PhD Thesis

Development of sustainable strategies for conservation and management of *Posidonia oceanica*, (Linneo) Delile 1813, meadow: a case study within a Site of Community Importance

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Development of sustainable strategies for conservation and management of *Posidonia oceanica*, (Linneo) Delile 1813, meadow: a case study within a Site of Community Importance

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A Nonno Pippo
e alla danza,
perchè mi accompagnino
sempre.

1. INTRODUCTION

1.1 *Posidonia oceanica*, species and ecosystem

The species *Posidonia oceanica* is endemic to the Mediterranean Sea. It forms extensive underwater meadows that grow on rocks and sandy bottoms in clean water at a depth from less than 1 meter to over 40 meters (Hemminga and Duarte, 2000). The rest of the Posidonia species (of which there are 7-8) are found in Australian waters, which illustrates the antiquity of the genus (den Hartog, 1970). This seagrass is a strictly marine species and is never found in estuaries or salt-marshes.

Specifically the taxonomy indicates Posidonia as monocotiledone of the *Potamogetonaceae* family; it has strap- shaped leaves 40-50 cm long and 5-9 mm wide, with 13-17 longitudinal veins; apex obtuse to emarginated. Peduncle 10-25 cm long, bearing 1-4 spikes, each with 2-5 flowers; stigma with numerous irregular branched or unbranched processes. Fruit ovoid, 10cm long. This species is the most robust seagrass in the Mediterranean region and can be easily identified by the numerous brown fibrous remains of old sheaths covering the rhizomes like a paintbrush.

Its flowers are hermaphrodite on an inflorescence spike (den Hartog, 1970). The seeds develop as monocarpic fruits. *P. oceanica* has low flowering frequencies and sets few seeds (Buia and Mazzella, 1991).

Seagrass meadows can be found along the entire Mediterranean coast, forming a kind of belt on the intralittoral zone, until maximum 40 m deep in very clean water (Bouderesque & Meisnesz, 1982, Mazzella et al., 1986).

Like other plants Posidonia has roots, stem, leaves, flowers and fruits. At the base of each plant is a rhizome, which is actually a modification of the stem, out of which grows roots of 10 to 15 centimeters in length. These attach the plant to the substratum. Large leaves grow from the rhizome each about 1 centimeter wide and up to 80 centimeters long.

The scientific name, *Posidonia oceanica,* seems strange as this plant only grows in the Mediterranean sea. However, Seagrass thrived and spread in the warm Tethyan seas of the Eocene. The present global distribution is likely to be far more limited than in the past due to continental drift, temperature changes and the impact of enormous variations in sea levels since the Pleistocene (80m lower/42 m higher than present), (Coles and Lee Long, 1999).

Main habitat features, ecology and variability

P. oceanica is a large, slow-growing seagrass , eventually forming a tightly knit set of rhizomes that holds the sandy seabed in place. It forms dense green meadows whose leaves can attain 1 meter in height during the summer, reaching heights of 4 meters above the seabed, producing reefs.

Old leaves are shed throughout the year, but especially in the autumn. In winter, the canopy appears shorter and sparser (10 to 40 cm high). Meadow density is maximal in shallow water (when it may attain more than 1000 shoots m^{-2}) and decreases exponentially with depth (70-80 shoots m^{-2} at 30 m). Enhanced sedimentation, combined with vertical rhizome growth, produces characteristic reefs called "matte". The matte is a network of dead rhizomes with shell/organic debris and sediments, which accumulate over centuries to attain several meters in height (Hemminga and Duarte, 2000).

P. oceanica meadows are able to support a relatively wide range of temperatures, as deduced from the wide latitudinal range of its distribution, from 31ºN in the coasts of Lybia to 45ºN in the Gulf of Trieste (Green and Short 2003). Therefore, although there are not specific experiments, from this latitudinal distribution we can deduce that the plant endures temperatures from approximately 10ºC to 29ºC.

P. oceanica needs clear, oligotrophic and oxygenated waters to survive. The depth to which the meadows grow is often limited by light (Duarte et al., 2007). The minimum light requirements of this plant are 0.1 - 2.8 mol PAR photons day^{-1} m^{-2} (Gattuso et al., 2006). *P. oceanica* also supports a narrow range of salinity, from 33‰ to 39‰ (Fernández-Torquemada and Sánchez-Lizaso 2005), however it is possible that East Basin populations may support higher salinities.

The seagrass uses the underwater substrate for anchorage and nutrient uptake. Sediment has to be relatively oxic (ie oxygenated). *P. oceanica* can grow on rocks or sandy bottoms. Muddy substrates are however not suitable as the plant is unable to attach itself and the water is too murky for plant growth.

The sedimentation/erosion balance also often limits meadow development. As a result, *P. oceanica* never grows near river mouths or in confined waters (e.g. hypersaline coastal lagoons). Wave action is another important criterion: in sheltered bays, meadows can grow up to the water surface, forming fringing reefs, but in open coasts they usually start growing several meters below the surface (3-10 m).

There are slight morphological and genetic differences between *P. oceanica* meadows from different regions. In particular, there is a genetic cleavage between the Eastern and Western Mediterranean meadows, which suggests that these meadows were temporally isolated from each other during last glaciations (Arnaud-Haond *et al.* 2007). Nevertheless, there are no clear geographical differences in meadow structure and function between the two basins, and the morph type differences disappear after some years of acclimatisation when transplanted to another site (Meinesz et al., 1993).

P. oceanica meadows constitute one of the main climax stages of Mediterranean coastal ecosystems. They harbour a highly diverse community, which varies according to depth, shoot density, adjacent communities, physico-chemical conditions and even historical events linked to larval recruitment (Hemminga and Duarte 2000).

Some species indicate seagrass perturbation: the overgrowth of epiphytic algae and especially the episodic formation of dense mucous layers of filamentous algae (Ectocarpales and Crysophyceae) on the meadow canopy is associated with water eutrophication and reduced hydrodynamics (Lorenti et al., 2005). The green algae *Caulerpa* spp. invades declining sparse meadows, especially when the sediment is enriched with organic matter (Terrados and Marbà, 2006). When nutrient inputs to the bed are too intense, sea urchins *Paracentrotus lividus* (normal densities 0-5 urchins m_{-2}) become over abundant (may attain 30 urchins m^{-2}) on meadows that grow near rocky substrates and consequently overgraze *P. oceanica* leaves (Ruiz et al. 2001). Their excess is therefore indicative of habitat eutrophication. Fire worms (e.g. *Hermodice carunculata*) also appear in degraded meadows with an excess of labile organic matter.

<u>Species that depend on the habitat</u>

A conspicuous and complex epiphytic community lives on the leaves of *P. oceanica.* This community is composed of large quantities of micro- (mainly cyanobacteria and diatoms) and macro-algae (over 94 species described). In healthy meadows, the red algae *Fosliella* spp. and *Hydrolithon* spp., and brown algae, like the complex *Giraudio-Myrionemetum orbicularis* Ben, 1971, cover the tips of the leaves. Sessile animals, such as hydroids (over 44 species identified such as the obligate taxa *Sertularia perpusilla* and *Plumularia obliqua posidoniae*), or briozoa (more than 90 species, like the obligate taxa *Electra posidoniae* and *Lichenopora radiata*) are also a common component of the leaf epiphytic community. Microscopic foraminifera are also very abundant, especially in the less illuminated leaf-sides (e.g. *Quinqueloculina* spp., *Planorbulina mediterranea, Nubecularia massutiana* or *Conorboides posidonicola*). Some species and associations of foraminifera are exclusive of Posidonia meadows and are currently used by palaeontologists to diagnose the existence of ancient meadows in geologic strata (Colom, 1974).

Within the rhizome substrate, some sessile species are only found on healthy *P. oceanica* meadows. This is true of the foraminifer *Miniacina miniacea* (whose shells are responsible for the characteristic pink colour of Mediterranean biogenic sands) and the large fan mussel *Pinna nobilis*, which, due to their filter feeding habits, longevity and slow growth, are good indicators of water quality and mechanical stability within the meadows. Other sessile species, such as the filterer worm *Sabella spallanzanii* are also indicators of water quality, but they are not restricted to Posidonia meadows (they also appear in rocky habitats). Algae adapted to low levels of light intensity (more than 74 species described, mostly red algae) colonize the rhizomes (e.g. *Peyssonnelia squamaria* and *Udotea petiolata*). Light dependent algae like *Jania rubens* may appear on meadow borders.

Mollusca (more than 185 species described) and Crustacea (more than 120 species of Copepoda, Decapoda and Amphipoda) are the most abundant faunal groups in *P. oceanica* meadows. There are some obligate taxa like the perfectly cryptic *Idotea hectica* and *Limnoria mazzellae* (Isopoda) or *Hippolyte inermis* and *Palaemon xiphias* (Decapoda). The Polychaeta are very abundant also (more than 182 species, like *Platynereis dumerlii* and *Syllis* spp.), although most species are ubiquitous. Sponges are abundant in the rhizome substrate (more than 15 species, like *Clathrina contorta* and *Sycon ciliatum*).

Among the Echinoderms, irregular detritivore sea urchins like *Echinocardium* and *Spatangus* spp. and regular herbivore sea urchins like *Spharaechinus granularis* and *Paracentrotus lividus* are common. The rare *Centrostephanus longispinus* can also be found in deep, rocky meadows. There are also Crinoidea (*Antedon Mediterranea*) and sea stars (e.g. *Ophioderma longicaudum* or the endangered, obligate species *Asterina pancerii*) but the most abundant Echinoderms are sea cucumbers (16 species described) which play an important ecological role as sediment filterers. Among them, *Holothuria tubulosa* redominates in dense, sandy meadows, while *H. polii* is more prevalent in sparse or degraded meadows, although it is very difficult to distinguish these two species. At night, many mobile species living within the rhizomes migrate to feed in the canopy.

Many fish species live in the *P. oceanica* meadows during their juvenile stage. There are also resident species, the most common of which are *Gobius* spp. (living on rhizomes), as well as *Labrus merula, L. viridis* (cryptic, specialist), *Symphodus* spp., *Diplodus* spp, *Sarpa salpa, Coris julis* and *Chromis chromis*. There are also some obligate species living within the leaf canopy, like the cryptic species *Opeatogenys gracilis* and *Syngnathus typhle*. The endangered species *Hippocampus hippocampus* is also found within the canopy.

Finally, the herbivorous green turtle *Chelonia mydas* feeds on tender seagrass leaves. Today it is an endangered species, but only a century ago, its population was probably several orders of magnitude larger. Their ecological role as seagrass grazers could have been of great importance in the past, judging by the effects they have on tropical underwater meadows (Jackson, 2001).

Related habitats

In soft bottoms, *P. oceanica* meadows are usually surrounded by fine-grained sand detritic communities (Natura 2000 codes 1160, 1110). They are often combined with facies of the smaller and sparser 4 seagrasses *Cymodocea nodosa* or *Zostera noltii* (the latter is more frequent in northern regions) or with the green alga *Caulerpa prolifera*. Sandbanks and dune systems accumulate large amounts of seagrass litter and biogenic sand, which is formed by the calcareous and siliceous debris of epiphytic fauna and flora. In turn, sediments may be exported from the beach to the meadow, determining their erosion-siltation balance (Medina et al., 2001). Therefore, the two habitats are strongly linked. Saltmarshes can also regulate nutrient inputs into seagrass meadows (Valiela and Cole 2002).

Cymodocea nodosa, it's a similar seagrass, forming less dense meadows, with smaller rhizomes (maximum few mm wide), it can overcome stressing situation better (Cavazza et al, 2000), usually it is common on instabile sandy bottoms with fine granulometry; for these reasons Cymodocea can be define as pioneer species, colonizing areas left by Posidonia after an environmental stressing situation (Bianchi & Peirano, 1995; Relini et al., 2000); in fact it is often found on dead matte (Tunesi, 2001).

On rocky coasts, *P. oceanica* meadows are usually preceded by rocky algal communities (Natura 2000 code 1170).

Deep meadows may be followed by soft-bottom maërl (red coralline slow-growing algae) assemblages or by coral/gorgonian communities. The former are important and sensitive communities, which still lack formal protection (only two maërl-forming species are protected in the Annex V of the Habitat Directive: *Phytomatolithon calcaereum* and *Lithothamnion corallioides*, their Mediterranean counterparts are not).

The environmental requirements of submersed associated habitats are similar to those of *P. oceanica* meadows, although *C. nodosa* and *Z. noltii* support a wider salinity range.

Ecological services and benefits of the habitat

Posidonia oceanica meadows are key ecosystems within the Mediterranean Sea. The high rate of plant production (0.25 ± 3 kg (dry weight) m^{-2} $year^{-1}$ (Ott, 1980, Pergent-Martini et al., 1994), mainly due to annual leaf growth, and the abundance of epiphytes (which can reach up 20–30% of the biomass of leaves), support a high secondary production *in situ* and in detritivore compartments of other communities (around 80% of total production, Cebrián and

Duarte 2001), thereby sustaining complex food webs from beaches to bathyal areas.

A moderately wide (1 km) belt of *P. oceanica* meadow may produce litter in excess of 125 kg of dry seagrass material per meter of coastline each year (mostly during Autumn). This material accumulates on the beach, developing cushions up to 4 meters high, which can in turn sustain a complex invertebrate food web, protect the shoreline from erosion, deliver sand in the form of carbonate and silica shells and, when transported further inland by the wind, act as seed material for dune formation (Borum et al. 2004).

In daylight, *P. oceanica* meadows oxygenate coastal waters (Bay 1984), producing net oxygen releases to the atmosphere above the meadows. Due to the slow decomposition of lignified rhizomes and roots, the reef structure or "matte" acts as a long-term carbon sink (e.g. Gacia et al., 2002). The leaves and rhizomes increase the surface available to sessile species and offer shelter to mobile species, thereby sustaining a diverse community (Templado, 1984). Posidonia beds are especially valuable as nursery grounds for several commercial species (Francour, 1997).

The leaf canopy increases particle retention (e.g. Terrados and Duarte, 2000), so enhancing water transparency. This function, combined with the active formation of calcareous and silica sand from shelled organisms (Canals and Ballesteros 1997) and cushions of seagrass litter, all contribute to reducing shoreline erosion. Specifically the presence of *P. oceanica* enhances sediment stability by preventing resuspension, despite a marginal effect of the vegetation on the primary sediment deposition. These results thus support recent conclusions on the role of seagrasses in near-shore sedimentary processes (Fonseca, 1996) indicating that much of the seagrass erosion prevention is due to sediment retention.

Posidonia leaves slow down wave movement and trap larger grains of sand. It is thanks to this natural filter that the water that reaches the shore is clearer and cleaner.

Finally, *P. oceanica* meadows are excellent indicators of environmental quality as they can only grow in clean unpolluted waters. Moreover, their rhizomes concentrate radioactive, synthetic chemicals and heavy metals, recording the environmental levels of such persistent contaminants.

1.2 The Habitats Directive

The continuing deterioration of natural habitats and the threats posed to certain species are one of the main concerns of European Union (EU) environment policy. The Habitats Directive (together with the Birds Directive) forms the cornerstone of Europe's nature conservation policy. It is built around two pillars: the Natura 2000 network of protected sites and the strict system of species protection. The Habitats Directive, is intended to help maintain biodiversity in the Member States by defining a common framework for the conservation of wild plants and animals and habitats of Community importance. The Directive establishes a European ecological network known as "Natura 2000". The network comprises "special areas of conservation" (SAC) designated by Member States in accordance with the provisions of the Directive, and special protection areas (SPA) classified pursuant to Directive 79/409/EEC on the conservation of wild birds.

Annexes I (Natural habitat types of Community importance) and II (Animal and plant species of Community importance) to the Directive list the habitats and species whose conservation requires the designation of special areas of conservation. Some of them are defined as "priority" habitats or species (in danger of disappearing). Annex IV lists animal and plant species in need of particularly strict protection.

All in all the directive protects over 1.000 animals and plant species and over 200 so called "habitat types" (e.g. special types of forests, meadows, wetlands, etc.), which are of European importance.

Special areas of conservation are designated in three stages. Following Artcle 6 of the Directive and the criteria set out in the annexes, each Member State must draw up a list of sites hosting natural habitats and wild fauna and flora, which should be proposed for designation as Sites of Community Importance. On the basis of the national lists and by agreement with the Member States, the Commission will then adopt a list of Sites of Community Importance.

The criteria for selecting sites eligible for identification as sites of community importance and designation as special areas of conservation- are defined in annex III of the Directive and they are:

(a) Degree of representativity of the natural habitat

(b) Area of the site covered by the natural habitat type in relation to the total area covered by that natural habitat type within national territory.

(c) Degree of conservation of the structure and functions of the natural
habitat type concerned and restoration possibilities.

(d) Global assessment of the value of the site for conservation of the natural habitat type concerned.

Each Member State should guarantee the conservation status of a natural habitat (Art. 1e). The conservation status of a natural habitat will be taken as ‘favourable’ when:

— its natural range and areas it covers within that range are stable or increasing, and

— the specific structure and functions which are necessary for its long-term maintenance exist and are likely to continue to exist for the foreseeable future, and

- the conservation status of its typical species is favourable as defined in Art. 1i;

The conservation status of a species will be taken as ‘favourable’

when:
— population dynamics data on the species concerned indicate that it is maintaining itself on a long-term basis as a viable component of its natural habitats, and
— the natural range of the species is neither being reduced nor is likely to be reduced for the foreseeable future, and
- there is, and will probably continue to be, a sufficiently large habitat to maintain its populations on a long-term basis.

Habitats Directive establish that Member States must take all necessary measures to guarantee the conservation of habitats in special areas of conservation, and to avoid their deterioration. The Directive provides for co-financing of conservation measures by the Community.

Member States must also:

* encourage the management of features of the landscape which are essential for the migration, dispersal and genetic exchange of wild species;
* establish systems of strict protection for those animal and plant species which are particularly threatened (Annex IV) and study the desirability of reintroducing those species in their territory;
* prohibit the use of non-selective methods of taking, capturing or killing certain animal and plant species (Annex V).

The Member States and the Commission must encourage research and scientific work that can contribute to the objectives of the Directive. Every six years, Member States must report on the measures they have taken pursuant to the Directive. The Commission must draw up a summary report on the basis thereof.

Planning and management Natura 2000 sites – including Sites of Community Importance and Special Protected Areas- which have been proposed to the European Commission and waiting to be designated as Special Areas of Conservation (SAC) represent an appication of the biodiversity protection law in the EC territory.

The Italian Environmental Ministry issued the DPR 357/97 ("Regolamento recante attuazione della Direttiva 92/43/CEE relativa alla conservazione degli habitat naturali e seminaturali, nonché della flora e della fauna selvatiche"), to implement the Habitats Directive at national level; this decree has been modified by annexes A and B of D.M. 20 gennaio 1999, to implement Directive 97/62/CE and by DPR 120/2003.
Guidelines for the management of N2000 Sites have been issued by the Environmental Ministry with D.M. 3 settembre 2002 (published on G.U. n.224 of September 24, 2002).
At regional level, the Lazio region issued through the DGR 1103/2002 **(**Linee guida per la redazione dei piani di gestione e la regolamentazione sostenibile dei SIC e ZPS) the guidelines for writing of N2000 sites' management plan and regulation.

Posidonia oceanica meadows are listed as priority habitat on Annex I of 92/43/CE. The Interpretation Manual Of European Union Habitats- EUR 27-issued in July 2007 defined them as:
"Beds of *Posidonia oceanica* (Linnaeus) Delile characteristic of the infralittoral zone of the Mediterranean (depth: ranging from a few dozen centimetres to 30 - 40 metres). On hard or soft substrate, these beds constitute one of the main climax communities. They can withstand relatively large variations in temperature and water movement, but are sensitive to desalination, generally requiring a salinity of between 36 and 39‰"
And the characteristic animal and plant species, including details of their occurrence in Annex II and IV (*=priority, #=nonpriority from Annex II/IV, +=Annex IV only) are:
Plants- *Posidonia oceanica*.
Animals- Molluscs- #*Pinna nobilis*; Echinoderms- *Asterina pancerii, Paracentrotus lividus*; Fish- *Epinephelus guaza*, *Hippocampus*

ramulosus.

1.3 Trends and threats of Posidonia meadows

Trends

Posidonia oceanica, is the dominant seagrass species in the Mediterranean, where it covers 50.000 km^2 (Bethoux & Copin-Montegut, 1986). It is known to be a reef-building organism (Peres & Picard, 1964) capable of long-term sediment retention (Mateo et al., 1997). *Posidonia oceanica* is however experiencing a widespread decline throughout the Mediterranean Sea (Marba` et al., 1996), which may reduce sediment retention and increase beach erosion in the coastal zone (Sestini, 1989).

Over the last decades, following the increasing coastal urbanisation and industrialisation, many meadows have disappeared or have been altered (e.g. Meinesz and Lefevre, 1978). A sample of 39 studies in 135 sites shows that 46% of the underwater meadows in the Mediterranean have experienced some reduction in range, density and/or coverage, and 20% have severely regressed since the 1970s. In European coastal waters, the most dramatic losses have occurred in the northern Adriatic Sea where meadows that were present at the beginning of the 20th century have almost disappeared (Zavodnik and Jaklin, 1990).

Given the extremely slow growth rate of this species (1-6 cm yr-1), such losses are virtually irreversible.

Moreover, underwater meadows may decline more rapidly below a certain shoot density threshold.

Shoot mortality exceeds recruitment in 60% of the Spanish Mediterranean meadows, yielding a median exponential decline rate of 5% yr_{-1} (19 meadows analysed, Marbà et al., 2005), which is more than double the 2% yr_{-1} global rate of decline in seagrass ecosystems (Duarte et al., 2008).

In 7 of these sites, there is no evident human perturbation (two of them are in pristine areas of an MPA).
This suggests the existence of a background decline trend, maybe related to general changes in the climate of the Mediterranean Sea (Duarte et al., 1999). If these trends are maintained, most of the *P. oceanica* meadows are predicted to halve in density over the next 20 years. Nevertheless, 6 pristine meadows, growing in MPAs around the Mediterranean were analysed through reconstructive techniques and showed positive net population growth in the last, indicating that there is no background decline trend linked to global factors, and that the decline observed throughout the Mediterranean would be the product of cumulative effects of natural and anthropogenic local processes (González-Correa et al., 2007a). However, a slight recovery has been observed in some meadows following corrective measures. For example *P. oceanica* meadows off Marseille have experienced a partial recovery in density and extent during the last decade following the installation of a sewage treatment plant (Pergent-Martini et al., 2002).
However, other cases indicate that meadow recovery is limited by the plant’s slow growth and by the altered environmental conditions, which often persist well after the cessation of the impacting activity.
The projections for the total recovery of meadows undergoing protective measures are in the order of centuries.
There is presently little understanding of cyclical change or long term trends and the implications for the management of seagrasses. This is particularly so for very long term changes such as global warming.

Meadows’ disappearing affects also related biocenosys: the loss of one linear meter of meadow can be responsible of the loss of few meter of the beach facing it (Mazzella et al., 1986).

Threats

Posidonia oceanica is under extreme pressure to survive in an almost enclosed sea, surrounded by countries that rely heavily upon fishing and tourism. As its growth rate is very slow, *Posidonia oceanica* cannot recover from physical damaged from drag-net fishing, anchoring, or marina construction nor compete well with invasive algae such as **Caulerpa taxifolia*. Requiring water that is clear enough to allow sufficient light penetration for photosynthesis, Posidonia is extremely sensitive to poor water clarity caused by pollution, nutrient loading or mechanical disturbance.

Nutrient loading has been found to be responsible for the deterioration of seagrasses on a national and regional scale. Nitrogen and phosphorus find their way into the sea from urban sewage outlets, industrial outlets, run off from agricultural areas, and atmospheric deposition from agriculture and the burning of fossil fuels. Nitrogen and phosphorus are the most important nutrients for regulating the growth of planktonic algae, and hence water transparency and light conditions for seagrasses. Nutrients also stimulate the growth of algae living on seagrass leaves, causing additional shading and further diminishing the plants' ability to carry out the process of photosynthesis by which it lives.
The seagrass is heavely damaged by these factors because its recovery time is very slow and the growing rate is also very slow. Moreover the Mediterranean Sea is characterized by low water mobility and low pollutant dispersion, which are easily accumulated along the coast.

Climate change effects

High temperatures and prolonged heatwaves reduce *P. oceanica* shoot growth (Mayot et al*.*, 2005) and increase shoot mortality (Díaz-

Almela et al., 2007). Sexual recruitment may be enhanced by temperature, but the balance is still negative.

The observed trend in Mediterranean sea warming and the expected increase in the number of heatwave episodes (Cubash et al., 2001), as well as other observed trends in Mediterranean sea climate (e.g. a general reduction in water transparency and the greater frequency of severe storms, Duarte et al*.,* 1999) suggest that *P. oceanica* meadows will have to cope with enhanced climatic stress in the coming decades.

1.4 Conservation of *Posidonia oceanica* meadows

Seagrass is a key community type and its protection enhance and involved the conservation of wider systems and the protection of the overall biodiversity of marine environment as seagrass meadows do not exist in nature as separate ecological componenet from other marine plants and are often closely linked to other community types (see above and Short. 2001).

As seagrasses are habitat for juvenile fish and crustaceans that form the basis of economically valuable subsistence and/or commercial fisheries, the need to manage fisheries in sustainable way is a motivating factor for the protection of seagrasses.

Coastal management decision is complex as it comprehends: policy, legal document and local/regional regulation. Europe central Governement has develop legislation to enhance biodiversity protection which is supposed to be implemented by Member State or Regional Authorities (the last is the case of Italy).

Protection of seagrass by authorities with legal responsibility requires the support of complex information on ecological systems at the land water interface and community, industry, agricultural, aquaculture, conservation and fisheries needs. It also requires a public perception of the worth of seagrasses and especially of role of Posidonia meadows in the Mediterranean Sea.

Impacts on Posidonia meadows can be classified following the classification (Short F.T. and Coles R.G., 2001) shown in the table 1.1.

<table>
<tr><td rowspan="2">NATURAL IMPACT</td><td rowspan="2">MANAGEMENT ACTIONS</td><th>LONG TERM</th><th>SHORT TERM</th></tr>
<tr><td>Global warming (Warmer Water => loss of light, increase water depth, increase chlorophyll, algal blooms=> LOSS DEEP WATER SEAGRASSES)
Sea level Rises => LOSS COASTAL NEARSHORE SEAGRASSES ?</td><td>Floods
Storms
DISTRIBUTION and ABOUNDANCE SEAGRASSES VARIATION
Disease outbreaks
Grazing herbivores
Difficult
- Reduce Nutrient
- Sediment outflows with high rainfall</td></tr>
</table>

<table>
<tr><td rowspan="3">HUMAN INDUCED CHANGE</td><td rowspan="3">MANAGEMENT ACTIONS</td><th>INDIRECT</th><th>DIRECT</th></tr>
<tr><td>Shading from structures, nutrient loading, changes in Hydrology, Alteration to land or Water Management Practices in Watersheds Agricultural Chemicals, Acid Sulphate run off, Thermal loads

Complex set of tools/approaches</td><td>Land reclamation
Dredging
Sand Mining
Destructive or inappropriate fishing methods

Use of legislation/sanction</td></tr>
<tr><td colspan="2">Research and monitoring information
Complex info on ecological system at the land-water interface
Community, Industry Agricultural, Aquaculture, Conservation and Fisheries needs
Public perception of worth of seagrass
Sectors involved do think that they can bear a cost and that this coast is less worth than conservation
Support of enforcement system
➔ Management decision providing credibility and to enable management decision to survive appeals through a legal system</td></tr>
</table>

Table 1.1 Impacts on Posidonia meadows

The tables also give an overview of the possible management actions to be proposed when facing these impacts.
Dealing with natural impacts is difficult and out of the scope of this study, that is focused on identify actions to reduce human induced impacts.
The same provisions of the Habitats Directives as for the terrestrial areas regulate human activities in marine Natura 2000 sites. The provisions of Article 6 of the Habitats Directive apply if the effect of an activity, or a combination of them is likely to be significant.
The Communication from the Commission to the Council and the European Parliament of 24 October 2005, "Thematic strategy on the protection and conservation of the marine environment" is also a relevant policy document in which different pressures to the marine environment are identified.
This communication takes into account the environmental quality of the seas and oceans, giving a summary and a more extensive description of the situation. It highlights that the marine environment is under a series of pressures. These include loss or degradation of biodiversity, changes in the ecosystem structure, loss of habitats, contamination by dangerous substances and nutrients, and the potential consequences of climate change.
Related pressures include commercial fishing, oil and gas exploration, shipping, water-borne and atmospheric deposition of dangerous hazardous substances and nutrients, waste dumping including dumping of dredged contaminated sediments, under water noise pollution and physical degradation of habitats due to dredging and extraction of sand and gravel.
Public education and awareness is the base to improve biodiversity conservation and protection, specifically in maine areas where overexploitation and anthropication are typicals.

