Regional workshop
"Human impacts on Mediterranean marine ecosystems and the economy"

Case studies on the North coast of the Mediterranean Sea

Luís Campos Rodrigues
18 October 2017


3 case studies on the potential implications for bivalve mollusc aquaculture, scuba diving tourism, and MPAs.
Sensitivity of Mediterranean Bivalve Mollusc Aquaculture to Climate Change, Ocean Acidification and Other Environmental Pressures: Findings from a Producers’ Survey

1 QUESTIONNAIRE STRUCTURE

- **Background information**
  - Years of establishment
  - Number of staff employed
  - (...)

- **Mollusc production and markets**
  - Total production
  - Seed source
  - (...)

- **Environmental issues**
  - Level of knowledge of environmental pressures
  - Perception of threat
  - Experience of past environmental impacts
  - (...)

• 49 surveys from 6 Mediterranean countries, 12 coastal regions, 15 production sites.
• Representativeness: 4.1% of total Mediterranean mollusc aquaculture production.
LEVEL OF THREAT POSED BY ENVIRONMENTAL PRESSURES

Sea level rise
Ocean acidification
Eutrophication
Invasive species
Marine pollution
Mollusc diseases
Gradual increase in SST
Harmful algal blooms
Summer heat waves

- High
- Moderate
- Low
- Did not know
- Did not answer
INFORMATION ON SUMMER HEAT WAVES EVENTS

- Étang de Thau (FR)

- Gruissan (FR)
  Heat waves forced to temporarily closing production zones and re-organizing sales.

- Ebro Delta (SP)
  SST frequently rises to 29 °C/30 °C in Summer season, a limit which leads to mollusc mortality.

- Lake Bizerte (TUN)
  High mortality of juvenile molluscs in August 2012; 90% of production losses.

- San Benedetto del Tronto coast (IT)
  Heat waves occurring each year in July cause detachment and loss of the molluscs.

- Venice Lagoon and coast (IT)
  SST exceeded 30 °C in 2003 causing large production losses.

- Gulf of Trieste (IT)
  Heat waves episodes in 2004 and 2012 caused reduction of the byssus production and mortality.

- Gulf of Kotor (MON)

- Thermaikos Gulf (GR)

- Vistonikos Gulf (GR)
  Anaerobic metabolism at SST > 28 °C and occurrence of mass mortalities.

- Strymonian Gulf (GR)
  In 2010, 70% loss of oyster spat, 20% of adult oysters, and 30% losses of mussels.

- Maliakos Gulf (GR)
  SST above 28 °C-30 °C in 2010, 2011, and 2012 caused mortalities of 70% for adult mussels and 60% for seeds.

No effects observed.
MEASURES TO RESPOND TO SUMMER HEAT WAVES

- Moving production to deeper water areas (13 producers)
- Collecting and selling mussels before the usual period (11)
- Hiring an insurance company (4)
- No action / no solution (5)
- Importing seeds (1)
- (....)
INFORMATION ON OCEAN ACIDIFICATION EFFECTS

Legend:
1. Seed recruitment source for mussels (M) and oysters (O) (%):
   - Natural environment near the production areas
   - Imported seeds from the natural environment
   - Hatchery
2. Observation of effects:
   - R Decrease in seed recruitment
   - T Decrease in shell thickness / resistance
• High uncertainty and lack of knowledge among producers regarding what OA could represent for the future of their sector.

• The provision of more information about environmental pressures could be beneficial for the mollusc sector in anticipating and adapting to such problems.

• Summer heat waves have occurred in almost all production sites in past years with detrimental effects on species.

