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Conservation plan on 1120 Posidonion oceanicae and 1140 Mudflats and sandflats not covered by seawater at low tide

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Summary

1. Introduction

The Conservation plan on 1120 Posidonion oceanicae and 1140 Mudflats and sandflats not covered by seawater at low tide is a delivery defined in project ASPEH-Adriatic SPEcies and Habitats of coastal areas funded by the Interreg Italy-Croatia Programme. Programme priority is green and resilient shared environment and project specific objective is enhancing protection and preservation of nature, biodiversity and green infrastructure, including in urban areas, and reducing all forms of pollution. ASPEH aims to face the loss of biodiversity by defining common tools and strategy to preserve the natural heritage and the landscape in the Adriatic Area, with priority for common species and habitats protected by the 92/43/EEC and 79/409/EEC Directives. For each species and habitat identified, that are important for their ecological value, extinction concerns or endemic aspects in the Adriatic Sea, project partners will jointly develop a common conservation measures, a training activities, a concrete actions, an awareness campaign and a joint strategy.

Habitat 1120 Posidonion oceanicae and Habitat 1140 Mudflats and sandflats not covered by seawater at low tide are two priority conservation targets in the Adriatic region. These habitats are protected under the EU Natura 2000 network due to their high ecological value and vulnerability. Posidonia oceanica meadows (also known as Neptune grass) form extensive underwater seagrass beds endemic to the Mediterranean Sea, while habitat 1140 comprises intertidal sand and mud flats exposed during low tide. Both provide crucial ecosystem services – Posidonia meadows sustain marine biodiversity and carbon sequestration, and mudflats support coastal food webs and waterbirds – yet both face significant anthropogenic pressures. This conservation plan focuses on habitat 1120 and 1140, outlining their status, threats, and a strategy for their protection and sustainable management, in line with the ASPEH project's goals of preserving common Adriatic species and habitats.

2. Situation analyses of habitat types 1120 Posidonion oceanicae and 1140 Mudflats and sandflats not covered by seawater at low tide

The ASPEH project focuses on the protection and preservation of biodiversity in the Adriatic region, with particular emphasis on species and habitats of significance according to EU directives. Among the key habitats covered by the project are 1120 Posidonion oceanicae and 1140 Mudflats and sandflats not covered by seawater at low tide , both of which are

crucial for the marine ecosystem. The analysis of the status of these two habitat types within the ASPEH project provides the foundation for long-term conservation measures, ensuring their ecological sustainability and a balance between the preservation of natural resources and socio-economic interests in coastal areas.

1120 Posidonion oceanicae consists of of Posidonia beds, which plays a key role in providing habitat for many marine species and contributes to the stability of the coastal ecosystem by acting as a natural barrier against erosion. However, despite its importance, it faces serious threats. The main threats include the development of coastal infrastructure and urbanization, anchoring and increased tourism, which lead to physical damage to the Posidonia beds. Climate change also negatively impacts the growth and reproduction of Posidonia oceanica, while water quality degradation further endangers this habitat.

On the other hand, habitat 1140 Mudflats and sandflats not covered by seawater at lowtide is extremely important for many species, particularly migratory birds that use it as a feeding ground and nesting site. This habitat also faces significant challenges. The main causes of degradation include human activities such as intensive tourism and recreational activities, construction works, beach cleaning and maintenance, as well as illegal constructions and sand dumping. Additionally, natural processes such as erosion and changes in sediment transport, further exacerbated by climate change, pose a serious threat. Pollution from urban wastewater and agricultural runoff also contributes to the degradation of this ecosystem.

2.1 Characteristics of the Natura 2000 sites

Habitat 1120 Posidonion oceanicae – Posidonia meadows occur in clean, clear marine waters from the surface to ~40 m depth in the Mediterranean. They typically grow on coarse sand or rocky substrates in the infralittoral zone where sufficient light reaches the seabed. In Croatia and Italy, these meadows are widespread in coastal Natura 2000 sites. For example, around Korčula Island (southern Adriatic), Posidonia beds are common in the subtidal zones of several protected areas. Significant Posidonia sites include the coasts of Korčula island, Pelješac peninsula, Elafiti islands, as well as various marine protected areas in the Adriatic Sea. According to Croatia's Ecological Network data, Posidonia oceanica meadows are present in dozens of Natura 2000 sites (it is listed as a conservation target in 104 sites), reflecting their broad but patchy distribution along suitable coastlines.

Habitat 1140 Mudflats and sandflats not covered by seawater at low tide – Intertidal mud and sand flats are less extensive in the Adriatic (due to its relatively small tidal range) but occur in certain sheltered bays, estuarine areas, and lagoon environments. These flats are typically found as part of complex coastal systems, often adjacent to habitats like coastal lagoons (1150) or estuaries (1130), and at the landward fringe of subtidal sand habitats (1110). In the Adriatic Natura 2000 sites, habitat 1140 is recorded in shallow coves and tidal inlets. These sites represent the rare locations where the tide reliably exposes seabed areas at low water. Regionally, habitat 1140 has a substantial overall range (in Croatia it spans an area corresponding to ~91 10×10 km grid cells, ~9100 km², including the extensive mudflat systems of the northern Adriatic). Many of these flats are protected within Natura 2000 and important bird areas, underscoring their value at both national and EU levels.

Table 1. Protected areas of the ecological network Natura 2000 that will be addressed in this Conservation Plan.

Site type	Site code	Site name	Site size (ha)	Marine part of the site (%)	1120 habitat type size (ha)	1140 habitat type size (ha)
SCI	HR3000150	Pelješac - od uvale Rasoka do rta Osičac	1022.95	100.00 %	910.00	-
SCI	HR3000152	Otok Proizd i Privala na Korčuli	639.03	100.00 %	500.00	-
SCI	HR3000153	Otok Korčula - od uvale Poplat do Vrhovnjaka	1903.20	100.00 %	1300.00	-
SCI	HR3000154	Pupnatska Luka	14.09	100.00 %	-	0.10
SCI	HR3000155	Uvala Orlanduša	6.75	100.00 %	-	0.06
SCI	HR3000156	Pavja Luka	9.13	100.00 %	-	0.05
SCI	HR3000162	Rt Rukavac – Rt Marčuleti	175.48	100.00 %	50.00	0.09
SCI	HR3000163	Stonski kanal	569.18	100.00 %	340.00	-

SCI	HR3000431	Akvatorij J od uvale Pržina i S od uvale Bilin žal uz poluotok Ražnjić	120.80	100.00 %	50.00	0.60
SCI	HR3000476	Uvala Divna – Pelješac	20.09	100.00 %	12.00	0.10
SCI	HR4000007	Badija i otoci oko Korčule	894.20	100.00 %	520.00	-
SCI	HR4000028	Elafiti	6778.14	59.46%	600.00	0.30
SCI	HR5000031	Delta Neretve	23814.31	3.68%	-	40.00

Pelješac - od uvale Rasoka do rta Osičac includes marine area from cove Rasoka to cape Osičac on the west side of Pelješac peninsula. Biggest coastal settlement in the area is small town Loviste. The coast is mostly rocky and indented with numerous bays and coves. The target habitats within this scope are 1110 Sandbanks which are slightly covered by sea water all the time, 1120 Posidonia beds (Posidonion oceanicae) and 1160 Large shallow inlets and bays. This area includes 910 ha of Posidonia beds, which form dense underwater beds on sandy and sedimentary bottoms. According to the SDF conservation status of habitat type 1120 is rated as average.

Otok Proizd i Privala na Korčuli is a representative area for the target habitat type 1120 Posidonion oceanicae. Site is surrounding the island of Prozid and cape Privala on the west coast of the island of Korčula. The target habitat within this scope apart from 1120 Posidonion oceanicae is 1170 Reefs. Posidonia beds in this area cover 500 ha and develop on sedimentary substrates under conditions of high sea transparency. Their typical depth ranges from 5 to 30 meters, with occasional extensions into shallower areas. According to the SDF conservation status of habitat type1120 Posidonion oceanicae is rated as good.

Otok Korčula - od uvale Poplat do Vrhovnjaka is spreading along the southwest coast of the island of Korčula and includes a number of smaller islands (Trstenik, Mali Pržnjak, Veli Pržnjak, Lukovac, Zvirinovik, Obljak, Stupa, Crklica, Sridnjak, Vrhovnjak). The coast is mostly rocky, sometimes steep with cliffs, and indented with numerous bays and coves. The site is a representative area for the target habitat type 1120 Posidonion oceanicae. The target habitats within this scope apart from 1120 Posidonion oceanicae are 1170 Reefs and 8330

Submerged or partially submerged sea caves. This is an area where the target habitat type 1120 Posidonion oceanicae take up 1,300 ha. Posidonia beds are located on the western coast of Korčula and spread over relatively steep slopes, with depths reaching up to 35 meters and according to the SDF conservation status of habitat type1120 is rated as good.

Pupnatska Luka encompasses bay Pupnatska luka on the south side of the island of Korčula near settlement Pupnat. It is an area of exceptional natural and landscape values with gravel beach at the bottom of the bay and a valuable geomorphological site with vertical cliffs towering above the bay. This site is a representative area for the target habitat type 1140 Mudflats and sandflats not covered by seawater at low tide. This habitat covers an area of 0.1 ha and occurs at the transition between marine and terrestrial ecosystems, covered with a thin layer of diatom algae and cyanobacteria. This habitat type appears in shallow parts of the bay, particularly during low tide. According to the SDF conservation status of habitat type 1140 is good. Habitat types that are also found in this area are 1110 Sandbanks which are slightly covered by sea water all the time and 1160 Large shallow inlets and bays.

Uvala Orlanduša encompasses bays Orlanduša and Bratinja luka with gravel beaches on the south side of the Island of Korčula. This site is a representative area for the target habitat type 1140 Mudflats and sandflats not covered by seawater at low tide. The area of this habitat is 0.06 ha and occurs in narrow strips at the transitional zones between the shore and the sea and the conservation status is rated as good according to the SDF. The substrate is muddy and rich in microorganisms. It is occasionally exposed to the air during low tide. The target habitat within this scope apart from habitat type 1140 is 1110 Sandbanks which are slightly covered by sea water all the time.

