EFFECTS OF FRESHWATER RIVER DISCHARGE ON TERRESTRIAL ARTHROPODS IN ATLANTIC AND MEDITERRANEAN SANDY SHORES

by

Colombini I., Chaouti A., Fallaci M., Gagnarli E., Scapini F., Bayed A. and Chelazzi L.

Florence 10th – 14th November 2005
MEDCORE PROJECT
(ICA3-CT2002-10003, 5° FP, INCO-MED Programme)

“FROM RIVER CATCHMENT AREAS TO THE SEA: A COMPARATIVE AND INTEGRATED APPROACH TO THE ECOLOGY OF MEDITERRANEAN COASTAL ZONES FOR SUSTAINABLE MANAGEMENT”

BILATERAL PROJECT
ITALY – MOROCCO

CNR - CNRST AGREEMENT
2002-2005

“SMALL-SCALE SPATIAL DISTRIBUTION OF MACROFAUNA ALONG ATLANTIC AND MEDITERRANEAN SANDY SHORES”
MAIN QUESTIONS ADDRESSED IN THE STUDY

- How do freshwater runoffs influence the community structure of terrestrial macroinvertebrates of sandy beaches?

- Are biological descriptors, such as species richness, diversity and abundance, influenced by increasing distances from freshwater discharges?

- Do gradients of physical factors change at increasing distances from the river mouth?
Both beaches were:

- exposed
- intermediate (sensu Short, 1996)
- low quantities of beach-cast material
- similar climatic regimes
- similar fluvial outputs
- small latitudinal differences
- high human impact around river mouths

Main differences were:

- beach stability
- tidal regimes: microtidal vs mesotidal excursions (Italian site tidal range $\leq 40$ cm; Moroccan site tidal range up to 3.7 m during spring tide).
- sea influence
Italian site
Dominant marine currents
ITALIAN SITE: Maremma Regional Park

Ombrone river mouth
MOROCCAN SITE: Mehdia beach
ITALY: STATIONS FROM THE RIVER MOUTH

Station 1

Station 2

Station 3

Station 4

Station 5
SAMPLING METHODS

Arthropod sampling
(Transects with pitfall traps)

Environmental samples

beach slope and width

sand samples
(sand moisture, salinity, pH, total organic matter, grain size)

beach penetrability
RESULTS

Mehdia beach

Beach slope and width

Oct 2002

June 2003

11.1%
12.9%

11.9%
17.5%
17.3%
16.8%
13.0%

21.2%
13.5%
10.0%

0.5 m
2 m

Station 1
Station 2
Station 3
Station 4
Station 5

dune scarp

sea 48 46 44 42 40 38 36 34 32 30 28 26 24 22 20 18 16 14 12 10 8 6 4 2 0 m land
RESULTS

Maremma Regional Park

Sand parameters

**September 2002**

- Organic matter (%)
- Sand moisture (%)
- pH
- Salinity (µScm⁻¹)
- Sand size (φ)
- Penetrability (mm)

**May 2003**

- Organic matter (%)
- Sand moisture (%)
- pH
- Salinity (µScm⁻¹)
- Sand size (φ)
- Penetrability (mm)
RESULTS

Mehdia beach

Sand parameters

October 2002

- Organic matter (%)
- Sand moisture (%)
- pH
- Salinity (µScm⁻¹)
- Sand size (ϕ)
- Penetrability (mm)

June 2003

- Organic matter (%)
- Sand moisture (%)
- pH
- Salinity (µScm⁻¹)
- Sand size (ϕ)
- Penetrability (mm)
RESULTS

TOTAL CAPTURES

Maremma Regional Park

- September 2002: n=11354
- May 2003: n=6430

Mehdia beach

- October 2002: n=3909
- June 2003: n=14337

Graph showing total captures at Maremma Regional Park and Mehdia beach in different months.
## RESULTS

