Building a monitoring approach of *Posidonia oceanica* meadows in Montenegro

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Outline

1. What is *Posidonia oceanica*

2. Why *Posidonia* is important, why it has to be protected

3. Why *Posidonia* has to be monitored

4. An overview of existing monitoring approaches

5. Which monitoring approach for *Posidonia oceanica* in MNE
What is *Posidonia oceanica*?

**Posidonia oceanica** (L) Delile

- endemic plant
- widespread throughout the Mediterranean (about 1% of seabed)
What is *Posidonia oceanica*?

- **roots**
- **leaves**
- **plagiotropic rhizome**
- **orthotropic rhizome**
- **flower**
- **fruits**
- **seeds**
Why Posidonia is important?

It plays a diversity of important roles in the coastal marine environment.
Why Posidonia is important?

High primary production
High $O_2$ production
$CO_2$ sequestration (blue carbon)
Why Posidonia is important?

Forms complex ecosystems supporting several trophic interactions

Nursery for fish and invertebrate species
Why Posidonia is important?

- Produces/traps sediments and reduce sedimentation
- Reduce beach erosion

Production of biogenic carbonate sediments

Biogenic sediments contribute to the sedimentary balance of the beaches

"banquettes" protect the profile of the emerged beach by sea erosion

The "matte" reduces the slope of submerged beach and influences the shoreline profile
Why Posidonia has to be protected?

It is sensitive to human impacts

- turbidity
- over-sedimentation
- excess of nutrients / organic matter
- mechanical damages
Why Posidonia has to be protected?

- Habitat Directive
- Bern Convention
- Barcelona Convention

• protection
  ↓
• knowledge
  ↓
• studies
  ◀ ◀
• research
  ◀ ◀
• monitoring
Why Posidonia has to be monitored?

Monitoring programs should be designed to:

• Assess status and trends in environmental quality
• Characterize emerging problems
• Quantify the causes of change and measure level of impact
• Design environmental management programs to guide conservation actions
• Evaluate performance of legislation
Why Posidonia has to be monitored?

To achieve effective monitoring

- Explicit objectives
- Proper variables
- Baseline assessment/measure (e.g. maps)
- Knowledge of spatial and temporal variations
- Defined field protocols
- Data management procedures
- Cost and labor effective approach
An overview of existing monitoring approaches?

*Posidonia oceanica* is considered a marine sentinel or biological indicator.

It is used to detect changes in the marine environment, that can derive for biotic and abiotic factors not measureable individually.

*Posidonia* meadows respond strongly to both natural and anthropogenic alterations and are able to register changes in environmental variables, providing a reliable indication of the overall status of coastal waters.
An overview of existing monitoring approaches?

Existing approaches within WFD, 2000/60/EC to calculate the Ecological Status (ES) of coastal waters

Biological Quality Elements (BQEs)

- Phytoplankton
- Macroalgae
- Angiosperms
- Benthic fauna

*P. oceanica* has been chosen as a representative of the angiosperm, considering:

- the amount and *consistency* of previous studies in most countries
- its sensitivity to disturbance
- its wide distribution along Mediterranean coasts
- good knowledge on *P. oceanica* specific responses to specific impacts
### Overview of existing approaches within WFD, 2000/60/EC

<table>
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<th>Index</th>
<th>Variables</th>
<th>Strengths</th>
<th>Weaknesses</th>
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<tr>
<td>Posware</td>
<td>Shoot density, Leaf width, Leaf production, Rhizome production and elongation</td>
<td>- sampling effort</td>
<td>+ dataware housing</td>
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<tr>
<td>POMI</td>
<td>Shoot density, cover, % plagiotropic rhizomes, Leaf surface, % foliar necrosis, P, N, sucrose content in rhizomes, δ 15N δ 34S isotopic ratio in rhizomes, N content in epiphytes, Cu, Pb and Zn content in rhizomes</td>
<td>+ sampling effort, ++ lab work, +++ lab material, expensive, destructive</td>
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<tr>
<td>Valencian system</td>
<td>Shoot density, meadow and dead matte cover, % plagiotropic rhizomes, Rhizome burial, Leaf surface and % foliar necrosis, Herbivory, Leaf epiphyte biomass</td>
<td>- lab material, - costs</td>
<td>+ sampling effort, + lab work, destructive</td>
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<tr>
<td>BIPo</td>
<td>Lower limit type and depth, Shoot density, Leaf surface/canopy height, Epiphytic biomass / leaf biomass, Lower limit type and depth</td>
<td>- sampling &amp; lab effort, - material, - costs &amp; non destructive</td>
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<tr>
<td>PREI</td>
<td>Shoot density, Leaf surface, Epiphytic biomass / leaf biomass, Lower limit type and depth</td>
<td>- sampling &amp; lab effort, - material, - costs</td>
<td>destructive</td>
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(modified from Gobert et al., 2009)
An overview of existing monitoring approaches?