Pauly (1995, cited in Day, 2001) defined an interesting point for fisheries that should be take into account, when dealing with public environmental education: “each generation accepts the species composition and stock sizes that they first observe as a natural baseline from which to evaluate changes. This, of course, ignores the fact that this baseline may already represent a disturbed state. The resources then continue to decline, but the next generation resets their baseline to this newly depressed state. The result is a gradual accommodation of the creeping disappearance of resource species and inappropriate reference poits for evaluating economic loss…” (Pauly, 1995, cited in Day, 2001).

Ecosystem approach

The Convention on Biological Diversity defines the Ecosystem Approach as “a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way” and the ecosystem can be defined as “an interacting complex of living communities and the environment, functioning as a largely self sustaining unit.” It recognizes that humans, with their cultural diversity, are an integral component of ecosystems”.

To provide greater specificity for the purposes of the European Marine Strategy the Ecosystem Approach is described as ‘a comprehensive integrated management of human activities based on best available scientific knowledge about the ecosystem and its dynamics, in order to identify and take action on influences which are critical to the health of the marine ecosystems, thereby achieving sustainable use of ecosystem goods and services and maintenance of ecosystem integrity.’ This description clearly places humans as part of natural ecosystems, and stresses that human activities in these ecosystems must be managed so that they do not compromise ecosystem components that contribute to the structural and functional integrity of the ecosystem.

The elaboration of guidelines for the implementation in the marine environment of the so-called Ecosystem Approach has been one of the activities undertaken under the aegis of the European Commission during the preparation of the Environmental Marine Strategy.

In this context, the Ecosystem Approach is embedded in the concept of sustainable development, which requires that the needs of future generations are not compromised by the actions of people today. The Ecosystem Approach puts emphasis on a management regime that maintains the health of the ecosystem alongside appropriate human use of the marine environment, for the benefit of current and future generations.

1.5 Qualitative reasoning modelling

Increasingly, international policies and programs, such as the European Union's Strategy for Sustainable Development (http://ec.europa.eu/sustainable/) and the United Nations' millennium Development Goals (http://www.un.org/millenniumgoals/), are emphasizing the importance of developing consciousness about the factors affecting sustainable development. To support this call, developing qualitative reasoning models of issues relevant to sustainability can be a useful tool; the models are aimed at supporting learning about sustainable development in online interactive environments (http://www.naturnet.org/). Model building involves transforming initially vague and general ideas into clearer and more formally specified representations.

Qualitative Reasoning models can be used as tools for education and decision-making, particularly in domains such as ecology for which numerical data are often unavailable or hard to come by (Petschel-Held, 2005). Furthermore, Qualitative Reasoning models are explicit thereby requiring domain experts to make definite statements concerning the mechanisms being modeled. This makes statements falsifiable and discussable, thereby aiding scientific advancement.

Qualitative Reasoning is a formalism that abstracts from real valued numerical data, focusing on system states exhibiting essential distinct behaviour. Garp3 is a fully operational workbench for knowledge capture that provides tools for building Qualitative Reasoning models, simulating them and inspecting the results, using various graphical aids (Bredeweg and Salles, 2009).

Typical Garp3 models involve many different ingredients: Entities represent the structural elements of the system, and agents represent the structural elements exogenous to the system. Configurations indicate the structural relations between entities (and agents). Quantities are associated to entities and agents, representing their dynamic properties. The behaviour of a Quantity is captured by its qualitative Values, symbolic abstractions of the object's continuous properties. The pair <magnitude, derivative> represents the amount and the direction of change of a quantity, respectively. The set of possible values for both magnitudes and derivatives is defined as their quantity space. In Garp3 (Bredeweg et al., 2006, 2009), the quantity space consists of a sequence of points and intervals. For magnitudes, the quantity space is defined by the user, e.g. {zero, low, medium, high}. Derivatives have a default quantity space: {minus, zero, plus}. Landmark Values capture critical points where the system dynamics change.

Important for QR models is the explicit notion of causality between different quantities. Garp3 represents the causal dependencies using direct and indirect influences (Forbus 1984). Direct influences (Influences: I+, I-), called influences for short, can be either positive or negative. If there is a quantity (Q1) with positive magnitude and it puts a positive direct influence on another quantity (Q2), then the derivative of Q2 increases by an amount equal to Q1, and causes the quantity Q2 to increase, while it will have no effect when magnitude

is zero. For a negative influence, it is the other way around.
The indirect influences, called proportionalities (Proportionalities: P+, P-), can be either positive or negative. They represent monotonic relations that propagate the effects of processes. If there is a quantity Q2 that is increasing (that is, has a positive derivative) and it is related to another quantity Q3 by a positive proportionality (P+), then the derivative of Q3 takes the same value of the derivative of Q2, and Q3 also increases. If the proportionality is negative (P-), then Q3 will change in the opposite direction.

Other dependences include several types of correspondences (indicating corresponding values) and inequalities {b, ≤, =, ≥, N}. Correspondences may establish value simultaneity either between specific values in the quantity space (V-correspondence) or between the whole quantity space (Q-correspondence). Inequalities may establish relations either between a quantity and a specific value (of magnitude or derivative), or between two quantities.

A model is built from scenarios representing starting configurations of ingredients, and model fragments that represent conditional knowledge chunks using the above described ingredients.

A simulation is generated by searching for all applicable model fragments for a given scenario, resulting in one or more states. These are then analysed for possible transitions (changing values, changing inequalities, etc) generating successor states. This process continues until no more new states are found.

The output is a state-graph showing all states and their transitions. Each state contains a substantial amount of information and can be inspected using several diagram types. The value history is an important diagram listing the successive magnitudes and derivatives for one or more quantities over the course of a number of states (also known as a 'behaviour path').

These modeling elements and their functioning are thoroughly described in Bredeweg and Salles (2009) and Bredeweg et al. (2009).

2. METHODOLOGY

2.1 The Studying Site

The study was conducted in a *P. oceanica* meadow within the N2000 SCI named IT6000007 “Fondali antistanti Santa Marinella”.

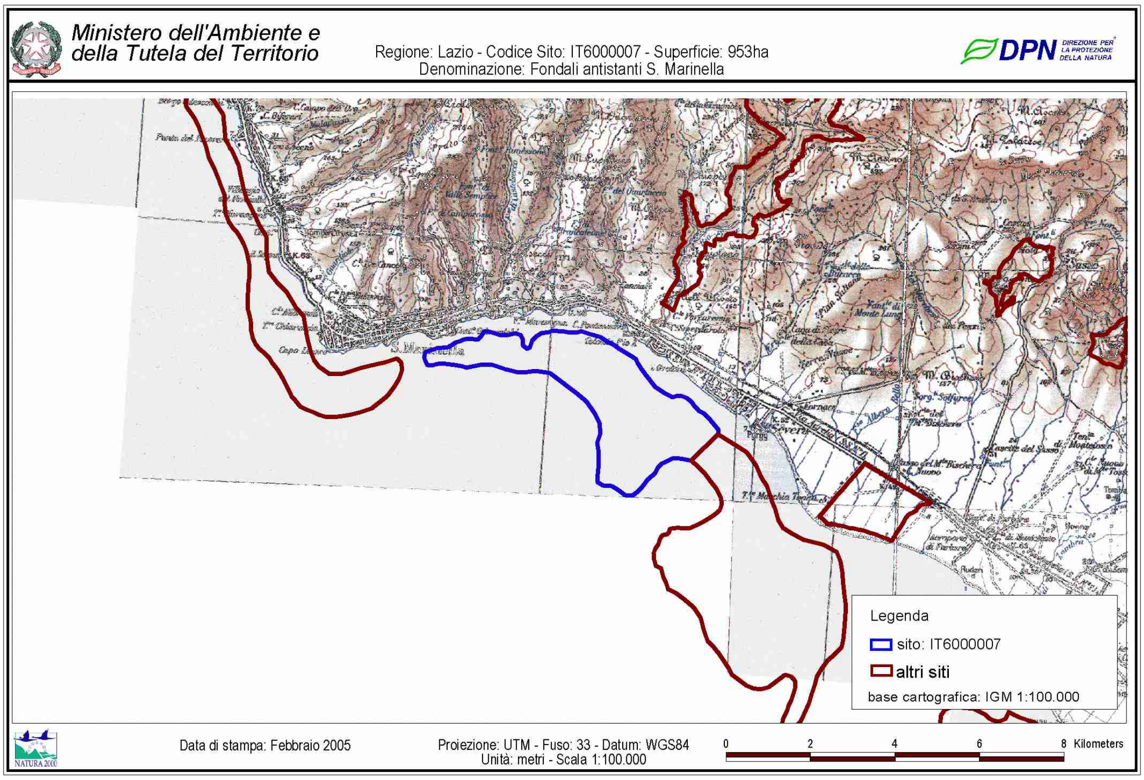


Figure 2.1. Study area

The site (fig.2.1) borders with two others marine N2000 and it is close to an inland SCI. Its surface is 953,00 sqm and it goes from –3 m to –25 m. It is located in the Mediterranean biogeographic region. 15% of the site is covered by habitat 1120*, *Posidonia oceanica* meadow. No other relevant information is provided in the official SDF.

S. Marinella area is located on the Tyrrhenian Coast approximately

65 km NW of Rome. It is a tourist place mainly for the inhabitants of Rome and the large population increase occuring in this area every summer has adversely affected the local environment; groundwater pumping has caused salt-water intrusion while uncontrolled waste disposal has created surface hazards and pollution sources. In addition, the inhabitants of S. Marinella are at risk themselves due to the presence of inadequately controlled ephemeral streams, which have caused enormous damage to people and property during past anomalous meteoric events (Chiocchini et al., 1997).

The sea area is between 5 and 25 m deep and it is characterized by rocky bottom, matte, sand and mixed bottom; the typical sediments are medium-fine and medium course sands. Medium-fine sands patches alternated by medium courses sand can be seen in the shallow areas. Medium course sands characterize intermatte patches within the meadow.

There are small areas with transverse sedimentary structures such as “ripple” or small underwater dunes (Ashley, 1990), which wave length range between 0.6 and 1.2 m. They are found on course sediment and they show a reduced idrodinamism.

The meadow of Santa Marinella begins north of Cape Linaro and stops at the estearn side of the mouth of Rio Fiume, a small patch can be also found in front of Santa Severa town; it is named “Santa Marinella” as the town where its main surface is found.

The area is characterized by high sea-water turbidity.

Morphological framework

The terrestrial study region consists of the urban area of S. Marinella, located between the Rome-Civitavecchia Highway (A12) and the Tyrrhenian Coast. This area represents the southern extension of the Tolfa Mountains, forming a cape (Cape Linaro) that ranges in

elevation from 85 m asl to sea level. This belt slopes gently towards the Tyrrhenian Sea, particularly between the Rome-Pisa rail line and the coast where the oldest urban part of S. Marinella is located, and could represent a marine erosional surface whose deposits were largely eroded.
The dominant winds during the 2006-2009 (fig.2.2) were S, SSE and NE, according to the data recorded by ISPRA- Rete Mareografica Nazionale (http://www.mareografico.it) with a frequency of about 15%, 12.5% and 12.5% respectively.

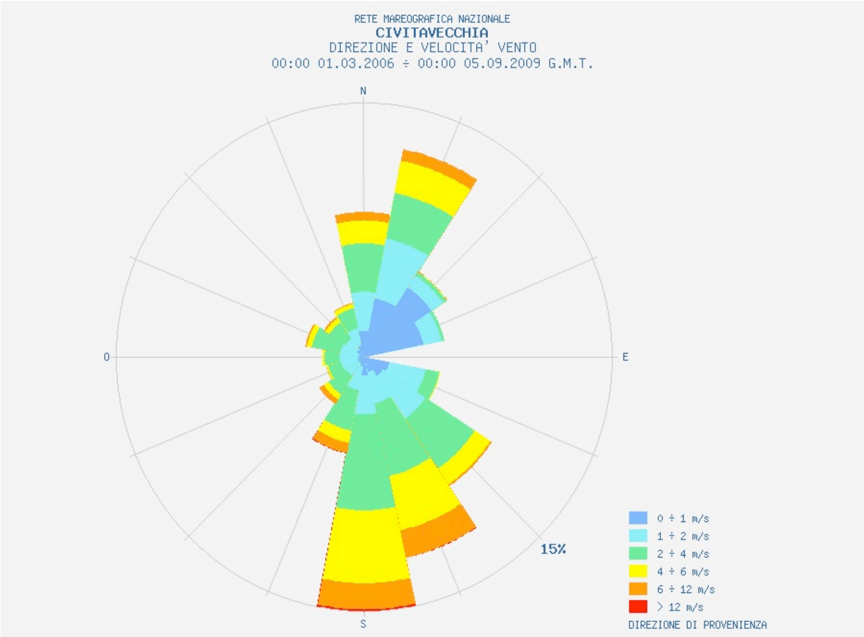


Figure 2.2. The dominant winds in the study area during the 2006-2009

The coast is almost low and largerly eroded, from the mouth of Marta river (north of S. Marinella) to Ladispoli (south of S. Marinella) often without sand, with outcrop of clayey river-lake bottom or high coast with small sandy *pocket beach*. Course sand is found only where sea bottom gentle decrease, as between Cape Linaro and Palo Laziale. This area has rocky sections and inlets with predominantly gravel beaches. With the exception for an old landslide, which occurred in the central part of the study area, the region is presently stable.

Sea Bottom types

The continental shelf here is influenced by the solid contribution of the Tevere River and until Ladispoli the bottom is mainly represented by sandy silt, which limit inland is connected with the bioconstruction distribution: where several bioconstructions are spread the sandy silt inland limit is in deepest bottom (eg. near cliffs), where there are inlets the inland limit of sandy silt is on shallow bottom.

The lackness of predominant sandy sediments is an indication of low contribution from inland and of the bioconstruction's block action SE.

Drift coastal sediments.

Specifically in the area the sediment is mainly (about 80%) characterized by course sediment (>200μ) and a lower percentage (about 20%) of fine sediment (from <2μ to 63μ). The organic substance's quantity is between 0,17 and 0,54%.

Hydrology

S. Marinella hydrology can be grouped within the larger Tolfa region, which consists of a number of variably sized basins. Locally 14 ephemeral streams, 1–10 km long and trending N–S, flow through S. Marinella before discharging into the Tyrrhenian Sea. These streams form a series of alternating ridges and valleys typical of the coastline, which have an average slope of 6% and a maximum valley width of a few hundred meters. Based on length and watershed size, Castelsecco Creek is the most significant of these ephemeral streams and its headwaters are located 10 km away from S. Marinella at an altitude of 500 m asl. Erosion occurs along these waterways during the "wet season" in winter and along the coast due to waves action.

The main aquifer in the S. Marinella area consists of the Pietraforte turbiditic sandstones, which permeability is due to fracturing of the rock mass. The piezometric surface indicates that aquifer recharge is from the Tolfa Mountains area to the north of S. Marinella. This observation concurs with findings reported by Boni and others (1986) in a hydrogeological study of central Italy. As expected the same piezometric contours follow the morphological trend of the coastline and groundwater flow is orthogonal to the coast.

Locally, the sediments of this area contain very limited and irregular perched water tables which are, for the most part, seasonal. One of these perched water tables was examined in some excavated wells near the coast on the Cape Linaro Belt (Chiocchini et al., 1997); the level in these wells fluctuate significantly, even disappearing (in some cases) during the summer months, showing the seasonality of the water regime.

The water sampled does not show high organic pollution; in addition, ammonium, nitrite and phosphate values are very low. Generally trace metal pollution is not significant, as low to medium levels are found for these elements. This fact is probably related to the absence of high industrialization in the area of S. Marinella (Chiocchini et al., 1997.)

Socio economic framework

The stable residential population of the S. Marinella area is around 16.800 inhabitants, whereas during the summer vacation period (June–September) the population expands, reaching a maximum of 80.000–100.000 in August.

Observing the data from the last available samples of ISTAT (Statistical National Institute), the stable population is increasing in the whole area (Allumiere, Cerveteri, Tolfa, Civitavecchia and Santa Marinella) and mainly in Santa Marinella and Civitavecchia. Probably high frequency trains (every 30 minutes) of Regional Service FR5 of the Province of Roma enhanced the chance of living in this area while working in Rome.

Tourism in the area is highly related to the vicinity of the city of Rome; tourism structures are mainly located in Civitavecchia and Santa Marinella; in 2004, the hotels' bed sites recorded there were 811 and 723 respectively. The solely camping site of the area is located in Civitavecchia and it can host 1000 persons.
Only 4 agritourisms have been recorded in the area and they are mainly located inland, in Cerveteri municipality. Two harbours are in the town of Santa Marinella: Riva di Traiano, located near Civitavecchia, hosting 1.180 boats thanks to 12 quays; Odescalchi, located near the SCI, hosting around 200 boats.

2.2 Biocenosys mapping and site boundaries assessment

The meadow of Santa Marinella has been studied in the past, around 1990 SNAM Progetti has done the first cartography of the meadow which has been published as Diviacco et al. (pers. com. Fresi), around 2000 Conisma processed a new cartography of the area during the monitoring financed by Port Body of Civitavecchia. (Autorità Portuale Civitavecchia and ConiSma – Monitoring of the coastal areas, 2001). The cartography here presented is based on bathy-morphological information on the sea bottom acquired thanks to survey with Single Beam and Side Scan Sonar system (GeoAcoustic 160Dwith a frequency between 100 and 500 kHz) during the first phase of the project "Recupero e reinserimento di *Posidonia oceanica*" financed by ENEL following the Ministry of Environment prescription for the widen of Torrevaldaliga thermo-electric power plant. The bathimetric survey has been undertaken between 25 m deep and the minimum deepness reacheable with the boat.
The cartographic data has been integrated by underwater video previously acquired and by a sample campaign to characterize coverage, density and phenology of the meadow This processs allowed the identification and description of the biocenosys and sea

bottom types at the area.

A GIS map has been edited after having acquired Autocad files in GIS environment. Poligon have been drawn using ArcView 3.2 and saved as shape files.

Quantification of the surface occupied by different biocenosis and sediment types has been calculated.

The legend has been elaborated to show the principal biocenosys found in the area following, wherever possible, the classification of Meisnez (Meisnez et al., 1983) and the habitats typology codified by the Directive 92/43 CEE Annex 1.

In the area 4 different themes corresponding to habitat 1120* have been identified: *P. oceanica* on rocks, *P. oceanica* on sand and *P. oceanica* on matte interspersed with dead matte.

The boundaries of the meadow have been detemined based on the positions of survey sites and the presence of seagrass, coupled with depth contours and other information from SSS samples. The edges have been classified following the 4rth typologies classification (Meisnez and Laurent, 1978; Pergent et al, 1995), which distincts between progressive edge; clear edge; erosive edge or regressive edge. The distinction between edges has been used to assess the quality state of the meadow.

Furthermore this map has been overlapped with the official perimeter of the site (Environmental Ministry database) identified by the Lazio Region and attached to the N2000 SDF. This process allowed the evaluation of the perimeter designation.

All the cartographies produced have been acquired or digitalized and georeferred in the Geographic System European Datum 1950 UTM zone 33 N.

Habitat coverage

The percentage of coverage of the whole site has been calculated thanks to ArcGis through the editing of the poligon of living Posidonia within the site's perimeter. The % of coverage has been calculated as the share of the total SCI surface covered by Posidonia sparse.

2.3 Posidonia meadow conservation status evaluation

Knowing the conservation status of the habitat is a fundamental step to identify and implement good conservation strategy for preserving a site in the long term.

According to the Habitats Directive, the degree of conservation of a habitat comprehends the consideration of the degree of conservation of the structure, the degree of conservation of the functions and the restoration possibility.

This study focused on the degree of conservation of the functions of the Posidonia meadow using the 'best expert judgment'. The methodology used to build the best expert judgement is here described.

<u>Building best expert knowledge</u>

To judge the conservation status of the meadow's function, a deep knowledge need to be constructed.

The fundamental steps used to build the expert knowledge were:

- Documentation on similar meadows in the same area
- Use of PosiPred- predictive model
- Data collection and processing
-

Documentation

Existing literature on density and production data for meadows located in similar area have been collected.

The area is defined as Central thyrrenian East sector and part of

northern Thyrrenian, as defined by the Italian marine service.
Several data used for the comparing comes from the RIPO project ("Rivisitazione di alcune praterie di *Posidonia oceanica* lungo le coste delle regioni Liguria, Toscana, Lazio, Basilicata e Puglia e progetto pilota per l'armonizzazione dei relativi dati cartografici esistenti"- Conisma-2002), implemented by Conisma for the Italian Environmental Ministry.
The expected Pergent Class (see next paragraph) has been calculated and per each data, references, locations, deepness, density and expected Pergent class were listed in a table, compared and discussed.

Data Sampling
Data on density were collected 4 times a year; data on production were collected ones a year (on march) during 2006 and 2009.
13 clearings were randomly set in the western part of the meadow, estaern to the Santa Marinella Harbour, within the area in which it was demonstrated the presence of phanerogams (i.e. 'weeds') by the SSS samples. This area has been chosen as it can be considered as representative of the whole site, in fact it comprehends all the different bathimetries found in the study meadow and all different typology of sea bottom: living and dead matte, fine and course sands. It has also be chosen because it is easy and cheap to reach with a small boat.
20 sampling stations were chosen in 13 clearings and their positionings were based on an UTM/UPS grid (zone 32T).
Every station point has been marked during the first sampling monitoring with a yellow buoy at to 2 meters from the sea bottom using a stake (fig. 2.3).

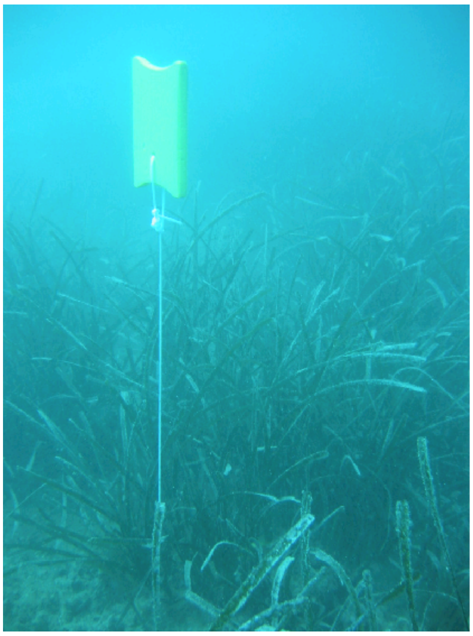


Figure 2.3. Sampling station

The station points have been marked during the first campaign using a narrow strip attached at the base of the rhizome (fig. 2.4). So they were easily recognizable during the following campaign.

Figure 2.4. Sampling station

Cartesian coordinates of the sampling stations as well as their clearing code, their depth and sea floor cover (S= sand; M= matte; R= rocks) are shown in the table below (tab 2.1).

station	clearing	coordinate		deep. (m)	Bottom
1	59PNA	740006	4657987	8,5	M
2	59PNB	740026	4657994	8,5	M
3	53PNA	740057	4657961	10	M-S
4	37PNA	740120	4657882	13	M
5	33PNA	739952	4657814	14	M-S
6	33PNB	739939	4657815	13	S-M
7	3PNA	738649	4657877	9,5	M
8	4PNA	738679	4657836	10,5	M-S
9	4PNB	738644	4657838	10,5	S
10	5PNA	738743	4657829	10,5	M
11	5PNB	738756	4657842	10	M
12	6PNA	738777	4657960	8,5	S
13	6PNB	738782	4657998	8	S
14	66PNA	738928	4657960	9	M-S
15	66PNB	738901	4657946	9	M-S
16	13PNA	739268	4658009	9	S
17	67PNA	738523	4657754	12	S
18	69PNA	738575	4657757	11,5	M
19	69PNB	738593	4657769	12	S
20	70PNA	738649	4657775	11	M

Table 2.1

Shoots' density was measured by SCUBA divers after diving from a boat and carrying a square frame and a chalkboard each; they counted the shoots within five square frames (40 x 40 cm) randomly located in the *P. oceanica* bed around each station point.

Afterwards, the mean value of the five counts was converted to density expressed as shoots x m^{-2}. Two divers have independently assessed the percentage of sea floor that was actually covered by *P. oceanica* within the circular sampling area. The percentage of the sea floor has been estimated as decimal number (semi-quantitative scale). Then the mean coverage percentage was assumed as the best estimate of sea floor cover, which is also needed for computing relative density (i.e. absolute density x R- sea floor cover, also defined as 'global density' by Romero, 1985).

The purpose of these two ways of evaluating density is obviously not the same, as well as their interpretation.

Absolute density is more closely related to the health of the bed and to its short-term dynamics; whereas relative (or global) density is more useful in ecosystem scale studies and reflects the outcome of long-term colonization dynamics (Romero, 1985). Both densities have been discussed to describe the meadow and its conservation status. Specifically the relative density has been used to classify the meadow following the Pergent classification (see next paragraph). Absolute density has been used to compare the real data with the expected density following the Posipred model.

The number and biometry of living leaves (leaf shoots) were determined using the method of Giraud (1979). The dry weight (72 h, 60 h) of the oldest leaf from each shoot was also measured.

Foliage growth has been measured following the method of Zieman (1974), and the average leaves's Primary production per shoots in g year^{-1} (Pps) has been calculated as (L x N x Dx Bat. correction coeff.).

The rhizomes weight (mg dry wt) has been determined by measuring the weight of a mature (fully expanded) rhizome segment (internode and associated note) after cleaning, rinsing in freshwater and drying for 24 hr at 60°C.

The production is calculated as the mean of the weights of every rhizome's part for every lepidochronological year (mg dw shoot^{-1} year^{-1}).

Statistical analysis

Data were analysed by univariate and multivariate techniques. Correlation between variables has been tested through draftsman's plot of a transformed matrix. Correlation lower then 0.7 have been considered as threashold to keep the variable for successive analysis.

Differences between the absolute density, the relative density, the primary production, the rhizomes production and the number of leaves per shoot in the two areas, at various depths and different

bottom types were analysed using Non-metric multidimensional scaling (nMDS; Clarke & Warwick 2001). The analysis has been performed on a Euclidean resemblance matrix of the fourth-root transformed data.
Based on the null hypothesis that no differences existed among the different depth values, absolute density and relative density vs depth have been analysed through a one-way ANOVA.
All the analyses were performed using the sofwares: PRIMER6 & PERMANOVA+ (Clarke & Warwick 2001; Anderson et al. 2008), and STATISTICA.

PosiPred prevision model use

To assess the status of *Posidonia oceanica* meadows a model developed by CoNISMa for the Environmental Ministry has been used. The model runs thanks to a specific software (PosiPred), and its development has been based on an artificial neural web and it allows the estimation of the absolute density and the rhizomes primary production of *Posidonia oceanica* meadows. PosiPred model can calculate the potential average absolute density and the potential rhizome production foreseen on the base of the morphological sea bottom characteristic in the observation point. The production estimation is much more accurate if the absolute density is known, thus the model have been run twice per each point:

1) Introducing only the predictive variables to calculate the absolute density;
2) Introducing the predictive variables and the absolute density to calculate the rhizomes production.

Specifically, the model is based on a heterogeneus group of predictive variables, from which density and production can be estimated. The variability range of each predictive variable is written in brackets near each of them and is specifically written as (0/1) for binary variable. Also for them it is possible to indicate an intermediate value (eg. 0.5), which can assume the meaning of a fuzzy coding (eg. To be used if the probability of mooring is limited, instead of asserting or excluding it at all).

In the figure below the list of the variables to be inserted in the software, is given (fig.2.5).

variabile		ID
lat. (gradi decimali)		LAT
long. (gradi decimali)		LON
profondità (m)		PROF
gradiente		GRAD
concordanza esposizione		CONCESP
concordanza venti dominanti		CONCVENT
conformazione profilo batimetrico	concavo	CONC
	piano	PIANO
	convesso	CONV
runs variazione profilo		RUNS
"apertura" litorale		APERTLIT
esposizione ai venti dominanti		ESPVENTI
tipologia fondale	sabbia	SABBIA
	roccia	ROCCIA
	matte	MATTE
sorgenti di disturbo	ancoraggio	ANCOR
	inquinamento	INQUIN
	immissioni	IMMISS
variabili da predire	dens ass media	DENSASS
	prod rizoma	PRODRIZ

Figure 2.5. List of the variables inserted in the software

Fundamental indication regarding the single predictive variables and the way of obtaining and expressing numerically them can be found below:

- **Latitude in degree and decimal (39.9-44.4)**

  Use degree and degree's fraction.

- **Longitude in degree and decimal (7.5-18.6)**

  Use degree and degree's fraction.

- **Deepness in meter (0.0-35.0)**

  Can be insert also not full value (es. 12.5).

- **Gradient (0.0-0.3)**

  As average slope of the sea bottom between the bathymetric curve closest to the observation point. Its value can be theorethycally between 0 and 1, but it is maximum 0.3 in the present data.

- **Concordance gradient- aspect (0/1)**

  Its value is 1 if the direction of the maximum slope of the sea bottom on the observation point is oriented to the fowlwind sector of the site, otherwise 0

- **Concordance gradient- dominant wind (0.0-1.0)**

  If the direction of the maximum slope of the sea bottom its on the same sector of one of the dominant wind, it has a value that represent this wind frequency in a range between 0 and 1, itherwise its value is 0.

- **Bathimetric outline conformation: concave, plain or convex (0/1)**

  Considering a line that spin on the observation point, it obviously intersects the upper and lower bathimetric, but in some cases it can intersect the upper or lower bathimetric twice.