### MAIN CAPTURED SPECIES

<table>
<thead>
<tr>
<th>Species</th>
<th>Maremma Regional Park</th>
<th></th>
<th>Mehdia beach</th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>September</td>
<td>May</td>
<td>October</td>
<td>June</td>
</tr>
<tr>
<td><em>Tylos europaeus</em></td>
<td>14.75 %</td>
<td>7.10 %</td>
<td>56.89 %</td>
<td>24.13 %</td>
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<tr>
<td><em>Talitrus saltator</em></td>
<td>72.92 %</td>
<td>49.63 %</td>
<td>22.05 %</td>
<td>58.85 %</td>
</tr>
<tr>
<td><em>Phaleria provincialis</em></td>
<td>9.27 %</td>
<td>25.19 %</td>
<td>5.70 %</td>
<td>3.61 %</td>
</tr>
<tr>
<td>Other Coleoptera</td>
<td>0.95 %</td>
<td>5.42 %</td>
<td>0.08 %</td>
<td>0 %</td>
</tr>
<tr>
<td></td>
<td>97.89 %</td>
<td>87.32 %</td>
<td>93.37 %</td>
<td>93.18 %</td>
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</table>
RESULTS

Abundance and species richness of Coleoptera at increasing distance from the river delta

Maremma Regional Park

Abundance n=3395

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<tr>
<th>Month</th>
<th>Station 1</th>
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<td>May</td>
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Species Richness n=55

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<th>Station 5</th>
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<tbody>
<tr>
<td>Sept</td>
<td>15</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>May</td>
<td>49</td>
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<td></td>
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Mehdia beach

Abundance=1039

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<th>Station 5</th>
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<tr>
<td>Oct</td>
<td>195</td>
<td></td>
<td></td>
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<tr>
<td>June</td>
<td>844</td>
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Species Richness n=94

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<td>Oct</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>June</td>
<td>77</td>
<td></td>
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<td></td>
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## Diversity indices (Coleoptera)

### Maremma Regional Park

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<th>3</th>
<th>4</th>
<th>5</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Sept</th>
<th>May</th>
<th>Total</th>
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<tr>
<td>α</td>
<td>1.18</td>
<td>1.31</td>
<td>0.93</td>
<td>1.19</td>
<td>2.68</td>
<td>0.73</td>
<td>3.44</td>
<td>6.02</td>
<td>6.37</td>
<td>5.84</td>
<td>2.72</td>
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<td>α diversity</td>
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<td>1.07</td>
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<td>5.51</td>
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<tr>
<td>α inf. l.</td>
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<td>0.66</td>
<td>0.84</td>
<td>1.86</td>
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<td>2.62</td>
<td>5.15</td>
<td>4.65</td>
<td>4.65</td>
<td>2.15</td>
<td>8.03</td>
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</tr>
<tr>
<td>β</td>
<td>0.11</td>
<td>0.02</td>
<td>0.05</td>
<td>0.02</td>
<td>0.01</td>
<td>0.01</td>
<td>0.12</td>
<td>0.08</td>
<td>0.05</td>
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<td>0.16</td>
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<tr>
<td>Brillouin</td>
<td>0.45</td>
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<td>0.25</td>
<td>0.83</td>
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<td>0.61</td>
<td>0.96</td>
<td>1.55</td>
<td>1.59</td>
<td>0.44</td>
<td>1.28</td>
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<tr>
<td>Pielou</td>
<td>0.35</td>
<td>0.27</td>
<td>0.18</td>
<td>0.14</td>
<td>0.38</td>
<td>0.12</td>
<td>0.23</td>
<td>0.03</td>
<td>0.05</td>
<td>0.53</td>
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<tr>
<td>Simpson</td>
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<td>0.53</td>
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### Mehdia beach