Pavja Luka is located in a small secluded bay of Pavja Luka on the southeast shore of the Island of Korčula about 15 km from Korčula Town and in more or less near vicinity of village of Zrnovo. Bay has rocky shores and a gravel beach at the bottom of the bay. This is a representative area for the target habitat type 1140 Mudflats and sandflats not covered by seawater at low tide. This habitat covers 0.05 ha and develops at the boundary between land and sea. The surfaces are covered with microalgae that participate in nutrient cycles. According to the SDF conservation status of this habitat type is rated as good. Another habitat type that is found in this area is 1110 Sandbanks which are slightly covered by sea water all the time.

Rt Rukavac – Rt Marčuleti includes marine area on sutheast of the Pelješac peninsula from cape Rukavac to cape Marčuleti which includes four bays: Smokvina, Prijezba, Marčuleti and Pržine. Coast is mostly rocky except for Pržina bay which has sand beach. Both 1120 Posidonion oceanicae and 1140 Mudflats and sandflats not covered by seawater at low tide are present in this site. Posidonia beds cover an area of 50 ha, primarily on sedimentary substrates. The depths range from 5 to 30 meters, and the density of the Posidonia beds varies depending on depth and light availability. The target habitat type 1140 Mudflats and sandflats not covered by seawater at low tide in this area take up a small area of 0.09 ha. In 2019, Sunce carried out research on this ecological network. Significant mechanical damage to the seabed, specifically to the Posidonia meadow habitat, has been recorded in Marčuleti and Pržina coves, in the form of large furrows and uprooted Posidonia rhizomes and roots. Estimates based on visual observations during the study suggested that the furrows were caused by anchoring and dragging of anchors and anchor chains, a conclusion supported by the presence of two larger excursion boats anchored at the surveyed location during the research. During the same research by the Sunce Association, the invasive species *Caulerpa cylindracea* was observed on 78% of the surveyed transects, at depths ranging from 9 to approximately 30 meters, across all present habitats. Additionally, a significant amount of large debris was recorded in Smokvina Cove, consisting mostly of glass and plastic bottles and other plastic items. According to the SDF conservation status of habitat types 1120 and 1140 are both rated as good.

Stonski kanal includes a long narrow bay that is cut deep into the land at the beginning of the Peljašac peninsula. The entering part of the channel is wide 1500-800 m and very deep (53-20 m). The inner part of the channel, further in from settlement Broce, abruptly narrows to only about 150 m and the depth also decreaseas rapidly (5-2 m). From Broce to Ston leads a narrow waterway, up to 50 m wide. Bottom is muddy. Quality and the size of meadows is reducing from the channel entrance towards inner part. It is unclear if it is due to naturally occurring increased sedimentation or due to influx of wastewater from the Ston area. The invasive algae *Caulerpa cylindracea* is present in the whole area of Stonski kanal. This is an area where the target habitat type 1120 Posidonion oceanicae take up 340 ha of the area and according to the SDF conservation status is good. The target habitat within this scope apart from habitat type 1120 is 1160 Large shallow inlets and bays.

Akvatorij J od uvale Pržina i S od uvale Bilin žal uz poluotok Ražnjić is marine area situated on the east side of the Island of Korčula encompassing coves Bili žal and Pržina and surrounding cape Ražnjić. Both 1120 Posidonion oceanicae and 1140 Mudflats and sandflats

not covered by seawater at lowtide. In this area, Posidonia beds take up 50 ha. The target habitat type 1140 Mudflats and sandflats not covered by seawater at lowtide in this part take up an area of 0.6 ha of the area and is found in shallow zones during low tide. The surfaces are rich in microorganisms and algae. Regarding the habitat quality, a collaborative effort in 2020 by project partners Public institution Dubrovnik-Neretva County and the Sunce Association involved field research on Posidonia beds and the meadow within this site remains in excellent condition. This survey revealed minimal pressures, with only a few traces of anchoring. The habitat type 1140 Mudflats and sandflats not covered by seawater at low tide unfortunately faces significant threats at the Pržina location due to several factors: wind-driven sand erosion, particularly during storms, intensive and disruptive beach cleaning practices, and the subsequent intensified wave action. Local reports indicate that attempts to restore the beach involve inappropriate refilling techniques, such as using excavators to dump. According to the SDF conservation status of habitat type 1120 is rated as good and 1140 is average.

Uvala Divna – Pelješac site encompasses bay Divna with gravel beach about 250 m in length without vegetation and small island Divna west of the settlement Trpanj on the north side of Pelješac peninsula. There is a camping accommodation near the beach and paved road leading to it. The target habitats within this scope are 1120 Posidonion oceanicae, 1140 Mudflats and sandflats not covered by seawater at lowtide and 1110 Sandbanks which are slightly covered by sea water all the time. Habitat 1120 Posidonion oceanicae take up 12 ha. Posidonia grows here on sedimentary seabeds of shallow waters and extends into the deeper parts of the bay. Habitat 1140 Mudflats and sandflats not covered by seawater at lowtide take up 0.1 ha of the area and is found along the coastal boundaries. According to the SDF conservation status of habitat types 1120 and 1140 are both rated as good.

Badija i otoci oko Korčule is group of smaller islands located in south Adriatic near the island of Korčula in the eastern part of the Pelješac channel. Largest in the group is the island Badija that is protected as a significant landscape due to its exceptional landscape value and high plant biodiversity. This site represent a significant area for the target habitat type 1120 Posidonia beds. In this area Posidonia beds take up 520 ha that extend across the shallow marine areas of the islands. Survey in 2020 by project partners Public institution Dubrovnik-Neretva County and the Sunce Association revealed numerous trenches, gouges, and disturbed meadows due to frequent anchoring, with the most severe damage occurring at depths exceeding 12 meters, often around 15 meters. Deep anchor marks, indicative of larger vessels, were prevalent across most locations. The Ježevica channel area showcased

near-complete destruction of the meadow's lower edge, typically found between 10 and 15 meters deep, due to anchoring. This implies a concerning state for the meadows in this zone. Additionally, the invasive *Caulerpa cylindracea* algae pose a significant threat, colonizing areas where the Posidonia meadows have died back. Frequent anchoring practices that disturb the seabed and fragment the algae significantly facilitate its spread. According to the SDF conservation status of 1120 is average. Another habitat type that is present in this area is 8330 Submerged or partially submerged sea caves.

Elafiti site includes group of islands (Olipa, Tajan, Jakljan, Crkvina, Mišnjak, Kosmeč, Šipan, Lopud, Koločep) in the South Adriatic between Pelješac Pennisula, island of Mljet and city of Dubrovnik. The sea is characterized by rocky habitats, richness of marine caves and diversity of benthic organisms. South sides of the Islands usually goes steep into the sea until they reach sandflats and mudflats plate. In supralittoral zone of sand lagoons endemic relict species of Copepoda, Ispoda and Amphipoda (Crustacea) are present. In lower mediolittoral reefs support benthic communities of red algae (genus Lithophyllum, Lithothamnium). Communities of vertical rock walls with numerous fissures, caves and half caves are well-developed with characteristic Gorgonians communities (Eunicella cavolinii, Paramuriacea spp.). Target habitats within this area are 1120 Posidonia beds (Posidonion oceanicae), 1140 Mudflats and sandflats not covered by seawater at low tide, 1110 Sandbanks which are slightly covered by sea water all the time, 1170 Reefs, 1240 Vegetated sea cliffs of the Mediterranean coasts with endemic Limonium spp., 2110 Embryonic shifting dunes, 5330 Thermo-Mediterranean and pre-desert scrub, 6220 Pseudo-steppe with grasses and annuals of the Thero-Brachypodietea, 8210 Calcareous rocky slopes with chasmophytic vegetation, 8310 Caves not open to the public, 8330 Submerged or partially submerged sea caves and 9340 Quercus ilex and Quercus rotundifolia forests. According to the SDF form, Posidonia beds take up 600 ha and Mudflats and sandflats not covered by seawater at low tide take up 0.30 ha of the area and conservation status of habitat type 1120 is rated as good and 1140 is average.

Delta Neretve is a representative area for the target habitat type 1140 Mudflats and sandflats not covered by seawater at lowtide. These areas are covered with cyanobacteria and diatom algae and are particularly important as feeding grounds for a large number of rare and endangered bird species, which find food there during low tide. According to the SDF this habitat covers an area of 40 ha, and the conservation status of habitat type 1140 is

average. The Neretva River and its tributaries comprise the largest complex of wetland habitats in the Croatian coastal zone, with well-developed coastal and other wetland vegetation (floating and submerged). The Neretva Delta has many lagoons, shallow sandy bays, low sandy shores, sand flats, salt beaches, etc. Though a large area of the wetland habitat has been transformed into agricultural lands, due to the branching network of channels, these areas are still important habitats for aquatic birds and a very important ichthyological area. The delta, lagoons and brackish waters are an exceptionally important habitat which creates room for the intensive growth of fry, which later spend their life cycle in the sea or fresh water. Furthermore, these areas are important for the migration of anodromous and catadromous fish species. With a large number of endemic species and great diversity, the mouth of the Neretva River is one of the most interesting areas of Croatia. There are three ornithological Special reserves in the area (Orepak, Pod gredom and Prud), ichthyological and ornithological Special reserve (Neretva Delta) and two Significant landscapes (Modro oko and Lake Desne, Predolac – Šibenica). Neretva River Delta is designated as internationally important wetland under the Convention on Wetlands (Ramsar, 1971).

2.2 Regulatory framework (International conventions, european directives, national legislation, local regulations and any management plans)

Both habitat 1120 and 1140 are subject to international, European, and national conservation frameworks. Habitat 1120 enjoys a strong legal protection status (international convention recognition, EU priority habitat, and national strict protection), and habitat 1140 is safeguarded as part of the Natura 2000 network with requirements for conservation measures and integration with bird habitat protection. Together, these frameworks provide a solid regulatory basis for conservation – the challenge is effective implementation and enforcement on site.