  In the first case the outline is considered concave- thus the point is on a sea bottom depression-, in the second case the outline is convex – thus the point is on a ridge higher than the closes areas. In the case there is no intersection within half miles of ray, the conformation to be choosen is neutral.

- **Runs outline variation (0-4)**

  It measures the heterogeneity of the bathimetry around the observation point. It is so defined: observing where it falls a point far away a quarter of mile from the observation point in direction of 0°, 45°, 90°, ..., 315°. The value is 0 if the point falls between the bathimetric that comprehend the observation point, the value is +1 if the point falls over or –1 if the point falls below. It is counted the number of value's changes between following elements of the so obtained's 8 elements series, including the case of the comparison between the eighth and the first value (the series is develop on an ideal circumference). This number is equal to the same value's sequence of the series, thus to the number of sectors within the same bathimetric area and around the observation point. In the particular case in which no changes are present, the homogeneity of the bathimetric is represented giving a void value.

- **Spread of the waterfront (1-5)**

  Expressed as the number of eighties within the foul wind sector.
- **Dominants winds aspect (0.0-1.0)**

  Expressed as the sum of the products between the membership to every eighty sector to the observation point's foul wind sector (expressed in binary form) and the frequency of the wind coming from the same eighty (expressed as value in the range 0 and 1 and considering only the dominant wind).
- **Sea bottom type: sand, rock and/or matte (0/1)**

  As binary values, not mutually exclusive, to indicate the presence or the absence of sand, rock and matte.
- **Disturbing sources: mooring, pollution and/or intake (0/1)**

  As binary values, not mutually exclusive, to indicate the presence or the absence of: (1) mechanical damage due to moorings, deads weights, etc; (2) industrial, urban, harbour pollution, etc.; (3) intake of sewage from rivers, water purifier, etc.

The predictive variables per each sampling station are listed in table 2.2.

	PREDICTIVE VARIABLES																			
	Geographycal coordinate (degree and decimal)												sea bottom types			disturbing sources			POSIPRED OUTPUT	
station	N	E	Deepness (m)	gradient	concordance gradient	concordance gradient/wind	concave streamline	plain streamline	convex streamline	runs	spread of waterfront	dominant wind aspects	sand	rocks	matte	mooring	pollution	intake	expected density (shoots m2)	expected production gm-2 year -1
M.1	42,036589	11,899405	8,5	0:02	1	0,15	0	1	0	2	3	0,28	0	0	1	1	1	1	**288**	**24**
M.2	42,036646	11,899649	8,5	0:02	1	0,15	0	1	0	2	3	0,28	0	0	1	1	1	1	**288**	**24,7**
M.3	42,03634	11,90001	10	0.009	1	0,15	0	1	0	2	3	0,28	0,5	0	0,5	1	1	1	**291**	**30,8**
M.4	42,03561	11,900737	13	0.008	1	0,15	0	1	0	2	3	0,28	0	0	1	1	1	1	**229**	**20,3**
M.5	42,034986	11,898692	14	0.009	1	0,15	0	1	0	2	3	0,28	0,5	0	0,5	1	1	1	**238**	**18,5**
M.6	42,035062	11,898526	13	0.009	1	0,15	0	1	0	2	3	0,28	0,5	0	0,5	1	1	1	**251**	**19,2**
M.7	42,036012	11,882987	9,5	0:01	1	0,15	1	0	0	4	3	0,28	0	0	1	1	1	1	**471**	**28,6**
M.8	42,035634	11,883332	11	0:01	1	0,15	1	0	0	4	3	0,28	0,5	0	0,5	1	1	1	**402**	**26,6**
M.9	42,035663	11,882911	11	0:01	1	0,15	1	0	0	4	3	0,28	1	0	0	1	1	1	**325**	**22,3**
M.10	42,035552	11,884102	11	0:01	1	0,13	1	0	0	3	3	0,28	0	0	1	1	1	1	**399**	**29,7**
M.11	42,035665	11,884264	10	0:01	1	0,13	1	0	0	3	3	0,28	0	0	1	1	1	1	**408**	**24,8**
M.12	42,03672	11,884565	8,5	0:01	1	0,13	1	0	0	4	3	0,28	1	0	0	1	1	1	**367**	**31,7**
M.13	42,03706	11,884641	8	0,01	1	0,13	1	0	0	3	3	0,28	1	0	0	1	1	1	**322**	**30,4**
M.14	42,036674	11,886387	9	0:01	1	0,13	1	0	0	4	3	0,28	0,5	0	0,5	1	1	1	**377**	**28,6**
M.15	42,036556	11,886056	9	0:01	1	0,13	1	0	0	4	3	0,28	0,5	0	0,5	1	1	1	**435**	**29,5**
M.16	42,037011	11,890509	9	0:02	1	0,15	0	0	1	4	3	0,28	1	0	0	1	1	1	**365**	**22,2**
M.17	42,034944	11,881417	12	0:02	1	0,15	0	0	1	2	3	0,28	1	0	0	1	1	1	**240**	**20,4**
M.18	42,034955	11,882045	12	0:02	1	0,15	0	0	1	2	3	0,28	0	0	1	1	1	1	**377**	**19,3**
M.19	42,035057	11,882267	12	0:02	1	0,15	0	0	1	2	3	0,28	1	0	0	1	1	1	**240**	**18,9**
M.20	42,035094	11,882945	11	0:01	1	0,15	0	0	1	2	3	0,28	0	0	1	1	1	1	**383**	**22,2**

Table.2.2. Predictive variables per each sampling station

Expected Pergent class

The status of the meadow has been assess also classifying the meadow using the Pergent classification which is based on the fact that density and meadow depth are strictly connected; although density is also related to light intensity, to turbidity, to bottom type, etc.

Based on the shoot density (calculated as n° of shoots/sqm)40 Pergent et al. (1995), differentiated between balanced meadow (characterized by normal or exceptional density), disturbed meadow (characterized by low density) and high disturbed meadow (characterized by abnormal density) (see also the table below for the classification values between 5 and 15 m depth).

40Deep 40(40m 40)40	**High disturbed meadow**	**40Disturbed meadow**	**Balanced meadow**	
	Abnormal density40 40(40shoots/sqm 40)40	**Low density40 (40shoots m^{-2})40**	**Normal density (40shoots m^{-2})4040**	**Exceptional density (40shoots m^{-2})40**
5	40Less then 413	40Between 413 and 52540 40	40Between 525 and 749	40More then 749
406	40Less then 367	Between 367 and 479	Between 479 and 703	More then 703
40740 40	40Less then 327	Between 327 and 439	Between 439 and 663	40More then 66340
40840 40	40Less then 294	40Between 294 and 406 40	Between 406 and 630	40 More then 630
9	Less then 264	Between 264 and 376	Between 376 and 600	More then 600
4010	40Less then 237	Between 237 and 349	Between 349 and 573	More then 57340
401140 40	40Less then 213 40	Between 213 and 325	Between 325 and 549	More then 549
401240 40	40Less then 191	Between 191 and 303	Between 303 and 527	More then 527
401340 40	40Less then 170	Between 170 and 282	Between 282 and 506	More then 506
401440 40	40Less then 151	40Between 151 and 263 40	Between 263 and 487	More then 487
401540 40	40Less then 134	Between 134 and 246	Between 246 and 470	More then 470

Table 2.3.

Both relative and absolute density have been discussed calculating Pergent class, in fact absolute density is more closely related to the health of the bed and to its short-term dynamics; whereas relative (or global) density is more useful in ecosystem scale studies and reflects the outcome of long-term colonization dynamics (Romero 1985).

Specifically, when comparing with other meadows already studied by authors, absolute density and correspondent Pergent class (1995) has been used (tab 2.3).

2.4 Human activities and threats

The Human activities at the site have been identified using the classification and the codes proposed by the Natura 2000 Standard Data Form, Explanatory Notes. Per each activity it has been assessed, the impacts related to all human activities and natural process that may have an influence, either positive or negative, on the conservation and management of the site.

The categories used are eight and they are:

- Agriculture, Forestry and animal breeding
- Fishing, hunting and collecting
- Mining and extraction of materials
- Urbanisation, industrialisation and similar activities
- Transportation and communication
- Leisure and tourism
- Pollution and other human impacts/activities
- Human induced changes in hydraulic conditions (wetlands and marine environments)

The identification of threats and their location in the territory around the SCI has been shown in a map.

In order to achieve the environmental objectives, the planning scale should be the river basin district with its associated coastal waters, thus the area considered for drawing the map and the related elaborations is the water basin district.

The EC, in fact, suggests the development of conservation measures for marine SCI as part of a wider river basin management plan, thus analyzing the land at this scale has been considered fundamental.

The map has been edited using ESRI, ArcView 3.2 and adding different layers. The layers have been collected from the Database of the Regional Public Administrations of Lazio- SIRA (Sistema Informativo Regionale Ambientale) or through local investigations undertaken in the last year (2008-2009).

Layers contains tables associated to lines, polygons or points, themes have been developed by the information listed in the tables.

The themes edited and how they were developed is explained below.

AGRICULTURAL AREAS: from Corine Land Cover 2000 poligons of codes

2111, Arable land prevailingly without dispersed vegetation

2112, Arable land with scattered vegetation

2113, Greenhouses

2121, Permanently irrigated land

2122, Arable land with scattered vegetation in irrigated land

2123, Greenhouses in irrigated land

221, Vineyards

222, Fruit trees and berry plantation

223, Olive groves

231, Pastures

241, Annual crops associated with permanent crops

242, Complex cultivation patterns

243. Land principally occupied by agriculture, with significant areas of natural vegetation

URBAN AREAS: from Corine Land Cover 2000 codes

11, Urban fabric

1111, Areas of urban centre

1112, Areas of ancient cores

1121, Discontinuous built-up areas with multiflat houses prevailingly without gardens

1122, Discontinuous built-up areas with family houses with gardens

1123, Discontinuous built-up areas with greenery

1221, Road network and associated land

1222, Rail network and associated land

1225, Energy ditribution, production and transport network

1226, Water distribution network and areas and catchment system

1332, Artificial soils

1421, Sport facilities

1422, Leisure areas

1423, Fun Parks

143, Burying grounds

FORESTAL AREAS from CLC2000 code

22411, Poplar, Willow and other broad-leaved forest

22412 Conifers rapidly growing

2242, Chestnut grove for fruit

2243, Other cultivation (eucalyptus)

244, Agro-forestry areas

3242, Natural young stands

NATURAL LAND AREAS from CLC2000 codes

311, Broad leaved forests

312, Coniferous forest

313, Mixed forest

321, Natural grassland

322, Moors and heathland

323, Sclerophyllous vegetation

3241, Young stands after cutting (and/or clear cuts)

331, Beaches, dunes, sands

332, Bare rocks

333, Sparsely vegetated areas

NATURAL WETLANDS and WATER BODIES from CLC2000 codes

411, Inland marshes

421, salt marshes

422, Salines

5121, Natural water bodies

521, Coastal lagoons

522, Estuaries

INDUSTRIAL AREAS from Corine Land cover 2000 code

1211, Industrial and commercial unit

1212, Areas of special installations

1213, Installations of Public and private services system

1214, Hospitals

1215, Technological system installations

1223, Big Commercial installation

1224, Communication system areas

1331, Construction sites

and from S.I.R.A.

Industrie a rischio. shp for the Risk industry

Siti industriali contaminati.shp for the Polluted industrial sites

PORT AREAS from CLC2000 code

123, Port areas;

CAVES from CLC20000 code

131, Mineral extraction sites

and from S.I.R.A. cave.shp

ARTIFICIAL WATER BODIES

5122, Artificial reservoir for irrigation

5123, Artificial reservoir for other productive scope

5124, Acquaculture

GREEN AREAS from CLC2000

141, Green urban areas

1424, Archeological sites

RIVERS from S.I.R.A.

Complete_water_network.shp

SEAWORKS from interpretation of aerial photographs confirmed by local investigation ;

MOORINGS AREAS from local investigations during summer 2009;

URBANS DISCHARGE from S.I.R.A.
Scar_urb.shp (points)
INDUSTRIAL DISCHARGE from S.I.R.A.
Scar_ind.shp (points).

The goal of the map is to show a view of the terrestrial and marine areas where the site is located underlying the humans' activities that characterize the studying site. The map edited includes information on environmental typologies, and also on their importance in terms of surface. It has also intrinsically included a quantitative estimation that allows us assess the degree of influence of the different land use pattern on the landscape conservation state.

Measuring Index of Landscape Conservation
In our starting assumptions the strong influence in the area of several anthropogenic factors on the landscape (agriculture, livestock, urbanization, harbour) was supposed. The 10 landcover typologies in the map used to classify the human activities at the study area, were grouped into 7 new categories, following the conversion table used by Pizzolotto and Brandmayr (1996). The coverage of each category was calculated by summing the realtive surface of the first mapped category. The whole study area extends over a surface of 28198,9 ha. It is possible to give a general idea of the conservation state of the study area by the GPLC (Graphical Pattern of Landscape Conservation state) (Pizzolotto & Brandmayr, 1996) drawn on the basis of the calcuklation of the cumulative percentage of each category. A sinthetic index of conservation degree (Index to evaluate Landscape Conservation- ILC) of the environment that can be applied at the landscape level has been calculated as ILC= 1- (A/Amax) where A= Xi -100 and Amax = 100*(nc-1) with nc as the number of the categories used. The index ranges from 0 to 1 and it is proportional to the importance of the conserved natural environments.

Identification of impacts

The impacts identified at the site on the Posidonia meadows have been classified as natural or human induced, as described in the table atttached in the introductive chapter. This study focused on the humans induced impacts, which can be differentiated as direct or indirect.

The identifications of threats and impacts caused by humans' activities on Posidonia meadows have been done analyzing the scientific available literature on that topic.

A table that shows the connections between humans' activities, threats and impacts on Posidonia meadows has been built. It is a fundamental tool for public administrators, helping them to understand these connections during the planning process.

The table also shows the intensity of the influence on the site of the activities, which represent a threat for the site protection.

The following categories have been used to classify the influences:

A: high influence

B: medium influence

C: low influence

An indication whether their influence is positive (+), neutral (0) or negative (-) is also specified.

The impacts and activities in the surroundings of the site have also been described using the same categories. The surroundings are the areas where the outside impacts and activities may affect the integrity of the site. It depends on local topography, the nature of the site and on the type of human activities; in our case it partially overlaps the water basin coastal area as suggested by the EC (Guidelines for the establishment of the Natura 2000 network in the marine environment).

Collecting data on fishery

The fishery activities of seven boats belonging to the artisanal fishermen of Santa Marinella have been monitored thanks to an undergraduate student (Massimiliano Sardone) during his final Thesis work.

Data have been collected during a one year campaign, held in 2004, through direct observation participating to fishing campaign on some boats and giving questionnaires and doing interviews to the other fishermen (going onboards on all boats was not possible as they boat all at the same time). Recording the type of fishing tools (length and height of the net, length of the mesh), the species and the quantity catched.

A scheme of the information collected for each boat is given below (see fig. 2.6).

Total number of days		
Fishing gear		
Mesh		
Height		
Length		
Sea bottom characteristic		
Deep		
Geo- coordinates of the fishing area		
Catch	**Species**	**Quantity (Kg)**
	TOTAL	

Fig. 2.6 Scheme of fishing report

Collecting data on sediment

Sediment sample have been collected in 13 sample stations (59 PNA; 53 PNA; 37 PNA; 33 PNA; 3 PNA; 4 PNA; 5 PNA; 6 PNA; 66 PNA; 13 PNA; 67 PNA; 69 PNA; 70 PNA) during the campaign of December 2006. Samples have been analyzed by Dr. M. Brandano, Department of Geology of University of Rome "La Sapienza". Grain size and mineralogic analysis (using diffractometer) plus determination of calcium carbonate contents have been carried on.

Statistical analysis

Correlations have been tested on the collected data against density and rhizome's production through the Analysis of correlation using STATISTICA.

Collecting data of marine water quality

Data sampled at Santa Marinella north, Cerenova and Fiumicino four times a year, during 2006 from Regional Environmental Protection Body (ARPAL) have been collected.

Trasparency (inversely related to turbidity) have been recorded at 200 m, 1000 m and 3000 m from the shore, using Secchi disk. The Secchi disk has the advantages of integrating turbidity over depth (where variable turbidity layers are present), being quick and easy to use.

The concentration of total Nitrogen, Nitrate, Nitrite, Total Phosphorus, orthophosphate, Chlorophyll a and Dissolved Oxygen % of saturation have been recorded using a multiparametric probe. Suspended nitrogen and phosphorus sediments have been calculated subtracting respectively from total Nitrogen and total Phosphorus the values of dissolved nitrogen (Nitrate, Nitrite) and phophorus (orthophosphate).

Considering that the meadow is located in between S. Marinella and

Cerenova (although very close to S. Marinella north), data from those two stations have been used and their specific values have been compared with the ones recorded at the station of Fiumicino, which can be considered as the worst point in the vicinity, in fact it correspond to Tevere mouth and thus it is almost eutrophyc.
Data comparisons have been used to discuss the SCI situation

Collecting data on stream quality
Biochemical oxygen demand (BOD) has been measured in several watercourses samples. ARPAL monitors at least twice a year, water quality of 4 streams located in the area of interest (Fosso Santa Maria Morgana, Fosso Castel Secco, Fosso Buche and Fosso Quartaccio). Samples data on Coliforms, Streptococcus, pH, O2, Surfactants, phenols and BOD5 has been used to classify each stream/river following the table 2.4. Data from 2004-2005 and 2006 have been collected.

	Low Pollution	Medium Pollution	High Pollution
Feces coliforms	< 1000	1000 - 12000	> 12000
Feces streptococcus	< 1000	1000 - 2000	> 2000
pH	6,5 - 8,5	5,5 - 9,5	< 5,5 - > 9,5
O2 (%saturation)	> 70%	50% - 70%	< 50%
Surfactants Substances	< 0,25	0,25 - 0,5	> 0,5
Phenols	< 0,05	0,05 - 0,5	> 0,5
BOD5	< 3	3,0 - 20	> 20

Table 2.4

2.5 Conservation strategies identification

The references documents for management planning, when working on the application of Habitats Directive, are:

- Guidelines for the establishment of the Natura 2000 network in the marine environment. Application of the Habitats and Birds Directives;

- Guidance document on Article 6(4) of the 'Habitats Directive' 92/43/EEC, 2007, European Commission;

The Guidelines manual for editing management Plan of Natura2000 Sites, edited by the Nature Conservation Direction of the Italian Environmental Ministry;

- Interpretation Manual of European Union Habitats (EUR 25/aprile 2003);
- The Assessment of Plans and Projects Significantly Affecting Natura 2000 Sites;
- Methodological guidance on the provisions of article 6(3) and 6(4) of the 'Habitats' Directive 92/43/eec november 2001;
- The European Guidelines for the preparation of Site Management Plans (AA.VV. 1992);
- The documents on habitats interpretation published by the Ecology and sustainable development Ministry of the French government.

Other important references for marine areas protection and conservation are:

- Barcelona Convention- for the Protection Of The Mediterranean Sea Against Pollution. Signed 16 February 1976, in force 12 February 1978 (revised in Barcelona, Spain, on 10 June 1995 as the Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean) and the ASPIM (Specially Protected Areas and Biological Diversity in Mediterranean) implementation protocol;
- The Code of Conduct for Responsible Fisheries issued by FAO (1995);
- The International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto (MARPOL).

All these listed documents represented the starting knowledge to develop the management strategy of the study site.

Management Strategic priorities

In order to develop a systematic approach to management, it is useful to identify the sort of activities that could have “a priori” significant negative impacts on the site, including listing the activities (e.g: shipping, fisheries, wind parks, oil and gas exploration) that could interact with the protected features of the site and effect the conservation status of the habitats types and species of Community Importance.

In such a context, several Member States use matrices as a tool for decision-making.

The matrix should clearly show whether different external human activities are expected to have significant effects on specific conservation features. The following matrix is being elaborated with the existing features in the Natura 2000 site and the foreseen human activities. Such matrices should be worked out and completed by specialists, preferably with the participation of stakeholders and ensuring that appropriate specialised knowledge is represented. In this case the matrix has been filled up without the partecipation of stakeholders but all the possible knowledge has been represented.

The matrix contains all the ecological features subject to protection and all users. Only relevant uses for that particular area/sub-area have been indicated. The first dimension of the matrices concerns the ecological features for which the site has been designated; necessary elements (habitats or species) for the favourable conservation status of the protected features under the Birds and Habitats Directives (e.g.: fish stock status needed for protected seals or birds) have been also included.

Not all individual marine habitats or species from the annexes of the Birds and Habitats Directives need to appear in the matrix, as they may be grouped according to similar sensitivities. Many species are sensitive to similar activities, and many activities have similar effects. The second dimension concerns human activities in relation to the specific sensitivity of the ecosystem.

Different activities/ users or stakeholders should be listed and grouped according to their possible interaction with habitats and species. Only relevant uses for that particular area/sub area have been indicated. It is important to underline that possible interactions refer to tangible (present or planned) activities rather than different economic sectors/ industries considered in global terms.

The matrix showing the two dimensions, looks as follow (tab. 2.5) (this is not filled in).

An example of the use of the matrix
Site NNN

Activities related to	Habitats			Species				Other elements of conservation concerns but not listed in EC Directives			
	1110 sandbanks	1170 reefs	1180 leaking	Cetaceans	Birds eating	Birds eating	Phoca vitulina	Large fish	Large moluscs	Natural physical processes	selected species xx
SPACE											
windmills											
Harbours											
Art. islands											
Oil and gas exploration											
Oil and gas exploitation											
Shipping channels											
Pipelines/cables											
Military practice											
Tidal energy											
FISHERIES											
Bottom trawling											
Shell fishery/dredging											
Collection biogenic structures											
Pelagic fishery											
Seines, driftnet, line fisheries											
Set nets											
MINING/DREDGING											
Sand mining											
Gravel mining											
Channel dredging											

not relevant
no impact
easy regulation
zoning of activity
conflict -> regulation

Table 2.5. The matrix showing the two dimensions

Different levels of interactions between biological features and relevant activities have been identified using different colours (fig.2.6).

	Not relevant
	No impact
	Easy regulation
	Zoning activity
	Conflict → Regulation

Figure 2.7 Levels of interactions

The first dimension includes habitat and species of Community Importance present at the site and other elements of conservation concerns but not listed in EC Directives, that can comprehend species, habitats, communities or natural processes, characteristic of the site.

The features listed in the matrix have been chosen after a thorough analysis of the existent bibliography on Posidonia meadows and on species that inhabit this ecosystem (see part 1).

The second dimension listed the anthropogenic activities that can affects the identified biological features.

The activities listed have been chosen starting from the ones listed in the annex E of the Natura 2000 Standard Data Form.

2.6 Model goals

- The approach already explained in the previous chapter has been followed to develop the qualitative reasoning model for the S.C.I. Santa Marinella.
- The documentation on the structure and functioning of the system is discussed in the previous and next paragraphs/sections of this study.

The implementation of a qualitative model for *Posidonia oceanica* ecosystem can show how meadows are affected by humans' activities and therefore what are the possible consequences of specific management proposals or decisions. With this regard the development of this model generally aims at supporting and explaining proposals and decisions to stakeholders and public administrators.

The specific goals of the model developed are:

1. Stressing the connection between boat tourism and conservation status decrease;
2. Supporting zoning as operational management measure to improve the conservation of the protected SCI.

In addition, we strive for a functionally 'clean model', which specifically means that the state-graphs generated when simulating should have no dead end paths. This concept is discussed thoroughly in the next chapter (discussion).

Although the focus of the model is the Site of Community Importance of Santa Marinella, the processes represented in the model have the potential to be generalized to other tourist Mediterranean SCIs where Posidonia meadow (habitat 1120*) occurs.

2.7 Model implementation

The conceptual map developed for the SCI (fig. 2.8) describes the dominant processes governing the behaviour of the entities included in the ecosystem. S. Marinella is a marine ecosystem whose behaviour depends mainly on water quality. The map underlines how human activities (in red) in some way, influence the marine biological components (in green) of the ecosystem. As it can be seen from the map, several different processes influence Posidonia meadow conservation status.

Developing our model we only considered few processes for sake of simplicity and avoided considering several relations that characterize this complex ecosystem. The two processes which the model focuses on, are:

1. Mechanical process – Tourist boats anchoring on the meadow, mainly during the summer season (mid July- end of August), pull up shoots and foliage enhancing the fragmentation of the meadow.
2. Biological process – Posidonia meadow conservation is related to changing of the sea bottom surface of the site occupied by the plants (coverage) and on the degree of fragmentation that the meadow has.

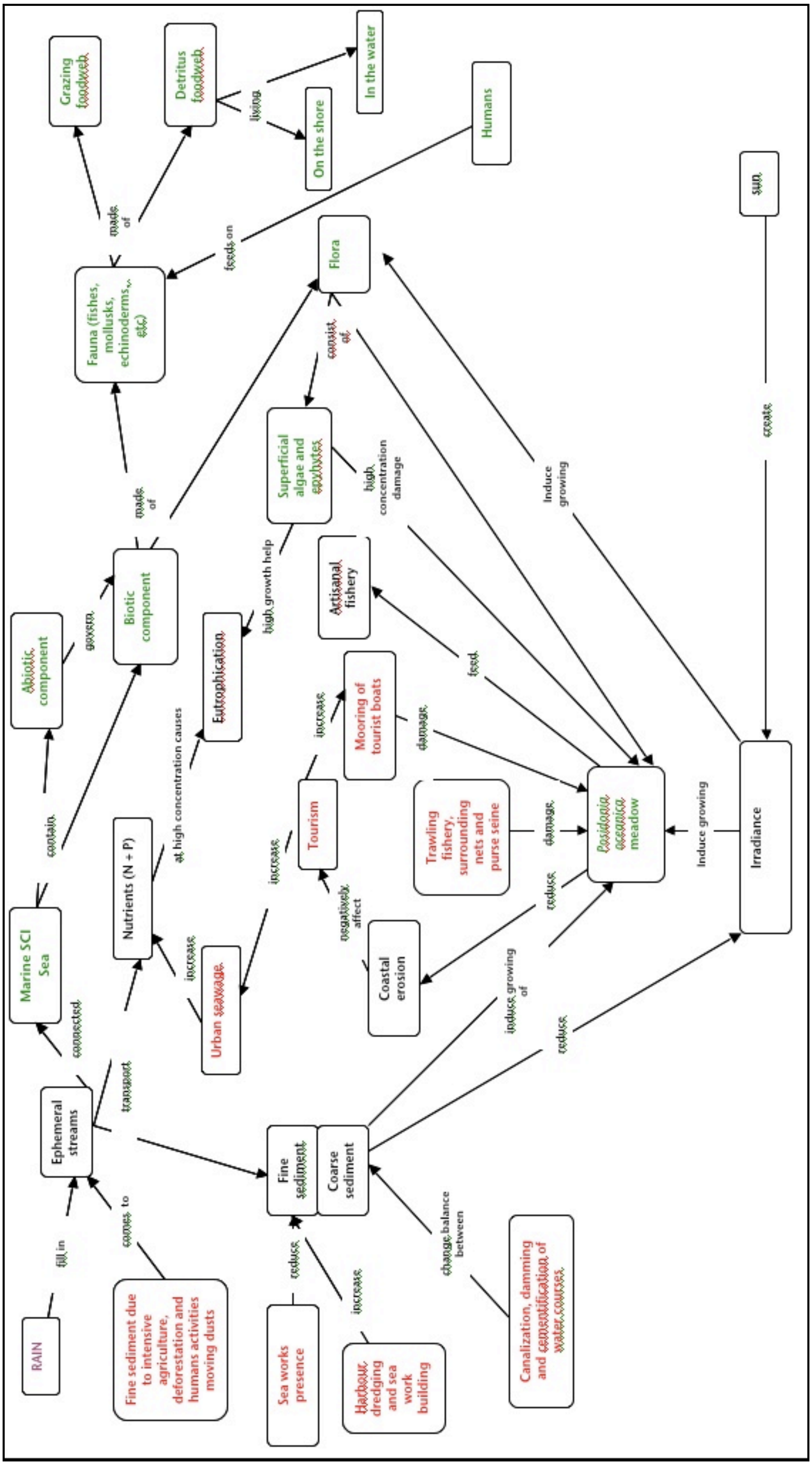


Fig 2.8 Conceptual map

System environment and external influences

The area where the S.C.I. is located, has been already described in the previous section.

We identify processes happening within the sea itself to be part of the system structure, whereas management proposals and independent events that are outside the system, but influencing its behaviour (such as Tourist boats), will be considered as external agents or as having exogenous behaviour.

Assumption concerning structure

In this version of the model we assume that anchoring is the only cause of meadow fragmentation and that growth is constant and is the only parameter counterbalancing destruction of meadow due to anchoring. Posidonia meadow's conservation status is dependent from coverage which is directly affected by fragmentation.

