicator. A correct and effective awareness-raising campaign highlights the value of an eco-sustainable managed beach, including the economic benefits. This, in turn,

may trigger a virtuous circle, with an increasing number of sites adopting the ecological beach model. The dissemination of the ecological beach concept is crucial: curiosity and expectation must be created amongst local stakeholders, including heterogeneous categories (citizens, students, municipalities, beach operators, etc.). With this aim, a series of training activities should be developed and implemented, with specific contents and approaches, according to the different categories of stakeholders. These activities should be conceived to achieve three main results: (i) the reappraisal of natural beach dynamics, (ii) a change in the perception of the *banquette*/beach casts and (iii) support for the adoption of the new management practices. These achievements are possible in the so-called “community”, a “virtual place” where people sharing common interests may identify themselves, may follow the brand they are familiar with, may receive valuable content continuously, and may comment on existing information or propose new ideas and new approaches. Creating a brand community around the positive concept of the on-site preservation of the *banquette* is a key strategy for supporting the people who are part of it [48]. Moreover, the involvement of testimonials in the awareness-raising activities (from social networks to gadgets) can be very effective. In this case, the term “testimonial” is used to define a real or fantasy character, somehow invested with authority in the sector, attesting to the truthfulness of the message.

Environmental Education Programs

The awareness of students about the ecological role of both *P. oceanica* and its *banquette* in beach protection from erosion are the main objectives of educational activities [4,49]. School-age children are those who will influence future consumption and production models, and it is possible to establish a privileged relationship with them and their teachers [50]. If environmental education activities are integrated in the school education cycle, they may contribute to stimulating responsible behavior in the younger generations. Furthermore, the acquired knowledge of the natural environment may become part of the cultural heritage of the new generations and their communities [50].

The educational activities take place both in the classroom (Phase I, interactive lessons and games) and outdoors (Phase II, visit to the local beaches), to trigger an active learning process, both cognitive and emotional; these are highly significant aspects of education oriented towards sustainability issues, especially in young people [49,51]. Experiencing direct contact with biological material, such as the plant parts that can be found on the beach (leaves, roots, stem, egagropiles or pieces of them) allows them to observe, manipulate and smell, another essential part of the educational and personal experience. A useful approach to evaluating a possible change of mind on *posidonia* beach casts and *banquette* consists of showing, at the beginning and at the end of the educational activities, a picture with two beaches representing opposite situations. The first one represents a sand beach with bathing services and furnishings; the second one shows an undisturbed beach within a natural context, with the typical vegetation of the Mediterranean bush and accumulations of *posidonia* leaves. The preferred beach provides indications of students’ basic knowledge of the topic and can be a measure of the increased awareness gained after educational activities. Additionally, the activities may include educational games aimed at strengthening the learned concepts and achieving strictly defined scores, which can be another valuable form of feedback [52].

4. Discussion

The management of the *posidonia* beach cast and its *banquette* represents a complex issue requiring a multidisciplinary approach. It should involve all stakeholders and take into account ecological and economical aspects, beside the regulatory framework.

In the Mediterranean countries, a critical issue is the lack of specific legislation at the basin scale and the implementation of already-existing local regulations (see Section 2.1). Despite the general principles declared in the Barcelona Convention, common approaches for *posidonia* beach-cast and *banquette* conservation are still missing for the Mediterranean basin. Moreover, even if in some countries, regional or national legislation forbidding its removal already exist (for instance, in France

and Spain), they can be easily ignored due to specific authorizations released case by case by the competent authorities for “beach-cleaning operations” [21,53,54].

In other cases (including Italy), specific legislation is still missing, and only “recommendations” are available (e.g., the circular n. 8838/2019 by the Italian Ministry of the Environment) [32]. As a consequence of this general lack of regulation, local administrations across the whole Mediterranean Sea are often the only body responsible for the management of the seagrass beach casts. Each country or region adopts different management strategies at the local scale, depending on different socio-economic contexts, resulting in a weak protection of posidonia beach casts and *banquette* within the Mediterranean basin. A unique case among Mediterranean countries is represented by Italian beaches that are partially private and therefore directly managed by beach managers more interested in tourism exploitation than in environmental protection. This entails a “do-it-yourself” management of the beaches, left to the beach manager’s decisions: in the best case, they eliminate the posidonia beach casts from their own beach by moving them to the adjacent free beaches, to avoid the costs of other expensive options [5].

Alongside the legislative gaps, there is a serious lack of scientific knowledge on the posidonia beach-cast phenomenon. Moreover, the scarce popularization of live and dead *P. oceanica* and their ecological importance leads to a preference for “artificial” cleaned beaches instead of the natural Mediterranean ones.

The Ecological Beach model aims to face these challenges, by combining the urgency of coastal ecosystem conservation with the pivotal role of touristic activities in the Mediterranean socio-economic context. The model falls within the broader context of the necessary change in perspectives of the conservation of the natural environment and its resources, going further beyond the pioneering French model, based on posidonia deposit maintenance and occasionally providing information to citizens.