- **International Conventions:** Posidonia oceanica meadows are explicitly protected under the **Barcelona Convention** (SPA/BD Protocol for specially protected areas in the Mediterranean) which recognizes Posidonia as a vital habitat to be conserved. Mudflat habitats (1140) do not have a habitat-specific Mediterranean convention, but their role in supporting migratory waterbirds ties them to the **Ramsar Convention** (Wetlands of International Importance) and the goals of the **AEWA** (African-Eurasian Waterbird Agreement) in relevant areas. Both habitats contribute to obligations under

the **Convention on Biological Diversity (CBD)**, and their conservation aligns with the 2030 target to protect 30% of EU seas.

- **EU Directives: Habitat type 1120** (Posidonia beds, *Posidonion oceanicae*) is listed as a *priority habitat* in **Annex I of the EU Habitats Directive (92/43/EEC)**, requiring strict protection and proactive conservation measures. Habitat 1140 (mudflats and sandflats) is also included in Annex I of the Habitats Directive (though not marked as priority), mandating its maintenance or restoration to favorable conservation status. Additionally, because 1140 mudflats serve as feeding grounds for shorebirds, their protection is reinforced by the **EU Birds Directive (2009/147/EC)**, which requires Member States to safeguard important habitats for wild birds. Many 1140 areas are designated as Special Protection Areas (SPAs) under the Birds Directive due to the bird species they support.

- **National Legislation and Designations:** In Croatia, both habitats are part of the **National Ecological Network/Natura 2000** (established by the Regulation on the Ecological Network, NN 124/2013). Posidonia meadows are identified as targets in numerous protected sites (listed in the Ecological Network regulation) and benefit from additional species-level protection: *Posidonia oceanica* is a strictly protected species under Croatian law (Regulation on Strictly Protected Species, NN 144/2013). National fisheries legislation also supports Posidonia conservation – the **Law on Marine Fisheries (NN 81/2013)** prohibits the use of bottom trawl nets in areas where seagrass beds (especially Posidonia) are, effectively reducing direct physical damage. For habitat 1140, national protection is implemented through site designation (it is protected wherever it occurs inside Natura 2000 sites). While there may not be a species-specific law, any development or activity affecting these intertidal flats must undergo appropriate assessment under nature protection law. Coastal zone management regulations also indirectly protect 1140 – for example, laws may restrict alteration of natural coastlines and require environmental impact assessment for projects (like coastal construction or beach nourishment) that could degrade intertidal habitats.

- **Local/Regional Regulations and Plans:** Site-specific management plans (e.g. for nature parks, marine protected areas, or county-level protected areas) often include measures for these habitats. In the Dubrovnik-Neretva County, for instance, the county public institution's management plan for Korčula's coastal Natura sites

identifies Posidonia beds and intertidal flats as conservation targets and sets rules (e.g. anchoring restrictions, sustainable tourism guidelines) for their protection. Local maritime authorities may regulate anchoring and mooring through permits or designated anchorages to prevent damage to seagrass, and beach management guidelines may be issued to municipalities to ensure mudflat areas are not excessively "cleaned" or disturbed. These regional instruments operationalize the higher-level legal protections on the ground.

2.3 Context Analysis (territorial and phytoclimatic framework)

Posidonia oceanica meadows (1120) thrive in specific environmental conditions. They require clear, well-oxygenated marine waters with plenty of light, which is why they are typically found in oligotrophic (low nutrient), transparent seas like the Adriatic and Ionian. Posidonia is tolerant of a range of temperatures and water movement (currents and waves), but it is sensitive to salinity changes and heavy turbidity. This seagrass is an endemic Mediterranean species, adapted to the climate and sea conditions of the region – mild winters, warm summers, and micro-tidal regimes. The narrow tidal range in the Adriatic means Posidonia meadows remain submerged year-round (they do not get exposed), yet seasonal dynamics (e.g. occasional winter storms) and phytoclimatic factors like light availability limit their depth distribution. In the project area, Posidonia meadows often fringe islands and sheltered bays with sandy or rocky bottoms. Geological and oceanographic context is important: they tend to colonize gentle slopes of carbonate coastlines where sediment is stable. On Korčula island, Pelješac peninsula and Elafiti islands, for instance, extensive meadows are found in bays with broad sandy beds and clear water. Being a climax community, Posidonia forms persistent habitats given stable conditions; it grows slowly (rhizomes extending centimeters per year) and can live for centuries, building up "matte" (thick peat-like root/rhizome layers) over time. The presence of Posidonia is often a sign of high-quality, uncontaminated waters, making it a reliable bioindicator of environmental conditions.

Mudflats and sandflats (1140) in the Adriatic exist in a more transitional environmental context – at the interface of land and sea. These flats are shaped by tides and coastal geomorphology. Even though tides in the Adriatic are of low amplitude (typically <1 meter), certain shallow areas experience enough tidal ebb to expose the seafloor regularly. The development of mudflats requires relatively enclosed or gently sloping coastal areas where fine sediments (sands, silts, clays) can accumulate. Such conditions occur in lagoon systems

(e.g. the Venetian Lagoon in Italy), river deltas (e.g. the Neretva Delta has some intertidal zones), and sheltered coves. The substrate varies from clean sand to muddy sand to pure mud depending on local wave exposure and sediment supply. In general, the Mediterranean micro-tidal flats are smaller and patchier than the vast mudflats of oceanic coasts, but they function similarly. These habitats mark the boundary between marine and terrestrial environments and thus experience extreme variability – they are submerged at high tide and exposed at low tide, causing fluctuations in temperature, moisture, and salinity on a daily basis. Sun exposure when the tide is out can heat and desiccate the surface, while the returning seawater brings relief and feeding opportunities for marine life. The phytoclimatic setting (Mediterranean climate with dry summers and wet winters) means that organic input (like decaying seagrass or algae) often accumulates on mudflats, especially after winter storms, providing nutrients for benthic microbes. Territorial context is also key: many 1140 areas are adjacent to human-used zones like beaches and harbors, meaning they are influenced by coastal land use (e.g. tourism, fishing). For instance, the mudflat at Pržina (Korčula) lies next to a popular sandy beach, linking its fate to beach management practices. So, habitat 1140's extent and condition are governed by coastal geomorphology, sediment dynamics, and tidal influence, and it often exists in a mosaic with other coastal habitats.

2.4 Biology and status of the species or habitat (Type, description, current distribution, conservation status)

Habitat 1120 – Posidonia oceanica meadows: Posidonia meadows are among the most productive and important marine ecosystems in the Mediterranean Sea. Ecologically, they are often referred to as the "lungs" or "engine" of the sea due to their high primary production and oxygen output. These underwater prairies consist of the flowering marine plant *Posidonia oceanica*, which forms dense stands of ribbon-like leaves (up to 1.5 m long) anchored by extensive root-rhizome networks. A healthy Posidonia bed creates a: numerous species of algae, invertebrates, fish, and even seabirds (when dead leaves wash ashore) depend on it. Many organisms use Posidonia meadows as nurseries, feeding grounds, or shelter – including economically important fish and shellfish that find food and refuge among the seagrass blades. Because of their structural complexity and longevity, Posidonia meadows are considered one of the most representative and valuable habitats in the Mediterranean. They stabilize sediments with their roots and rhizomes, helping to secure the seabed and reduce coastal erosion by buffering wave action. They also sequester carbon effectively in the sediment (blue carbon ecosystem), contributing to climate change

mitigation. The "matte" (accreted root/peat mass) under ancient meadows can be meters thick, indicating how these habitats persist over millennia if undisturbed.
Conservation status: Posidonia meadows are globally in decline, which is why the EU considers them a priority habitat. However, at the site level, status can vary. In the Adriatic region, many Posidonia meadows are still in relatively good condition away from urban centers. Across the Adriatic, trends show decline in areas near coastal development or intensive boating, but stable or recovering populations in well-managed protected areas. Overall, Posidonia oceanica remains extant at most of its historical Adriatic range, but continuous monitoring is needed to ensure early detection of declines. It is noteworthy that Posidonia is slow to recover once damaged – without intervention, regrowth of a meadow (if completely destroyed) could take many decades. Hence, maintaining its current extent and health is critical.

Habitat 1140 – Mudflats and sandflats not covered by seawater at low tide: These intertidal flats are unique in their biota because they lack tall vegetation (no large plants can survive the daily exposure to air). Instead, their surfaces are often darkened by a film of microalgae and cyanobacteria – microscopic life that forms mats on the mud, which are primary producers in this habitat. Beneath the surface, the sediment is teeming with benthic invertebrates. Mud and sand flats support a rich community of worms (polychaetes like ragworms *Hediste diversicolor*), bivalve mollusks (e.g. clams *Cerastoderma glaucum*, *Abra alba*), small crustaceans (amphipods, isopods), and other meiofauna. These creatures are specially adapted to burrow in wet sand/mud and tolerate changing conditions. Ecologically, 1140 flats are famed for their importance to waterbirds: at low tide, shorebirds and waders flock to exposed flats to probe the mud for food. Species such as plovers, sandpipers, godwits, and herons feed on the abundant worms, shellfish, and crustaceans in the mud. Even waterfowl like ducks and geese graze on the biofilm or roost on mudflats. Thus, mudflats convert the productivity of benthic microbes and invertebrates into vital resources for higher trophic levels (birds and fish). At high tide, these flats get submerged and become shallow feeding or nursery areas for fish – many juvenile fish venture onto the flooded flats to hunt small prey or seek shelter until the tide recedes. In summary, though they might look like barren expanses of mud or sand to the casual observer, habitat 1140 flats are biodiversity-rich and dynamic, supporting a food web from microbes to birds. They also play a role in nutrient cycling and in dissipating wave energy (natural coastal flood protection).
Conservation status: Mudflats and sandflats in the Adriatic are generally less monitored than seagrass meadows, but some assessments exist. In sites Elafiti and Delta Neretve habitat 1140 is rated as average, in southern Korčula, the status of habitat 1140 has been mostly

rated as good in small bay sites where natural conditions persist. Pupnatska Luka, Orlanduša, and Pavja Luka flats are considered in good shape with no major alterations. However, in one noted case – Pržina/Bilin Žal site – the mudflat habitat is deteriorating. The conservation status there was assessed as reduced due to active erosion and human impacts. Over the years, Pržina's intertidal area has shrunk and lost sediment. Wind and wave erosion during storms have been carrying sand away. Additionally, intensive beach maintenance (mechanical cleaning of the beach and removal of seaweed and debris) has disrupted sediment deposition and made the shore more prone to erosion. As a result, the exposed area at low tide has decreased and become patchier. To combat this, unsustainable measures were reportedly taken (periodic dumping of sand by machines to replenish the beach), which can further alter the flat's sediment structure and ecology. This example illustrates that anthropogenic pressures can quickly degrade intertidal flats, turning a once-stable habitat into one needing restoration. In the broader Adriatic, large-scale mudflat systems (like in the Po delta or Venice lagoon) have experienced losses due to land reclamation or erosion, whereas smaller flats in protected areas remain stable. Climate change (sea-level rise) is a looming concern that could submerge some mudflats permanently, but gradual adaptation (mudflats migrating landward) could occur if space allows. Overall, many 1140 sites are currently stable but vulnerable – continued disturbance could tip them into decline, whereas protection and natural sediment dynamics can maintain them.