Entities, agents and configuration

The entities in this model are **Site**, ***Posidonia oceanica* meadow** and **tourist boats.**

The Site is defined as the marine area that contains abiotic components, made of not living elements such as suspended sediment, and biotic components, made of biological elements, such as marine flora (*Posidonia oceanica*) and fauna species (mainly juvenile fishes, mollusks, polychetes and echinoderms) designated from the Italian competent authority for conserving Posidonia meadow (habitat 1120*, protected according to the Habitat Directive).

Posidonia, as already written in the previous sections, is an endemic Mediterranean sea grass that forms extensive underwater meadows that grow on rocky and sandy bottoms in clean water at a depth from less than 1 meter to over 40 meters. It is a real ecosystem, being a nursery and a feeding place for several juvenile fish species and marine invertebrates.

- Within *Posidonia oceanica* meadows lives two others groups of primary producers: epyphytes and superficial algae; then two main groups of organisms lives on them and they constitute the detritus foodweb in the meadow and the grazing based foodweb (zooplankton, macroinvertebrates, mollusks, echinoderms, fishes, birds, cetaceans). It has been avoided considering them in the model, although it is important to underline that every decreasing of conservation status of the meadow will affect all the species living in them

Tourist boats present in the area can be made of timber, fiberglass or iron, they are mainly shorter then 10 m and with an engine; every boat has an anchor of different weight and shape.

Only one type of relation (attribute) among entities has been set and it is “contains”; the site “contains” tourist boats and Posidonia meadow.

Causal model and quantities overview

The causal model is a diagram produced by Garp3 during the simulation of a qualitative model, and shows all the causal dependencies active in a particular state (state 1-scenario 1-unfacceted site fig. 2.9).

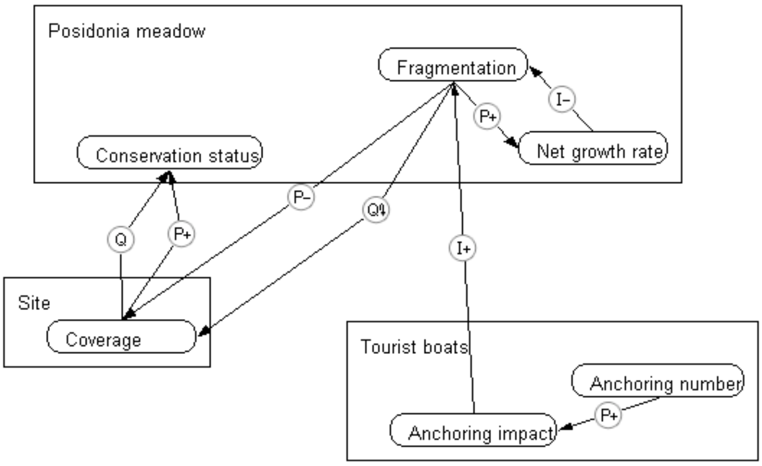


Fig. 2.9, State1, scenario1-

Eight model fragments have been implemented (fig. 2.10), one contains all knowledge that is always true, and the others are child fragments and conditional.

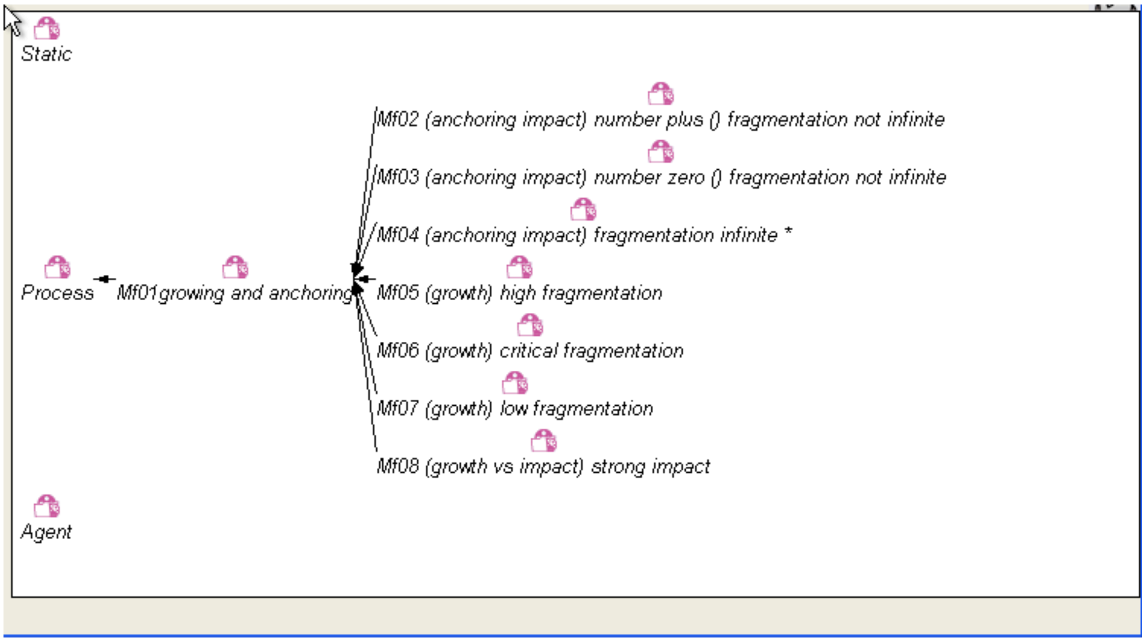


Fig.2.10 Model fragments edited

Central in the causal diagram and in the model is the amount of fragmentation that characterizes a Posidonia meadow.

The following sections discuss the causal structure of the model in detail.

Anchoring impact, Fragmentation and Anchoring number

Anchoring impact (with quantity space {Zero, Plus}) indicates the impact that anchors cause on a meadow, thus it is directly determined by anchoring number. Besides, anchoring impact is a function of fragmentation too because a high degraded (fragmented) meadow will be less affected by anchoring, in fact in such case the probability that anchors will pull up shoots or foliages is low.

A Posidonia meadow is always directly affected by anchoring but when anchoring number disappears or when the meadow no longer exists (fragmentation reaches infinite). In the latter case anchoring impact will not occur, whatever is the number of anchoring.

However anchoring number is directly linked to the number of boats (1 boat → 1 anchor). It should be noted that we assume that heavy and bigger anchors (usually used by motor-boats longer then 10 m) should be double counted. In fact for sake of simplicity the weight of the anchors is not considered in the model and anchoring number is an independent quantity, set as exogenous in all the scenarios.

Three conditional model fragments implement the combined effects of anchoring number and fragmentation on anchoring impact using a positive proportionality (P+), from anchoring number to anchoring impact, and a negative proportionality (P-), from fragmentation to anchoring impact. They occur together or separately depending on the situation. The knowledge captured by these model fragments and represented by different causal dependencies is summarized in

Conditions		Consequences		Model fragment
Anchoring number	Fragmentation	Anchoring impact		
Magnitude	Magnitude	Magnitude	Is qualitative influenced by	
> Zero	< Infinite	Plus	Both	Mf 02
Zero	< Infinite	Zero	Anch. number	Mf 03
Any	Infinite	Zero	Fragmentation	Mf 04

table 2.6.

Table 2.6 – Conditions and consequences of the model fragments implementing the combined effect of fragmentation and anchoring number on anchoring impact, using P- and P+ respectively.

The reason why the causal model changes as described in the table, lies in the fact that when either one of the factors is Zero, the result is Zero and therefore if the first factor remains Zero changes of the other factor have no influence on fragmentation. Note that if Anchoring number is Zero then Anchoring impact is zero; this has been modeled by using a single correspondence.

The three model fragments are so named:

MF 02- anchoring number plus and fragmentation not infinite

MF 03- anchoring number zero and fragmentation not infinite

MF 04- anchoring number (zero/plus) and fragmentation infinite.

They cover all the different situations identified.

Net growth rate and fragmentation

Net growth rate is a specific inner characteristic of a Posidonia meadowsince it is mainly related to physic parameters of a specific marine area (such as depth, light, nutrient availability, etc). For sake of simplicity we avoid including these factors in our model and we give only two values of magnitude {Zero, Plus} to the quantity space (Gro).

Net growth rate is a function of Fragmentation, it is zero when Posidonia meadow disappears and when maximal magnitude of coverage (landmark: carrying capacity), is reached. At this state in fact, the difference between lost and new biomass is null as the ecosystem can be assumed in balanced, having reached the climax stage. Thus net growth rate is assumed to be maximal (plus) whatever magnitude of fragmentation is occurring with exception for the extremes (zero and infinite). This behaviour is represented by a parabola function that is implemented by using some magnitude's values correspondences always active (MF01) between fragmentation and net growth rate and three conditional model fragments:

- infinite or zero fragmentation corresponds to zero net growth rate;
- all the fragmentation magnitudes between infinite and zero, correspond to plus net growth rate;
- if fragmentation is bigger then critical, a negative proportionality from fragmentation to net growth is implemented (MF05 high fragmentation);
- if fragmentation is equal to critical, then net growth rate derivative is steady (MF06 critical fragmentation);
- if fragmentation is smaller then critical, a positive proportionality is activated between fragmentation and net growth rate (MF07 low fragmentation).

Fragmentation is a factor measuring the degree of isolation of patches of Posidonia within a meadow. Its magnitudes are defined by the quantity space Frag {Zero, Plus, Critical, High, Infinite}, thus two big ranges are identified plus (which includes low values very close to zero) and high.

Fragmentation is assumed as caused and increased only by anchoring impact while the only power that counterbalances the loss of biomass is the growing of the meadow which is always active (see fig. 2.11, MF01) but two extreme situations, previously described.
These opposite powers have been implemented by setting two influences (a positive and a negative one) from anchoring impact and net growth rate respectively to fragmentation,
A specific situation happens when several anchoring occurs in a low impacted (fragmented) meadow, in fact in such case net growth rate would never be enough to counterbalanced the lost of shoots and foliage. Thus an additional model fragment (MF08 growth vs impact) explaining the dominance in influences has been implemented, where high anchoring number (higher or bigger then critical) and low fragmentation (lower or equal to critical) lead to anchoring impact being larger then net growth.

Coverage

Coverage represents the share of surface occupied by the Posidonia meadow in a certain site; it is directly dependent on fragmentation. In fact when fragmentation increases the seagrass coverage of the site decreases and when fragmentation decreases it is the other way round. This relation is modelled using a negative proportionality (P-) and an inverse correspondence between quantity spaces' (Cov {Zero, Low, Medium, High, Carrying capacity} and Frag {Zero, Plus, Critical, High, Infinite}).

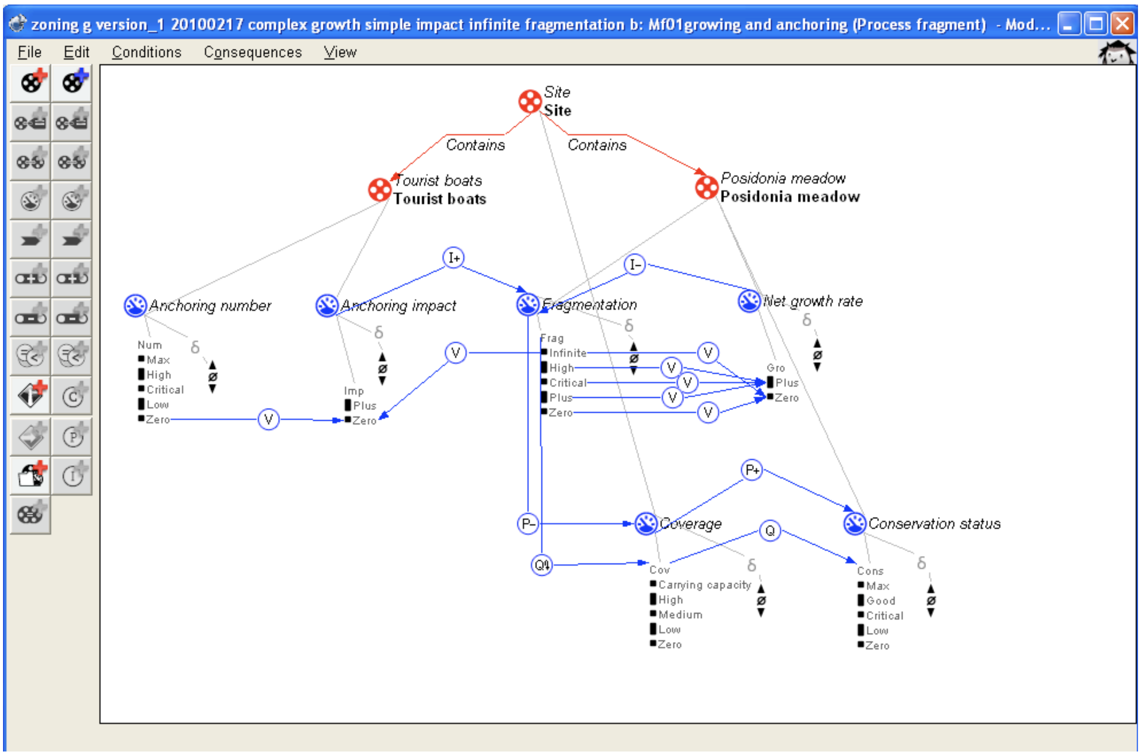


Fig. 2.11 MF01 Growing and anchoring

Conservation status

Conservation status of the seagrass meadow is a complex parameter, as previously and further discussed in this work. It can be assessed using several methodologies and considering different biological parameters. In this model it is assumed for sake of simplicity to be influenced only by Coverage, (avoiding to take into account density, primary production and rhizomes production which are standard monitoring indicators for measuring Posidonia meadow's quality): the higher is coverage the higher is conservation status.

This dependence is implemented in the model through a positive proportionality (P+) going from coverage to conservation status and direct correspondence between the quantity spaces (Cov and Cons {Zero, Low, Critical, Good, Max}).

3. RESULTS

3.1 Biocenosys mapping and site boundaries assessment

Map and perimeter

The meadow of Santa Marinella is discontinuous (considering both distribution and depth) and sparse (considering its coverage). The shape of the meadow is a narrow belt from the mouth of Rio Fiume to Santa Marinella harbour, it widen in Cape Linaro.

The shallow part of the meadow is mainly sparse on rocks with very small patches on sand. In deep areas (between 10 m and 20m) Posidonia is mainly implanted on matte and, on dead matte mixed with dead leaves accumulated or medium-course sediment. The lower limit is around 16-18 m and only in few patches of the central area it reaches 20-25 m.

The specific description is done starting from the west side of the meadow and going southeast, following the coastline.

West of the harbour the meadow has the upper limit around 4 m on rocky bottom, on sandy patches between rocks a sparse *Cymodocea*'s meadow has been observed; below 10 m depth Posidonia is implanted on sand or matte. The lower limit is clear and it is at 17 m deep.

In front of Villa Maravigna and in front of Le Grottacce the shallow meadow is implanted on rocks and medium course sands; going deep, around and below 15 m depth, the seagrass is found highly shelved, sparse on matte interspersed with dead matte, and medium and course sands; between 20 and 25 only dead and alive mixed shoots have been observed.

East of the harbour and between Villa Maravigna and Le Grottacce two channel orthogonal to the coast characterized by medium fine sands surrounded by medium course sand has been observed.

In front of Villa Lessona another wide area of only medium fine sands has been found.

Between Le Grottacce and Rio Fiume mouth, Posidonia sparse on matte, interspersed with patches of medium course sands has been found until 20 m alternated with areas were Posidonia is implanted on matte and channel of medium course sand and isolated shoots mixed with patches of dead matte. West of Rio Fiume mouth, the lower limit is characterized by the presence of a step of matte and, under this, orthotropes rhizomes began to be prevalent.

East of Rio Fiume mouth and west of Santa Severa at 5 m depth a narrow belt of Posidonia implanted on rocks has been found, its lower limit is found around 14 m deep and then, a wide surface of dead matte is found, with only few isolated shoots of living Posidonia.

In front of Santa Severa the meadow implanted on rock widen and before reaching 10 m depth it is substituted by a mixture of Posidonia alive and dead that stops only in a small depression shallow then 10 m, where Posidonia sparse on matte has been found.

Official Standard Data Form and Map analysis

The map processed (fig. 3.1) shows how Posidonia is distributed within the SCI perimeter. Two features have been identified: Posidonia meadow and dead matte.

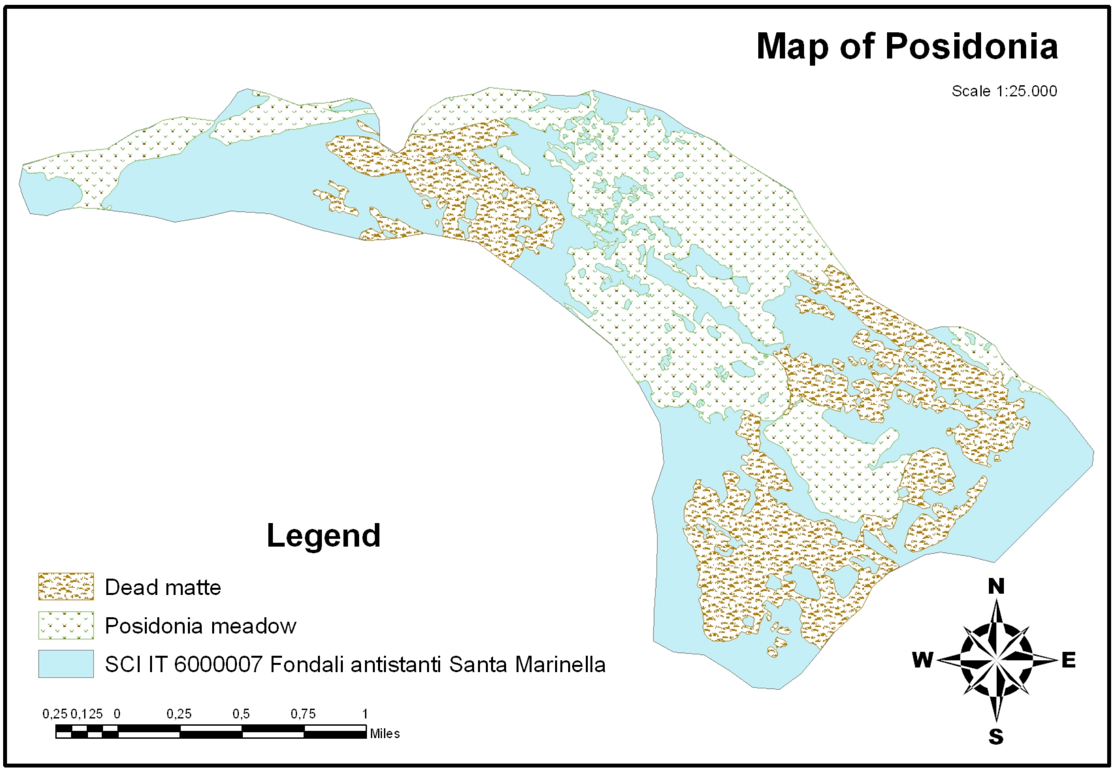


Fig 3.1. Distribution of Posidonia within the SCI

The coverage's percentage of habitat 1120* recorded in the official SDF is 15% corresponding to 143 ha. Considering that the site is 953,2 ha wide. After developing the Posidonia map of the studied site, the exact percentage of Posidonia's coverage within the site has been calculated, using ARCGIS and it corresponds to 32.2% or 307.3 ha. A high degree of dead matte has also been found in the site: 236 ha corresponding to 24.7% of the site.

3.2. Posidonia meadows conservation status assessment

<u>Data analysis</u>

Absolute density and Relative density have been analyzed considering depth, areas and typology of sea bottom (matte, sand or rock) as factors. A preliminary nMDS test (stress of

0,11, fig.3.2) has been performed and it shows how depth is the only factor influencing the distribution of the data. 2 range of depth have been set: shallow site, above 10 m depth and deep site below 10 m.

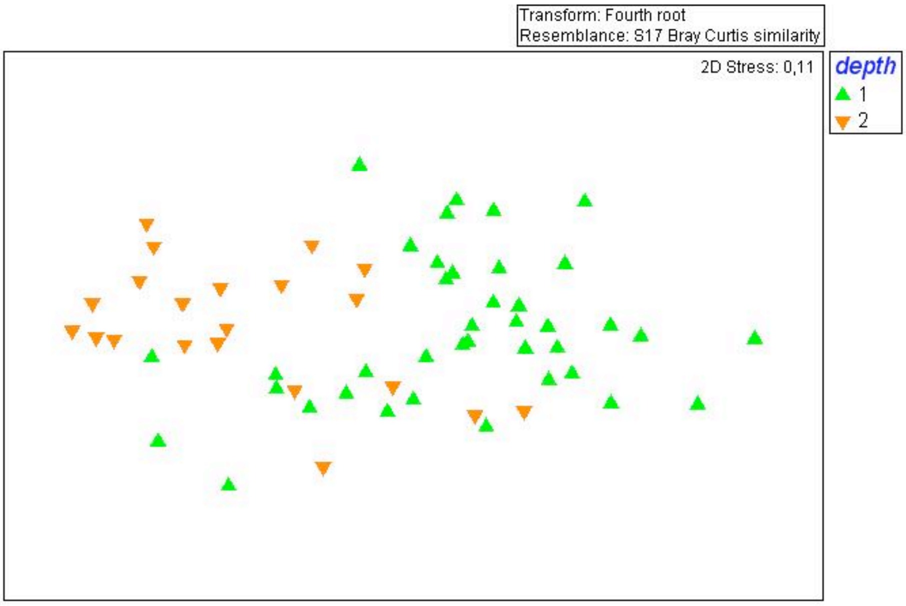


Figure 3.2. Results for Absolute density

To statistically confirm these results, One-way ANOVA has been performed.

The result shows that both absolute density and relative density change significantly when depth changes.

- Absolute density $F_{6,233}$=17,93; $p<0.05$
- Relative density $F_{6,53}$=3,23; $p<0.05$.

<u>Documentation on similar meadows in the same area</u>

The majority (11 out of 15) of the studied Central Thyrrenian meadows are characterized by normal or exceptional density and they are also classified as in balance, following the Pergent classification (1995). Only 4 meadows have been classified as disturbed, because of low density and one of them is Santa Marinella (see tab 3.4).

References	location	deep (m)	density (shoots* m-2)	Pergent Classification (1995)
Acunto et al. (1996)	Follonica 1	5	450	disturbed
	Follonica 2	7	421	disturbed
	Baratti 1	12	489	balanced
	Baratti 2	6	525	balanced
Pergent-Martini et al. (1994)	Ischia	5	473	disturbed
		10	351	balanced
		20	253	balanced
Piazzi et al. (2000)	Baia Inferno	10	500	balanced
Rende et al. (2005)	Isola Dino	10	354	balanced
Torricelli e Peirano (1997)	Monterosso	5	249	high disturbed
		11	300	disturbed
		18	204	balanced
MINISTERO DELL'AMBIENTE – SERVIZIO DIFESA MARE (2002) (dati raccolti dal Conisma nell'ambito della convenzione "Rivisitazione di alcune praterie di Posidonia oceanica lungo le coste delle regioni Liguria, Toscana, Lazio, Basilicata e Puglia e progetto pilota per l'armonizzazione dei relativi dati cartografici	Punta Molara	7	465	disturbed
		12	397	balanced
		22	190	balanced
	s. michele di pagana	5	530	balanced
		12	412	balanced
	cogoleto marino	7	601	balanced
		12	446	balanced
		18	292	balanced
	maratea	7	446	balanced
		18	303	balanced
		27	206	balanced
	vada	5	671	balanced
		14	515	balanced
		24	442	balanced
	talamone	5	500	disturbed
		10	520	balanced
		14	446	balanced
	meloria	4	547	disturbed
		11	455	balanced
		20	387	balanced
	terracina	13	202	disturbed
		15	205	disturbed
		22	197	balanced
Presente lavoro (2009)	s.marinella	8	338	disturbed
		12	255	disturbed

Table 3.4

Mean primary production of Santa Marinella is 1,25 g dry weight
/shoots*year and it can be considered within the range of values already recorded in previous studies by Pergent-martini et al. (1994), Torricelli and Peirano (1997), and Environmental Ministry- Conisma (2002), (table 3.5).

Reference	**location**	**depth**	**Pps**(g dw/ shoot*year)	**mean**
Pergent-Martini et al. (1994)	ischia	5	1,54	1,27
		10	1,32	
		20	0,95	
	olbia	7	0,77	0,83
		10	0,92	
		20	0,8	
Torricelli e Peirano (1997)	Monterosso	5	1,18	1,10
		11	1,17	
		18	0,95	
MINISTERO DELL'AMBIENTE – SERVIZIO DIFESA MARE (2002) (dati raccolti dal Conisma, within R.I.P.O. program)	Punta Molara	7	0,531	1,51
		12	1,914	
		22	2,082	
	s. michele di pagana	5	0,873	1,11
		12	1,342	
	cogoleto marino	7	1,075	1,61
		12	1,829	
		18	1,935	
	maratea	7	0,626	0,71
		18	0,762	
		27	0,751	
	vada	5	1,236	1,30
		14	1,232	
		24	1,426	
	talamone	5	0,751	1,26
		10	1,296	
		14	1,721	
	meloria	4	0,973	1,27
		11	1,299	
		20	1,538	
	terracina	13	0,929	0,88
		15	0,851	
		22	0,853	
presente lavoro (2009)	santa marinella	8	1,2	1,25
		12	1,29	

Table 3.5

PosiPred- predictive model

Observing the data it is clear how the real densities are lower then the ones expected by using the Posipred model estimator. This is highlighted by the negative difference between real density and the expected one (red colored in the table 3.6). For all our station points the difference is negative and it can be assumed as an indication of low conservation status of the study meadow. It is particularly interesting to note that this result is constant in all the observed station points.

EXP_DENS	REAL_DENS	differences
307	302	-5
307	300	-7
309	381	72
250	221	-29
262	197	-65
272	208	-64
506	345	-161
452	321	-131
382	258	-124
440	381	-59
460	302	-158
433	391	-42
402	387	-15
494	360	-134
494	359	-135
441	270	-171
441	272	-169
421	237	-184
301	245	-56
434	278	-156

Table 3.6

The opposite situation happens observing rhizomes production results. Here, the differences between the real data and the expected ones are always positive. This result has been highlighted by red color in table 3.7 and it can be assumed as an indication of unusual status and unexpected quality of the study meadow. It is particularly interesting to note that this result is constant in all the observed station points.

EXP_PROD	REAL_PROD	differences
25,1	50	25
24,9	54	29
30,6	71	40
19,7	31	11
17,9	47	29
18,7	49	30
28,1	121	93
25,8	79	53
21,5	71	49
29,1	59	30
24,1	63	39
31,2	99	68
30	73	43
29,1	68	39
29	74	45
22,4	53	30
20	61	41
18,6	44	25
18,4	52	34
21,7	73	51

Table 3.7

3.3 Human activities at the site

An extract of the map of the threats in the water basin can be found in fig.3.4.

The water basin is mainly characterized by agricultural land, and forest (Tolfa mountains). Specifically 136.799 ha of the land are addressed to arable cultivation, 19.910 ha, to olive and wine trees, 9.975 ha to grasslands used as pastures and 5.188 ha to heterogeneous agriculture.

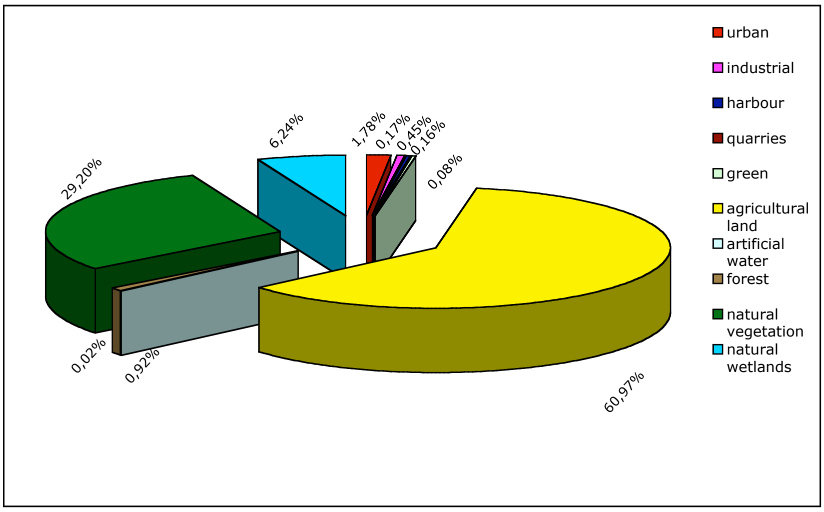


Fig. 3.3

82.313 ha of forests and 17.588 ha of wetlands also characterize the water basin.

The chart (fig. 3.3) summarized the percentage of each land uses observed and mapped within the water basin.