Therefore, the application and success of our Ecological Beach model at a larger scale requires some fundamental steps (see Figure 3): (i) improving the knowledge and awareness of the *P. oceanica* meadows and their *banquette*, (ii) encouraging perception changes regarding natural beach dynamics, (iii) supporting local administrations and relevant stakeholders in the application of this model, and (iv) disseminating and replicating the model among the Mediterranean countries.

The Ecological Beach model is aimed at setting some key elements in posidonia beach-cast and *banquette* management, which show both strengths and critical points, briefly discussed below.

First of all, the seagrass beach-casting phenomenon should be better investigated and characterized within the Mediterranean basin. The mapping of the deposits, such as in terms of their spatial and temporal dynamics, must be strongly improved, to better understand where, when and how they occur. Furthermore, the life-cycle of the *banquette*—a sequence of generation and disassembly phases [55–57]—must be taken into consideration, as it depends on the action of different factors such as (i) seasonality and weather/sea conditions; (ii) the distance, characteristics and conservation of the posidonia meadows; (iii) the geomorphological structure of the coast and seabed; and (iv) currents and coastal dynamics [4].

To obtain this information, local administrations may provide data by answering questionnaires and/or filling in survey forms (arranged for the BARGAIN project, as described in Section 2.2 and Supplementary File S1). In particular, the application of a common survey form may help with the collection of homogeneous data and the implementation of a national database. Additionally, the application of novel techniques to survey seagrass beach casts, including the DGPS topographic survey, a Terrestrial Laser Scanner, UAV instrumentation and remote-sensing techniques, can be also useful [39,45,58–60]. Nevertheless, these sophisticated methods have some limitations, related to both the technical knowledge required for their use (they must be conducted by expert researchers) and the high cost of the surveys, resulting in a limited resolution or geographic covering of the phenomenon. Therefore, a more comprehensive approach for beach-cast monitoring and characterization should include alternative methods, as such citizen science, less detailed in beach-cast characterization but more effective in monitoring their temporal dynamics and achieving a wide geographic coverage of data. For example, Coastsnap is a friendly tool for collecting beach images by using smartphones;

it requires limited economic investment to collect and merge data and, by involving all beach users, allows an almost continuous monitoring of coastal dynamics [46]. This approach could be useful both for collecting data about posidonia beach casts/*banquette*, and for creating and reinforcing a wide monitoring network by spreading photos at the Mediterranean basin scale. Furthermore, the citizen science approach will also help to involve the beach users and stakeholders in the direct monitoring of the phenomenon, improving their commitment to beach conservation [46]. Beyond citizen science, local communities can also provide valuable data by transferring their historical and cultural knowledge to the scientific/managing community. This expert knowledge, also known as Local Ecological Knowledge (LEK), may offer new opportunities to study and monitor the Mediterranean Sea (see [61] and references within). This approach has been successfully used to assess effective monitoring practices related to global change and its effect on fish communities; it could be implemented in the monitoring of other natural phenomena, such as seagrass beach-cast/*banquette* occurrence in space and time, and previous practices used by local communities.



Figure 3. The virtuous circle of the Ecological Beach model.

In the framework of the Ecological Beach model, the best practices for posidonia beach-cast management have been described in detail (see Section 3.1), as a support for the decision-making and implementation process. Moreover, the Ecological Beach model proposes different, flexible and/or integrated solutions in order to achieve the most correct form of management, according to the site peculiarity and socio-economic context. However, the Ecological Beach is also favorable for coastal environment preservation, recognizing the ecological role of the posidonia beach cast/*banquette* and promoting the conservation of the beach and biodiversity [12]. The Ecological Beach is also advantageous for citizens and tourists, who can enjoy increased natural value without giving up the facilities of beach resorts. Furthermore, the Ecological Beach is convenient for administrations and/or beach resort managers, the adoption of this model resulting in significant economic savings. In particular, the on-site maintenance of the posidonia beach casts reduces the costs of the beach-cleaning operations, disposal in landfills and beach nourishment activities often needed when the natural barriers (i.e., *banquette*) are lacking [8,15]. Finally, institutional recognition as “Ecological Beach” (flags,

awards, etc.) may represent added value for the specific beach stretches, increasing their economic value and rewarding those adopting virtuous management of the coastal areas.

The on-site preservation and temporary displacement of the posidonia beach casts are the best solutions, but not the only ones possible, within the Ecological Beach model. Plant residues along the coasts have historically been used for different purposes, such as construction materials, thermal and acoustic insulation, artifacts, materials for packaging or padding, etc.; Parente and Santamaria [62] reviewed the most recent uses of posidonia residues in different sectors, including phytocosmetics, green building and design. These reuses of the “posidonia resource” (in specific contexts and conditions) undoubtedly represent a much better alternative to landfill disposal. However, the disadvantage inherent in this type of industrial application is the exploitation of the natural resource and its permanent removal from the coastal marine environment. In the Ecological Beach model, plant biomass can be used for beach furniture or walkways, improving the accessibility and enjoyment of the beach with the double benefit of a temporary use, with no exploitation or removal of the posidonia resource from the coastal environment [6].

