Assessing the environmental impacts of beach nourishment:

Universal lessons about the need for rigorous design and effective process to assess projects of all kinds

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Increasing rates of shoreline retreat
Increasing rates of shoreline retreat

Increasing coastal development
Beach Nourishment

Dredge

Fill
Beach Coastal Ocean

- sea turtle nest
- shorebirds
- beach invertebrates
- surf fishes
- coral reefs and live bottom
- reef fishes
- bottom invertebrates
- soft-bottom fishes

Fill Site
Dredge Site
Paradox

– 1922-1987: 400 miles of US shoreline nourished
– permits for beach nourishment typically require ecological monitoring ⇒ scores of monitoring studies

Why is there great uncertainty regarding ecological impacts of nourishment?
Resolution of paradox

• Synthesis of designs of previous monitoring studies
• Review agency process of permitting beach nourishment
Assessment of study designs

• All available (45) US studies evaluating ecological impacts of beach nourishment

• 2 independent reviews of each (some published in multiple forms)
  – type of study
  – biological and physical variables measured
  – sampling design
  – statistical analyses
  – interpretation of data
  – scholarship
Presentation of monitoring studies

Majority have never been subjected to peer review
Subject of monitoring studies

Of the 45 studies:
• 11 – impacts of dredging only
• 23 – impacts of filling only
• 11 – impacts of dredging AND filling
• 1 – included manipulative experiments;
• 0 – included modeling

Most studied – impacts of filling on macroinvertebrates
(53% of studies)
% of studies (by taxon) examining impacts of DREDGING that measure important environmental variables

<table>
<thead>
<tr>
<th>Environmental Variable</th>
<th>Macroinvertebrates</th>
<th>Fish</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Soft Bottom (n = 16)</td>
<td>Hard Bottom (n = 8)</td>
</tr>
<tr>
<td>turbidity</td>
<td>13</td>
<td>25</td>
</tr>
<tr>
<td>sedimentation</td>
<td>13</td>
<td>50</td>
</tr>
<tr>
<td>mean grain size</td>
<td>56</td>
<td>13</td>
</tr>
<tr>
<td>sediment grain size distribution</td>
<td>56</td>
<td>38</td>
</tr>
<tr>
<td>sediment mineralogy</td>
<td>25</td>
<td>0</td>
</tr>
<tr>
<td>organic content of sediment</td>
<td>44</td>
<td>13</td>
</tr>
<tr>
<td>sediment compaction</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>topography</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>direct physical contact</td>
<td>0</td>
<td>25</td>
</tr>
<tr>
<td>no environmental variables measured</td>
<td>25</td>
<td>38</td>
</tr>
</tbody>
</table>

Analyses testing for relationships between biological and physical variables only included 4% of the time.
### % of studies (by taxon) examining impacts of FILLING that measure important environmental variables

<table>
<thead>
<tr>
<th></th>
<th>macroinvertebrates</th>
<th>fish</th>
<th>sea turtles</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>soft bottom $(n = 26)$</td>
<td>hard bottom $(n = 5)$</td>
<td>$(n = 10)$</td>
</tr>
<tr>
<td>turbidity</td>
<td>27</td>
<td>0</td>
<td>50</td>
</tr>
<tr>
<td>sedimentation</td>
<td>4</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>mean grain size</td>
<td>62</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>sediment grain size distribution</td>
<td>58</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>shell cover</td>
<td>4</td>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>sediment mineralogy</td>
<td>27</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>organic content of sediment</td>
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</tr>
<tr>
<td>sediment compaction</td>
<td>4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>slope of swash zone</td>
<td>31</td>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>topography (other)</td>
<td>27</td>
<td>0</td>
<td>30</td>
</tr>
<tr>
<td>no environmental variables measured</td>
<td>15</td>
<td>80</td>
<td>10</td>
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</tbody>
</table>

Analyses testing for relationships between biological and physical variables only included 11% of the time.
49% of studies fail to include both spatial AND temporal components in their design.

Only 37% of studies include multiple controls (usually not interspersed). 17% contain NO controls.

Of the 51% of studies that do include spatial and temporal components, only 8% test for an impact using a BACI analysis.
39% of studies do not control for seasonal variability.

Emerita

Donax

Mean Abundance

Date

Mar 99  Apr 99  May 99  Jun 99  Jul 99  Aug 99  Sep 99  Oct 99  Dec 99  Feb 00  Apr 00  May 00  Jun 00  Jul 00  Aug 00  Sep 00

Control

Nourished
**Statistical analysis of data**

Interpretation

![Bar chart showing the percentage of studies per type of writing (final report, unref paper, thesis, ref paper) categorized by statistical analysis (none, adequate, inadequate).](image)

![Another bar chart showing the percentage of studies per type of writing (final report, unref paper, thesis, ref paper) categorized by interpretation (all correct, mostly correct, much misinterpreted, all misinterpreted).](image)
Statistical Power

- Only 1 study included an appropriate *a priori* power analysis
- 1 study included an appropriate *a posteriori* power analysis
Scholarship

- 7% of studies did not review literature; 42% included a review below publication (MEPS) standard
- 21% of studies did not discuss results with respect to potential mechanisms
- 54% of studies drew conclusions not supported by results and analyses
Most critical shortcomings

1. Uniform absence of experimental manipulations and modeling
2. Widespread omission of tests of relationships between biological and physical variables
3. Failure to employ the required BACI design to test for impact
4. Lack of consideration of statistical power
5. Failure to reach conclusions of publication standard
6. High proportion reaching conclusions that are not supported by data
Who pays for this?

Federal Contribution

Protection of public shore: 50-65%
Recreational purposes: 50%
Protection of private private property: 0%

Where federal funds involved, responsibility of US Army Corps of Engineers
Why is quality so poor?

• Neither state nor federal permitting agencies employ anonymous process of peer review of sampling designs or final reports
• Failure to incorporate manipulative experiments and modeling into monitoring projects
• Lack of explicit goals
  [1. Address unanswered questions about environmental impacts
  2. Identify injury to public trust so as to allow compensatory mitigation]

Not for lack of funding...
“because inter-annual variation of surf zone fish community dynamics is considerable, it is unlikely that anything other than catastrophic impacts on surf zone fishes would be evident.”

USACE $8.6 million dollar monitoring project, NJ
Acknowledgements: Financial support was provided by the North Carolina Sea Grant College Program, the Julian Price Foundation, the Packard Foundation, and the University of North Carolina.