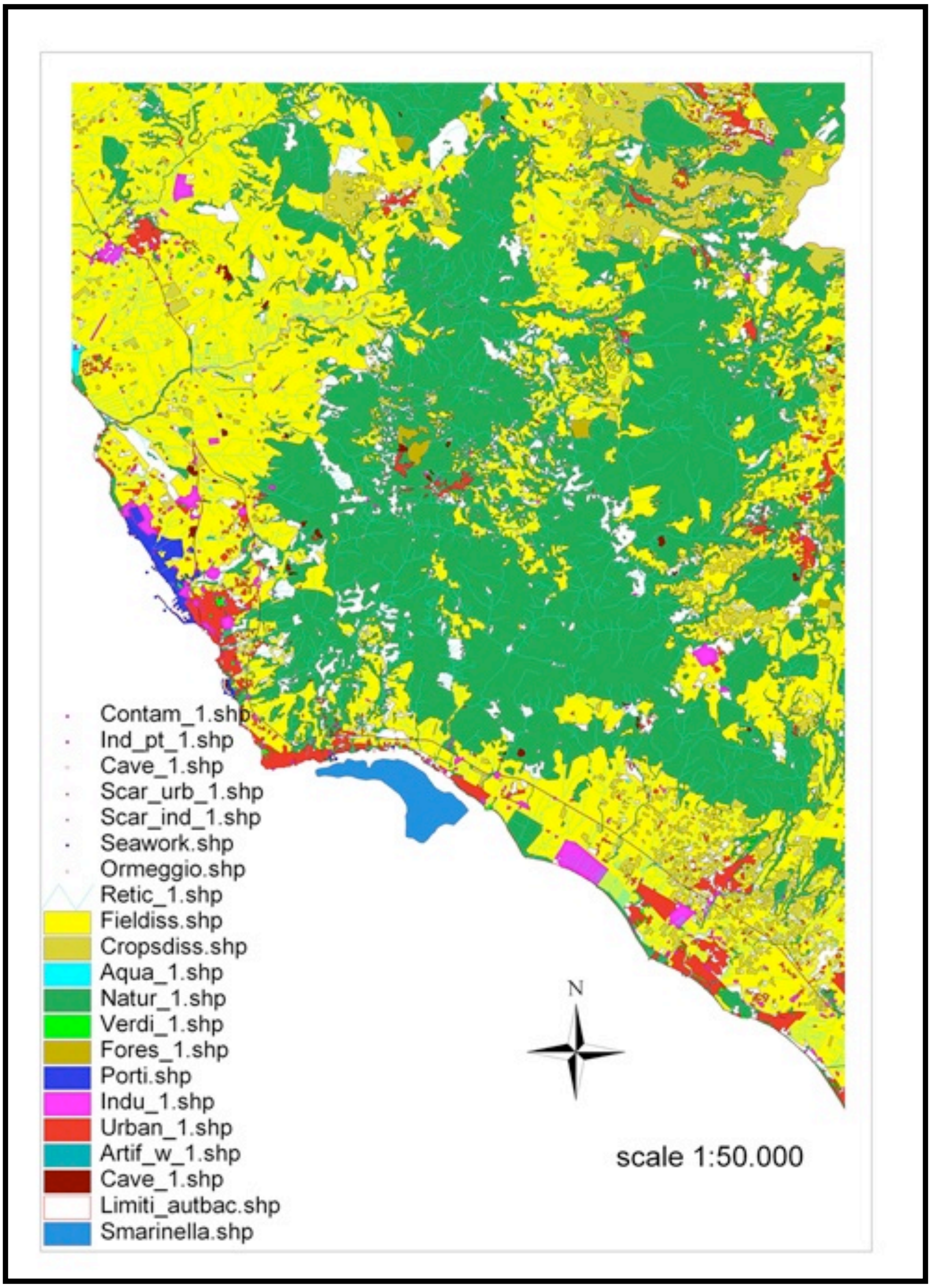


Fig. 3.4 Map of the land uses in the water basin beyond the study Site

Index of Landscape Conservation

A general idea of the conservation state of the study area is given by the Graphical Pattern of Landscape Conservation state (GPLC), drawn on the basis of table 3.8 (last column).

categories for ILC	landscape typologies	Ha	%ILC	% cumul.
	urban	5004,45		
	industrial	1273,58		
bare soil	harbour	493,05	2,40	2,4
ruderal	quarries	462,84	0,16	2,56
artificial green	green	231,70	0,08	2,65
fields	fields	136799,00	48,53	51,17
permanent crops	crops	19910,00	7,06	58,24
pastures	pasture	9975,00	3,54	61,78
heterogeneus agric. Areas	agricultural land	5188,00	1,84	63,62
artificial water	artificial water	57,64	0,02	63,64
artificial forest	forest	2602,60	0,92	64,56
paraclimax and climax forest	natural vegetation	82313,00	29,20	93,76
azonal ecosystem	natural wetlands	17588,00	6,24	100,00

Table 3.8

The green area in the GPLC graph (see figure 3.5) is proportional to the importance of the conserved environment. The ILC tied to this GPLC has a value of 0,54, which corresponds to medium naturalness, following the scale suggested by the Park Regional Body (ARP) of Lazio (Attorre et al., 2005).

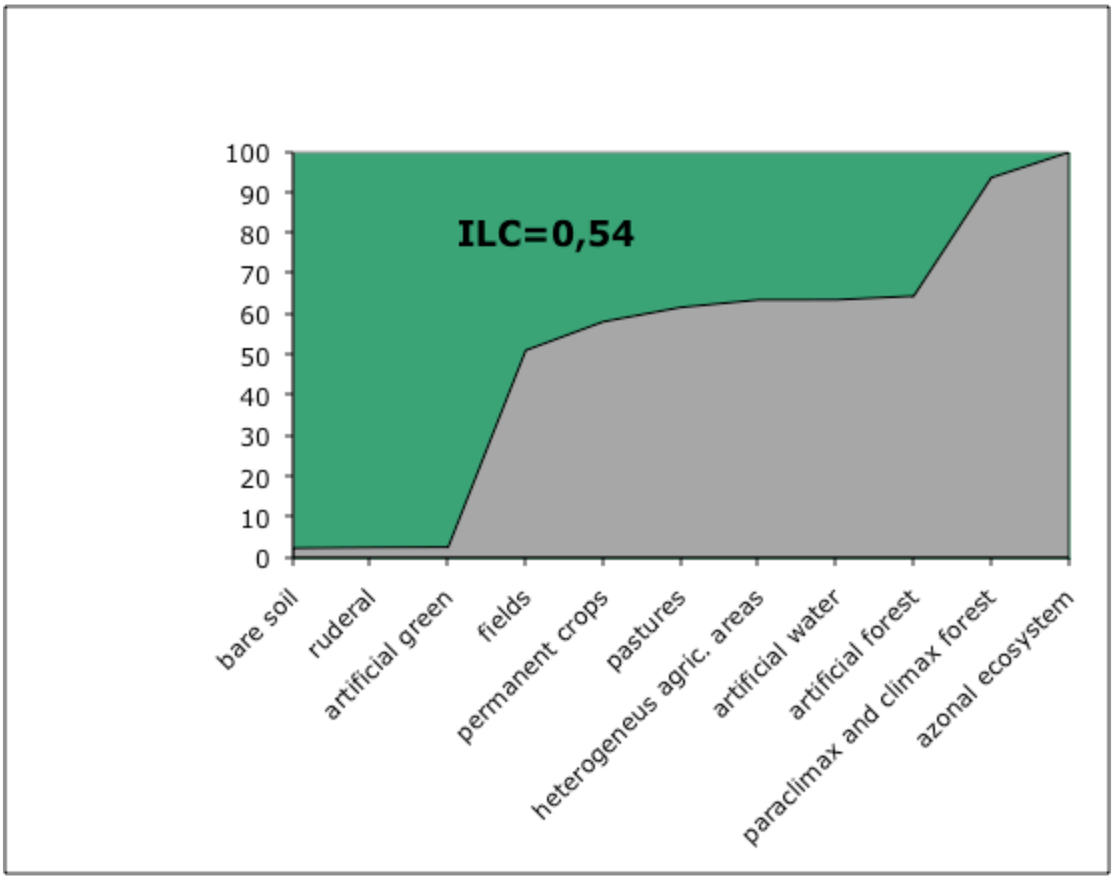


Fig. 3.5 Graphical Pattern of Landscape Conservation state

Impacts at the site

The activities identified as important for the conservation status of the site are attached in Annex III. The table gives also information on the effects each activity is responsible for, and on the degree of influence of each activity at the site.

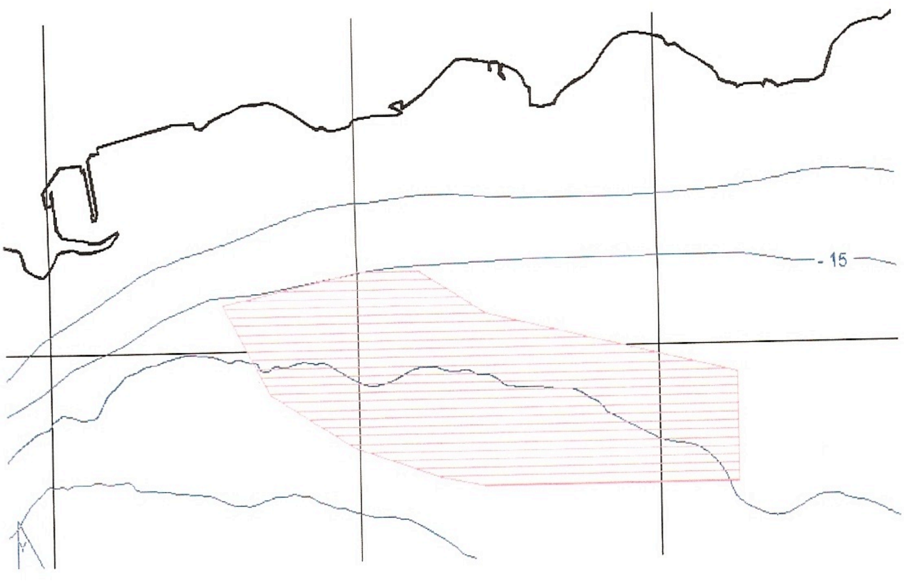
The majority of the activities negatively influence the conservation of Posidonia bed at the site, and they are mainly located around the site. Only one activity with positive influence is implemented at the site and it is Artisanal fishery. The majority of the activities affect the meadow because they cause an increasing of water turbidity, an increasing of fine sediment contribution, and consequently they can push changes in the hydro-sedimentological balance; the direct destruction of shoots and foliage is also a clear threat for the Posidonia bed at the site and it is mainly due to tourist boat's anchoring during the summer season. It is important to note that agriculture, which represents the activity occupying bigger surface is also causing an increasing of nutrients contribution in the streams and then in the coastal sea area. These impacts are both direct and indirect.

Eleven activities identified have high influence on the meadow's conservation, five have medium influence and nine low influence.

Fishery data

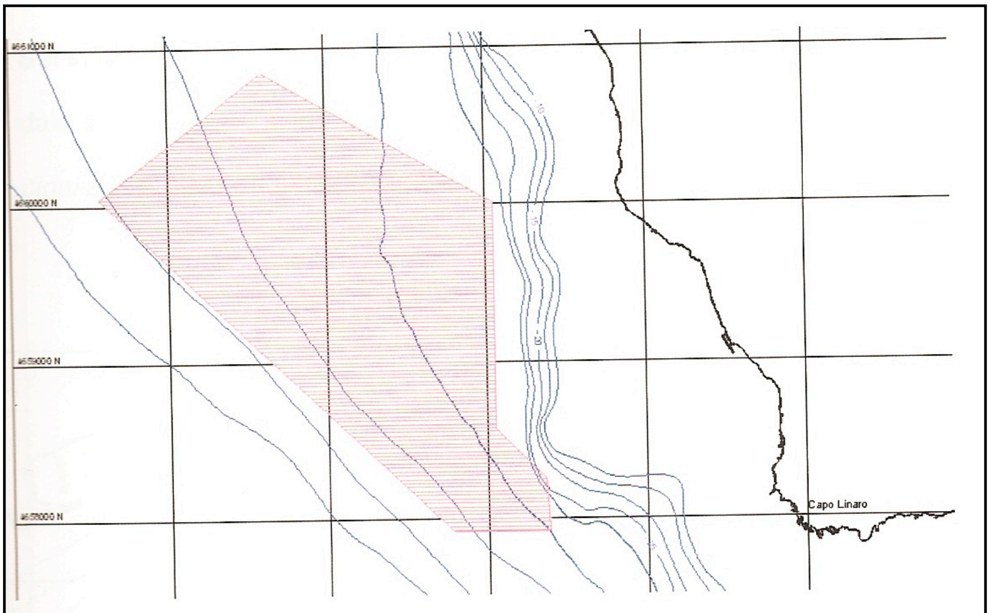
Data recorded during the fishing campaigns described how fishery in the study site is diversified according to the target preys, preferred fishing gear, sea bottom, time of the year and weather conditions.

Specifically data from seven sample stations on *Posidonia oceanica* meadow on matte, show that when using modified gill-net (Italian name: incastellato) between September and December, the main fished species are *Umbrina cirrosa, Dicentrarchus labrax, Sparus aurata* and *Pagellus eritrinus*.



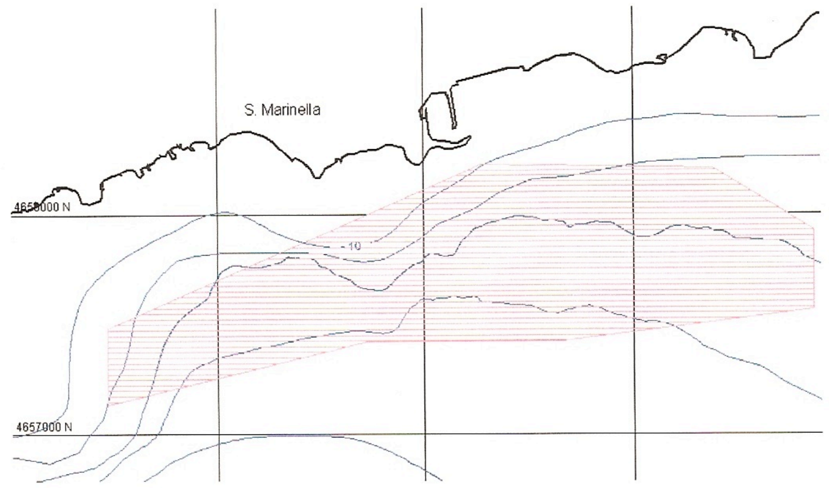
Santa Marinella: da settembre a dicembre - *Umbrina cirrosa, Dicentrarchus labrax, Sparus aurata* e *Pagellus erythrinus*

Data from other seven stations on rocky bottom or on *P. oceanica* on rocks and partially on matte show that using gill net between April and September, the species mainly fished is *Mullus surmuletus;* occasionally on rocks can be fished also *Octopus vulgaris*.



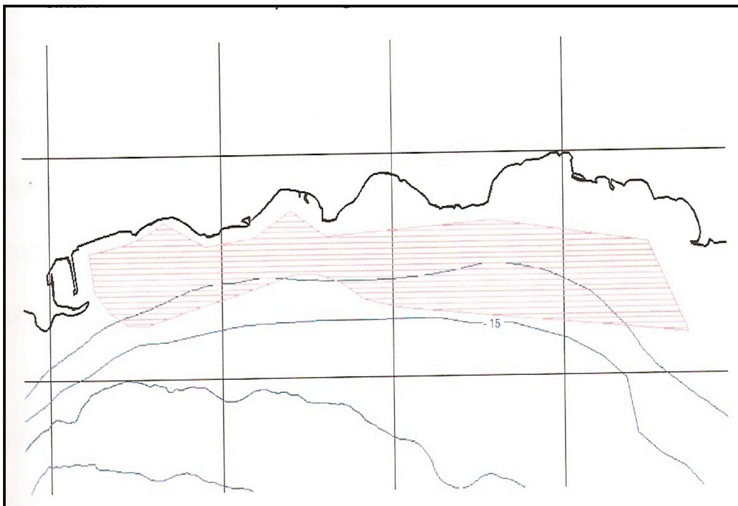
Santa Marinella: da settembre a dicembre - *Scorpaena spp., Trigla spp, Phycis blennoydes*

Six stations very close to the coastline on sandy bottom are the target areas for fishing *Sepia officinalis* and *Octopus vulgaris* from January to April.



Santa Marinella: da aprile a settembre – *Mullus surmuletus*

In the resting six stations another kind of gill net (Italian name: schiette) are used but only with particular kind of weather (after atmospheric disturbance) and with high sea, thus this activity is not predictable before. The most captured species are little fishes or invertebrates predators (*Dicentrarchus labrax, Diplodus sargus* and *Pagellus erythrinus*).



Santa Marinella: da gennaio ad aprile – *Sepia officinalis, Octopus vulgaris*

Sediment data

The sediment is mainly sand, in fact the sandy grain size class represents 95% (mean value) of the total composition in the most part of the samples.

The mineralogic analysis (using diffractometer) has shown that the terrigenous component is dominant on the carbonate one in all sample; 70,31% is the mean value registered, however the maximum value (56,68%) has been registered on station 6 and the minimum value (76,85%) on station 37. This has been also demonstrated by the share of calcium carbonate contents, which mean value is 11,6%; its maximum value, 18,9%, has been recorded in sample station 37 while its minimum value 6,3% in the sample station 6. This carbonate content is mainly represented by parts of echinoderms and red algae.

Data have been analyzed checking for correlations between absolute density or rhizomes production and the percentage of sand/ terrigenous component or carbonate contents of the sediment in the sample stations. The results showed how there are not relationships between the percentage of sand/ terrigenous component or carbonate contents of the sediment and the biological variables monitored.

Environmental data

Data on water transparency (m), concentration of total Nitrogen (μg/L), Nitrate (μg/L), Nitrite (μg/L), Total Phosphorus (μg/L), orthophosphate (μg/L), Chlorophyll a (μg/L) and Dissolved Oxygen % of saturation, collected from the Database Regional Environmental Protection Body (ARPAL, 2006; attached in Annex I) from S. Marinella, Cerenova and Fiumicino have been compared one by one.

The values and the behaviour of total Nitrogen mainly due to the suspended sediment fraction are similar in Fiumicino, Cerenova and S. Marinella showing that the concentration of this nutrient in the SCI studied is similar to the one at the mouth of Tevere (fig. 3.6; 3.7; 3.8).

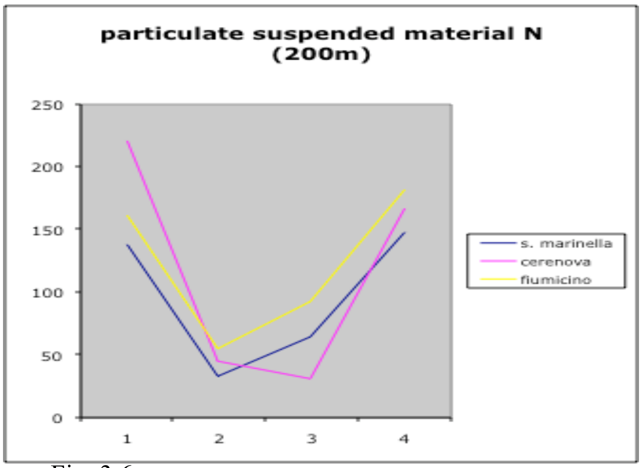


Fig. 3.6

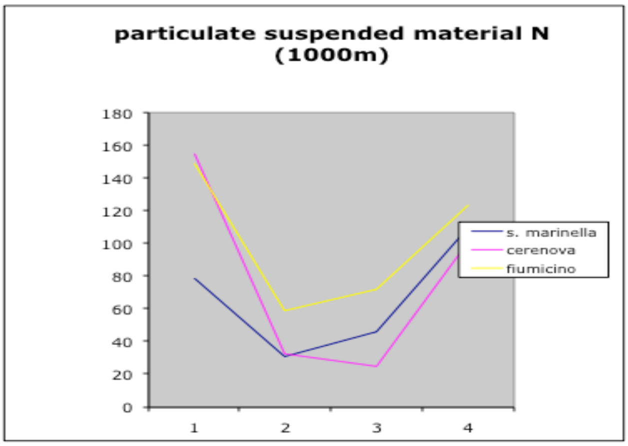


Fig 3.7

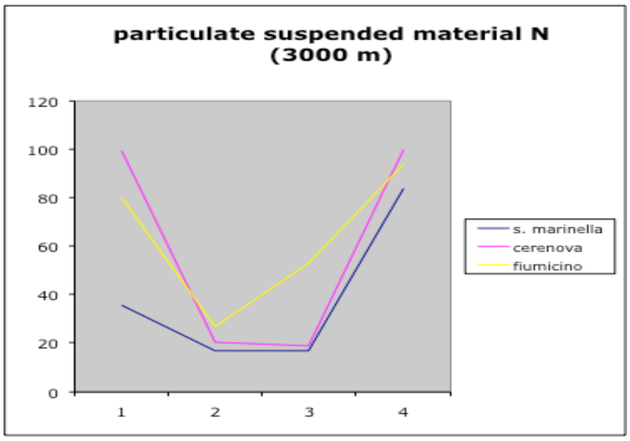


Fig. 3.8

The registered average values of transparency are shown on the table 3.9. Considering that the minimum and maximum distances between the meadow and the shore is respectively about 250m and about 3000m the registered transparency is never more then 10m and its average value is 6,45 which correspond to a high turbidity.

TRASPARENCY (m)		
	2005	**2006**
200 m	3.5	6
1000 m	5.5	8.75
3000 m	5.75	9.25

Table 3.9 (original data from http://www.arpalazio.net)

Considering the values of Coliforms, streptococcus, pH, O2, surfactants, phenols and BOD5, the streams, which contribute to the water quality of Santa Marinella sea area, have been classified by ARPAL as high polluted during 2004, 2005 and 2006.

This result can be also seen yet looking at BOD-5 results (table 3.10) and knowing that most pristine rivers will have a 5-day carbonaceous BOD below 1 mg/L; moderately polluted rivers may have a BOD value in the range of 2 to 8 mg/L.

	fosso santa maria morgana	fosso castelsecco	foce fosso delle buche	fosso quartaccio
BOD mg/LO2 2005	4,4	6,36	3,8	4,76
BOD mg/LO2 2006	48	5,9	3,9	4,2

Table 3.10

This level of pollution happens although the local Municipality is equipped with three water purifiers (managed by ACEA, ATO2): one in “Le fondacce” that serves Santa Severa population, one in “Castelsecco” that serves who lives in the centre and south of Santa Marinella and one in “Perazzata”, that serves who lives in Santa Marinella north (pers. Com. Santa Marinella Municipality technicians).

3.4 Conservation strategies

The analysis of the whole collected information regarding the site and the structures of Posidonia meadows, allows the identification of other important species and habitats, living within the SCI. Listing all the features important for conservation, goes through the decision making process, since the fundamental management actions to be proposed should come from an integrated view of the site, thus the purpose of conservation can be applied to the whole ecosystem and processes which characterize it.

The area of Santa Marinella is characterized by a multiple use of the resources; Nature conservation is often in conflict with those humans necessary uses. Observing the matrix filled in (table 3.11), the several red boxes for Urban sewage and Agriculture and forestry highlight a big conflict of these uses with the protection of the Posidonia bed of Santa Marinella,.

Boat tourism anchoring is also in conflict with Posidonia protection, and yellow boxes show that zonation of the site can face the problem caused by such activity.

Green boxes highlight that easy regulation such as compulsory Environmental Impact Assessment and consequent mitigation actions, could be proposed to reduce the impact of activities that for socio-economic reasons must be implemented. This is the case of harbour’s dredging, sea works building, canalizations and damming.

Artisanal fishery could be an activity to be kept as example of sustainable use of the resources as all the boxes are blue showing that this activity does not cause any impact on the biological features characterizing the meadow.

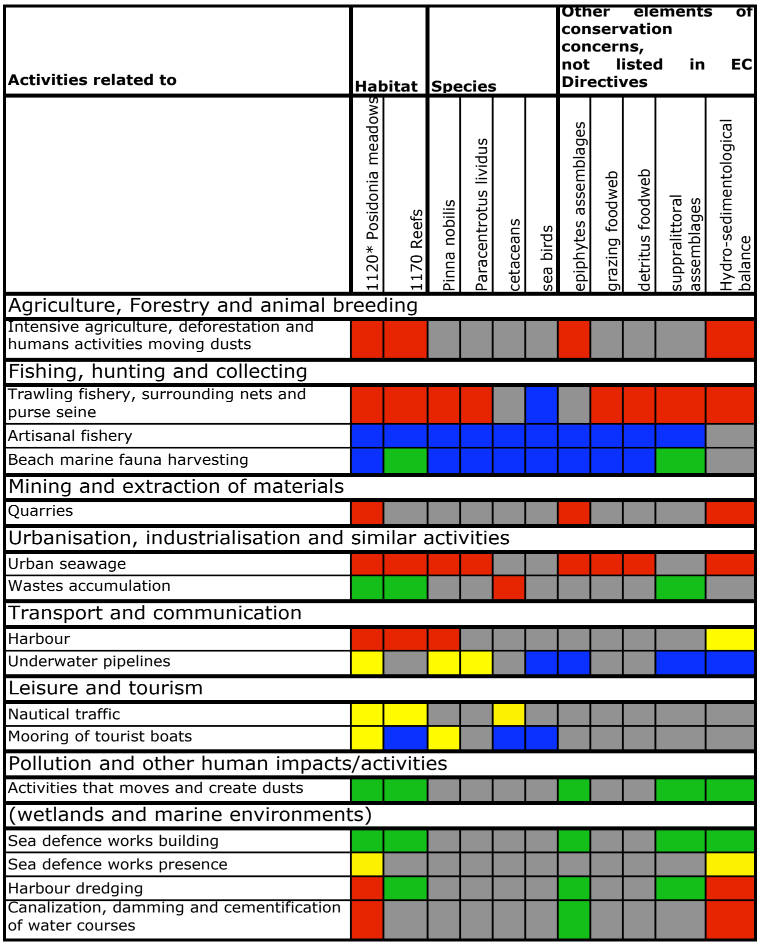


Table 3.11

3.5 Model results

Scenario overview

The model contains 6 scenarios. In each scenario anchoring number has a “leading” role.

In the next paragraph we describe interesting and representative simulations belonging to the scenarios listed on table 3.12.

Number	Scenario	Initial AN	Initial FR	Exogenous behaviour
01	Unaffected site with increasing anchoring	Zero	Zero	Increasing
02	Unaffected site with some anchoring	Low	Zero	Steady
03	Highly affected site with decreasing anchoring	Max	High	Decreasing
04	Highly affected site with zero anchoring (zoning activated)	Zero	High	Steady
05	Maximally affected site with zero anchoring (zoning activated)	Zero	Infinite	Steady

Table 3.12 Scenarios implemented. Abbreviations: Anchoring impact (AN) and Fragmentation (FR).

<u>Scenarios</u>

In Garp3, the initial scenario brings about the essential information for the simulation to start: the system structure and the initial values of relevant quantities (fig. 3.9).

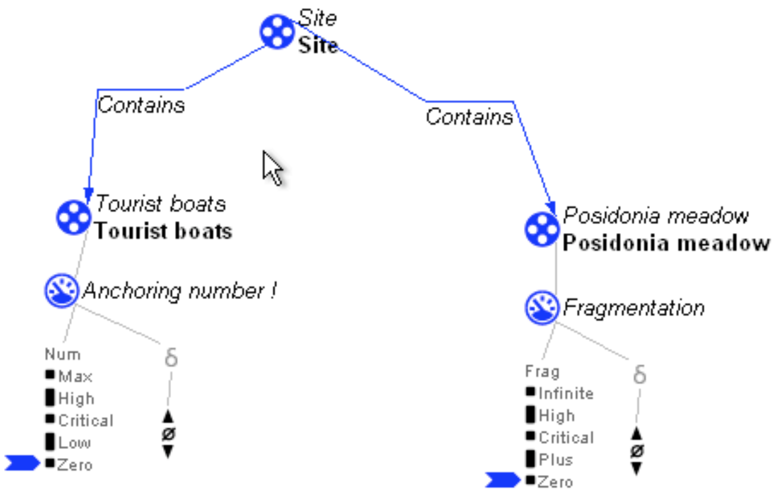


Fig. 3.9 Scenario stating the condition of unaffected site with increasing anchoring. The two entities have quantities associated to them with initial values. Quantity with a "!" behind their names have been assigned to exogenous behaviour

Unaffected site with increasing anchoring

SCE 01 shows how anchoring will affect a meadow; it is the primary scenario showcasing the problem due to free anchoring within a marine site, where Posidonia meadow occurs.

The system structure describes Posidonia meadow being influenced by nautical tourism. The quantity that drives changes in the system is anchoring number, representing the physical object responsible for damaging the ecosystem. This quantity starts the simulation with the value Zero (representing the moment when the meadow was not disturbed yet) and increases during the last decades, when nautical tourism has been spreading.

When running the scenario, 38 states are generated with two possible ends (state 22 and 24).

