Beta, alpha and gamma benthic diversity on estuaries: What to expect?

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## Estuaries: functions and multiple services

<table>
<thead>
<tr>
<th>Function</th>
<th>Carbon sequestration</th>
<th>Climate regulation</th>
<th>Fisheries production</th>
<th>Pharmaceutical</th>
<th>Pollution buffering</th>
<th>Recreational</th>
<th>Tourism</th>
<th>Aquaculture production</th>
<th>Erosion control</th>
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</thead>
<tbody>
<tr>
<td>Biodiversity</td>
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<td>Carbon Cycling</td>
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<td>Nursery area</td>
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<td>Sediment trapping</td>
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<td>X</td>
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<td>Wave attenuation</td>
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Adapted from Granek et al 2010 Cons. Biol.
An estuary is a partially enclosed coastal body of water that is either permanently or periodically open to the sea and which...

...receives at least periodic discharge from a river(s), and thus, while its salinity is typically less than that of natural sea water and varies temporally and along its length,...

...it can become hypersaline in regions when evaporative water loss is high and freshwater and tidal inputs are negligible.

Potter et al 2010 ECSS
Estuarine Quality Paradox

High degree of variability in their physico-chemical characteristics (e.g. oxygen, temperature and salinity) in the water column and bed sediment dynamics

Natural stress $\approx$ Anthropogenic stress

Detection of the anthropogenic stress more difficult than in other systems (e.g. marine, freshwater)

Elliott and Quintino 2007 ECSS
Many studies described the variation on the structure of biological assemblages (e.g. mangroves, salt-marshes, benthic invertebrates, benthic diatoms, bacteria, phytoplankton, fish) **along estuarine systems**
1. Estuaries are really importante (function, services)
2. Different types os estuaries (large variability between)
3. Large variability (large variability within)
4. Different sample designs (”technical” variability)
1. Estuaries are really importante (function, services)
   +
2. Different types os estuaries (large variability between)
   +
3. Large variability (large variability within)
   +
4. Different sample designs ("technical" variability)

General models hard to built
Estuarine diversity model

Remane 1934

(source: Whitfield et al 2012 ECSS)
Beta, alpha and gamma diversity...
**Gamma diversity**: Region A > Region B

**Alpha diversity**: Site1 = Site2 > Site 4 > Site 3

**Beta diversity**: Between sites in Region B > Between sites in Region A
Beta diversity may reflect two different phenomena:

1 - turnover (or sps replacement)

2 - nestedness


Nestedness

Site 1

Site 2

Site 3

Turnover (replacement)

Site 1

Site 2

Site 3

≠ Strategies to Conserve Biodiversity
In areas with greater effects of glaciation (i.e. stronger glaciation) beta diversity will be mostly driven by nestedness than turnover

stronger glaciation in temperate - - -

extinctions and colonization - high nestedness

weaker effects of glaciation in tropics - - -

high endemism - high turnover

Existing theory…

Baselga 2010 (beetles)

Dobrovolsky et al, 2012 (birds, mammals and amphibians)
Benthic invertebrates in rivers

(i) to evaluate if benthic macrofaunal assemblages would show higher turnover than nestedness in tropical than in temperate estuarine systems;

(ii) to evaluate whether impacted estuaries would show greater nestedness than pristine (or less polluted) systems;

(iii) to propose a framework for studying benthic macrofaunal beta diversity along estuaries and suggest potential modifications due to climate changes.
Fig. 1. Map showing sampled estuaries and stations (black dots).
Where the data come from?

San Francisco Bay
Regional Monitoring Program (RMP)
San Francisco Estuary Institute largest program.

Elkhorn Slough
Several projects Benthic Ecology Lab at Moss Landing Marine Labs, CA, US

French Estuaries
French Adour-Garonne Water Agency (Agence de l’Eau Adour-Garonne), France

Brazilian Estuaries
Several projects CNPq, FAPESB, Brasil
Did you sample enough?
Alpha
Not a general pattern
R package for computing total dissimilarity as Sørensen index, as well as it turnover and nestedness components

\[ \beta_{sor} = \beta_{sim} + \beta_{sne} \equiv \frac{b + c}{2a + b + c} = \frac{b}{b + a} + \left( \frac{c - b}{2a + b + c} \right) \left( \frac{a}{b + a} \right) \]
Example....

\[ \beta_{SOR} \rightarrow \text{TOTAL BETA} = \]

\[ \beta_{SNE} \rightarrow \text{Nestedness component} + \]

\[ \beta_{SIM} \rightarrow \text{Turnover component} \]

"Mostly turnover (replacement) situation"
Totally nested
Total replacement
Mostly replacement
Replac.= Nest.
Mostly nested
Totally nested
Benthic macrofaunal assemblages do not show higher turnover than nestedness in tropical than in temperate estuarine systems.

Preserved (less impacted) estuaries show greater turnover than nestedness.
Climate changes:

*Extreme events: increasing in rain/heavy drought*

*Habitat compression and/or habitat shifting*

Changes in salinity will likely shortening estuarine gradient (together with existing anthropogenic impacts) will push estuarine systems even far from their natural states.
To understand the effects of climate changes on estuaries we need to:

- Preserve entire estuarine systems

- Monitoring programs at preserved and not preserved estuaries around the globe
Obrigado

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