• Mollusc farms experiencing a decrease in seed recruitment from natural environment near production sites in the future may need to turn to other sources such as hatcheries, meaning extra operational costs.
The Cost of Mediterranean Sea Warming and Acidification: A Choice Experiment among Scuba Divers at Medes Islands, Spain

MEDES ISLANDS MARINE PROTECTED AREA (MPA)

- Located in Catalonia (N-W Mediterranean).
- Study carried at L’Estartit (~3,230 inhabitants) in 2013.
- Annual tourism revenues associated with the MPA were >70% of local GDP in the last decade.
- 55,647 dives (2012).
- Main features: coralligenous, posidonia oceanic meadows, and species (e.g., gorgonians, grouper, eagle ray).
- Non-market valuation technique.

- Assess preferences of tourists regarding diving experiences under conditions of sea warming and OA characterized by changes in gorgonians and jellyfish species.
<table>
<thead>
<tr>
<th>Attributes</th>
<th>Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of divers found on a diving trip</td>
<td>5; 15; 25</td>
</tr>
<tr>
<td>Underwater landscape</td>
<td>Hard bottoms with boulders, vertical walls, and caves/tunnels</td>
</tr>
<tr>
<td></td>
<td>Hard bottoms with boulders and vertical walls</td>
</tr>
<tr>
<td></td>
<td>Hard bottoms with boulders</td>
</tr>
<tr>
<td>Presence of Jellyfish species</td>
<td>Not present</td>
</tr>
<tr>
<td></td>
<td>Abundance of non-stinging jellyfish species</td>
</tr>
<tr>
<td></td>
<td>Abundance of stinging jellyfish species</td>
</tr>
<tr>
<td>Expected state of gorgonians (red coral, red gorgonian, white</td>
<td>All gorgonians are of good quality</td>
</tr>
<tr>
<td>gorgonian)</td>
<td>50% of the gorgonians have disappeared due to climate change</td>
</tr>
<tr>
<td></td>
<td>All gorgonians have disappeared due to climate change and ocean</td>
</tr>
<tr>
<td></td>
<td>acidification</td>
</tr>
<tr>
<td>Price of the dive (includes boat trip, air and tank to dive,</td>
<td>€30; €50; €70; €90; €110</td>
</tr>
<tr>
<td>Medes Island tax, and dive insurance)</td>
<td></td>
</tr>
</tbody>
</table>
## DESIGN OF CHOICE SETS

<table>
<thead>
<tr>
<th>Characteristics of the dive</th>
<th>Dive A</th>
<th>Dive B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of divers found on a diving trip</td>
<td>15</td>
<td>25</td>
</tr>
<tr>
<td>Underwater landscape</td>
<td>Hard bottoms with boulders and vertical walls</td>
<td>Hard bottoms with boulders</td>
</tr>
<tr>
<td>Presence of jellyfish species</td>
<td>Not present</td>
<td>Abundance of stinging jellyfish</td>
</tr>
<tr>
<td>Expected state of gorgonians (red coral, red gorgonian, white gorgonian)</td>
<td>All gorgonians are of good quality</td>
<td>All gorgonians have disappeared due to climate change and ocean acidification</td>
</tr>
<tr>
<td>Price of the dive (includes boat trip, air and tank to dive, Medes Island tax, and dive insurance)</td>
<td>€50</td>
<td>€30</td>
</tr>
</tbody>
</table>

*Which diving experience do you prefer to undertake, A, B, or neither?*

[ ] Dive A  [ ] Dive B  [ ] Neither
- General dive experience
- Past dive experience in Medes
- The choice experiment
- Socio-economic questions
- (…)

QUESTIONNAIRE STRUCTURE

2
- **390 valid surveys**: 6 choice sets/diver = 2,340 observations.

- Mainly **male divers** (80%).

- Mean monthly household income close to €3,500.