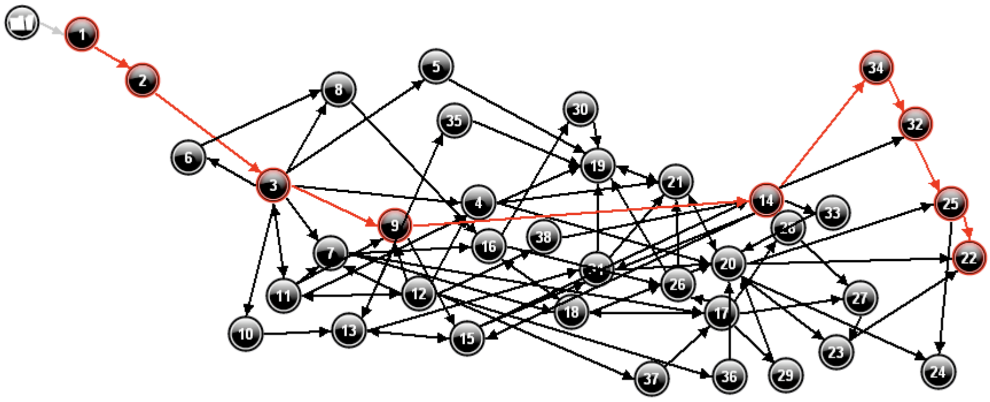


Fig. 3.10 Behaviour graph of a simulation starting with Scenario 01

Both end states show how far can lead anchoring impact in degrading a Posidonia meadow. In the very long term it can even result in an infinite fragmentation and thus zero coverage, zero net growth rate and zero conservation status (state 22). This means no possibility for recovery of the meadow, which is mainly disappeared. A possible path leading to end state 22 is shown in fig 3.10 and its relative value history on fig. 3.11.

A better end happens when Fragmentation does not reach the infinite value and a possibility of meadow recovery still exists. This is represented by path ending with state 24. In fact, in such state anchoring number reaches the maximum value while the fragmentation is high and coverage and conservation status are low.

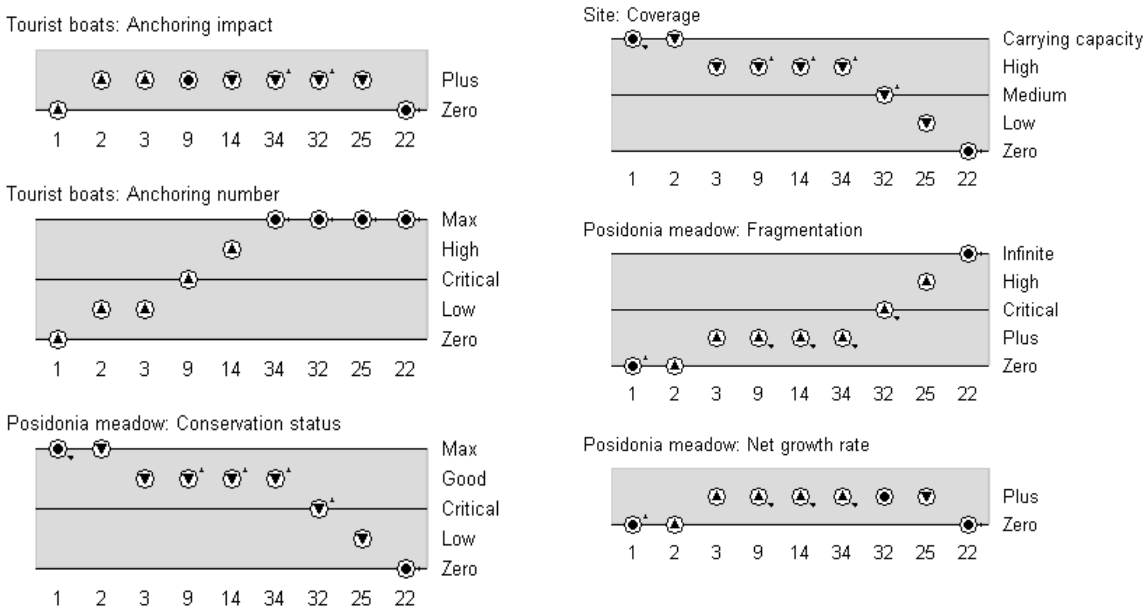


Fig. 3.11 Value history Scenario 01, the consequence of anchoring impact increasing

Unaffected site with some anchoring

When running simulations for scenario 02 (see fig. 3.12), although only eight states are generated, the end states are several (four) and they cover all the possible value for the quantities modelled.

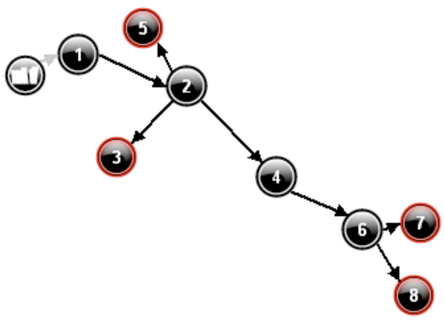


Fig. 3.12 Behaviour graph of simulation starting with Scenario 02, (in red the end states)

The value histories of the end states (fig. 3.13) show how the consequences of a constant low impact are hardly predictable. This kind of impact in fact can lead to nearly all the magnitude values of quantities (anchoring number/impact, conservation status, coverage, fragmentation and net growth rate)

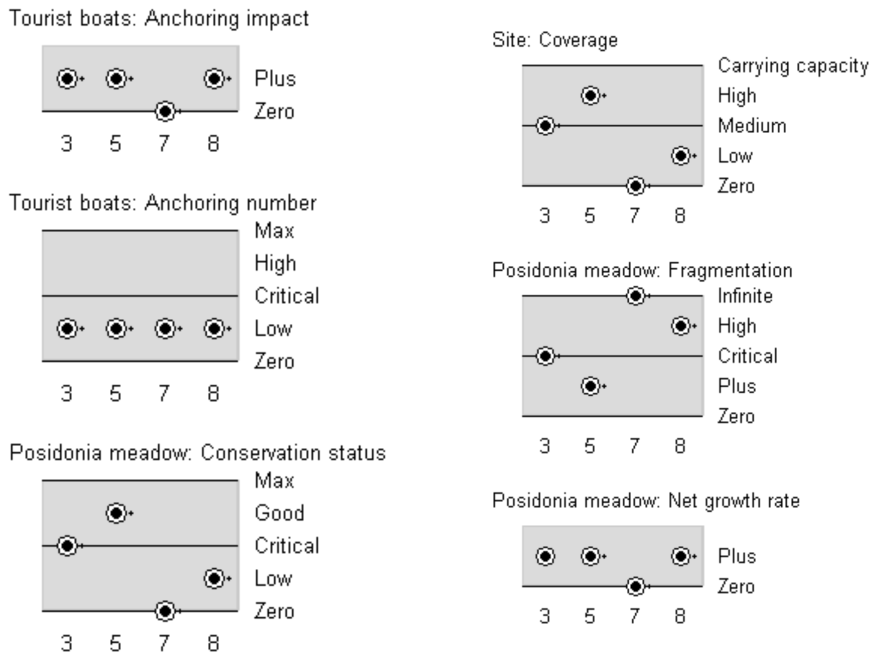


Fig. 3.13 Value history for the four end states, Sce 02

Highly affected site with decreasing anchoring

Running scenario 03, 34 states are generated with two possible end states (25 and 34).

The simulation shows that anchoring could be still leading to extinction of the meadow (see value history in fig. 3.14), even if it is slowly decreased (Scenario 03); for instance by implementing measures such as limiting anchoring to a smaller number of boats each year. This result can be explained considering that the rate of recovery (net growth rate) could be too low to counterbalance the lost of coverage. In fact if by case anchoring damages have been so much that the distances between patches of Posidonia are too high, the time scale needed for colonizing again the area is too long to be overcome just by a slow decreasing anchoring.

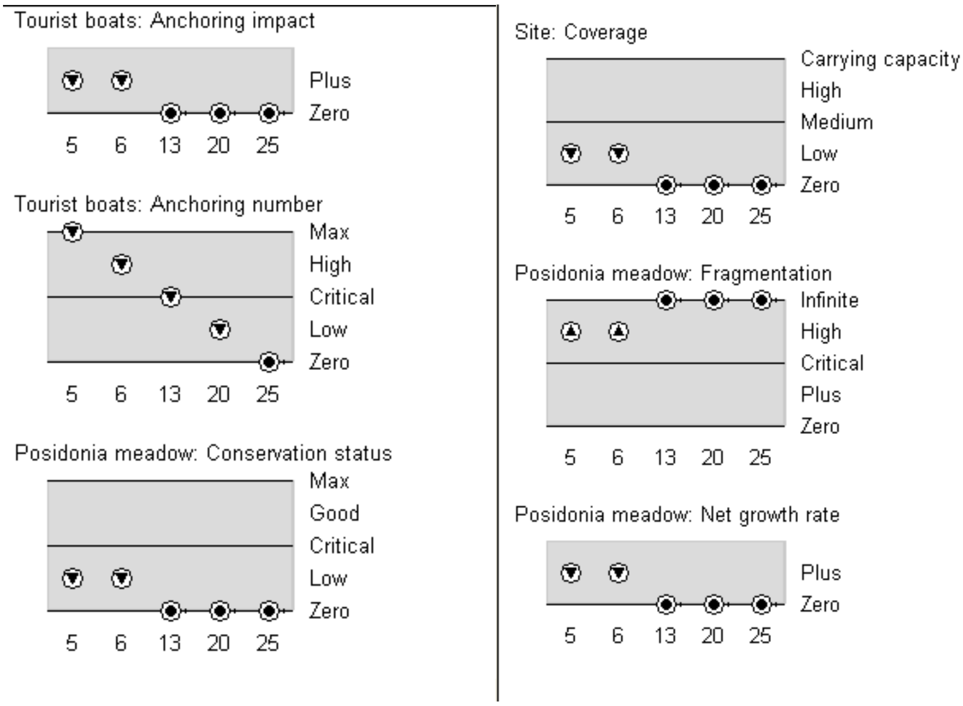


Fig. 3.14 Value history path, Sce 03, if the capacity of recovery is lost

However, if the patches are not so far away each other, decreasing anchoring, can be sufficient to restore the "wounds" of the meadow created by anchoring. This situation can be clearly observed in the value history (see fig. 3.16) of the path underlined in red in fig. 3.15. Here the decreasing of the cause affecting the meadow will indeed lead to Fragmentation decreasing and to Coverage and Conservation status increasing.

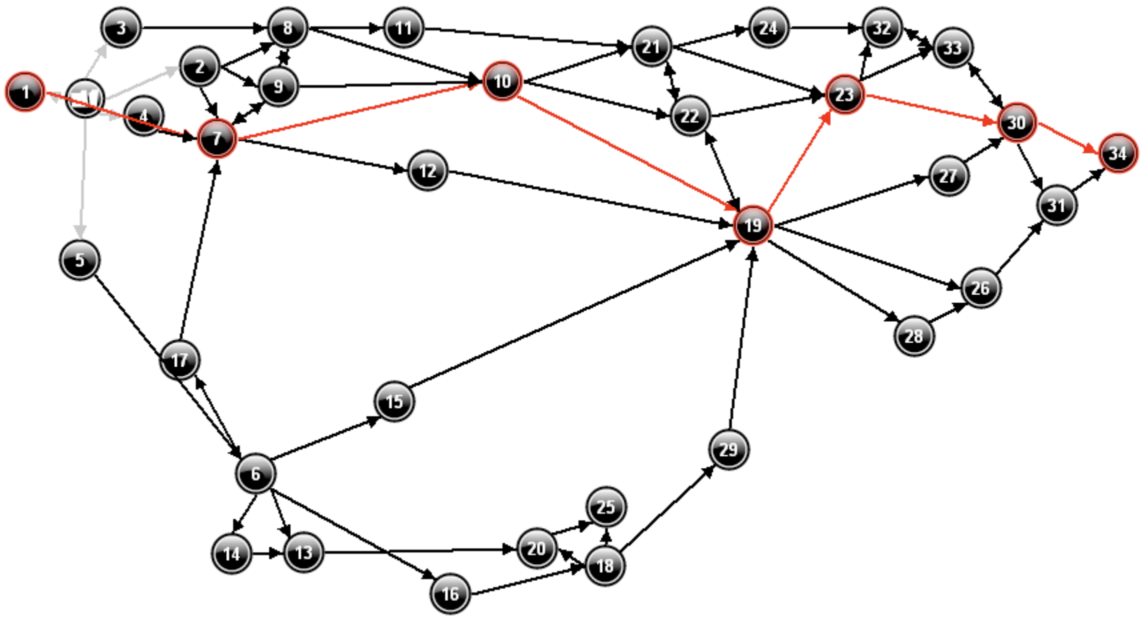


fig.3.15 Behaviour graph of a simulation starting with Scenario 03

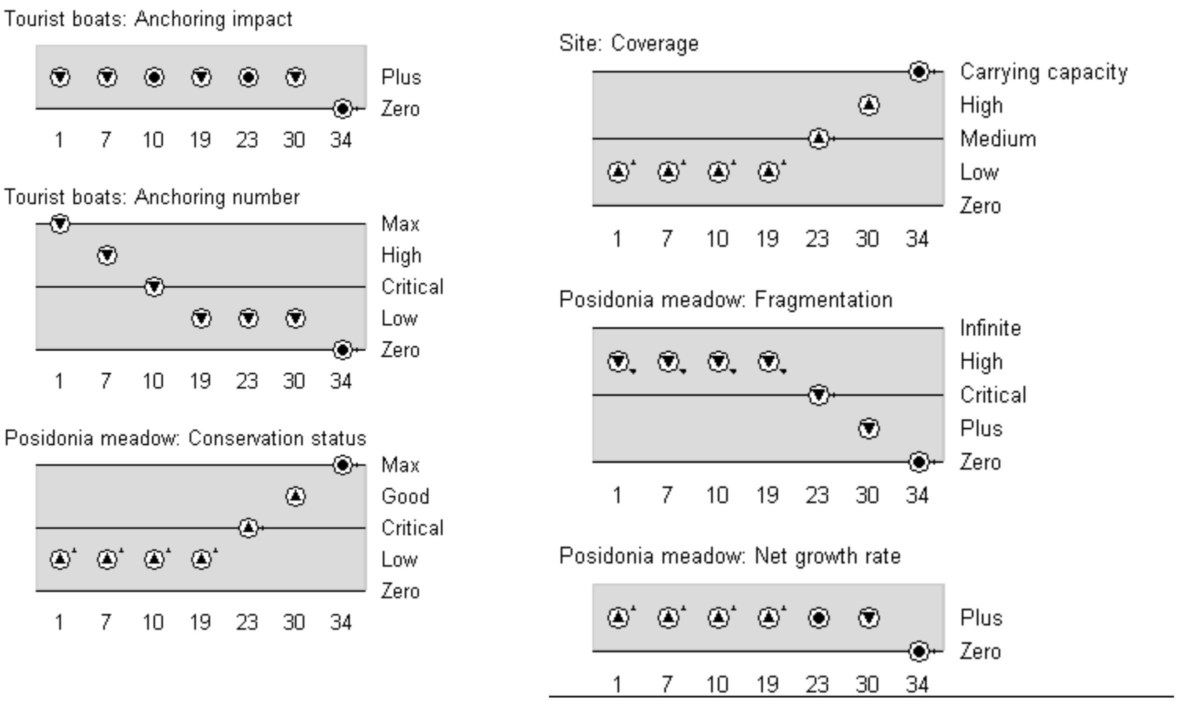


Fig. 3.16 Value history path, Sce 03, when there is still capacity of recovery

Zero anchoring (zoning activated)

The simulation of Scenario 04 clearly shows (see value history on fig. 3.17) how Posidonia meadow ecosystem is able to

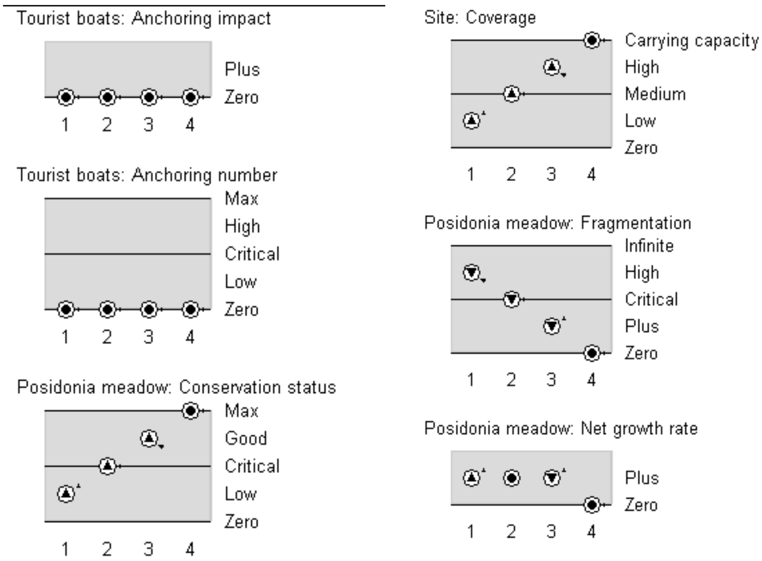


Fig. 3.17 Value history path. Scenario 04, when zoning helps meadow recovery

recover the "wounds" created by anchoring if zoning is promptly activated and for long enough. The simulation of this scenario generates only one path with four states, leading to the natural restoration of the meadow, represented by an end state where fragmentation is zero, coverage reaches the carrying capacity and conservation status is maximum.

The capacity of recovery is for ever lost if the simulation starts when fragmentation has already reached the infinite magnitude. This, indeed, is a no-return state represented by the simulation of scenario 05 where initial fragmentation is set as infinite and only one state is generated. No way of changing state.

4. DISCUSSION

4.1 Biocenosys mapping and official information assessment

Map and perimeter

Although the high degree of dead matte found shows how the meadow should be extensive in the past decades and so the evidence of a regression process, a high percentage of the site (32%) can still be considered as covered by a sparse Posidonia meadow.

It is important to note that our results are mainly coherent with what have been observed by others authors that studied the meadow previously, such as Ardizzone and Belluscio (1996). They identified and mapped a physionomic entity between Capo Linaro and Santa Severa with three vertical profiling; at Grottini and around Grottini they described a rocky bottom in the shallow sites (7-8m), with sparse Posidonia shoots (coverage of 10%) and dead matte and then a sparse alive *Posidonia* intersparse with dead matte, rocks, sandy basins, until 20 m. At Santa Marinella the meadow is described as mainly characterized by dead matte, with a wide channel and basins and steps around -12/13 m followed by scrub of seagrass (coverage of 30%). A sparse meadow of *Cymodocea nodosa* between 7 and 9 m depth has been observed.

Diviacco et al. (2001) also identified a meadow overlapping with the one studied, naming it of Santa Severa. According to their description the meadow is characterized mainly by dead matte around the lower limit and small patches of *C. nodosa* have been observed, the upper limit is found around 6 m depth.

The main part of meadow, east of the harbour and west of Rio

Fiume, is characterized by a high presence of dead matte interspersed with living Posidonia on matte showing a highly degraded community mainly in front of the streams' mouth and near the harbour, this can be due to a reduction of light. From this point of view, it is well known on a world scale that human activities and discharges causing restrictions in the penetration of light into the water column create one of the most significant threats to seagrass growth and survival (Short et al., 1989; Short and Wyllie- Echevierra, 1996). Also Diviacco et al. (2001) described the majority of northern Lazio's meadows as characterized by a high percentage of dead matte.

The living shoots interspersed within dead matte are highly buried by fine materials. This shows that fine particulate material is mobilized in the area and it can also increase turbidity and possibly exacerbating meadow regression or inhibiting recolonization (De Falco et al., 2000).

East of Rio Fiume the presence of a wide surface of dead matte with few living shoots clearly shows that the meadow has regressed because light is no more enough to survive, and it is probably connected to the low level of transparency registered in the area (ARPAL, 2006). Diviacco et al. (2001) also inferred that the degradation of northern Lazio meadow is caused by an increasing in water turbidity happened in the last decades and to the change of the current's sedimentary regime.

The construction of the harbour of Civitavecchia, Riva di Traiano, the widen of the harbour of Santa Marinella, the sea works due to the thermo-electrical centre of Torre Valdalica and Montalto di Castro and the canalization of several river in the area (Mignone, Marta, Fiora and Arrone) surely combines to bring up the decline observed (Diviacco et al., 2001).

West of Rio Fiume is localized the smallest part of the meadow, here the presence of a step of matte and, under this, a high preponderance of orthotropes rhizomes, show that the meadow's limit is eroding. This is an indication that, in this area, the progression of the meadow is limited by the hydrodynamic of bottom underwater currents (Pergent et al., 1995), the area is in fact highly subject to sea events.
Another demonstration that the degradation and disappearing of the meadow is caused by a reduction of available light is due to the presence of a unique patch of Posidonia on matte at 10 m depth on an underwater hill, within a big area of dead and alive Posidonia in front of Santa Severa, showing how Posidonia found condition to grow only when reaching a depth where light is enough to supporting the photosynthetic process.
The presence of several channel and patches of medium course sand and isolated shoots mixed showed a high degree of meadow's fragmentation, which can be an indicator of moderately anchoring (Francour at al. 1999).

Official Standard Data Form and Map assessment

The official geo-referred map provided by the Ministry of Environment's database is not consistent with the information listed on the official SDF. According to the SDF, minimum and maximum bathymetry of the site are respectively –3m and –25m, but the site's perimeter of the official map is located in an area where bathymetry ranges between more then 5 m and more then 30. Moreover the site's perimeter includes deep zones (such as 30 m deep) that are over the lower limit of Posidonia meadows observed during our monitoring program. Also past literatures on this area (Diviacco et al, 2001; Ardizzone & Belluscio, 1996) never report a lower limit

below 20 m depth in this area.
Although the perimeter did not overlap the seagrass distribution exactly, the widest areas colonized by Posidonia are included in the SCI.

It should be noted that the official map has been originally drawn on paper at 1:100.000 scale and such scale does not allowed a high definition of the boundaries if the map is used at a local scale. Thus official map should be drawn in GIS environment, now largely available, and the border towards the coastline and out to the sea should be better drawn, making them overlapping with bathymetry (as identified by nautical official chart) of 5 and 20 m. This could help competent authorities and boaters to easily identify the site's boundaries.

4.2. Posidonia meadows conservation status assessment

Observing the data collected on absolute densities (Annex I), it is clear that this parameter is highly variable during the year. These results can be considered as normal trend for a short term monitoring (Scardi et al, 2006); moreover, considering that the station points are so close each other, the identification of the cause of such differences can be detected only if using a specific sediment trap at each station point.

Our results clearly show a significant difference in the values of absolute density between shallow (above 10 m depth) and deep (below 10 m depth) sites' samples as already underlined in by several authors in the past (such as Dalla Via et al, 1998; Torricelli and Peirano, 1997; Pergent et al., 1995).
Comparing the Pergent classification of Santa Marinella with other Thyrrenian meadows, Santa Marinella is disturbed

meadow. It is interesting to note how the disturbed meadows are registered in shallow sites (maximum 15 m). The meadows, classified as disturbed (Terracina, Follonica and Santa Marinella), are mainly located in highly urbanized area or not far from a big harbour or city.

Monterosso is the only meadow which expected value would be higher considering that it borders on the National Park of Cinque Terre.

The primary leaf production per shoot (Pps) of Santa Marinella is around 1145 mg dw shoot^{-1} year^{-1} (average value), it is a high value according to Pergent-Martini et al. (1994) identified range (310 to 1540 mg dw shoot^{-1} year^{-1}) of Pps for Mediterranean region meadows; this can also be affirmed if looking the average values of Pps of other Thyrrenian meadows (shown on chapter 3). Since the meadow is highly productive we would expected a meadow in a good status although it is contradicted by the low values of absolute density observed, the shallow lower limit (maximum 17 m) and the high surface of dead matte. Considering the moderate concentration of nutrients observed in the ephemeral streams flowing within the SCI, that are also classified as highly polluted (ARPALazio and Province of Rome, 2006) we could inferred that this value of production can an indication of a low or moderate increasing in nutrient loading in the sediment (Burkholder et al., 2007).

<u>PosiPred</u>

Absolute density

Evidences have shown that the observed absolute density is significantly lower then the Posipred expected value, this can be assumed as a demonstration of the presence of a disturbance at the meadow of Santa Marinella, which lower the availability of light to the plant. Considering that the distribution of seagrass is restricted to infralittoral depth at which the irradiance of photosynthetically active radiation (PAR) is above approximately 4.5% of the subsurface value, as Ott underlined in 1980 and 1996 and that turbidity is directly negatively influencing lightness availability in the water column even at shallow station (above 10 m). The high level of turbidity registered (ARPAL, 2006) in the site can be assumed as the main cause of low density values.

Rhizomes production

The anomalous values of rhizomes' production, much lower than the predicted ones, indicate how Santa Marinella's meadow differs from the majority of Italian meadows with same morphological characteristics. It has been already observed that beautiful and omogeneus meadows are characterized by low values of production and high level of density (e.g. Porto Conte, Scardi et al., 2006), while disturbed meadows are more productive although with lower density (pers. Comm. Fresi). Thus we assumed as a sign of stress of the meadow these high values of rhizomes production, considered mainly connected to the amount of available nutrients in the sediment or water column.

In fact, the limited available evidence to date has already revealed an expected response of increased growth with low to moderate nutrient enrichment, especially from sediment sources (Burkholder et al., 2007), although little is known about the basic nutritional physiology of many seagrass species and the many interacting, indirect effects of eutrophication in stressing seagrass ecosystem are poorly understood.

Although the present sutdy has not monitored nutrients simultaneosly with biological samples, the available data on particulate suspended material can be assumed as an

indication of anomalous trophic state in the area.
Moreover the high level of BOD5 recorded in the streams around the sites and the percentage of intensive agriculture land uses in the coastal area surrounding the site, highlighted how disturbed is the area.
While light limitation is a common mechanism for seagrass declines under nutrient over-enrichment, the available evidence suggests that direct physiological responses of seagrasses can be contributing or major underlying factors (Burkholders et al., 2007).

4.3 Human activities at the site

Considering that the major sources of impact for Posidonia meadow in this area are due to terrestrial land uses, all the streams and watercourses have been identified as critical areas for being responsible of leading pollutant, fine sediment and nutrients to the sea area.
The development of the map and the calculation of the ILC showed how agriculture has a determinant role in the area, thus this activity and the operators working with agricultural should be targeted and involved by the competent authorities managing the marine area.

Sediment

Although the types of sediments found in the site are not specifically influencing density or production of the meadow, the unexpected high presence of terrigenous component in the sediment analyzed can be assumed as a sign of unbalanced sedimentologic dynamic to be further investigated in the future.

Fishery

Data collected clearly shows how the fishermen in the study area are mainly sedentary and set in one’s way. They mainly used fishing gears are: tangle net, modified gill-net (original name: incastellato) and gill net. Each gear is used in a specific time of the year on a specific sea bottom and with a specific structure of catchments:

- During autumn fishery is mainly located south-eastern of S. Marinella harbour on the meadow, preys are mainly whitefish (*Umbrina cirrosa, Dicentrarchus labrax, Sparus aurata* and *Pagellus eritrinus*) and the incastellato is the preferred gear;
- Between April and September fishermen prefer rocky area outside the meadow, north-western of Capo Linaro, preys are mainly scorpion fish and modified gill-net is again the gear used;
- During the same months (April to September) is also time for mullets (*Mullus surmuletus*), which seems to be the most profitable activity for the fleet. Gill net is the preferred gear and it is carried out southern of S. Marinella Harbour, between 10 and 20 m depth;
- Between January and April squids (*Sepia officinalis* and *Octopus vulgaris*) are the main target species and they are found on sand or Posidonia eastern of S. Marinella Harbour;
- When adverse sea conditions happen another kind of gill net (schiette) are used to catch valuable species (*Dicentrathus labrax, Sparus aurata, Diplodus sargus* and *Pagellus erythrinus*) in the same areas dedicated to mullet fishing.

This description clearly underlines how fishery in the area is very selective and thus not impacting so much on the marine ecosystem. For this reason it should be considered as compatible with the conservation of Posidonia biocenosys.

The impacts at the site

The study meadow is disturbed and in regression as other Posidonia's meadows located north of Tevere's (the biggest river of the region) mouth. These meadows have been already identified as more fragmented (Diviacco et al., 2001), with smaller surface and shallow lower limit then the ones located southern of the Tevere's mouth. Diviacco et al. (2001) correlated these to a higher degree of anthropication of the coastal area and to a higher influence of the Tevere, which is responsible of sediment and nutrients loading. Although the study area is not facing the Tevere water basin, this river is strongly affecting this area.

In fact, past studies underlined how the main contribution, in terms of loading both liquid and solid, along the continental shelf of Lazio is due to Tevere. Tevere has a mean yearly loading capacity of 236 m^3/a, with maximum during March-April that heavily influences local water circulation (IRSA, 1983). The river water follows the wind and circulation forces: riverine water slides on more dense marine water and consequently *plume* can happen, causing dispersion of fine materials (Bellotti et al., 1993).

Increasing the distance from the mouth the waters mixed each other and are pushed to NW from coastal current (Hopkins et al., 1992; Bellotti et al., 1993) easily reaching Santa Marinella coast (see also chapter 3).

Following our analysis on human activities and their effects on the meadow at the site, it comes that three main impacts, described below, are affecting the study meadow: nutrients loading, disruption of the sedimentation/erosion balance and direct erosion by boat anchoring. Specific actions should be planned to deal with these threats to improve the conservation of the study meadow.