<table>
<thead>
<tr>
<th>Stations</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Oct</th>
<th>June</th>
<th>Total</th>
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<tr>
<td>α inf. l.</td>
<td>0.79</td>
<td>1.36</td>
<td>9.67</td>
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<td>3.52</td>
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<td>8.04</td>
<td>13.30</td>
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<td>6.24</td>
<td>19.25</td>
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<tr>
<td>β</td>
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<td>0.10</td>
<td>0.03</td>
<td>0.002</td>
<td>0.05</td>
<td>0.07</td>
<td>0.11</td>
<td>0.12</td>
<td>0.003</td>
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<tr>
<td>Brillouin</td>
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<td>0.60</td>
<td>1.66</td>
<td>1.01</td>
<td>2.18</td>
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<td>2.20</td>
<td>1.38</td>
<td>2.31</td>
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<tr>
<td>Pielou</td>
<td>0.32</td>
<td>0.41</td>
<td>0.84</td>
<td>0.34</td>
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<td>0.37</td>
<td>0.76</td>
<td>0.81</td>
<td>0.59</td>
<td>0.71</td>
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<tr>
<td>Simpson</td>
<td>0.77</td>
<td>0.66</td>
<td>0.14</td>
<td>0.70</td>
<td>0.17</td>
<td>0.55</td>
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<td>0.10</td>
<td>0.24</td>
<td>0.16</td>
<td>0.47</td>
<td>0.20</td>
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</table>
Simple linear regression analysis

<table>
<thead>
<tr>
<th>September 2002</th>
<th>May 2003</th>
<th>September 2002</th>
<th>May 2003</th>
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</thead>
<tbody>
<tr>
<td>Sand moisture (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salinity (µS/cm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Organic matter (%)</td>
<td></td>
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</tr>
<tr>
<td>Penetrability (mm)</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Beach slope (%)</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Beach width (m)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M₂ (φ)</td>
<td></td>
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</tr>
<tr>
<td>σ₁ (φ)</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Sk₁</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>K_C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>m from delta</td>
<td>2230</td>
<td>5990</td>
<td>2230</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5990</td>
</tr>
</tbody>
</table>

| Total arthropods (n) |           |           |
| Tylos europaeus ad. (n) |       |           |
| Tylos europaeus juv. (n) |       |           |
| Talitrus saltator ad. (n) |     |           |
| Talitrus saltator juv. (n) |     |           |
| Arctosa perita       |           |           |
| Coleoptera (n)       |           |           |
| Coleoptera spp (n)   |           |           |
| Phaleria provincialis ad. (n) | |           |
| Phaleria provincialis l. (n) | |           |
| α div. (Coleoptera)  |           |           |
| β div. (Coleoptera)  |           |           |
| m from delta         | 2230     | 5990          | 2230     |
|                       |          |               | 5990     |
# RESULTS

## Mehdia beach

### Simple linear regression analysis

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand moisture (%)</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Salinity (µS/cm)</td>
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</tr>
<tr>
<td>pH</td>
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</tr>
<tr>
<td>Organic matter (%)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Penetrability (mm)</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Beach slope (%)</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Beach width (m)</td>
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<tr>
<td>$M_z (\varphi)$</td>
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<td>$\sigma_1 (\varphi)$</td>
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<tr>
<td>$Sk_{I}$</td>
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<tr>
<td>$K_C$</td>
<td>50</td>
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<td>5720</td>
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<td>m from delta</td>
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<td>5720</td>
<td>50</td>
<td>5720</td>
</tr>
<tr>
<td>Total arthropods (n)</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td><em>Tylos europaeus</em> ad. (n)</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td><em>Tylos europaeus</em> juv. (n)</td>
<td></td>
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<tr>
<td><em>Talitrus saltator</em> ad. (n)</td>
<td></td>
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<td></td>
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<tr>
<td><em>Talitrus saltator</em> juv. (n)</td>
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<td></td>
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<tr>
<td><em>Talorchestia brito</em> ad. (n)</td>
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<tr>
<td><em>Talorchestia brito</em> juv. (n)</td>
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</tr>
<tr>
<td><em>Talorchestia spinifera</em> ad. (n)</td>
<td></td>
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</tr>
<tr>
<td><em>Talorchestia spinifera</em> juv. (n)</td>
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<tr>
<td>Coleoptera (n)</td>
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<tr>
<td>Coleoptera spp (n)</td>
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<td><em>Phaleria cadaverina</em> ad. (n)</td>
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<tr>
<td><em>Phaleria cadaverina</em> lar (n)</td>
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<tr>
<td><em>Labidura riparia</em></td>
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<tr>
<td>$\alpha$ div. (Coleoptera)</td>
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<td></td>
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<tr>
<td>$\beta$ div. (Coleoptera)</td>
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</tr>
<tr>
<td>m from delta</td>
<td>50</td>
<td>5720</td>
<td>50</td>
<td>5720</td>
</tr>
</tbody>
</table>
RESULTS