The importance of mapping

Maps provide a general framework on the presence and status of *P. oceanica* meadows

- Meadow distribution and surrounding habitats
- Depth range
- Substrate type
An overview of existing monitoring approaches?

The importance of mapping

Information on meadow distribution is crucial to achieve proper management actions

• Zoning areas to be subjected at different degree of protection
• Solve conflicts between users and management targets
• Assess disturbances and possible actions for protection
• Identify mooring / anchoring areas
• Detect changes in meadow distribution and the dynamics of upper and lower limits
An overview of existing monitoring approaches?

Methods for mapping

Aerial / satellite remote sensing and image processing
- upper limit
- shallow meadows

Acoustic method (Side Scan Sonar, Multibeam)
- meadow distribution
- lower limit

Remote Operated Vehicle (ROV)

Direct survey (scuba diving)
- visual assessment and sampling
An overview of existing monitoring approaches?

Structural variables (e.g. density, % cover) and morphology of the meadow (regressive structures: dead matte, intermatte channels) represent a characteristic imprint of environmental conditions.
An overview of existing monitoring approaches?

Percent cover

% of substrate covered by plants with respect to that not covered (sand, rocks, dead *matte*)

- continue meadow (100%)
- discontinue (sand, intermatte channels)
- discontinue (human impacts)
- discontinue (rock, peebles)
An overview of existing monitoring approaches?

Percent cover

Line Intercept Transect (LIT) (Bianchi et al., 2004; Montefalcone et al., 2007)

4 or more random replicates (each 10 m long) at each sampling station

% substrate under the meadow
mud
sand
rock

% substrate covered by *P. oceanica* (P)

% substrate covered by dead *matte* (D)
An overview of existing monitoring approaches?

Percent cover

% Cover = \( \sum (L_x / L_{tot} \times 100) \)

(L = length)

Line Intercept Transect (LIT)

\[\begin{align*}
L_1 &= 0.4 \, \text{m} = \text{dead mate} \\
L_2 &= 3.0 \, \text{m} = P. \text{oceanica} \\
L_3 &= 0.3 \, \text{m} = \text{dead mate} \\
L_4 &= 2.2 \, \text{m} = P. \text{oceanica} \\
L_5 &= 1.5 \, \text{m} = \text{sand} \\
L_6 &= 2.1 \, \text{m} = P. \text{oceanica} \\
L_7 &= 0.5 \, \text{m} = \text{sand}
\end{align*}\]

\( L_{tot} = 10 \, \text{m} \)

\( P. \text{ oceanica} = L_2 + L_4 + L_6 = 7.4 \, \text{m} \quad 74\% \)

\( \text{dead mate} = L_1 + L_3 = 0.6 \, \text{m} \quad 6\% \)

\( \text{sand} = L_5 + L_7 = 2.0 \, \text{m} \quad 20\% \)
An overview of existing monitoring approaches?

Percent cover

**Conservation Index (CI)**

(Moreno et al, 2005; Montefalcone, 2008)

\[ CI = \frac{P}{P+D} \]

- \( P \) = Posidonia % cover
- \( D \) = dead *matte* % cover
An overview of existing monitoring approaches?

Shoots density

no. of leaf shoots per m²

changes according to depth, substrate and environmental conditions
An overview of existing monitoring approaches?

Shoots density

8 or more *random* replicates (frame 40 x 40 cm) at each sampling station

*meadow density = average counts in 40 x 40 cm frame x 0.16*
An overview of existing monitoring approaches?

<table>
<thead>
<tr>
<th>Pergent et al. (1995)</th>
<th>densità anormale (AD)</th>
<th>densità inferiore alla norma (LSD)</th>
<th>densità normale (ND)</th>
<th>densità superiore alla norma (HSD)</th>
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<tr>
<td>Buia et al. (2004)</td>
<td>praterie molto disturbate</td>
<td>praterie disturbate</td>
<td>praterie in equilibrio</td>
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Shoots density classification of *P. oceanica* beds according to depth

Pergent et al., 1995
Buia et al., 2004
An overview of existing monitoring approaches?