Nutrients loading

Posidonia meadows are very sensitive to water and sediment enrichment with organic matter and nutrients; this kind of over-enriching is the most probable cause of the anomalous production of our meadow; in fact an increased growth happened with low or moderate nutrient enrichment, especially from sediment sources (Burkholder et al., 20007). Agriculture and livestocking (which represent the main land uses at the water basin) enhance pesticides and nutrients contribution to inland watercourses thus indirectly they are the major cause of increasing marine water trophic state (Short et al., 1996). In fact when dissolved nutrients are high, the trophic water level increases and it could happens that the amount of epiphytes and superficial free algae increases directly affecting the available photosynthetic surface (Ruiz & Romero, 2003) and thus the meadow production. In extreme case when presence of primary producer becomes very high, eutrophication happens (Short at al., 1996).

However the study site is not yet eutrophic, the high level of nutrients, the anomalous values of density and production and the regression observed in the lower limit should be read as signal of a nutrient over-enriching that could cause an increasing regression of natural marine ecosystems.

It should be underlined how recovery of seagrass meadow is difficult following nutrient reductions (e.g. Duarte et al., 2006; Walker et al., 2006), in fact the natural cycle of Posidonia is disrupted, slowed or indefinitely blocked by eutrophication process. However researchers who assessed recovery of P. oceanica beds in Cabrera Archipelago National Park (Spain) concluded that while regulation has improved the status of seagrasses in the park, full recovery may even require centuries, and will be threatened by organic inputs from visitors to the park (Marbà et al., 1996). In fact, the time scale of recovery appears to be very slow for more long-lived genera such as Posidonia and Thalassia, ranging from several years to centuries (Birch and Birch, 1984; Duarte, 1995; Walker et al., 2006).

With this regards at the very first advise of nutrients overloading, specific management measures should be applied to avoid coming at a no-returning point.

Disruption of the sedimentation/erosion balance

The anomalous level of sediment in the water column shown by high turbidity data can be also performed as linked with the last decades coastline transformation increasing. In fact anthropication of the coastal areas, such as buildings roads, houses, piers, houses, water regime management have direct consequences on marine environment already underlined by several authors.

Specifically the proliferation of roads and houses and the regulation of continental river-flow, such as the dam and the cementation of water courses, sharply reduces sediment inputs to the submersed coastal habitats, thereby promoting meadow erosion in their area of influence and locally there can be also sediment or suspended material over accumulation. Building piers and other coastal constructions destroy the underlying communities and may alter the pattern of coastal currents creating calm zone where fine material can settle (Cavazza et al., 2000), thus passing on the effects of siltation or erosion to other meadows. Harbour or channel dredging and sand reclamation activities close to meadows have a high risk of direct meadow removal and may produce bed siltation or erosion. On the other hand, removing the seagrass leaf litter from the beach may produce the reverse effect, enhancing shallow meadow erosion.

At the study meadow shoots density reduction and leaves per shoot number can be clearly related with a lower light penetrating in the water surface because of the enhances water turbidity due to the increasing of suspended sediment amount (Savini *et al.*, 1999). The regression of the lower meadow limit which occur in Santa Marinella is the demonstration that this threat have been persisting at the site (De Falco et al., 2000; Guidetti e Fabiano, 2000; Short et al., 1989).

In fact it should taken into account that *P. oceanica* meadows can cope, through vertical rhizome growth, with sedimentation rates that do not exceed 4-5 cm yr^{-1} (Gacia and Duarte, 2001), and are very sensitive to erosion.

Direct erosion by boat anchoring

The meadow of Santa Marinella shows several areas damaged by boats anchors.

In fact other authors already demonstrated how, in sites frequently visited by pleasure boats, there is significant removal of seagrasses (mainly leaves and vertical rhizomes) by boat anchors (Francour et al. 1999). The worst damage seems to be caused by the effects of weighting the anchor (Milazzo et al., 2004) and by the chains movement on the sea bottom due to boat piching because of sea waves, wind or current (Francour et al., 1999).

Moreover the size of the damage is in relation to the type, the weight of the anchor, of the boat and to the Posidonia morphology (Duarte, 1994).

In the study area erosion of the meadow may even be accelerated by enhanced hydrodynamics in the clearings where shoots have been destructed. These clearings persist for many years as the slow regrowth of seagrass further prolongs the impact of wounds, which can sometimes run into decades

(González-Correa et al., 2005).

4.4 Conservation strategies

After evaluating the different impacts of human activities on the ecosystem at the site of Santa Marinella and having assessed what are the interactions between such human activities and biological features at the site; it is clear that there is a conflict between nature conservation and humans activities inland and at sea. From these it follows the necessity to plan and apply management strategy to overcome these conflicts; giving to manager the commitment to push local administrators in changing politics and behaviour.

To find a way for saving such important ecosystem for next generation should be a priority for the coastal administrations.

The information and knowledge developed in the previous chapter allowed the identification of:

The Objectives of the management Plan for the site;

The Management Plan Structure;

The Specific objectives at the Site;

The proposal of SDF's updating.

Objectives of the management Plan

The main objective of the plan for the marine SCI IT600007 is the CONSERVATION OF THE MEADOWS OF *Posidonia oceanica* (HABITAT 1120*), AND OF THE SPECIES THAT LIVES, FEEDS AND USE IT AS SHELTER OR NURSERY.

Considering the complexity and the ecological structure of the Posidonia oceanica meadows the objective can be reached only if the threats are kept down and thus a sustainable development is permitted, promoting information and awareness on environmental values.

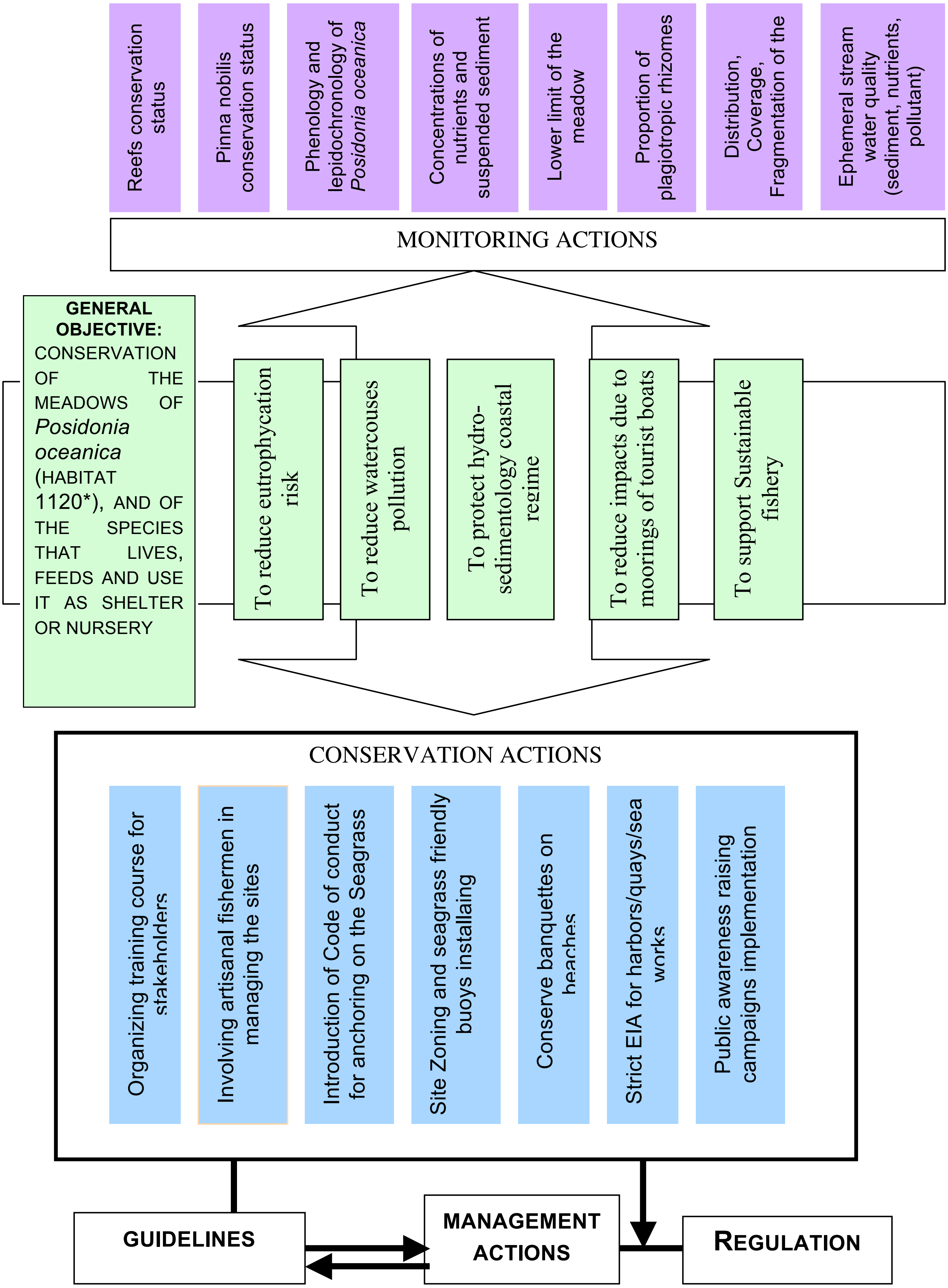
Understanding that *Posidonia oceanica* is mainly affected by a not sustainable use of sea and of the terrestrial areas facing the sea, it follows that working with public administration to change politics should be fundamental.

In fact local administrators, stakeholders and population should be aware of the consequences of their behaviours and on the value of the nature conservation for next generations.

Management Plan structure

The diagram below summarizes the process and the structure of the management Plan.

It also shows how the identification of monitoring and conservation actions is directly linked to the objective of the management plan of the site. The conservation actions can be included in specific guidelines for the management/use of the site or in the regulation of the site.


Reefs conservation status
Pinna nobilis conservation status
Phenology and lepidochronology of Posidonia oceanica
Concentrations of nutrients and suspended sediment
Lower limit of the meadow
Proportion of plagiotropic rhizomes
Distribution, Coverage, Fragmentation of the
Ephemeral stream water quality (sediment, nutrients, pollutant)
MONITORING ACTIONS
GENERAL OBJECTIVE: CONSERVATION OF THE MEADOWS OF Posidonia oceanica (HABITAT 1120*), AND OF THE SPECIES THAT LIVES, FEEDS AND USE IT AS SHELTER OR NURSERY
To reduce eutrophycation risk
To reduce watercouses pollution
To protect hydro-sedimentology coastal regime
To reduce impacts due to moorings of tourist boats
To support Sustainable fishery
CONSERVATION ACTIONS
Organizing training course for stakeholders
Involving artisanal fishermen in managing the sites
Introduction of Code of conduct for anchoring on the Seagrass
Site Zoning and seagrass friendly buoys installaing
Conserve banquettes on beaches
Strict EIA for harbors/quays/sea works
Public awareness raising campaigns implementation
GUIDELINES
MANAGEMENT ACTIONS
REGULATION

Specific Objectives

The integration of our results allowed the identification of four main issues, which should be the targeted by the Site's management Plan.

a. To reduce eutrophycation risk

Intensive agriculture is the main land use of the Water basin of S. Marinella, it affect the site because of the use of fertilizers which slowly comes to the sea through leaching. As the activity cannot be reduced for its high socio-economic value; the involvement of water basin management body, municipality and regional administration should focus on promoting organic agriculture or at least, integrated agriculture.

Fertilizers are the main cause of nutrients enrichment in river and, thus, at sea. As the dynamic regulating concentrations of nutrients and suspended sediments area not yet known, the research for reliable early indicators of nutrient over-enriched seagrass meadows should be improved. Coastal resource managers could benefit from the results of such research to prevent "endpoints" of severe disruption of ecosystem function manifested by seagrass die-off and increased high-biomass algal blooms (Kemp et al., 1983; Orth and Moore, 1983; Short and Burdick, 1996).

In fact although more than a decade ago, Tomasko et al. (1996, p. 448) wrote that "Despite the well-documented relationship between increased water-column nutrient input and degradation of seagrass habitats, seagrass losses continue at unprecedented rates on a global scale"; more then a decade later there has been no change in that trend. Catastrophic losses of seagrass meadows continue worldwide along rapidly urbanizing coastal zones (Walker et al., 2006), despite recognition of the enormous ecological and economic value of seagrass meadows (Orth et al., 2006).

b. To reduce watercourses pollution

Concentrated and unpurified urban sewage discharge decreases the water quality and pollutes sea, especially during summer when population inhabiting coastal village and towns increases. The water purifiers supplied by the municipality of S. Marinella do not solve the problem of the pollution in the ephemeral streams, and no sufficient studies have been implemented to discover why it is happening.

Several policies and legal documents describe how the water pollution should be kept down. The Water Framework Directive represents the main useful ones and it already includes enough prescription to contain water pollution. Although it does not help identifying a unique authority competent and responsible for protecting sea water quality. In fact, sea water comes from all the catch basin network thus its quality is directly influenced by the management strategy applied to the whole water basin.

The management body of the Santa Marinella SCI should monitor water quality of the ephemeral streams around the meadow, and introduce regulation and elaborate a contingency plan in case pollution reaches critical limits. Besides, the management body should promote awareness raising campaigns on the problem of marine pollution and should push and do lobbying on the administrations responsible for managing terrestrial land surrounding the SCI: the Water basin management body, the Environmental Ministry, the Regional environmental Department of Lazio, the Rome's Province environmental department and Santa Marinella's municipality environmental department.

c. To protect hydro- sedimentology coastal regime

The maintenance of the hydro-sedimentology balance is an objective of the water basin authority, it cannot be reached by the SCI management body solely. Thus the management body should promote actions aiming on collaborating with the Water Basin Authority and then plan to conserve Posidonia *banquettes* in the beaches and introduce strict regulation for the Incidence Assesment Study to build harbours or quays or any sea works.

d. Reduce impacts due to moorings of tourist boats

Anchoring destroys all the bottom dwelling organisms and therefore it should be not compatible with SCI that are implemented because of these organisms or bottom habitats, such as *Posidonia oceanica* meadow.

Several tourists boats come along Santa Marinella coast with small boats every summer for daily tour. The creation of temporary forbidden area should be proposed to stop destruction of the meadow, at least in some areas. In addition anchoring buoys could be installed outside the meadow. In fact dead weights installing has been identified recently as causes of similar impact as anchoring if done within the meadow.

Rotation of restricted area is the best but if such a rotation period is shorter then 5 years a recovery of the meadow will not be allowed (Francour et al., 1999).

To control the efficacy of “no anchoring zones” the proportion of plagiotropic rhizomes and the fragmentation of the meadow should be monitored. The proportion of plagiotopic rhizomes is a quick indicators of the impact due to boat anchoring; while fragmentation (measured as number of inter-matte channel) would show some changes only after 5 years

(Francour et al., 1999).

At S. Marinella it could be important also to implement a self regulatory approach (Antonini and Sidman, 1994) based on educating and informing boaters on correct anchor type to use when anchoring on *P. oceanica* to reduce the impact of anchoring in the areas of the SCI where mooring would not be restricted and small boats frequentation is common rather then big boats. The promotion of the Code of Conduct for Anchoring on the Seagrass meadows (CASE) equivalent to the Code of Conduct for Anchoring on the Reef (CARE) proposed by Hunnam (1987) for the Great Barrier Reef. Through this code it should be also sustained the improvement of the use of low impact anchors such as Hall anchor (Milazzo et al., 2004). Chain and rope can be used indifferently as no differences where found by those authors.

Big boats' anchoring should be forbidden on the meadow and limited in areas (at least 100- 200 m diameter) where the meadow has already disappeared; in those areas the management body could also decide to install a dead weight.

e. Sustainable fishery supporting

The sustainable management of fishery is fundamental to protect marine biodiversity and, specifically, the Posidonia meadow of Santa Marinella.

The principles enunciated in the Conduct Code for Responsible Fishery (FAO) should be taken into account as it gives important suggestion to increase sustainability of this activity.

In Santa Marinella SCI artisanal fishery is the main activity thus it is a good site where enhancing the function and the importance of artisanal fishermen.

The management body should support project promoting the use of fishery funds (EFF); involve fishermen and local cooperatives managing the site; organize training courses to fishermen on marine biology to help recognizing and controlling illegal fishing; involve fishermen in scientific monitoring, promote the presence of students or researchers on fishery boats to monitor the fishing community living at the site.

Updating the Official SDF

The present research has shown that the official SDF lack of several information regarding the study site.
Habitat 1170 (reefs) should be add in section 3.1 and the species *Pinna nobilis* and *Paracentrotus lividus* should be add in section 3.3 of the official SDF.
Moreover on the official SDF of the study area no activities are listed in section 6. After having analyzed the data and the information regarding Santa Marinella, several human activities according to appendix E of the Guidelines, have been identified and should be added to the revised form; the complete list of these activities with the relative N2000 code is attached in Annex II.

4.5 Qualitative reasoning model

During our modeling implementation it comes often how modellers must always specify the time scale necessary or supposed to reach the change state. The number of states is not linked with the time each path will take.

Dead end simulations

As mentioned in the previous chapter we strive for clean models that produce simulations without dead ends. These are said to occur in behaviour paths in the state-graph when the last state, in a sequence of states, does not reach a valid successor state despite having potential transitions. In the case of such a dead end there exists at least one quantity that is moving in the direction of the next value in its quantity space, but that does not reach this value (often due to inconsistencies in the model). Contrary, in a ‘clean end state’ each quantity has one of the following options: (i) stable ($\partial Q=0$), (ii) increase in highest interval, or (iii) decrease in lowest interval. Notice that, in each of these three cases no transitions will be found for a quantity.

The reason for dismissing models with dead ends is that such a model must be incorrect or at least be incomplete at this point. Its behaviour with infinite movement on a bounded interval does not comply with the limit analysis (e.g. Forbus, 1984) that is used. For an intuitive explanation of this concept consider Zeno's paradox of the arrow that never reaches its target because it always has the remaining half of the distance to travel. This is of course an infinite but converging series with a therefore finite outcome. All our scenarios have been assessed for the presence of such end states. And in development these have been present, always indicating problematic modelling decisions. In our final implementation all the produced simulations are free of dead ends.

<u>Model discussion</u>

This tool successfully supports and organizes the capture of conceptual knowledge about the study ecosystem and its behaviours. More in general, qualitative reasoning process helped in understanding what are the principal relationships to be considered when decision-making on sites’ uses will start.

The model described here aims at showing how the conservation of Posidonia meadow is strictly connected with

boats' tourism.
The absence of regulation for site using and thus the presence of unregulated anchoring is here considered the unique cause of Posidonia meadows's fragmentation. Our model highlights how fragmentation of the meadow reduces the coverage and consequently the conservation status of the protected habitat 1120* targeted by this study.
During the building process it comes clear that only by implementation, the model and its dynamic consequences can be evaluated under different scenarios. When unexpected simulation results were produced, it was deemed necessary to change details in the set of model ingredients. Hence, only after simulation it became clear that the model was not representing the intended causality or that the representation was too vague to be useful. Also this part of the model building process has been useful to pinpoint important relationships between variables (quantity in garp3).
The identification of the influence of anchoring impact on fragmentation, given certain values of anchoring number, highlighted how a high fragmented meadow is less affected by anchoring. This is mainly because the capacity of recovery of a high-fragmented meadow is very low, even in the long term.
The determination of which is the stronger influence on fragmentation between anchoring impact and growth under certain condition has been also another important issue to be solved. Inequalities have been used to help representing these relations.
Model implementation has pinpointed that the capacity of Posionia ecosystems to recover is maximum when they are left undisturbed for enough time. In such case the system has the possibility to find a new balance and so to start recovery. The time necessary to achieve this result is different from one site to another because of a number of factors, which we are

not considering in this model for sake of simplicity.
The simulations generated by two scenarios (03 and 05) showed that there are not possibilities for recovery if infinite fragmentation is reached, thus it should be avoided that this threshold is reached.
Furthermore the simulations of scenario 03 support our proposal of establishing areas where anchoring is forbidden through zoning of the site, in contrast with the proposal of slowly decreasing of anchoring (such as limiting anchoring to a smaller number of boats each year) which could be still leading to extinction of the meadow.
Such zoning should be implemented before the ecosystem has lost its capacity of recovery in order to guarantee the conservation of this valuable and sensitive ecosystem.

Like in any other model, simplification was required to produce models that are able to capture significant aspects of reality and still be useful and manageable for learning and decision-making.
Future works could investigate how simulations will change if more interactions between variables that are involved in Posidonia meadow living are added.
It would make the model much similar to the real world although simplification would be always needed when modeling. It is also more necessary for coastal marine ecosystems, which complexity is very high overall because of the high number of influences (which can come from both terrestrial or sea areas) interacting and that are responsible of the conservation status and health of the species and habitats living in there.

5. CONCLUSION

With the aim of identifying and then sustaining and supporting management strategic priorities original solutions and different approaches have been experimented during this research.

In the study area the regression of lower limit, the high dead matte surface, the low density values show to what extent the meadow is disturbed. This disturbance can be correlated with the high water turbidity observed in the area, which can be mainly attributed to the high suspended sediment contribution of Tevere river (that is the main river in the area and which water moves north along the Lazio coastline) and seasonally, to the water transported by the ephemeral streams located on the coast of S. Marinella.

Moreover high level of primary production and rhizomes production can be correlated with the high concentration of total nitrogen and suspended nitrogen sediment, observed in the area.

The presence of several "wounds" ad channels in the meadow show that the high presence of small boats anchoring at the site is enhancing the fragmentation of the meadow and reducing its coverage in the long term.

The present work helped to identify what is needed to monitoring Posidonia meadow with the aim of avoiding its further decline through the application of management measure.

Specifically, to help better understanding the dynamic for which this meadow is so highly productive and so disturbed, monitoring of concentrations of nutrients and suspended sediments should be implemented in the future, through the development and installing of specific small sediment traps. In fact, at present there are no available, reliable tools for early

assessment of nutrient over-enrichment in seagrasses (Burkholders et al., 2007).
A research in this topic represents a further needs for Posidonia conservation, as it would benefit coastal resource managers in efforts to prevent "endpoints" of severe disruption of ecosystem function (Kemp et al., 1983; Orth and Moore, 1983; Short and Burdick, 1996).
This research experience underlines how planning and management measures for marine areas should involved the whole water basin terrestrial area beyond marine areas.
The involvement in the decision making process through "concerting table" of the regional and local administrations responsible for both sea and water basin area and, thus, the developments of tools useful to communicate and "teach" scientific concepts to stakeholders, administrators and population is a fundamental step to help implementing protection of Posidonia for future generations.
Concerted, strengthened local and national policies and actions, thus far mostly lacking, are needed worldwide to protect remaining Posidonia meadows from accelerating cultural eutrophication in rapidly urbanizing coastal zones.

Our major findings suggest that the software Garp3 together with the use of different approaches criteria are valuable tools that should be incorporated earlier in the protected area management planning process. Qualitative reasoning modelling helped indeed in understanding what are the principal relationships to be considered when decision-making on the uses of the site starts.
Model implementation has confirmed that the capacity of Posidonia ecosystems to recover is maxim when they are left undisturbed for enough time. In such case the system has the possibility to find a new balance and so start recovering.

The model also supports our proposal of zoning of the site that should be established before the ecosystem has lost its capacity of recovery, in order to guarantee the conservation of this valuable and sensitive ecosystem.

Although the integrated process for identifying Management Plan Guidelines appears complex, the whole results discussed previously represent the basic knowledge to build the management Plan for the study Site of Community Importance and therefore, operationally implement conservation measures for a so important and vulnerable ecosystem.

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Annex 1

Marzo 2006									Giugno 2006								
Conte Stazioni	1	2	3	4	5	*media*	***densità***	**Giraud**	Conte Stazioni	1	2	3	4	5	*media*	***densità***	**Giraud**
M.1.4	23	37	33	32	36	*32,2*	***201,3***	**IV**	M.1.5	33	28	30	36	25	*30,4*	***190,0***	**IV**
M.2.4	26	46	28	33	40	*34,6*	***216,3***	**IV**	M.2.5	29	39	50	44	35	*39,4*	***246,3***	**IV**
M.3.4	58	44	56	43	30	*46,2*	***288,8***	**IV**	M.3.5	50	33	49	55	70	*51,4*	***321,3***	**III**
M.4.4	43	51	36	34	55	*34,0*	***212,5***	**IV**	M.4.5	40	39	35	41	44	*34,0*	***212,5***	**IV**
M.5.4	29	33	37	40	34	*34,6*	***216,3***	**IV**	M.5.5	26	27	30	20	25	*25,6*	***160,0***	**IV**
M.6.4	23	34	22	20	33	*26,4*	***165,0***	**IV**	M.6.5	16	26	24	33	36	*27,0*	***168,8***	**IV**
M.7.4	51	55	61	47	54	*53,6*	***335,0***	**III**	M.7.5	50	74	55	62	73	*62,8*	***392,5***	**III**
M.8.4	45	43	48	51	38	*45,0*	***281,3***	**IV**	M.8.5	63	55	70	53	75	*63,2*	***395,0***	**III**
M.9.4	41	38	31	18	27	*31,0*	***193,8***	**IV**	M.9.5	21	19	30	15	23	*21,6*	***135,0***	**V**
M.10.4	75	58	70	57	67	*65,4*	***408,8***	**II**	M.10.5	58	50	54	57	65	*56,8*	***355,0***	**III**
M.11.4	41	73	54	29	50	*49,4*	***308,8***	**III**	M.11.5	25	32	40	28	29	*30,8*	***192,5***	**IV**
M.12.4	46	54	62	70	74	*61,2*	***382,5***	**III**	M.12.5	47	53	49	60	54	*52,6*	***328,8***	**III**
M.13.4	75	73	84	86	78	*79,2*	***495,0***	**II**	M.13.5	67	88	57	48	66	*65,2*	***407,5***	**II**
M.14.4	74	53	56	61	65	*61,8*	***386,3***	**III**	M.14.5	49	53	64	66	55	*57,4*	***358,8***	**III**
M.15.4	69	74	49	89	54	*67,0*	***418,8***	**II**	M.15.5	30	43	25	47	39	*36,8*	***230,0***	**IV**
M.16.4	29	36	41	39	46	*38,2*	***238,8***	**IV**	M.16.5	42	35	38	45	40	*40,0*	***250,0***	**IV**
M.17.4	48	54	45	47	50	*48,8*	***305,0***	**III**	M.17.5	63	39	46	55	48	*50,2*	***313,8***	**III**
M.18.4	57	39	52	47	42	*47,4*	***296,3***	**IV**	M.18.5	20	19	27	30	22	*23,6*	***147,5***	**V**
M.19.4	22	30	41	25	29	*29,4*	***183,8***	**IV**	M.19.5	37	40	27	25	30	*31,8*	***198,8***	**IV**
M.20.4	46	44	47	53	38	*45,6*	***285,0***	**IV**	M.20.5	58	53	49	59	53	*54,4*	***340,0***	**III**

Settembre 2006									Dicembre 2006								
Conte Stazioni	1	2	3	4	5	*media*	***densità***	**classe**	Conte Stazioni	1	2	3	4	5	*media*	***densità***	**classe**
M.1.6	39	42	27	50	35	*38,6*	***241,3***	**IV**	M.1.7	22	37	45	54	43	*40,2*	***251,3***	**IV**
M.2.6	43	49	41	45	36	*42,8*	***267,5***	**IV**	M.2.7	53	45	42	54	37	*46,2*	***288,8***	**IV**
M.3.6	46	62	49	54	44	*51,0*	***318,8***	**III**	M.3.7	52	63	58	62	48	*56,6*	***353,8***	**III**
M.4.6	32	30	23	26	28	*27,8*	***173,8***	**IV**	M.4.7	44	52	40	49	53	*47,6*	***297,5***	**IV**
M.5.6	15	12	18	16	22	*16,6*	***103,8***	**V**	M.5.7	45	47	44	43	55	*46,8*	***292,5***	**IV**
M.6.6	17	25	22	19	24	*21,4*	***133,8***	**V**	M.6.7	43	48	45	39	42	*43,4*	***271,3***	**IV**
M.7.6	39	72	36	59	48	*50,8*	***317,5***	**III**	M.7.7	45	48	63	65	50	*54,2*	***338,8***	**III**
M.8.6	41	45	48	40	56	*46,0*	***287,5***	**IV**	M.8.7	55	43	51	58	54	*52,2*	***326,3***	**III**
M.9.6	48	39	51	54	47	*47,8*	***298,8***	**IV**	M.9.7	23	15	36	40	32	*29,2*	***182,5***	**IV**
M.10.6	56	44	72	61	54	*57,4*	***358,8***	**III**	M.10.7	53	60	72	46	59	*58,0*	***362,5***	**III**
M.11.6	34	52	44	37	42	*41,8*	***261,3***	**IV**	M.11.7	65	46	57	51	54	*54,6*	***341,3***	**III**
M.12.6	15	23	28	16	18	*20,0*	***125,0***	**V**	M.12.7	49	70	62	57	67	*61,0*	***381,3***	**III**
M.13.6	48	35	52	62	54	*50,2*	***313,8***	**III**	M.13.7	70	53	74	67	80	*68,8*	***430,0***	**II**
M.14.6	28	22	30	27	33	*28,0*	***175,0***	**IV**	M.14.7	41	64	42	46	62	*51,0*	***318,8***	**III**
M.15.6	18	27	34	32	28	*27,8*	***173,8***	**IV**	M.15.7	58	70	51	49	64	*58,4*	***365,0***	**III**
M.16.6	35	28	32	42	33	*34,0*	***212,5***	**IV**	M.16.7	45	37	51	33	49	*43,0*	***268,8***	**IV**
M.17.6	38	45	42	47	39	*42,2*	***263,8***	**IV**	M.17.7	31	43	38	37	50	*39,8*	***248,8***	**IV**
M.18.6	32	28	25	30	35	*30,0*	***187,5***	**IV**	M.18.7	45	62	54	52	49	*52,4*	***327,5***	**III**
M.19.6	28	30	22	24	35	*27,8*	***173,8***	**IV**	M.19.7	40	37	35	39	36	*37,4*	***233,8***	**IV**
M.20.6	19	23	30	20	18	*22,0*	***137,5***	**V**	M.20.7	44	42	36	41	37	*40,0*	***250,0***	**IV**