- Average of **12.6 years of experience with diving**.
ECONOMETRIC MODELS ASSESSING WELFARE CHANGES

REFERENCE DIVE

- 5 divers
- High geomorphology complexity
- Non-presence of jellyfish
- All gorgonians are of good quality

OTHER TYPES OF DIVE EXPERIENCES

- 15 divers
- Medium complexity
- Abundance of non-stinging jellyfish
- 50% have disappeared

- 25 divers
- Low complexity
- Abundance of stinging jellyfish
- 100% have disappeared

REFERENCE DIVE

OTHER TYPES OF DIVE EXPERIENCES
## MEAN WELFARE COSTS FOR CHANGES IN ATTRIBUTE LEVELS

### Single dive (€)

<table>
<thead>
<tr>
<th>Number of divers found on a diving trip&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Non statistically significant</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 divers</td>
<td></td>
</tr>
<tr>
<td>25 divers</td>
<td>-24.87***</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Underwater landscape&lt;sup&gt;b&lt;/sup&gt;</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Hard bottoms with boulders and vertical walls</td>
<td>-25.68***</td>
</tr>
<tr>
<td>Hard bottoms with boulders</td>
<td>-44.57***</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Presence of jellyfish species&lt;sup&gt;c&lt;/sup&gt;</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-stinging jellyfish</td>
<td>6.95*</td>
</tr>
<tr>
<td>Stinging jellyfish</td>
<td>-26.17***</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Expected state of gorgonians&lt;sup&gt;d&lt;/sup&gt;</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Less 50% of gorgonians</td>
<td>-17.15***</td>
</tr>
<tr>
<td>All gorgonians have disappeared</td>
<td>-60.22***</td>
</tr>
</tbody>
</table>

---

**Reference levels:**<sup>a</sup> 5 divers; <sup>b</sup> hard bottoms with boulders, vertical walls, caves and tunnels; <sup>c</sup> non presence of jellyfish species; <sup>d</sup> all gorgonians are of good quality.

* **, **, * indicate statistical significance at 1%, 5%, 10% level, respectively.
REJECTION RATES FOR DIVING UNDER DIFFERENT SCENARIOS (%)

- Baseline: 0.4%, 0.7%, 1.3%，2.4%, 4.4%
- Abundance of stinging jellyfish: 0.8%, 1.4%, 2.6%, 4.8%, 8.6%
- 50% decrease of gorgonians: 1.7%, 3.0%, 5.5%, 9.7%, 16.6%
- Total disappearance of gorgonians: 3.2%, 5.8%, 10.2%, 17.2%, 27.6%
- Stinging jellyfish become abundant and all gorgonians disappear: 6.2%, 10.9%, 18.4%, 29.2%, 42.8%
CONCLUSIONS

- Total disappearance of gorgonians was considered the most disliked change.

- Jellyfish could be considered as repulsive/attractive to divers, whenever they present a risk of stinging or not.

- Economic costs may involve recreational welfare losses for scuba divers, and a reduction of tourism revenues with possible effects for the local economy, and management budgets of MPAs.

- The magnitude of estimated costs could be higher if repercussions in the entire ecosystem are considered.
Value Transfer of Sea Warming and Acidification: An Economic-Ecological Impact Study of EU-Mediterranean MPAs

Criteria of similarity:
1) EU- Med MPAs
2) MPAs w/ gorgonians
3) MPAs w/ scuba diving

Sample:
36 MPAs
(31% of EU-Med MPAs)

Italy: 16
Spain: 9
France: 5
Croatia: 4
Greece: 2
■ **Background information**
  - Years of establishment
  - Area of the MPA
  - (…)

■ **Scuba diving sector**
  - Number of dives/year
  - Existence of a scuba dive fee
  - (…)

■ **Environmental issues**
  - Perception of threat
  - Monitoring of seawater chemistry components
3 MAIN CHARACTERISTICS OF THE POLICY SITES

- Total marine surface area of 5,656.7 km².
- Total of 543,051 dives made in a year (Calanques, France - 125,000).
- 15 MPAs had scuba dive fees.
- SST was the most monitored component (17 MPAs), followed by pH (9), and alkalinity (6).
LEVEL OF THREAT POSED BY ENVIRONMENTAL PRESSURES (Nº; %)