Maremma Regional Park

Long-shore distribution of most abundant species

A. perita
P. provincialis ad
P. provincialis larvae
T. europaeus ad.
T. europaeus j.
T. saltator ad.
T. saltator j.

Station 2
Station 3
Station 4
Station 5

3.000 3.500 4.000 4.500 5.000 5.500 6.000

m from the river mouth

Sept
May
RESULTS

Mehdia beach

Long-shore distribution of most abundant species

- T. spinifera ad
- T. spinifera j
- T. sp ad
- T. sp j
- T. brito ad
- T. brito j
- T. saltator ad
- T. saltator j
- T. europaeus ad
- T. europaeus j
- T. spinifera j
- T. sp j
- P. cadaverina larvae
- P. cadaverina ad
- P. cadaverina j
- L. riparia

Station 1  Station 2  Station 3  Station 4  Station 5
0  1000  2000  3000  4000  5000  6000

Oct
June

m from the river mouth
## RESULTS

### Maremma Regional Park

**Multiple regression analysis**

<table>
<thead>
<tr>
<th></th>
<th>moist. (%)</th>
<th>Sal. (µS/cm)</th>
<th>pH</th>
<th>O. mat. (%)</th>
<th>Pen. (mm)</th>
<th>slope (%)</th>
<th>width (m)</th>
<th>Mz (φ)</th>
<th>R²</th>
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<tr>
<td><strong>Total arthropods</strong></td>
<td>+</td>
<td>+</td>
<td></td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>0.992</td>
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<tr>
<td><strong>T. europaeus ad.</strong></td>
<td>–</td>
<td>+</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>+</td>
<td>−</td>
<td>−</td>
<td>0.989</td>
</tr>
<tr>
<td><strong>T. europaeus j.</strong></td>
<td>+</td>
<td></td>
<td>–</td>
<td>+</td>
<td>+</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>0.769</td>
</tr>
<tr>
<td><strong>T. saltator ad.</strong></td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>0.989</td>
</tr>
<tr>
<td><strong>T. saltator j.</strong></td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
<td>−</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>0.993</td>
</tr>
<tr>
<td><strong>Coleoptera</strong></td>
<td>–</td>
<td></td>
<td>+</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>+</td>
<td>−</td>
<td>0.969</td>
</tr>
<tr>
<td><strong>Coleoptera spp</strong></td>
<td>−</td>
<td>+</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>+</td>
<td>−</td>
<td>0.767</td>
</tr>
<tr>
<td><strong>P. provincialis ad</strong></td>
<td>−</td>
<td></td>
<td>+</td>
<td>−</td>
<td>−</td>
<td>+</td>
<td>−</td>
<td>−</td>
<td>0.958</td>
</tr>
<tr>
<td><strong>P. provincialis l.</strong></td>
<td>−</td>
<td>–</td>
<td>+</td>
<td>−</td>
<td>−</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>0.952</td>
</tr>
<tr>
<td><strong>α div. (Cole.)</strong></td>
<td>−</td>
<td>+</td>
<td>−</td>
<td>+</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>+</td>
<td>0.874</td>
</tr>
<tr>
<td><strong>β div. (Cole.)</strong></td>
<td></td>
<td></td>
<td>+</td>
<td></td>
<td>−</td>
<td>+</td>
<td>−</td>
<td>−</td>
<td>0.890</td>
</tr>
</tbody>
</table>
## RESULTS