Absolute density- 2006

Marzo 2007									Giugno 2007								
Conte Stazioni	1	2	3	4	5	*media*	***densità***	**classe**	**Conte Stazioni**	1	2	3	4	5	*media*	***densità***	**classe**
M.1.8	57	56	43	40	54	*50,0*	***312,5***	**III**	M.1.9	46	44	55	46	53	*48,8*	***305,0***	**III**
M.2.8	52	45	52	56	63	*53,6*	***335,0***	**III**	M.2.9	32	30	43	52	38	*39,0*	***243,8***	**IV**
M.3.8	64	72	67	81	59	*68,6*	***428,8***	**II**	M.3.9	54	66	71	56	64	*62,2*	***388,8***	**III**
M.4.8	26	35	32	29	24	*29,2*	***182,5***	**IV**	M.4.9	33	24	45	32	36	*34,0*	***212,5***	**IV**
M.5.8	34	28	26	28	30	*29,2*	***182,5***	**IV**	M.5.9	23	31	27	33	25	*27,8*	***173,8***	**IV**
M.6.8	48	45	36	38	41	*41,6*	***260,0***	**IV**	M.6.9	42	33	27	34	28	*32,8*	***205,0***	**IV**
M.7.8	65	53	51	44	48	*52,2*	***326,3***	**III**	M.7.9	37	45	45	54	65	*49,2*	***307,5***	**III**
M.8.8	37	35	42	45	51	*42,0*	***262,5***	**IV**	M.8.9	35	42	37	41	34	*37,8*	***236,3***	**IV**
M.9.8	32	25	42	33	35	*33,4*	***208,8***	**IV**	M.9.9	18	30	47	35	40	*34,0*	***212,5***	**IV**
M.10.8	50	71	47	54	48	*54,0*	***337,5***	**III**	M.10.9	54	69	67	49	61	*60,0*	***375,0***	**III**
M.11.8	52	57	62	41	53	*53,0*	***331,3***	**III**	M.11.9	35	70	56	41	57	*51,8*	***323,8***	**III**
M.12.8	73	46	51	54	55	*55,8*	***348,8***	**III**	M.12.9	79	61	68	57	73	*67,6*	***422,5***	**II**
M.13.8	35	45	57	62	49	*49,6*	***310,0***	**III**	M.13.9	53	38	60	72	59	*56,4*	***352,5***	**III**
M.14.8	59	53	76	68	73	*65,8*	***411,3***	**II**	M.14.9	77	58	73	65	70	*68,6*	***428,8***	**II**
M.15.8	61	53	64	42	56	*55,2*	***345,0***	**III**	M.15.9	68	77	67	72	71	*71,0*	***443,8***	**II**
M.16.8	32	29	37	42	27	*33,4*	***208,8***	**IV**	M.16.9	45	56	60	49	53	*52,6*	***328,8***	**III**
M.17.8	41	39	31	32	30	*34,6*	***216,3***	**IV**	M.17.9	35	42	44	45	41	*41,4*	***258,8***	**IV**
M.18.8	27	29	35	22	40	*30,6*	***191,3***	**IV**	M.18.9	45	49	32	37	39	*40,4*	***252,5***	**IV**
M.19.8	24	33	29	42	35	*32,6*	***203,8***	**IV**	M.19.9	35	63	49	42	50	*47,8*	***298,8***	**IV**
M.20.8	30	44	39	41	29	*36,6*	***228,8***	**IV**	M.20.9	51	49	54	47	53	*50,8*	***317,5***	**III**

Settembre 2007									Dicembre 2007								
Conte Stazioni	1	2	3	4	5	*media*	***densità***	**classe**	**Conte Stazioni**	1	2	3	4	5	*media*	***densità***	**classe**
M.1.10	49	42	43	48	45	*45,4*	***283,8***	**IV**	M.1.11	68	51	54	33	65	*54,2*	***338,8***	**III**
M.2.10	36	37	31	40	39	*36,6*	***228,8***	**IV**	M.2.11	52	49	37	54	46	*47,6*	***297,5***	**IV**
M.3.10	62	63	58	71	66	*64,0*	***400,0***	**III**	M.3.11	70	69	63	74	73	*69,8*	***436,3***	**II**
M.4.10	36	37	36	34	42	*37,0*	***231,3***	**IV**	M.4.11	33	40	54	32	39	*39,6*	***247,5***	**IV**
M.5.10	34	24	22	29	21	*26,0*	***162,5***	**IV**	M.5.11	29	30	31	27	34	*30,2*	***188,8***	**IV**
M.6.10	43	46	42	40	30	*40,2*	***251,3***	**IV**	M.6.11	35	29	42	30	32	*33,6*	***210,0***	**IV**
M.7.10	37	43	35	39	45	*39,8*	***248,8***	**IV**	M.7.11	70	67	63	65	51	*63,2*	***395,0***	**III**
M.8.10	42	38	48	40	37	*41,0*	***256,3***	**IV**	M.8.11	49	64	55	63	66	*59,4*	***371,3***	**III**
M.9.10	56	52	43	55	58	*52,8*	***330,0***	**III**	M.9.11	44	60	40	49	35	*45,6*	***285,0***	**IV**
M.10.10	53	71	63	69	51	*61,4*	***383,8***	**III**	M.10.11	71	77	65	59	57	*65,8*	***411,3***	**II**
M.11.10	52	32	35	45	42	*41,2*	***257,5***	**IV**	M.11.11	49	63	57	43	55	*53,4*	***333,8***	**III**
M.12.10	62	56	89	78	59	*68,8*	***430,0***	**II**	M.12.11	53	48	58	64	49	*54,4*	***340,0***	**III**
M.13.10	66	80	62	74	81	*72,6*	***453,8***	**II**	M.13.11	42	71	56	46	39	*50,8*	***317,5***	**III**
M.14.10	58	44	36	35	46	*43,8*	***273,8***	**IV**	M.14.11	45	41	43	55	49	*46,6*	***291,3***	**IV**
M.15.10	63	72	49	61	67	*62,4*	***390,0***	**III**	M.15.11	41	46	39	45	61	*46,4*	***290,0***	**IV**
M.16.10	39	42	46	37	48	*42,4*	***265,0***	**IV**	M.16.11	38	45	54	44	61	*48,4*	***302,5***	**III**
M.17.10	52	67	54	50	53	*55,2*	***345,0***	**III**	M.17.11	35	39	37	43	42	*39,2*	***245,0***	**IV**
M.18.10	25	26	22	21	23	*23,4*	***146,3***	**V**	M.18.11	59	61	52	35	46	*50,6*	***316,3***	**III**
M.19.10	43	31	34	32	37	*35,4*	***221,3***	**IV**	M.19.11	53	44	29	32	50	*41,6*	***260,0***	**IV**
M.20.10	38	27	41	31	34	*34,2*	***213,8***	**IV**	M.20.11	42	39	49	31	35	*39,2*	***245,0***	**IV**

Absolute density- 2007

Marzo 2008									Giugno 2008								
Conte Stazioni	1	2	3	4	5	*media*	***densità***	**classe**	**Conte Stazioni**	1	2	3	4	5	*media*	***densità***	**classe**
M.1.12	84	72	75	71	69	*74,2*	***463,8***	**II**	M.1.13	48	45	52	49	46	*48,0*	***300,0***	**IV**
M.2.12	52	75	55	82	67	*66,2*	***413,8***	**II**	M.2.13	52	76	66	45	38	*55,4*	***346,3***	**III**
M.3.12	56	61	72	62	65	*63,2*	***395,0***	**III**	M.3.13	63	61	71	75	55	*65,0*	***406,3***	**II**
M.4.12	34	31	35	41	28	*33,8*	***211,3***	**IV**	M.4.13	21	35	42	27	39	*32,8*	***205,0***	**IV**
M.5.12	32	27	25	23	26	*26,6*	***166,3***	**IV**	M.5.13	28	35	39	33	51	*37,2*	***232,5***	**IV**
M.6.12	21	30	25	28	17	*24,2*	***151,3***	**IV**	M.6.13	27	41	42	45	36	*38,2*	***238,8***	**IV**
M.7.12	72	55	63	41	76	*61,4*	***383,8***	**III**	M.7.13	52	45	59	42	47	*49,0*	***306,3***	**III**
M.8.12	62	54	45	48	52	*52,2*	***326,3***	**III**	M.8.13	55	57	44	73	81	*62,0*	***387,5***	**III**
M.9.12	73	62	65	49	50	*59,8*	***373,8***	**III**	M.9.13	46	44	61	73	32	*51,2*	***320,0***	**III**
M.10.12	67	72	83	82	77	*76,2*	***476,3***	**II**	M.10.13	82	80	67	59	62	*70,0*	***437,5***	**II**
M.11.12	71	46	59	55	57	*57,6*	***360,0***	**III**	M.11.13	51	56	54	46	61	*53,6*	***335,0***	**III**
M.12.12	47	54	65	72	52	*58,0*	***362,5***	**III**	M.12.13	106	78	87	107	84	*92,4*	***577,5***	**II**
M.13.12	62	64	86	61	68	*68,2*	***426,3***	**II**	M.13.13	54	56	64	63	52	*57,8*	***361,3***	**III**
M.14.12	85	54	81	64	71	*71,0*	***443,8***	**II**	M.14.13	74	94	78	79	66	*78,2*	***488,8***	**II**
M.15.12	95	62	55	41	66	*63,8*	***398,8***	**III**	M.15.13	69	73	49	46	68	*61,0*	***381,3***	**III**
M.16.12	33	28	42	31	25	*31,8*	***198,8***	**IV**	M.16.13	67	50	35	57	63	*54,4*	***340,0***	**III**
M.17.12	51	36	31	43	38	*39,8*	***248,8***	**IV**	M.17.13	50	61	45	54	46	*51,2*	***320,0***	**III**
M.18.12	34	33	32	33	29	*32,2*	***201,3***	**IV**	M.18.13	28	35	45	48	29	*37,0*	***231,3***	**IV**
M.19.12	25	32	40	33	45	*35,0*	***218,8***	**IV**	M.19.13	42	34	45	43	32	*39,2*	***245,0***	**IV**
M.20.12	41	56	45	50	48	*48,0*	***300,0***	**IV**	M.20.13	52	64	45	51	42	*50,8*	***317,5***	**III**

Settembre 2008									Dicembre 2008								
Conte Stazioni	1	2	3	4	5	*media*	***densità***	**classe**	**Conte Stazioni**	1	2	3	4	5	*media*	***densità***	**classe**
M.1.14	44	45	60	79	54	*56,4*	***352,5***	**III**	M.1.15	62	57	67	53	71	*62,0*	***387,5***	**III**
M.2.14	48	37	40	46	55	*45,2*	***282,5***	**IV**	M.2.15	80	64	68	71	65	*69,6*	***435,0***	**II**
M.3.14	55	64	73	57	45	*58,8*	***367,5***	**III**	M.3.15	82	74	64	73	81	*74,8*	***467,5***	**II**
M.4.14	27	36	29	40	36	*33,6*	***210,0***	**IV**	M.4.15	35	48	41	37	44	*41,0*	***256,3***	**IV**
M.5.14	35	49	40	44	29	*39,4*	***246,3***	**IV**	M.5.15	32	34	47	36	44	*38,6*	***241,3***	**IV**
M.6.14	46	34	40	34	32	*37,2*	***232,5***	**IV**	M.6.15	32	31	27	38	37	*33,0*	***206,3***	**IV**
M.7.14	75	89	77	58	67	*73,2*	***457,5***	**II**	M.7.15	52	37	65	42	70	*53,2*	***332,5***	**III**
M.8.14	97	65	59	30	58	*61,8*	***386,3***	**III**	M.8.15	39	59	55	64	51	*53,6*	***335,0***	**III**
M.9.14	37	47	32	45	42	*40,6*	***253,8***	**IV**	M.9.15	51	31	43	54	61	*48,0*	***300,0***	**IV**
M.10.14	80	52	56	78	40	*61,2*	***382,5***	**III**	M.10.15	54	52	26	31	67	*46,0*	***287,5***	**IV**
M.11.14	42	53	37	61	49	*48,4*	***302,5***	**III**	M.11.15	44	36	34	47	58	*43,8*	***273,8***	**IV**
M.12.14	84	89	85	91	82	*86,2*	***538,8***	**II**	M.12.15	94	81	60	73	59	*73,4*	***458,8***	**II**
M.13.14	57	62	54	58	64	*59,0*	***368,8***	**III**	M.13.15	54	76	64	61	69	*64,8*	***405,0***	**II**
M.14.14	40	65	43	39	48	*47,0*	***293,8***	**IV**	M.14.15	71	75	62	69	86	*72,6*	***453,8***	**II**
M.15.14	72	85	58	73	84	*74,4*	***465,0***	**II**	M.15.15	69	74	69	57	56	*65,0*	***406,3***	**II**
M.16.14	39	47	61	63	44	*50,8*	***317,5***	**III**	M.16.15	41	37	55	69	45	*49,4*	***308,8***	**III**
M.17.14	44	45	39	45	47	*44,0*	***275,0***	**IV**	M.17.15	38	32	33	43	35	*36,2*	***226,3***	**IV**
M.18.14	48	34	63	58	79	*56,4*	***352,5***	**III**	M.18.15	33	41	27	25	32	*31,6*	***197,5***	**IV**
M.19.14	62	50	73	49	57	*58,2*	***363,8***	**III**	M.19.15	37	53	61	57	60	*53,6*	***335,0***	**III**
M.20.14	60	69	76	62	49	*63,2*	***395,0***	**III**	M.20.15	49	54	44	45	56	*49,6*	***310,0***	**III**

Absolute density- 2008

anno	radura	Numero medio delle foglie per anno per fascio	Densità media delle foglie (mg/cm)	Produzione primaria fogliare media per anno (gr ps/fascio)	Produzione primaria fogliare media per anno (gr ps/m^2)	Velocità di crescita media dei rizomi per anno (mm)	Produzione media dei rizomi per anno (mg ps)	Densità assoluta media annuale (fasci /m2	Densità relativa (D absmarzo copertura)
		N	**D**	**Pps**	**Ppm**	**Vr**	**Pr**	**Dabs**	**Drel**
2006	**59A**	8,1	5,03	1,53	307,8	7,6	52,2	**220,9**	16,77116
	59C	7,6	4,70	1,07	231,8	5,1	34,0	**254,7**	12,93813
	53A	8,0	4,35	1,47	423,9	7,1	62,7	**320,6**	22,63613
	37A	6,6	3,43	0,72	153,3	4,2	29,0	**224,1**	9,477844
	33A	7,3	4,21	1,07	231,9	5,5	56,7	**193,1**	10,62188
	33B	7,1	4,42	1,07	175,8	7,2	66,3	**184,7**	13,27903
	3A	7,1	3,43	1,03	346,2	9,4	56,0	**345,9**	32,6565
	4A	8,3	3,07	0,97	272,5	9,8	60,4	**322,5**	31,44375
	4B	8,4	4,67	1,71	331,1	11,6	74,0	**202,5**	23,46207
	5A	7,7	9,36	3,28	1340,0	11,0	63,4	**371,3**	40,8375
	5C	7,8	4,36	1,33	411,1	9,3	60,3	**275,9**	25,55181
	6A	8,3	5,26	2,26	863,9	19,6	138,1	**304,4**	59,59663
	6D	7,6	5,16	1,73	856,1	12,4	84,0	**411,6**	50,86913
	66A	7,3	4,61	1,50	578,3	8,8	55,0	**309,7**	27,11226
	66B	7,6	3,75	1,44	602,1	13,6	74,3	**296,9**	40,49375
	13A	7,9	4,89	1,29	307,8	6,0	49,9	**242,5**	14,42875
	67A	7,1	4,45	1,30	396,7	21,1	55,0	**282,8**	59,58859
	69A	7,7	4,88	1,42	421,9	7,3	59,3	**239,7**	17,37734
	69B	6,9	5,23	1,48	272,4	8,6	72,4	**197,5**	17,04425
	70A	9,0	5,42	1,81	515,7	8,4	79,1	**253,1**	21,23719
2007	**59A**	7,5	4,60	1,31	410,3	6,4	39,8	**310,0**	19,7625
	59C	8,8	5,50	1,70	568,8	15,3	85,1	**276,3**	42,12813
	53A	7,0	4,69	1,50	644,8	8,5	59,0	**413,4**	34,965
	37A	6,5	3,99	0,71	128,7	4,9	32,3	**218,4**	10,63063
	33A	7,1	4,07	0,90	164,8	4,9	32,7	**176,9**	8,657566
	33B	6,8	4,64	0,96	248,4	4,6	32,4	**231,6**	10,59844
	3A	7,4	4,95	1,48	482,3	13,3	114,0	**319,4**	42,62769
	4A	7,9	4,80	1,41	370,3	12,1	85,3	**281,6**	34,06906
	4B	8,1	4,53	1,63	341,0	11,7	86,7	**259,1**	30,42807
	5A	7,8	3,79	1,31	442,8	9,8	61,1	**376,9**	36,984
	5C	6,9	4,45	1,23	408,4	5,4	37,7	**311,6**	16,73988
	6A	7,1	3,75	1,18	412,5	8,2	59,9	**385,3**	31,70571
	6D	7,8	4,49	1,70	525,5	12,5	62,8	**358,4**	44,80469
	66A	6,9	5,13	1,46	601,6	12,2	69,7	**351,3**	42,9483
	66B	7,6	4,29	1,45	500,2	13,3	85,1	**367,2**	48,71354
	13A	7,7	5,30	1,20	250,0	16,2	75,0	**276,3**	44,63618
	67A	7,7	4,81	1,33	287,7	19,7	73,7	**266,3**	52,37524
	69A	7,4	5,28	1,21	230,7	5,9	38,2	**226,6**	13,36719
	69B	6,4	4,28	0,85	173,5	4,9	34,9	**245,9**	12,05094
	70A	7,9	4,22	1,10	252,0	7,8	71,5	**251,3**	19,64318
2008	**59A**	7,5	5,77	0,90	415,08	7,90	58,34	**375,9**	29,6991
	59C	7,9	5,59	0,93	383,23	7,20	43,56	**369,4**	26,595
	53A	7,3	5,65	0,65	258,15	13,13	89,84	**409,1**	53,6895
	37A	6,7	3,96	0,56	118,78	4,45	32,00	**220,6**	9,81401
	33A	6,7	5,07	0,63	105,34	5,50	52,32	**221,6**	12,1859
	33B	7,5	4,46	0,66	99,92	6,94	47,07	**207,2**	14,3695
	3A	7,1	7,49	1,01	388,18	9,32	193,34	**370,0**	34,4971
	4A	6,8	5,43	0,66	213,76	11,72	91,41	**358,8**	42,0535
	4B	7,5	4,52	0,63	234,85	7,86	51,43	**311,9**	24,5168
	5A	7,3	5,27	0,84	400,25	7,63	52,44	**395,9**	30,2086
	5C	7,2	6,05	0,81	291,08	11,45	92,50	**317,8**	36,404
	6A	6,9	4,22	0,67	243,47	10,21	99,24	**484,4**	49,4347
	6D	7,1	5,92	0,70	299,28	8,90	71,47	**390,3**	34,7378
	66A	6,8	5,71	0,77	340,47	10,62	78,81	**420,0**	44,5846
	66B	7,1	4,38	0,56	221,95	7,59	62,02	**412,8**	31,3479
	13A	7,0	5,04	0,83	164,61	5,00	32,80	**291,3**	14,5625
	67A	7,2	5,30	0,70	175,36	8,36	53,50	**267,5**	22,3554
	69A	7,1	4,45	0,68	135,93	5,23	33,40	**245,6**	12,8395
	69B	7,5	4,56	0,67	146,24	6,04	48,57	**290,6**	17,5639
	70A	8,6	9,74	1,78	533,56	10,76	68,77	**330,6**	35,5908

Biological data set used for statistical analysis

Environmental Variables						
station points	station	depth	depth range	Matte	Sand	area (east/west)
59A	**1**	9	1	1	0	e
59C	**2**	9	1	1	0	e
53A	**3**	10	2	0,5	0,5	e
37A	**4**	12,5	2	1	0	e
33A	**5**	13,5	2	0,5	0,5	e
33B	**6**	12	2	0,5	0,5	e
3A	**7**	10	2	1	0	w
4A	**8**	10	2	0,5	0,5	w
4B	**9**	10,5	2	0	1	w
5A	**10**	10,5	2	1	0	w
5C	**11**	9,5	1	1	0	w
6A	**12**	7,5	1	0	1	w
6D	**13**	8	1		1	w
66A	**14**	9	1	0,5	0,5	w
66B	**15**	8,5	1	0,5	0,5	w
13A	**16**	8	1	0	1	w
67A	**17**	12	2	0	1	w
69A	**18**	11,5	2	1	0	w
69B	**19**	11,5	2	0	1	w
70A	**20**	11	2	1	0	w

Environmental data

where		1 trim/06			2 trim./06			3 trim/06			4 trim/06		
	parameters	200	1000	3000	200	1000	3000	200	1000	3000	200	1000	3000
s. marinella north	ortofosfato	14	<10	<10	<10	<10	<10	22	12	<10	10	<10	<10
	fosforo totale	20	<10	<10	<10	<10	<10	30	18	<10	12	<10	<10
	materiale sospeso particellato P	6	ns	ns	ns	ns	ns	8	6	ns	2	ns	ns
	azoto totale	200	120	60	80	60	40	120	80	50	184	141	108
	azoto nitrico	50	32	20	42	24	18	40	30	28	28	26	19
	azoto nitroso	12	10	<5	<5	<5	<5	16	<5	<5	8	<5	<5
	materiale sospeso particellato N	138	78	35	33	31	17	64	45	17	148	110	84
	trasparenza	5	6	9	3,5	10	10	7	9	8	4,5	9	10
	clorofilla	1,1	1	0,9	1,3	1	0,9	1,3	1,5	1,2	0,9	0,6	0,7
	ossigeno	97,5	97,2	94,6	101,1	103,2	106,1	95,5	104	111	100,5	99,5	98,3
cerenova	ortofosfato	10	10	<10	11	<10	<10	<10	<10	<10	11	<10	<10
	fosforo totale	12	12	<10	15	<10	<10	<10	<10	<10	14	<10	<10
	materiale sospeso particellato P	2	2	ns	4	ns	ns	ns	ns	ns	3	ns	ns
	azoto totale	286	208	130	80	60	40	62	52	40	208	128	125
	azoto nitrico	55	44	26	30	22	15	26	22	16	31	19	17
	azoto nitroso	10	9	<5	5	<5	<5	<5	<5	<5	10	8	8
	materiale sospeso particellato N	221	155	99	45	33	20	31	25	19	167	101	100
	trasparenza	3	3	4	3	5	9	7	11	14	4	5	6
	clorofilla	1,4	1,3	1	1,8	1,4	1,3	0,9	0,8	0,8	2,6	1,4	1,2
	ossigeno	108	107	106	124,5	124,8	125,3	104	102	104	106,5	107	102
fiumicino	ortofosfato	11	10	<10	<10	<10	<10	22	16	11	12	<10	<10
	fosforo totale	13	12	<10	<10	<10	<10	30	20	14	14	<10	<10
	materiale sospeso particellato P	2	2	ns	ns	ns	ns	8	4	3	2	ns	ns
	azoto totale	202	188	106	74	80	42	200	140	98	220	152	118
	azoto nitrico	33	31	21	14	16	10	86	48	40	30	21	17
	azoto nitroso	8	8	<5	<5	<5	<5	22	20	<5	8	8	7
	materiale sospeso particellato N	161	149	80	55	59	27	92	72	53	182	123	94
	trasparenza	3	4	6	4,5	6	9	1,5	2	3	2	2,5	3
	clorofilla	3	2,8	2,2	1,8	1,5	1,2	1,9	1,2	0,9	2,4	1,6	1,2
	ossigeno	106	110	110	105	104,7	108	116	118	114	102,2	101	102

Marine water quality (Arpa Lazio, 2006)

Annex II

Impacts at the site

Activity	Impacts	Type Direct / indirect	N2000 Appendix E code	Site (S) or/and Around (A)	Influence (+); (-)	Intensity (A; B; C)
Agriculture, Forestry and animal breeding						
Intensive agriculture, deforestation and humans activities moving dusts	1. Nutrients contribution increasing 2. Water turbidity increasing	Indirect	100 Cultivation	A	(-)	A
			110 Use of pesticides	A	(-)	A
			120 Fertilisation	A	(-)	A
			exploitation without	A	(-)	B
			170 Animal breeding	A	(-)	B
Fishing, hunting and collecting						
Trawling fishery, surrounding nets and purse seine	1. Destruction of foliage and shoots of Posidonia 2. Biodiversity reduction 3. Increasing Posidonia vulnerability	Direct	210 Professional fishing	A	(-)	B
Artisanal fishery	1. Help sustainable management of fish stock living/feeding in/on the meadows	Direct	210 Professional fishing	S	(+)	B
Beach marine fauna harvesting	1. Biodiversity reduction	Direct		A	(-)	C
Mining and extraction of materials						
Quarries	1. Fine sediment contribution increasing	Indirect	300 Sand and gravel extraction to be verified	A	(-)	C
	2. Change of coastal hydro-sedimentological regime		301 quarries	A	(-)	C
Urbanisation, industrialisation and similar activities						
Urban seawage	1. Nutrients contribution increasing	Indirect	401 Continuous urbanisation	A	(-)	C
	2. Water turbidity increasing		402 Discontinuous urbanisation	A	(-)	B
	3. Pollution increasing		420 Discharges	A	(-)	A
Wastes accumulation	1. Pollution increasing	Indirect	424 other discharges	S	(-)	C
Transportation and communication						
Harbour	1. Local increased water turbidity 2. Local eutrophication	Indirect	504 port areas	A	(-)	A

Leisure and tourism						
Nautical traffic	1. Pollution increasing 2. Hydrocarbons release 3. Metabolic damage on living organisms and damaging animals	Indirect	621 nautical sports	S	(-)	C
Mooring of tourist boats	1. Destruction of foliage and shoots of Posidonia 2. Biodiversity reduction 3. Increasing of Posidonia vulnerability	Direct	690 Other leisure and tourism impacts not referred to above	S	(-)	A
Pollution and other human impacts/activities						
Activities that moves and enhance dusts	1. Fine sediment contribution increasing 2. Water turbidity increasing 3. Change of coastal hydro-sedimentological regime	Indirect	750 Other pollution or human impacts/activities	A	(-)	C
Human induced changes in hydraulic conditions (wetlands/marine env.)						
Sea defence works building	1. Fine sediment contribution increasing 2. Change of coastal hydro-sedimentological regime 3. Water turbidity increasing 4. Increasing of Posidonia vulnerability 5. Destruction of foliage and shoots of Posidonia 6. Biodiversity reduction	Direct	871 sea defense or coast protection works	S and A	(-)	A
Sea defence works presence	1. Reduction of sediment's contribution to the meadows 2. Changing of hydro-sedimentology balance	Indirect	871 sea defense or coast protection works	S and A	(-)	A
Harbour dredging	1. Fine sediment contribution increasing 2. Water turbidity increasing 3. Water pollution increasing	Direct	810 Drainage	A	(-)	C
Canalization, damming and cementification of water courses	1. Coastal erosion increasing 2. Fine sediment contribution increasing 3. Change of coastal hydro-sedimentologic 4. Water turbidity increasing	Indirect	830 Canalisation	A	(-)	A
			852 modifying structures of	A	(-)	A
			870 Dykes, embankments, artificial beaches, general	A	(-)	A

Activities influencing the conservation status of the site in the site to update the official SDF

210 Professional fishing

621 Nautical sports

690 Other leisure and tourism impacts not referred to above

871 Sea defense or coast protection works

871 Sea defense or coast protection works

900 Erosion

940 Natural catastrophes

Activities influencing the conservation status of the site around the site to update the official SDF

100 Cultivation

110 Use of pesticides

120 Fertilisation

167 Forestry exploitation without replanting

170 Animal breeding

300 Sand and gravel extraction to be verified

301 Quarries

401 Continuous urbanization

402 Discontinuous urbanization

424 Other discharges

420 Discharges

504 Port areas

750 Other pollution or human impacts/activities

830 Canalization

852 Modifying structures of inland watercourses

870 Dykes, embankments, artificial beaches, genera