- **Eutrophication**: 11 High, 18 Moderate, 3 Low, 2 Did not answer or invalid answer
- **Ocean acidification**: 5 High, 17 Moderate, 12 Low, 10 Did not answer or invalid answer
- **Sea level rise**: 4 High, 19 Moderate, 10 Low, 11 Did not answer or invalid answer
- **Summer heat waves**: 15 High, 11 Moderate, 6 Low, 1 Did not answer or invalid answer
- **Invasive species**: 20 High, 9 Moderate, 1 Low, 11 Did not answer or invalid answer
- **Harmful algal blooms**: 9 High, 18 Moderate, 5 Low, 10 Did not answer or invalid answer
- **Gradual increase in SST**: 9 High, 13 Moderate, 7 Low, 10 Did not answer or invalid answer
- **Marine pollution**: 8 High, 9 Moderate, 3 Low, 12 Did not answer or invalid answer
ECOLOGICAL MODEL OF CORALLIGENOUS SUITABILITY

- Based on 17 environmental factors that may constrain growth and survival of the coralligenous (Martin et al. 2014): bathymetry, temperature, salinity, nutrient concentration, pH, etc.

- Based on IPCC RCP 8.5 and ‘Deep Blue’ land use scenarios.

- Assesses likely changes in suitability between near past (2001-2010) and medium-term future (2041-2050).
LIKELIHOOD OF HABITAT UNSUITABILITY [2041-2050; %]

Average 33.4%
EXAMPLE OF A COST CATEGORY ASSESSED IN THE STUDY

- Tourism revenue losses
  - Choice probabilities for rejecting to dive with a 50% and 100% decrease in gorgonians.

<table>
<thead>
<tr>
<th>Price of a dive (€)</th>
<th>Rejection rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>70</td>
<td>5.5% - 10.2%</td>
</tr>
</tbody>
</table>

**Basic cost estimates**

- Rejection rate multiplied by total dives made in a year in MPAs.
- Estimated value of dives not occurring.
TOURISM REVENUE LOSSES (Million €) – Basic cost estimates (2014)

- Average for MPAs
- Maximum (Calanques, FR)
- Total of MPAs

<table>
<thead>
<tr>
<th>Percentage</th>
<th>Average for MPAs</th>
<th>Maximum (Calanques, FR)</th>
<th>Total of MPAs</th>
</tr>
</thead>
<tbody>
<tr>
<td>50%</td>
<td>0.06</td>
<td>0.5</td>
<td>2.3</td>
</tr>
<tr>
<td>100%</td>
<td>0.116</td>
<td>0.9</td>
<td>4.3</td>
</tr>
</tbody>
</table>

Average for MPAs: 0.06
Maximum (Calanques, FR): 0.5
Total of MPAs: 2.3

Average for MPAs: 0.116
Maximum (Calanques, FR): 0.9
Total of MPAs: 4.3

Average for MPAs: 0.222
Maximum (Calanques, FR): 1.4
Total of MPAs: 6.6
• OA is considered as a **low threat**, and there is a high **uncertainty** about how to classify this pressure in terms of threat.

• Potential **lack of knowledge by MPA managers about seawater conditions** may be counterproductive for the development of adaptation actions.

• A majority of MPAs is **likely to experience a decrease in coralligenous suitability**.

• Various MPAs that may be vulnerable to sea warming and OA were **not assessed**, meaning that estimates could represent a lower bound to the impact of both pressures.
Other key insights
Challenges of Socio-economic Analysis

- Addressing uncertainty about effects of these pressures on species, habitats and ecological processes.
- Understanding the synergetic effects of multiple environmental pressures.
- The difficulty of deriving subsequent economic impacts.
- Uncertainty about effective adaptation of ecosystems and economic sectors to future ocean conditions.
To value or not to value?

Iconic vs (non)-iconic species

Other social sciences coming into the analysis?

Sectors assessed are also contributing to the problem!

Interests and conflicts between different stakeholders

short vs medium/long-term
Thank you for your attention!

Luís Campos Rodrigues | lcampos@ent.cat