2.5 Carried out or in progress conservation measures

Conservation efforts for these habitats are already underway in various forms. Some measures are broad policies, while others are site-specific actions or pilot projects. Below is an overview of key conservation measures carried out or in progress for habitat 1120 and 1140. While conservation actions for 1140 are somewhat less developed than for Posidonia (reflecting historically less attention), they are ramping up thanks to Natura 2000 requirements and cross-border projects. The measures in place – from adjusting beach management to regular monitoring – create a foundation to improve and maintain the status of these intertidal flats. The Public Institution has adopted management plans for select Natura 2000 areas in Dubrovnik-Neretva County, outlining measures for both habitat types. These plans were approved in late 2023, with activities being implemented according to the institution's available financial and human resources. A significant number of activities have been postponed, but planning for them has already commenced.

For Posidonia oceanica meadows (1120)

- **Protected Area Management:** Several Posidonia meadows fall within marine protected areas or Natura 2000 sites where management plans include active measures for their conservation. This includes surveillance against illegal activities (like illegal trawling or destructive fishing practices) and zoning that keeps intensive activities away from sensitive meadows. For instance, in Korčula's management plan, cooperation between the nature park authorities and the county maritime department was initiated to incorporate Posidonia protection into local maritime spatial plans. By establishing these collaborations, authorities aim to ensure that, for example, new marinas or coastal constructions avoid key seagrass areas or mitigate impacts via EIAs.

- **Water Quality Improvement:** Because Posidonia thrives in clear, low-nutrient water, ongoing efforts to reduce marine pollution and eutrophication indirectly benefit it. In accordance with EU water policies (Water Framework Directive and Marine Strategy Framework Directive), Public Institution advocates for coastal municipalities to upgrade sewage systems and manage runoff to maintain high water quality. Many stakeholders identified the lack of proper sewage and waste management as a pressing issue for coastal ecosystems; addressing this (through new wastewater treatment plants, etc.) is part of both environmental and public health projects and has positive effects on seagrass health (preventing algal overgrowth on the meadows).

- **Monitoring and Research:** A significant measure in progress is the establishment of systematic monitoring programs for Posidonia. Under a national project standard protocols for seagrass monitoring have been developed. In 2020, field surveys were conducted in Natura 2000 areas (e.g. Korčula sites) to collect baseline data on Posidonia cover, density, and condition. These surveys, often done by scientific divers using visual census techniques, are now being continued on a periodic basis. The data will allow conservationists to track trends in meadow extent and health. Additionally, international research collaborations (such as the **"Seagrass mapping" project mentioned in the technical study has aim to improve knowledge of Posidonia distribution using satellite imagery. Such research-backed monitoring is an ongoing effort that underpins adaptive management.

- **Habitat Restoration Trials:** Recognizing that some meadows have been damaged, small-scale Posidonia restoration experiments have been initiated in a few areas (mostly in the western Mediterranean, but with lessons applicable to the Adriatic). In the Adriatic context, there is interest in developing a "restoration model" for Posidonia. This may involve transplanting seagrass shoots from donor areas to degraded patches, or installing structures that encourage natural recolonization. Though still experimental, these actions are being considered and tested as part of EU projects.

- **Public Awareness and Engagement:** Various NGOs and park authorities have ongoing awareness campaigns about Posidonia. For instance, informational buoys and signage inform boaters about the presence of seagrass and urge them to avoid anchoring on it. Environmental groups like Sunce Association have actively campaigned and even directly collaborated by documenting damage and pushing for mooring solutions. Education programs for divers and local communities (showcasing the "underwater forests" and their importance) are continuous efforts to build public support for Posidonia protection.

For Mudflats and sandflats (1140):

- **Natural Beach Management:** A key conservation measure for intertidal flats is promoting eco-friendly beach maintenance. Traditionally, some beaches adjacent to mudflats have been subject to frequent mechanical cleaning (removing seaweed, debris, and even surface sediment to "clean" the beach for tourists). This practice can severely disturb habitat 1140. In response, Public Institution is working with local municipalities and tourist boards to change this approach. Guidelines have been introduced to limit intensive beach grooming especially in Natura 2000 sites. For example, instead of daily raking/removal of natural detritus, management plans suggest periodic manual cleaning focusing only on trash, leaving organic material that stabilizes the sand. The Korčula management plan specifically calls for a campaign with the tourist boards to highlight the ecological value of the wrack and plants on the shoreline and the dangers of removing them. This awareness campaign is an ongoing measure aimed at preserving the integrity of the tidal flats' sediment and nutrient cycles.

- **Erosion Control Measures:** Where erosion of mudflats has been identified (e.g. at Pržina beach), local stakeholders have started to consider soft engineering solutions. An ongoing action is to collaborate with relevant institutions (like water management agencies) to modify or remove structures that block natural sediment flow. In the Pržina case, there is mention of partially removing a seaside wall that was restricting sediment movement – doing so could allow sand and mud to redistribute naturally and the mudflat to regenerate. Additionally, dune restoration and planting of native vegetation behind the beach are encouraged to trap sand and reduce erosion of the flat. While these measures are still in planning or early implementation, they represent a proactive approach to protect habitat 1140 from physical loss.

- **Protected Area Inclusion and Zoning:** Many mudflat areas are now within protected sites (nature reserves, regional parks, etc.) where specific regulations apply. For example, if a mudflat is within a bird reserve, there may be rules to minimize disturbance (like prohibiting motorized vehicles or limiting access during bird breeding/feeding times). Ensuring that mudflat habitats are recognized in site management plans is an ongoing task. In practice, this means updating management plans to list habitat 1140 as a conservation feature, which then triggers the application of conservation measures (e.g. no construction of seawalls or drainage that could dry out the flat). The integration of mudflat protection into coastal zone plans (spatial plans) is also underway, preventing future encroachment or land reclamation.

- **Monitoring and Research:** Similar to Posidonia, a monitoring program for habitat 1140 is being established. The national monitoring guidelines (developed in 2021) include protocols for assessing the extent and condition of intertidal flats. Because these areas can be monitored remotely when exposed, aerial or drone surveys are an option being tested to map shoreline changes and surface area of mudflats over time. Baseline data (e.g. mapping the current outline of key mudflat areas and measuring sediment composition) is being collected. Annual or seasonal monitoring (during extreme low tides) is planned to detect if the habitat area is shrinking or if substrate characteristics change (e.g. excessive mud loss or gain). This scientific monitoring is an ongoing measure that will inform whether other actions (like erosion control) are effective. Additionally, bird counts are regularly done by ornithologists in mudflat areas (as part of wintering bird censuses), which indirectly monitor the ecological function of these flats as feeding sites.

- **Community Engagement:** Local communities are gradually being involved in caring for mudflat areas. For instance, citizen science initiatives encourage volunteers to report illegal dumping or changes they observe on local beaches. In some places, guided nature walks on mudflats (where safe) educate the public about the small creatures in the mud and the importance of tidal ecosystems. Such educational activities, though modest, are ongoing and help build a constituency for mudflat conservation.

2.6 Analysis of threats and limiting factors for restocking (for species) or conservation (for habitat). (*Transformation of habitat use, Abandonment of the habitat, Scarcity and irregular availability of resources, Evolution of plant communities and invasive alien species, Absence of ecological connections*)

Posidonia meadows are most threatened by direct human activities (anchors, trawls) and indirect impacts (pollution, IAS, climate). Their intrinsic slow recovery rate and requirement for clear, stable conditions make them very sensitive to these pressures. Habitat 1140 is primarily threatened by physical alterations – erosion (natural or human-accelerated) and habitat mismanagement (over-cleaning, construction) – as well as external environmental changes (pollution, hydrology shifts, climate change). Unlike Posidonia, which is a discreet organism one can directly damage, mudflats are more of a system that can degrade if its delicate balance of sediment and biota is upset. The challenge is to allow these flats to remain as natural as possible in the face of human use of coasts.
Both habitats also suffer from some cross-cutting limiting factors such as limited public awareness (which can impede support for needed regulations) and constraints in enforcement capacity. Additionally, in both cases, the lack of comprehensive data until recently meant threats could go unnoticed – a gap that ongoing monitoring is trying to fill. Identifying and addressing these threats is fundamental to the next steps in this conservation plan.

Threats to Posidonia oceanica meadows (1120):

- **Mechanical Damage from Anchoring and Fishing:** One of the most acute threats to Posidonia meadows is physical destruction by boat anchors and mooring chains. In popular bays, frequent unregulated anchoring by tourist boats rips out Posidonia rhizomes and creates scars or bare “sand holes” in the meadows. Over time, repeated

anchoring can fragment a continuous meadow into patches, reducing its ecological function. Likewise, illegal trawling or dragging of nets (despite being banned) can devastate seagrass – a single pass of a heavy trawl net can uproot plants and leave furrows. These activities directly remove biomass and also churn up sediment, making it harder for Posidonia to regrow. Physical damage is often cited as the primary cause of local Posidonia decline.