### Mehdia beach

<table>
<thead>
<tr>
<th>Moist (%)</th>
<th>Sal. (µS/cm)</th>
<th>pH</th>
<th>O. mat (%)</th>
<th>Pen. (mm)</th>
<th>Slope (%)</th>
<th>width (m)</th>
<th>$M_z (\phi)$</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total arthropods</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tylos europaeus ad.</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>0.804 0.553</td>
</tr>
<tr>
<td>Tylos europaeus juv.</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.533 0.704</td>
</tr>
<tr>
<td>Talitrus saltator ad.</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>0.628 0.693</td>
</tr>
<tr>
<td>Talitrus saltator juv.</td>
<td></td>
<td></td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>0.942 0.813</td>
</tr>
<tr>
<td>Talorchestia brito ad.</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.389</td>
</tr>
<tr>
<td>Talorchestia brito juv.</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>0.597 0.326</td>
</tr>
<tr>
<td>Talorchestia spinifera ad.</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>0.536</td>
</tr>
<tr>
<td>Talorchestia spinifera juv.</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>0.987</td>
</tr>
<tr>
<td>Talorchestia sp ad.</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>0.769</td>
</tr>
<tr>
<td>Labidura riparia</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>0.992 0.958</td>
</tr>
<tr>
<td>Coleoptera</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.729 0.918</td>
</tr>
<tr>
<td>Coleoptera spp</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.834 0.861</td>
</tr>
<tr>
<td>Phaleria cadaverina ad.</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>0.750 0.915</td>
</tr>
<tr>
<td>Phaleria cadaverina lar.</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>0.333 0.770</td>
</tr>
<tr>
<td>$\alpha$ diversity (Cole.)</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>0.939 0.976</td>
</tr>
<tr>
<td>$\beta$ diversity (Cole.)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>0.603 0.428</td>
</tr>
</tbody>
</table>
Forcing factors in ecosystem functioning

Maremma Regional Park
(closed system)

OMBRONE river
low sediment input

INSTABILITY
erosion and progradation processes

Finer sand transported by dominant NS marine water currents

Changes in beach slope and width according to the season & distance

Higher sand moistures and salinities, lower penetrability with increasing distance

Seasonal changes of pH under direct influence of river

CONCLUSIONS

Species preference for certain beach features

Highest species richness
α diversity

Increased habitat diversity

Species long-shore distribution seasonal shifts

Station 3 Dynamic equilibrium

Arthropods increased with distance from river (isopods & amphipods)

Amelioration of beach-dune features

Lower human impact

Human disturbance

CONCLUSIONS

Mediterranean coast
CONCLUSIONS

Forcing factors in ecosystem functioning

Mehdia beach (open system)

Atlantic coast

Ocean

- Heavy wave action & high tidal excursions

Sidi Bou Ghaba retro-dune water basin

June linear trends with distance

October no linear trends with distance (except for pH and sand size)

Weak long-shore drift that deposited fluvial sediments near river mouth

Finer sand, higher pH, greater organic matter at station 2

Shifts in species long-shore distribution between seasons

Human disturbance

Differences in sand parameters due to season and heavy rain

Well developed beach dune system & high environmental complexity with diverse vegetation cover

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Oued Sebou

Allochthonous flying species from dune blown by eastern winds

June higher species richness α diversity of Coleoptera

Amphipods and Coleoptera species: significant linear trends with distance in June

Higher number of Amphipod species (Talorchestia species)

Preferences to specific beach features

Higher α diversity compared to Maremma

CONCLUSIONS

Habitat

- Dune system

- Vegetation

- Sediments

- Species diversity

- Human disturbance

Atlantic coast

Mehdia beach (open system)

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