**matte compactness**

4 or more *random* replicates (shots) at each sampling station

- **strong compactness**
  - penetration < 50 cm

- **medium**
  - 50 cm < penetration < 100 cm

- **weak**
  - penetration > 100 cm

Francour *et al.* (1999)

Picture by P. Panzalis
An overview of existing monitoring approaches?

Its morphology varies in relation to the environmental conditions.

**Progressive** ⇒ improvement of water transparency

**Sharp** ⇒ stable condition of water transparency

**Erosive** ⇒ conditioned by seabed currents

**Regressive** ⇒ increase of water turbidity

(Pergent *et al.*, 1995)
An overview of existing monitoring approaches?

“Balisage”

Concrete markers (“balises”) along the lower limit permit to evaluate its temporal evolution (regression or progression) pointing out the evolution of water turbidity (or transparency).
An overview of existing monitoring approaches?
An overview of existing monitoring approaches?

Collection of samples
An overview of existing monitoring approaches?

Lepidocronology

Once leaves fall (in autumn), the bases may persist attached to the rhizomes for many years.

They are now called “SCALES”.

The thickness of the scales has a cyclic variation along the year.
Tiny scales are formed during the winter.
Tick scales during the summer.
An overview of existing monitoring approaches?

The thickness of the scales shows cyclic variations which permit to assess the age of the rhizomes and their past production.

variables

✓ Age of the rhizome
✓ Past production of the rhizome in terms of no. of leaves per year
✓ Annual elongation of the rhizome
✓ Annual biomass of the rhizome
An overview of existing monitoring approaches?

Reconstruction over the years of the history of the rhizomes offers a picture of the variations produced by the environmental stresses affecting the ecosystem.

Assessment of past production in impacted and reference sites

Rhizome production in impacted sites is 50% lower than in reference ones.

(Buia et al., 2003)
An overview of existing monitoring approaches?

Metals (Hg, Fe, Zn, Pb, Cd and Cu) can be accumulated in rhizomes and scales of *P. oceanica*

Historical trend of heavy metal contamination can be assessed by lepidocronology

Stopping of mining activity is well documented by the decreasing heavy metal concentration in *P. oceanica* tissues in recent years

(Caredda et al., 1999)
Which monitoring approaches for MNE?

- CI = P/(P+D)
- Datawarehouse
- Rapid Easy Index
- EQR
- POMI
- Leaf surface
- Coverage
- Lepidochronology
- Rhizome biomass
- Density
- Substitution Index
- Balisage
- Mapping
- WFD
- Valencian system
- SCI
- BiPo
- Epiphyte
- Leaf biomass
Which monitoring approaches for MNE?

Selection of a monitoring approach depends on:

- Resource availability
- Availability of experts
- Monitoring objectives

Preferred approach should be:

- Non destructive
- Simple
- Cost effective

- Get immediate information on the ecosystem health
- Proper for managing issues
- Maintain & improve *Posidonia* meadows
Which monitoring approaches for MNE?

Mapping of *Posidonia oceanica* meadows integrated by the assessment of structural variables (density, % cover, CI, compactness, lower limit) meets monitoring objectives in most of Mediterranean MPAs and other coastal areas.
Which monitoring approaches for MNE?

Tavolara MPA (Sardinia, Italy)
Which monitoring approaches for MNE?

Tavolara MPA (Sardinia, Italy)

% cover of substrates
Which monitoring approaches for MNE?

SCI Berchida (Sardinia, Italy)
Which monitoring approaches for MNE?

SCI Berchida (Sardinia, Italy)
Which monitoring approaches for MNE?

MedPAN South Project

Croatia Pilot Project
“Strengthening the Marine Protected Areas Network in Croatia”
Which monitoring approaches for MNE?

Lastovo

sunc
Which monitoring approaches for MNE?

Conservation Index

Shoot density

Lastovo
Which monitoring approaches for MNE?

Some remarks

• Site (and depth) selection depend on the purpose for monitoring

• Sites have to be representative of the area to be monitored

• Stressors and responses can vary at different spatial scale, Hierarchical sampling is recommended
Which monitoring approaches for MNE?

Some remarks

- Monitoring can be expensive, involving training, material, data analysis, etc.
- Descriptors can be added to the protocol as needed (e.g. new stressors or impacts).
- Analysis and interpretation of data can be challenging.
- Be wary of jumping to conclusions based upon short term data.
- Remember the principles of adaptive management, baselines can shift!
protect our Posidonia!

Thanks!