- **Coastal Development and Habitat Modification:** Construction of coastal infrastructure can eliminate Posidonia habitat or alter conditions. Dredging increases water turbidity and can bury nearby seagrass under sediment. Shoreline modification (like building seawalls or beach re-nourishment) can change sedimentation patterns and potentially smother meadows or alter currents that the plants depend on. In addition, land reclamation directly replaces seagrass meadows with land. For example, any plan to expand a harbour into shallow coastal areas often poses a threat to existing Posidonia beds unless mitigation (transplantation or avoidance) is done. Such habitat loss is irreversible on human timescales.

- **Pollution and Water Quality Degradation:** While Posidonia can tolerate moderate changes, chronic pollution is detrimental. Nutrient enrichment (eutrophication) from sewage or agricultural runoff can lead to algal blooms that reduce light penetration and cause epiphytic algae to overgrow seagrass leaves. Oil spills or chemical pollution can be directly toxic. Sediment runoff from construction or river inputs can create turbidity, limiting the depth range where Posidonia can survive (since it needs light). In many Mediterranean coastal areas, declining water transparency due to human activity has led to “deep edge” regression of Posidonia, meaning the lower depth limit of the meadow moves shallower.

- **Invasive Species:** The spread of invasive algae is a growing concern. In particular, the invasive green alga *Caulerpa cylindracea* (formerly *Caulerpa racemosa var. cylindracea*) has been observed encroaching on Posidonia meadows. In sites where Posidonia has been disturbed or partly killed (e.g. by anchoring), *Caulerpa* quickly colonizes the bare areas. This alga forms dense mats that can inhibit Posidonia re-establishment and alter habitat structure. Once *Caulerpa* is established, it can also spread vegetatively to adjacent healthy meadows, especially if fragments are broken off (anchors and chains can contribute to fragmenting and dispersing *Caulerpa*). Other invasive species like *Lophocladia lallemandii* (a red alga) and *Womersleyella* have similarly been noted as

threats in parts of the Mediterranean. Invasive algae create competition for space and light, potentially leading to further decline of native seagrass.

- **Climate Change (Warming and Storms):** Climate change poses a multifaceted threat. Rising sea temperatures can stress Posidonia, particularly if temperatures exceed tolerance thresholds in summer. It has been observed that sustained anomalously warm waters can cause Posidonia die-back or reduced growth. Climate change is also expected to increase the frequency of intense storms, which can physically damage shallow meadows and erode sediments. Additionally, as waters warm, pathogen activity may increase – for example, outbreaks of the pathogenic slime mold *Labyrinthula* (which causes seagrass wasting disease) could become more likely. Climate-driven shifts can also favour invasives and reduce the resilience of Posidonia. Measures to mitigate climate impacts (like monitoring for unusual necrosis or regression not linked to local pollution) have been identified as necessary.

- **Limited Regeneration and Connectivity:** Posidonia oceanica has slow growth and limited dispersal capability. It produces floating fruits ("sea olives") but successful seedling recruitment is rare; most spread is vegetative and slow. This means that if a meadow is fragmented, it may not naturally recolonize the gaps quickly, especially if distances are large. Additionally, if ecological corridors are broken (for instance, large stretches of coast lose their meadows), genetic flow and propagule exchange between meadows diminish. The absence of ecological connections was noted as a limiting factor – meadows need to be close enough to support each other's resilience (e.g. if one area is damaged, nearby areas can provide seeds or shoots). When Posidonia habitats become isolated, any local extinction risk is heightened.

Threats to Mudflats and sandflats (1140):

- **Coastal Erosion and Sediment Loss:** Mudflats are highly susceptible to changes in sediment balance. Increased erosion, due to natural forces or human interference, is a major threat. Storms and wave action can erode the fine sediments of a mudflat, especially if protective features (like coastal vegetation or dunes) have been removed. Climate change-induced sea-level rise and more frequent storms exacerbate this erosion. At sites like Pržina, strong winds during storm events were noted to blow away sand from the beach and flat, thinning the habitat. If sediment outflow (erosion) is not balanced by new sediment input, the mudflat will shrink or disappear over time.

Hard coastal defenses (sea walls, groynes) can further starve mudflats of sediment by interrupting alongshore transport, leading to a phenomenon known as "coastal squeeze" – the mudflat is trapped between rising seas and fixed shorelines, gradually being submerged and eroded.

- **Habitat Disturbance from Beach Maintenance:** Many intertidal flats in tourist areas suffer from intensive beach cleaning and maintenance. This often involves using machinery to remove accumulated seaweed (like Posidonia leaf litter) and to level the sand for aesthetics. Such practices can strip the upper layers of the mudflat of organic matter and the microalgal film, which are crucial for the invertebrate community. The Korčula plan specifically cites intensive and invasive cleaning of the beach as a threat at the Pržina mudflat. Mechanical raking or sand sifting can kill bivalves and worms in the top sediment. Over-cleaning also removes the natural wrack that would decay and enrich the mudflat, and it can compact the sediment making it less hospitable for burrowers. Essentially, treating a living mudflat like a groomed bathing beach undermines its ecological function.

- **Unsustainable Beach Nourishment and Construction:** In response to erosion or for resort development, beach nourishment (adding sand) and other construction can threaten mudflats. Dumping new sand onto a mudflat area (to widen a beach) can bury the existing benthic community and alter the grain size composition of the sediment (e.g. if the added material is coarser). At Pržina, inappropriate refulation (sand infill by bulldozers) was reported as a reaction to erosion. Such practices, done without ecological considerations, can effectively smother the mudflat or change it into a different type of habitat (perhaps a drier sand beach) that no longer functions as an intertidal flat. Likewise, construction of jetties, breakwaters or land reclamation in mudflat areas will directly remove habitat 1140 and potentially cause changes in water flow that affect adjacent flats.

- **Pollution and Water Flow Changes:** Mudflats in estuaries can be impacted by upstream activities. Pollution (such as heavy metals, chemicals, or oil) tends to accumulate in fine mud. This can harm the infauna and reduce the food available to birds (toxins can also bioaccumulate in the food web). While water quality in the Adriatic is generally good, localized pollution (harbour runoff, aquaculture waste, etc.) can degrade mudflat ecosystems. Additionally, changes in freshwater flow (for example, damming a river that feeds an estuarine flat) can alter salinity and sediment

supply, leading to changes in species composition or even conversion of a mudflat to dry land if less water reaches it. Changes in salinity regimes can shift the balance of species (e.g. certain polychaetes might be replaced by others) – while the mudflat might continue to function, its community structure can change.

- **Disturbance to Fauna (Birds and Benthos):** The ecological role of mudflats can be compromised by disturbance. Frequent disturbance by humans (e.g. people walking across mudflats at low tide, clam digging, or dogs running through) can scare away birds, reducing feeding time for migratory species that rely on these short low-tide windows. In popular coastal areas, high human presence means birds may not use the mudflat even if it's in good condition. Also, activities like recreational harvesting of shellfish or bait digging can deplete the invertebrate populations if not controlled. While these are more subtle threats, they can limit the habitat's ability to support wildlife (an element often captured under the function aspect of conservation status).

- **Climate Change – Sea Level Rise:** Over the longer term, sea level rise is expected to impact intertidal flats significantly. As ocean levels rise, today's mudflats could be increasingly submerged (spending less time exposed, which alters the community) or lost underwater entirely. If coastal development prevents the mudflat from naturally shifting landward, the habitat area will shrink. Moreover, warmer temperatures might affect the microalgae and infauna productivity, and changes in storm patterns could either erode or conversely deposit more material unpredictably. While these effects are gradual, they are a looming threat that necessitates adaptive planning (e.g. reserving space for the shoreline to move).

2.7 Identification of Decision Makers and Stakeholders directly involved in the management of the habitat and SWOT analysis

Effective conservation of habitats 1120 and 1140 requires the involvement of a range of stakeholders and decision-makers, each bringing different roles, interests, and capacities. The main actors identified include:

- **National Government Authorities:** Ministry of Environmental Protection and Green Transition is a key decision-maker, responsible for national policy, legislation, and reporting (e.g. Article 17 Habitats Directive reports). They set conservation objectives

and ensure laws (fisheries regulations, environmental impact assessments, etc.) are enforced in line with EU directives. Fisheries authorities (for enforcing trawl bans) and maritime authorities (for regulating anchorage and navigation) at the national level are also crucial.

- **Regional/Local Government and Management Bodies:** This includes County-level public institutions for protected area management and local government units (municipalities) that control local land-use and issue permits. They are directly involved in implementing conservation measures on the ground – from installing mooring buoys, to adjusting beach cleaning regimes, to patrolling protected sites. Regional and local administrative departments for maritime affairs, tourism, and spatial planning have influence: e.g. a county maritime department can designate official anchoring zones away from seagrass, and a municipality can pass ordinances about beach management. Coordination between these bodies is needed to integrate conservation into regional and consequently local development plans.

- **Protected Area Authorities:** Many habitat 1120 and 1140 occurrences lie within National Parks, Nature Parks, or Natura 2000 areas that have dedicated management (e.g. rangers, conservation staff). For instance, Posidonia meadows in certain marine protected areas (like Mljet National Park in Croatia, or Torre Guaceto in Italy) are managed by park authorities who can enforce no-anchoring zones, run outreach programs, and monitor ecological conditions. These authorities are stakeholders with on-ground responsibility and expertise.

- **Environmental NGOs and Research Institutions:** Organizations such as conservation NGOs (e.g. WWF Adria, local NGOs like project partner Sunce Association in Split or BIOM in Croatia) play a stakeholder role by advocating for habitat protection, conducting research, and engaging the public. They often participate in projects to restore or monitor these habitats and can influence decision-making by providing data and raising awareness. For example, project partner Sunce Association has been involved in Posidonia monitoring and in pushing for management changes in anchoring practices. Universities and marine research institutes (e.g. Institute of Oceanography and Fisheries in Split, or university departments) are important stakeholders for providing scientific backing, developing monitoring protocols, and advising on management (many are involved in the ongoing monitoring program design).

- **Local Communities and Resource Users:** This group includes local fishermen, boaters/yacht owners, tourist operators (such as dive centers or boat excursion companies), beach concessionaires, and residents. They are directly affected by – and can impact – conservation measures. Artisanal fishermen, for instance, benefit from healthy Posidonia (as it supports fish stocks) but may be concerned about restrictions on gear or zones. Tour boat operators and yachters need anchoring or mooring solutions that both protect seagrass and accommodate their activities. Beach concession operators may need to adjust how they maintain beaches in front of hotels. Engaging these stakeholders through participatory planning is essential to gain their support. Many local stakeholders have valuable knowledge (e.g. fishers know areas of seagrass, locals observe beach changes) and can act as stewards if properly informed.

