An index of ecosystem status for Southern California shallow rock reefs

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Failures of fishery management

- CA has struggled to effectively manage many harvested species associated with rocky reefs
- Functional extinctions
- Changes in abundance & size structure
- Non-fishery impacts – water quality, habitat loss, climate...
A new strategy: ecosystem-based management

- Holistic approach
- Marine spatial management
- MPAs, South Coast in 2012
- Nearly all encompass some reef habitat
- Buffer against uncertainty
- Consideration of spatially varied
  - Abiotic conditions (SST, depth, relief)
  - Anthropogenic stressors
Monitoring whole ecosystems is challenging

- Large natural variability – spatial & temporal
- Large variation in anthropogenic stress – fishing pressure, water quality
- MPA effects obscured by this variation
- Large disconnected data sets
- Need quantitative, repeatable method for evaluating ecosystem integrity
Overall approach

• Link resources and water quality communities
• Create quantitative indices of stressors and ecology
• Which has more impact, fishing or water quality?
3 regional scale indices

Fishing Pressure
Dan Pondella, Amanda Zellmer
VRG, Occidental College

Water Quality
Ken Schiff, Becky Shaffner
SCCWRP

Biological Response

Ron McPeak
Quantifying fishing pressure

• How do we allocate fishing pressure to individual reefs?
  • Current vs. historical
  • Catch amount vs. effort
  • Some fisheries more damaging than others?

• Commercial and recreational fishing are regulated and documented in CA

• Using these reports, quantify total amount harvested, historical & current

• Synthetic index integrates across
  • Time
  • Species
  • Gear types
  • Types of fishermen
  • Regulatory regimes

• Straightforward approach, but never attempted
- California Commercial Fisheries Data
  - (1972 – 2009)
  - CA Fish & Wildlife
- California Sport Fishing Data
  - (1980 – 2009)
  - CPFV Logbook

Original Data:

Filter:
- So CA
- Reef Species

Summarize:
- Com
- Rec

Spatial Fishing Pressure Index

Time
1980-2009

Graph: Commercial fishing pressure index from 1980 to 2009.
Most Fished Species

- Commercial
- Recreational

- Sea urchin red
- Bass barred sand
- Crab rock unspecified
- Bass kelp
- Lobster California spiny
- Scorpionfish California
- Sheephead California
- Abalone red
- Abalone black
- Sea cucumber warty

Commercial and Recreational Total Pounds Extracted per Year
Total Pounds Extracted Per Year Per km² Reef Area
Commercial & Recreational 1980-2009
3 regional scale indices

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**Biological Response**
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Quantifying pollution impacts

- Risk-based framework
  - Function of magnitude (load) and frequency of exposure (plume frequency)
- Focus on 2 major sources
  - POTWs
  - Stormwater
- Focus on nitrate, copper & TSS
- Generate a GIS layer of the Water Quality Index for the entire Bight
  - A map like this has never been attempted
  - Scored on a scale of 0-3
3 regional scale indices

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Biological Response
Ron McPeak
What is the biological impact?

- Other monitoring programs
  - Ecosystem described by status of each individual species
- Develop a multivariate, ecosystem-level biological index
  - Integrate direct & indirect effects due to organism interactions
  - Framework to account for habitat variability and focus on variation from stress
- Body of research in fresh water ecosystems
- Little research in marine ecosystems
Biological Data

- CRANE, Bight, SC MPA Baseline
- 140 Sites
- 3 survey types
  - Fish
  - Mobile macroinvertebrates & algae
  - Sessile, colonial invertebrates & algae
O/E Index

\[
\frac{\text{Observed Biological Community}}{\text{Expected Biological Community}} = \text{Index Score}
\]

- **Observed** - measured on transect surveys
- **Expected** - what should be living at this site?
- Reference site approach
- Model biological community & habitat relationships at reference sites
- \(1 = \text{“reference condition”}\)
- Use model to predict expected values at test sites
Reference sites experience a relative absence of stress

< 30\textsuperscript{th} percentile of lbs taken + No water quality impact =
• Qualities of good reference sites
  • Wide geographic spread
  • Wide range of natural gradients
  • Truly little anthropogenic impact
Habitat at reference & non-reference sites
Index evaluation

- Accuracy, precision, bias
- Sensitivity (to stress)
- Best assemblage
Accuracy & precision

* Null vs. predictive
* Accuracy indicated by reference means close to 1
* Precision indicated by small SD

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<th>Calibration</th>
<th>Validation</th>
<th>Test</th>
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<td>Predictive</td>
<td>Mean: 1.017</td>
<td>Mean: 1.030</td>
<td>Mean: 0.987</td>
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<tr>
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<td>SD: 0.131</td>
<td>SD: 0.076</td>
<td>SD: 0.174</td>
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<td>Mean: 0.981</td>
<td>Mean: 0.995</td>
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<td>SD: 0.156</td>
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<tr>
<td>% Precision Improvement</td>
<td>16</td>
<td>43</td>
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Sensitivity

- Mean O/E scores significantly different for reference and non-reference samples ($p=0.005$)
Index application: understanding stress impacts

• A weight of evidence approach
• Threshold delineation
• Stress relative to O/E performance
  • Ranking sites: chi square
  • Comparing means: t-tests
• Continuous data: multiple regression
Threshold delineation
Chi squared test: number of low performing in impact categories

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<tr>
<th>Impact Level</th>
<th>Low</th>
<th>Med Low</th>
<th>Med High</th>
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<tbody>
<tr>
<td>Fishing Pressure</td>
<td></td>
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<td>-</td>
<td>↑</td>
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<tr>
<td>Water Quality</td>
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Comparing means of stressors relative to threshold
Multiple predictors of O/E scores

- Multiple regression
  - Dependent variable: O/E scores
  - Independent variables: Stressors & key habitat variables
- Stepwise procedure reduced model
- Fishing pressure has strongest influence
  - Highly significant negative relationship
- TSS weakest
- Habitat important: low relief, bedrock, sand, cobble
Conclusions

- Successful collaboration between water quality and resources
- We can build a biological index for a marine habitat
  - Separates reference from non-reference conditions
  - Room for improvement
  - Preliminary application indicates fishing may be a more important stressor than water quality
- Potentially useful web portal tool