The effective applicability of the Ecological Beach model will depend on its acceptance. It is therefore clear that education and awareness-raising activities play a central role. The school educational programs will be pivotal to ensuring the success of posidonia beach-cast and *banquette* preservation. A multidisciplinary approach should be preferred to encourage the cultural, emotional and physical bonds of the students with their own territory. Moreover, the updating of teachers and wide and free-of-charge access to school education material should be pursued. Environmental education has been proven to successfully modify individual consciousness towards promoting more sustainable behaviors [63]. Particularly, if environmental education activities are integrated in the school education cycle, they may contribute to stimulating responsible behavior in the younger generations [64]. Furthermore, the acquired knowledge of the natural environment may become part of the cultural heritage of the new generations and their communities [50]. A critical point in each education program is whether environmental education can help to improve and sustain connectedness with nature, even after the end of the educational programs [65]. A post-education evaluation process will be both important to guarantee young life-lasting learning and crucial for the success of the Ecological Beach model. To this end, it will be essential to evaluate the change in perception of the posidonia beach casts/*banquette* from “waste” to a natural resource, as well as the improvement of knowledge on the topic, after the educational programs. In addition, the evaluation process may help to verify the effectiveness of the education programs, helping to identify weaknesses and, eventually, re-calibrating the activities according to needs and requirements. To our best knowledge, there are no standardized indicators available for long-term evaluations of the effectiveness of educational activities regarding posidonia beach casts and *banquette*. Educational games, playful activities and selections of images (see Section 3.3) are useful for monitoring the students’ immediate feedback in the classroom and/or on the beach. However, specific monitoring programs should be developed to assess the “impact” of educational activities in the long run. To this end, a possible approach may consider a selected sample (at least 20% of the students involved in the educational program) compared to a control group (students not involved in the programs) to be monitored for 3–5 years. The assessment should consider (i) knowledge acquisition, (ii) the assumption of responsibility and (iii) behavioral change, at least. The development of specific indicators must be carried out in collaboration with experts (pedagogists or psychologists), taking into account the several possible outcomes available in the literature [64].

Finally, the broad and effective dissemination of the Ecological Beach model and its replication among Mediterranean countries must be encouraged. Particular attention must be paid to developing personalized information campaigns for the heterogeneous categories involved (see Section 3.3). Special efforts in supporting local authorities and stakeholders should be made; the organization of annual community consultations and ability-building courses, from a local to a regional scale, would enable two-way communication between managers and stakeholders [12]. Moreover, the Ecological Beach model should be adopted permanently within the MPAs and National Parks, implementing their

management plans with specific guidelines and regulations. In fact, the involvement of MPAs, National Parks and institutional bodies will surely improve the success of awareness and educational activities. Possible information strategies/activities include the use of websites, social media, video spots, webinars, information boards on site, etc. Marketing approaches advertising natural beaches would promote the acceptance of posidonia beach casts as peculiar elements of Mediterranean beaches.

Within the BARGAIN project, various initiatives have been highly successful, despite the limitations due to the COVID-19 emergency. A non-exhaustive list is reported below:

- (a) The publication of the technical guidelines for the Ecological Beach model (https://www.isprambiente.gov.it/en/publications/handbooks-and-guidelines/the-ecological-beach-sustainable-management-of-the-posidonia-banquette-along-the-lazio-shorelines?set_language=en);
- (b) The realization of the first two ecological beaches in the Lazio Region (June 2020) with informative panels, demonstration spaces for on-site preservation, the possible reuse of posidonia residues and the distribution of dedicated gadgets (Figure 4);
- (c) Distance-learning activities with the schools involved in the project, through webinars and short video-lessons, now available online free of charge (<https://www.youtube.com/playlist?list=PLgiaZpXFwy3utkWifKTC6-S5A9CWL1n1W>);
- (d) The creation of a comic (see Supplementary Material, File S2) and a cartoon both in Italian and English;
- (e) The high diffusion of the key information of the project through mass media (radio and TV interviews) and participation in scientific divulgation events and scientific festivals of national and international relevance.



Figure 4. The realization of the Ecological Beach model within the BARGAIN project. (a) Demonstration space at Circeo National Park beach. (b) Gadgets and comics distributed to beach visitors.

5. Conclusions

The eco-sustainable management of posidonia beach casts and a *peaceful coexistence* between beach protection and touristic activities are possible, although they require a deep socio-cultural innovation. To this end, this work aims to be a call to both the scientific and the managing communities to reach, together, the final goal of the ecosystem-based management of beach systems across the Mediterranean. Indeed, the Ecological Beach model (and its further development) represents a methodological approach that should be implemented, replicated and adopted at the Mediterranean basin scale, benefiting from the experiences of the different countries and triggering a domino effect. The wide dissemination of the model will contribute to *P. oceanica* conservation (live and dead), further promoting the effective application and implementation of targeted protection measures.

Supplementary Materials: The following are available online at <http://www.mdpi.com/2073-4441/12/11/3238/s1>. File S1: Beach-cast survey form; File S2: BARGAIN comic.

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