- **Tourism Sector and General Public:** The broader tourism industry (tourist boards, eco-tour companies, marina operators) is a stakeholder given that pristine seas and beaches are a draw for tourists. They have an interest in sustaining the natural beauty (which includes thriving seagrass meadows for clear water and abundant marine life, and intact tidal flats for birdwatching or aesthetic sunsets). By aligning conservation with sustainable tourism, this sector can be a partner – for example, tourist boards helping with awareness campaigns about not anchoring on seagrass, or promoting snorkel trails in Posidonia meadows as an attraction (educating tourists in the process). The general public, especially youth and local beachgoers, are stakeholders whose behaviour (littering, respecting signs, etc.) can influence habitat health.

- **Others:** This can include Mariculture operators (fish or shellfish farms must avoid seagrass areas and manage waste to not impact them) and Infrastructure agencies (port authorities, hydrographic institutes) which have to consider these habitats in their projects. Also, funding bodies (EU Interreg programs, national environment funds) are stakeholders in that they support the implementation of conservation actions financially.

Stakeholder landscape is broad, and successful conservation will depend on strong collaboration. The decision-makers (government bodies at various levels) must work in concert with stakeholders (from NGOs to fishermen) to leverage strengths and opportunities (legal tools, funding, local knowledge) while mitigating weaknesses and threats (gaps in

enforcement, ongoing pressures). This plan's actions are designed with this multi-stakeholder approach in mind.

SWOT analysis helps summarize internal strengths/weaknesses and external opportunities/threats for conserving these habitats:

- **Strengths:** High ecological value and legal protection status of 1120 and 1140 (e.g. priority habitat designation is a strong tool); growing scientific knowledge and monitoring data; existence of active local conservation institutions and NGOs; and increasing public appreciation (clear water and biodiversity are recognized benefits).
- **Weaknesses:** Limited enforcement capacity (e.g. difficulty in policing hundreds of anchoring boats or every beach cleanup); fragmentation of authority (many different bodies must coordinate); sometimes insufficient baseline data in the past (now being improved); local economic reliance on activities that can harm habitats (tourism/fishing), making regulation sensitive; and historically low awareness (some stakeholders did not realize, for instance, that removing seagrass litter from beaches could be harmful). Additionally, funding and resources for long-term management can be a constraint (project-based actions need to be sustained beyond project life).
- **Opportunities:** Access to EU funds and international projects to implement conservation measures and capacity building; potential for ecotourism and sustainable blue economy initiatives centered on these habitats (e.g. snorkeling trails in seagrass, birdwatching tours on mudflats) which can provide economic incentives for conservation; new technologies (remote sensing, drones) to improve monitoring efficiency; and cross-border cooperation between Italy and Croatia offering knowledge exchange and a unified strategy for the Adriatic. Also, public interest in climate action can support habitat protection.
- **Threats:** As outlined above, ongoing external threats like climate change, increasing marine traffic, coastal development pressures, and invasive species. Also, unforeseen events (e.g. a large oil spill or ship grounding could devastate local seagrass/meadow areas). Potential lack of political will or competing priorities (development vs. conservation) can threaten implementation of plans – e.g. if economic pressure for a new marina overrides habitat concerns. Finally, insufficient stakeholder buy-in or conflicts (like fishermen vs conservation restrictions) can pose challenges if not addressed via engagement and compromise.

3. Management and conservation objectives for the targeted species and habitat types

The overarching management objective for habitats 1120 (Posidonia meadows) and 1140 (mudflats/sandflats) is to ensure their long-term conservation and favourable condition in the targeted Natura 2000 sites and the broader Adriatic context. This means preventing further loss or degradation, enhancing their ecological integrity, and securing the ecosystem services they provide.

3.1 Definition of general and specific objectives ensuring conservation of habitat in the short, medium and long periods.

General Goal: Achieve and maintain a favourable conservation status for Posidonia oceanica meadows (1120) and intertidal mudflats (1140) in the project area. Favourable status includes stable or increasing habitat area, intact structure and function, and a secure future outlook (i.e., threats controlled). This aligns with Habitats Directive requirements and contributes to international targets.

Specific Objectives:

- **Short-term (next 1-3 years):** Halt ongoing degradation and stabilize habitat conditions. This involves implementing urgent protections to stop the most immediate damages. For Posidonia, the short-term objective is to eliminate destructive anchoring practices in key meadow areas and enforce the regulate bottom trawling effectively, so no new anchor scars or trawl damage occur. Also, to prevent any net loss of seagrass coverage during this period. For mudflats, the short-term goal is to prevent further erosion and habitat disturbance – e.g. by ceasing harmful beach cleaning/nourishment at sites like Pržina so that the mudflat area does not shrink any further in the immediate future. Monitoring should detect a halt in negative trends (stabilization of habitat extent and quality indices). Additionally, initiate stakeholder engagement so that all relevant parties are aware of the new measures and supportive.
- **Medium-term (by ~5-7 years):** Improve habitat condition and resilience. Once acute losses are halted, the aim is to start seeing improvements. For Posidonia meadows, a medium-term objective is measurable recovery in previously impacted areas – for

example, an increase in Posidonia shoot density or cover in areas that were scarred by anchors, due to natural regrowth aided by the absence of disturbance or active restoration. If pilot restoration is undertaken, success would be new Posidonia patches establishing in degraded zones. Also, medium-term water quality targets could be set (e.g. maintaining water transparency at a level sufficient for Posidonia depth range to extend, indicating pollution control). For mudflats, the objective is restored natural dynamics – signs like sediment accumulation returning to normal patterns, benthic communities re-establishing in previously disturbed flats, and perhaps slight expansion of mudflat area if conditions allow. For example, at Pržina, success would be a reduction in erosional retreat (or even gain of intertidal area if sediment flow is restored) and an observed increase in invertebrate abundance as habitat stability improves. Medium-term should also see functional connectivity maintained or enhanced: e.g. ensure that multiple Posidonia sites remain continuous (no further fragmentation) and that mudflat habitats remain linked to their supporting environments (no blocking of tidal flow).

- **Long-term (10+ years):** Secure the habitats for future generations with adaptive management in place. Long-term objectives include expanding protection and ensuring resilience to climate change. For Posidonia, a long-term goal could be to increase the total area of meadows by a certain percentage (through either natural expansion or restoration success) and to maintain a broad depth range (healthy shallow and deep edges), indicating robust populations. Another long-term indicator would be the sustained absence or low level of invasive species in seagrass beds (meaning the ecosystem is healthy enough to resist invasives, or management keeps them in check). For mudflats, long-term success means mudflat ecosystems persisting despite sea-level rise, achieved by allowing them space to migrate or by bolstering their sediment supply. Ideally, no net loss of mudflat extent in the face of external changes, or losses in one area are offset by gains in another (managed realignment). Also, maintaining the ecological roles – e.g. in 10 years, the same (or higher) number of bird species and individuals continue to use the flats as they do now, showing that the habitat remains productive. Both habitats should be fully integrated into local management frameworks by then, with regular monitoring and community stewardship such that conservation is self-sustaining.

- **Educational/Community Objective (cross-cutting):** By the medium-to-long term, achieve a high level of local awareness and stakeholder participation in habitat conservation. Success here would be measured by the inclusion of habitat topics in school curricula, active volunteer programs (like citizen science monitoring of seagrass or mudflat clean-ups focusing on removing litter not natural debris), and general public pride in these natural features. While not purely ecological, this social objective is key to long-term sustainability.

4. Action plan

To achieve the stated objectives, a comprehensive Action Plan has been formulated. It consists of integrated actions spanning protection, management, education, evaluation, and resource mobilization. Each action is designed to target specific threats or needs identified in the previous sections. The plan is structured into sub-components: (4.1) integrated management actions, (4.2) stakeholder information and awareness, (4.3) impact evaluation, (4.4) resource and partnership development, and (4.5) monitoring. The actions are prioritized and, where possible, time-bound and assigned to responsible parties.

4.1 Identification of a Plan of integrated actions for the correct protection and management of habitats (interventions for extension and improvement of habitat, incentives for compatible anthropic practices in agricultural, tourism and residential place), also through educational programs, elaboration of specific interventions (regulations, active interventions, incentives for sustainable companies that have as a business enterprise the environmental sustainability and the protection of the habitat)

Integrated Protection and Management Actions (Habitat 1120 & 1140)
These actions are on-the-ground interventions and management measures to directly protect or improve the habitats. They often require coordination across sectors. Key actions include:

- **A. Regulate and Manage Anchoring and Coastal Activities:** Establish and enforce no-anchoring zones or eco-mooring areas in all sensitive Posidonia sites (habitat 1120). This involves deploying sufficient mooring buoys in popular bays with Posidonia, clearly mapping and signalling the protected seagrass zones (using marker

buoys, maps in marinas, and navigation charts). For habitat 1140, regulate activities like bait digging or vehicle access on mudflats – e.g. ban vehicles (ATVs, tractors) from driving on exposed flats and limit any shellfish harvesting to sustainable levels via permit. Coordinate with fisheries authorities to ensure any shellfishing does not deplete the benthic community. Additionally, any coastal construction near these habitats must go through strict environmental impact assessment and appropriate assessment under Natura 2000 rules, with a bias towards avoidance of impact: if a project would remove or significantly alter a Posidonia meadow or mudflat, it should be re-sited or cancelled unless there are imperative reasons and no alternatives (and then compensatory measures would be needed, per Habitats Directive).

- **B. Install Physical Protections and Restoration Interventions:** For Posidonia, if anchoring is a chronic issue, consider installing seabed anchoring blocks or fixed mooring points in strategic locations to physically prevent boats from dropping anchor in meadows (these would be coupled with mooring buoys for use). Investigate the feasibility of restoration planting in areas of the meadow that have been destroyed – for example, transplanting healthy Posidonia cuttings or seedlings to patch up anchor scars, possibly protected by temporary cages until established. This action would likely be experimental and done in partnership with scientific experts. For mudflats, perform coastal habitat restoration where needed: e.g. reprofile a beach to more natural contours to encourage mudflat formation, or plant salt-tolerant vegetation (like *Spartina* grasses or dune plants) at the upper edge of a mudflat to stabilize sediment and encourage landward migration of the flat as sea levels rise. Also, perform coastal habitat restoration where needed: as noted, a partial removal of the stone wall at Pržina is planned to allow sediment flow – this kind of intervention will be executed carefully (ensuring no negative effect on human safety). In summary, use nature-based solutions to restore or mimic natural processes (e.g. allow flooding of a coastal lowland to create new mudflat if possible, or install permeable sea walls that trap sediment on a mudflat instead of traditional hard sea walls).
- **C. Pollution Prevention and Water Quality Management:** Work with municipal authorities to upgrade sewage infrastructure and reduce nutrient and sediment runoff into coastal waters near these habitats. Specific actions include ensuring villages and towns near Posidonia sites have proper wastewater treatment (no raw

sewage outfalls onto meadows) and promoting green infrastructure (like vegetated buffer strips) to filter runoff. Also enforce maritime pollution rules: no dumping of bilge or trash in coastal waters (with fines and surveillance). For areas like estuaries affecting mudflats, coordinate water management (ensure minimal ecological flow in rivers to support estuarine flats, avoid drastic salinity changes). Regular beach clean-ups focusing on removing plastic and waste (but not natural wrack) will also help maintain habitat quality.

- **D. Climate Adaptation and Long-term Habitat Securing:** Develop a managed retreat/realignment plan for coastal habitats in the face of sea-level rise. This means identifying zones where, if the sea rises, the mudflat or seagrass could shift landward, and ensuring those zones remain free of development. Practically, this could involve setting back or relocating a coastal path or infrastructure in the future to let the habitat move. Additionally, protect and possibly expand adjacent habitats that interact with 1120 and 1140: for example, conserve Posidonia banquette (dead leaf accumulation) on beaches as it forms natural breakwaters that protect mudflats and dunes. Maintain healthy adjacent sandbanks (habitat 1110**)**, as they often feed sediment to mudflats. Include climate resilience measures such as monitoring for disease or thermal stress in Posidonia and having contingency plans (e.g., if a heatwave causes mass seagrass decline, be ready to reduce other stresses like pollution to help recovery).
- **E. Integrate into Spatial Planning and Sustainable Use:** Encourage to update local and regional spatial plans to explicitly zone critical habitat areas as non-developable and to allocate space for conservation. Conduct research to obtain data on the habitat, data on the present species, and data on the threats, based on which guidelines will be developed for the maintenance of beaches where these habitat types are present, and ultimately, incorporate these guidelines into spatial plans. Encourage sustainable tourism uses of these habitats: for Posidonia, create snorkelling trails with information panels – this turns the meadow into a feature that tourists enjoy responsibly (with guide ropes so they don't kick the seagrass). For mudflats, build bird observation platforms a short distance away (so visitors can watch feeding birds without stepping on the flats). Promote the concept of "no-take" or quiet zones. Also, explore incentives for sustainable business – e.g. a certification or award for dive centres that actively

protect seagrass, or for beach operators that follow eco-friendly cleaning guidelines. Possibly encourage to provide small grants for local initiatives that contribute to habitat conservation (like a marina installing a pump-out station to prevent boats dumping waste, or fishermen switching to seagrass-friendly fishing gear). These integrated actions tie conservation needs with community benefits, fostering a culture of co-existence.

4.2 Information and sensitization measures for Stakeholder and the local population

Education and awareness are critical to the success of the action plan. The following measures will inform and engage stakeholders, ensuring they understand the importance of habitats 1120 and 1140 and how they can help:

- **Educational Campaigns:** Launch a targeted education campaign about Posidonia meadows and mudflats. This will include informational materials such as brochures, short videos, and social media content. For boaters and tourists, produce simple guidelines (multi-language) explaining why anchoring in seagrass is harmful and how to use moorings, and why leaving natural debris on the beach helps prevent erosion. Distribute these in marinas, at tourist info points, dive shops, and beach kiosks. For local schools, develop modules on marine ecology of the Adriatic – possibly organizing field trips for students to see a Posidonia meadow via glass-bottom boat or to observe mudflat creatures at low tide, instilling appreciation early on.
- **Workshops and Participation:** Conduct regular stakeholder workshops and meetings. For example, hold an annual pre-summer meeting with boat tour operators, yacht charter companies, and the port authority to discuss anchoring rules and demonstrate the locations of protected zones (using maps and GPS coordinates). Similarly, meet with municipal beach managers and tourism boards before the season to review eco-friendly beach maintenance protocols, sharing data on how these habitats benefit tourism (e.g. clear waters from seagrass, bird diversity from mudflats) so they see the upside of protection. Encourage an open dialogue where stakeholders can voice concerns – for instance, fishermen can discuss any issues with new restrictions and collaboratively find solutions (perhaps alternative fishing spots or methods).

- **Signage and Interpretation:** Install interpretive signage at strategic locations. At boat launch sites and anchorages, put up signs "Seagrass Meadow Below – Anchor in Sand or Use Buoys" with graphics to show the do's and don'ts. At beaches adjacent to mudflats or seagrass areas, put educational panels about the "Hidden Life of the Mudflat" or "Neptune's Underwater Meadows," including photos of the species found and why the habitat should be respected. These signs not only inform locals and visitors but also signal that these areas are special and protected. On the shore near a mudflat, for example, a sign could explain how birds feed on the mudflat and ask people to minimize disturbance during low tide (maybe even providing a viewing binocular station so people watch from a distance).
- **Citizen Science and Involvement:** Initiate citizen science programs that involve the community in monitoring and caring for the habitats. For Posidonia, one idea is a "Seagrass Watch" program where volunteer divers or snorkelers adopt a meadow patch and report on its condition (perhaps with an app or simple form). For mudflats, engage birdwatchers to record bird usage regularly or have volunteers help measure shoreline profiles with simple tools. Another activity could be organizing "Bio-blitz" events during low tide where families and experts gather to observe and catalog mudflat organisms, thereby raising interest and knowledge. Public events such as "Posidonia Day" celebrations can be held, featuring talks, beach clean-ups, and demonstrations (like how a single seagrass meadow oxygenates the water). These involvement activities create a sense of stewardship.
- **Media and Outreach:** Use local media (newspapers, radio, TV) to disseminate key messages. For instance, a short segment on local radio about the new anchoring regulations and why they matter, or a piece in the newspaper highlighting a success story (like "Seagrass on the rebound thanks to community efforts"). Maintain an online presence with updates on conservation actions – e.g. posting before-and-after photos of a restored area, or short interviews with fishermen who support the initiative. Positive storytelling can shift public attitudes in favour of conservation measures.
- **Training Programs:** Provide specialized training for certain stakeholder groups. Train tourist boat skippers and marina staff on environmental friendly practices (perhaps even certify them as "Seagrass Friendly Operators" if they pass the training). Train beach maintenance crews on the new protocols (what to remove vs leave, how to

recognize signs of erosion or habitat presence). Also train local enforcement officers (rangers, maritime inspectors) on how to identify violations affecting these habitats and the importance of strict enforcement. Building capacity ensures that those on the front lines are knowledgeable and motivated.

4.3 Evaluation of impact of the Action Plan for the correct protection and management of the habitats

To ensure the Action Plan is achieving its goals, a framework for evaluation and assessment of outcomes is established. This involves defining indicators, monitoring those indicators, and conducting periodic reviews to adjust actions as necessary (adaptive management). Key components of the evaluation include:

- **Performance Indicators:** For each objective and action, clear indicators and targets are set. Examples of indicators: *Posidonia meadow extent* (in hectares) in target sites; *Seagrass shoot density* (shoots/m²) in permanent sample plots; *number of boats anchoring illegally* as a measure of compliance; *area of mudflat exposed at spring low tide* (from mapping); *invertebrate diversity/abundance* on mudflats (from benthic sampling or visual counts of key species like clams, worms); *water clarity (Secchi depth)* near seagrass beds; *incidence of beach mechanical cleaning* (days per year) as a measure of reduced disturbance; *bird counts* on mudflats (number of feeding shorebirds during census); and *stakeholder awareness level* (perhaps via surveys). Many of these indicators are aligned with what is monitored under Natura 2000 reporting and the ongoing monitoring plan. Each indicator has a baseline (from initial surveys) and a target (e.g. no decrease in seagrass extent, or increase in shoot density by 10% in 5 years, reduction of illegal anchoring to zero, maintaining mudflat area within X% of baseline, etc.).
- **Monitoring and Data Collection for Evaluation:** The Monitoring Plan described below provides the data for evaluation. Essentially, regular monitoring reports will feed into evaluating if actions are working. For example, if mooring buoys are installed (action A), monitoring will show a drop in anchor damage indicators; if not, the action might need reinforcement (more buoys or enforcement). The evaluation process will compile results from annual monitoring of habitats and pressures. Additionally,

stakeholder feedback (from workshops or questionnaires) will be considered a qualitative metric of success (e.g. are fishermen perceiving more fish due to seagrass recovery or are tourists satisfied with the "wilder" look of beaches with natural debris).

- **Mid-term and Final Reviews:** Establish a schedule for formal evaluations of the plan – for instance, a mid-term review after 3 years and a final review after 6 years (assuming a 6-year plan aligned with Natura 2000 reporting cycles). The mid-term review will analyze monitoring data collected thus far and assess progress towards short- and medium-term objectives. Successes will be noted (and perhaps can allow some actions to be scaled back if objectives are met sooner), and shortcomings will be identified. If some indicators are not trending in the right direction, the reasons will be investigated. The plan can then be adaptively adjusted: e.g., if illegal anchoring is still an issue at mid-term, perhaps the strategy needs altering (more patrolling or community engagement). The final review will evaluate overall achievement of objectives and document lessons learned. Ideally, by the final review, many actions will transition from "project" mode to regular ongoing management.
- **Impact Assessment:** Beyond tracking habitat status, the evaluation will also consider the impact of the actions themselves. For instance, evaluate the effectiveness of the awareness campaign: did knowledge or behavior metrics improve? (could be measured by surveys or) Evaluate any unintended consequences: e.g., did regulating anchoring in one bay lead to overcrowding in another (and do we need to mitigate that) Did limiting beach grooming lead to any public complaints, and how were those addressed? The evaluation should weigh ecological gains against socio-economic outcomes to ensure the plan is sustainable and balanced.
- **Reporting and Transparency:** Prepare evaluation reports summarizing findings, to be shared with stakeholders and funding bodies. This maintains transparency and accountability. The report would include maps, graphs of indicator trends and a narrative explanation. For Natura 2000, these findings will feed into the national reporting and update of site management plans.
- **Adaptive Management Decisions:** Based on evaluation, specific adaptive actions might be taken: for example, if monitoring shows a new threat (like a sudden outbreak of an invasive alga in a seagrass meadow), the plan might adapt by adding an action

to address it (like manual removal or research into control). Or if a certain restoration technique is not yielding results, try an alternative method. The evaluation process ensures the plan is not static but evolves with new information.

By setting up this evaluation structure, we ensure that the action plan remains effective and responsive. Essentially, "plan, do, check, adjust" is the cycle employed. As an example from our monitoring plan: if after implementing mooring buoys and education (plan/do), the monitoring reports still show damage or no improvement, the evaluation will flag this and we might adjust by increasing enforcement or tweaking the buoy placement. Conversely, if goals are met early (e.g., zero anchoring infractions for a year), we can focus resources on other issues or raise the bar for objectives. The goal is to have a demonstrable positive impact on the habitats – something we will verify with robust data and then communicate as a success of the plan (or learn from as a needed change).

4.4 Identification of human and financial resources which will be included into the project through partnerships with public and private authorities.

Achieving these actions requires sufficient resources – both human capacity and financing – and strong partnerships across institutions. This section identifies how the needed resources will be mobilized and coordinated:

- **Lead and Supporting Organizations:** The implementation will be led by the relevant managing authority (for example Public Institution for the Management of Protected Natural Areas of Dubrovnik-Neretva County on the Croatian side, and the corresponding agency/park authority on the Italian side for their sites, given ASPEH is cross-border). A dedicated Project Team or working group is established, including project managers, marine ecologists, outreach officers, and representatives of key stakeholder agencies.

- **Human Resources:** Many actions will be carried out by existing staff of organizations: rangers, environmental inspectors, researchers, and educators. However, some new roles or additional manpower may be needed. Volunteers and citizen scientists are also a resource to tap into for tasks like monitoring assistance or outreach events. Training has been allocated (as mentioned) to improve the skill set of staff and

volunteers – this is effectively an investment in human resources. Partnerships with universities can provide student interns to help with surveys or campaigns (mutually beneficial as students gain experience). In essence, leveraging both professionals and community members in a structured way provides the human capacity.

- **Financial Resources:** Funding for the action plan will come from multiple sources. The ASPEH project (Interreg Italy-Croatia) provides initial funding for developing common conservation measures, training, concrete actions, and a joint strategy. The Natura 2000 sites could also access the EU Recovery and Resilience Facility or Structural Funds earmarked for green infrastructure and biodiversity. Locally, tourism taxes or dive fees could be channeled into a conservation fund. Private sector partnerships might also be explored: for example, a marina or an eco-tour company might sponsor a buoy or an info panel as part of their corporate social responsibility. The action plan includes a budget plan detailing costs of each action and identifying funding sources to cover them, ensuring no action is unfunded.

- **Partnerships:** Collaboration is formalized through agreements or memorandums of understanding. A partnership with the maritime authorities ensures their boats and personnel help enforce marine regulations. Partnership with fishermen's associations might involve agreements on surveillance (fishermen can report illegal trawling if they see it) and on trialling alternative practices (with possible subsidies to offset any short-term costs). NGOs might partner to lead specific tasks, like an NGO could take charge of the citizen science program or run the school education component, funded by the project. Cross-border partnerships are also crucial: Italian and Croatian teams working on Posidonia and mudflat sites will share data and techniques – for instance, if Italy has expertise in seagrass transplantation, they will assist Croatian partners to implement it, and if Croatia has developed effective monitoring protocols, these will be shared with Italian sites. At the scientific level, partnerships with institutions mean we can use advanced tools without duplicating effort. Also, international bodies or EU agencies can be consulted for best practices.

- **Sustainability of Resources:** The plan includes strategies to sustain resources beyond the project period. For financial sustainability, incorporating habitat management needs into the regular operating budgets of the managing institutions is key – for example, the county nature authority will allocate a yearly amount for buoy maintenance and monitoring in its annual budget (just as it does for terrestrial tasks).

By mainstreaming these activities into normal operations and securing a commitment from government budgets, the actions can continue long term. The partnerships established will also continue to function as networks for problem-solving and support, reducing costs through shared expertise.

4.5 Monitoring Plan for checking the effectiveness of actions

A robust Monitoring Plan underpins the entire conservation strategy, as it provides the data to evaluate success and inform adaptive management. The monitoring plan is designed to track the effectiveness of the actions and the status of the habitats through specific indicators, and is aligned with national conservation monitoring requirements. Key features of the monitoring plan include:

- **Habitat Condition Monitoring (1120 & 1140):** Both habitats will be monitored for their structure and function parameters. For Posidonia meadows (1120), this means periodic surveys to measure: aerial extent of the meadow (mapping via GPS and aerial imagery), density of shoots (counting shoots within quadrats along transects), percent cover, and health indicators (presence of epiphytic algae, necrotic leaves, etc.). Divers conduct visual censuses and point-intercept transect methods to quantify the seagrass and associated biota. Photo documentation (underwater photographs of fixed points) complements quantitative data to visually track changes. This is done annually or biennially. For mudflats (1140), monitoring focuses on extent (using drone or satellite images to measure how much area is exposed at low tide), sediment characteristics (sampling sediment cores for grain size and organic content), and biological communities (using core samples or observation grids at low tide to count key species like bivalves, worms, crustaceans). Also, observations of surface algal cover (the microalgal film) can be noted. Such surveys will likely be done at least once a year (e.g. late summer when biological activity is high) in accordance with financial capabilities. All these data establish whether habitat conditions are improving, stable, or declining relative to baseline.

- **Threat/Pressure Monitoring:** The plan also monitors the pressures directly. For example, track the number and distribution of boats in sensitive zones – this can be done through ranger patrol logs or even new technology like AIS data for larger vessels, or drone counts on busy days. If an anchoring ban is in place, every observed violation is recorded (and ideally penalized), and the trend in violations is reviewed.

Similarly, water quality is monitored: parameters like turbidity, chlorophyll-a (for algal blooms), and nutrient levels in water around seagrass beds are measured periodically to ensure no deterioration (some of this might be done in partnership with existing national water monitoring programs). For mudflats, beach topography surveys (perhaps using a GPS) after storm seasons help assess erosion or accretion. Photopoints are set up (fixed locations where photographs are taken regularly) to visually document shoreline changes or the accumulation/removal of organic material. Invasive species presence is also monitored – divers look for invasive algae in Posidonia, and intertidal surveys note any new species on mudflats. Each key threat identified before has a corresponding indicator: e.g. extent of Caulerpa algae in a meadow, or length of seawall affecting a mudflat (with a goal to reduce it). The monitoring plan incorporates these so that management can respond quickly if a threat intensifies.

- **Wildlife Monitoring (as indicators):** Certain species can serve as indicators of the habitat's health and the success of actions. For Posidonia, indicator species could be the noble pen shell (Pinna nobilis) – if juveniles start appearing, it suggests improving conditions (though note this species is currently suffering mass mortality in the Med). Fish populations (like sea breams, pipefish) in meadows can be surveyed by visual census to see if they increase with habitat recovery. For mudflats, waterbird counts (already done via national bird monitoring schemes) are key – an increase or maintenance of high numbers of shorebirds feeding on the flat is a positive sign that the flat is productive. These counts can be done monthly during migration/winter. Also, the presence of crabs or other top invertebrates on mudflats can be noted. These biological indicators add context to the physical habitat data.

- **Frequency and Responsibility:** The monitoring plan details who does what and how often. Typically, the nature protection institution's experts or contracted marine biologists will do the ecological surveys. For example, a Posidonia monitoring team (with divers from perhaps a research institute and the local diving club for assistance) will conduct surveys every summer, while a mudflat monitoring team (possibly involving park rangers and marine scientists, and local volunteers for bird counts) will do seasonal checks. The plan calls for annual summary reports of monitoring, which are then fed into the evaluation process. Partnerships with academic institutions ensure scientific rigor, and citizen science contributions (like seagrass watch or bird counts) are verified by professionals. Modern tools will be used where possible – e.g.

drones to map mudflat extent or photogrammetry for seagrass if water clarity permits; these can improve efficiency and coverage.

- **Data Management:** All collected data will be stored in a database (likely an extension of the national biodiversity database or Natura 2000 monitoring database). Georeferenced data such as maps of seagrass and mudflat distribution, and shapefiles of any changes, are compiled. This allows visualization of change over time. Having data well-organized also means it can be readily reported to the EU (Article 17 reports) and shared among project partners.

- **Feedback to Management:** Importantly, the monitoring plan is not just academic – it directly feeds back to management decisions in real time. If, for instance, monitoring finds that a new anchor scar appeared in a supposedly protected bay, this will trigger an investigation and potentially increased patrolling or an adjustment of buoy placement immediately rather than waiting for year-end. Likewise, if water quality drops (perhaps signaling a pollution event), authorities can react (find the source, mitigate it). Monitoring results are discussed in stakeholder meetings as well, keeping everyone informed of progress or issues.

In essence, the Monitoring Plan acts as the plan's "eyes and ears," ensuring that we quantitatively know how the habitats are faring and how well our actions are working. By continuously checking the pulse of habitat 1120 and 1140, we can celebrate successes (e.g. "Seagrass meadow area increased by 5% in two years in X bay") and detect problems early, thereby making conservation of these vital habitats an ongoing, responsive process rather than a one-off effort.

5. Literature and Appendixes

5.1 Literature

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5.2 Appendixes (stakeholders list and habitat list)