Are U.S. Coral Reefs on the Slippery Slope to Slime?

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Materials and Methods

To determine the state of U.S. coral reefs along a global gradient of reef degradation, we used the methodology proposed by Pandolfi et al. (S1). The method consists of (i) determining the status of guilds of organisms for each reef using published data, (ii) performing a (multivariate) indirect gradient analysis on the guild status database, and (iii) estimating the location of each reef along a gradient of degradation from pristine to ecologically extinct reefs.

Guilds of organisms were defined on the basis of mode of nutrition (herbivore, carnivore), life habit (mobile free-living, sessile architectural), and size (for free-living species, large > 1 m, small < 1 m). The four free-living guilds with common examples are large herbivores (sea cows, green turtle, bump-head parrotfish), small herbivores (most parrotfish, sea urchins), large carnivores (sharks, crocodiles, monk seals, loggerhead and hawksbill turtles, barracuda, large groupers), and small carnivores (most fish and invertebrates). The three sessile, architectural guilds are reef corals, seagrasses, and suspension feeders (sponges, oysters).

Ecological status was scored on the basis of the most frequent status of species within each guild. The ecosystem state was scored for all 7 guilds for all regions. Each data entry was converted to an ordered multistate ranging from 1 (pristine) to 6 (globally extinct) (Table S1). The analysis conducted in (S1) included data on seven cultural periods, from prehuman to present, for 14 reef regions. In the present analysis, we used the entire database with all cultural periods used in (S1) plus data on only the present state of Florida Keys, main Hawaii islands, and northwest Hawaiian archipelago. The final data matrix had 714 cells (Table S2). Each of the scored cells had one or more literature references (Table S3).

We used standard principal components analysis (PCA). For this analysis, we added a single depleted reef with all 7 guilds classified as ecologically extinct (S1). To focus on patterns among regions rather than among guilds, eigenvectors were normalized to 1 and the analysis was calculated on the variance-covariance matrix. Thus, we preserved the Euclidean distances among the region-times in the reduced space and the 7 guilds could then be used to help explain the patterns in the regions. A scree plot of eigenvalues versus PC showed that only PC1 was significant ($\lambda_1 = 6.35$, $\lambda_2 = 0.36$, $\lambda_3 =0.26$). PC1 explained 90% of the variance. To determine the degradation state of reefs we plotted the percent degradation as a function of the scores of each reef on the PC1 axis normalized so that the pristine state was equal to 0% degradation and the ecologically extinct state was 100% degradation.
<table>
<thead>
<tr>
<th>Ecological state</th>
<th>Criteria for classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pristine</td>
<td>Marine resource lacks any evidence of human use or damage. Example: Any prehuman population</td>
</tr>
<tr>
<td>Abundant/common</td>
<td>Human use with no evidence of reduction of marine resource. Example: No reduction in relative abundance or size of species</td>
</tr>
<tr>
<td>Depleted/uncommon</td>
<td>Human use and evidence of reduced abundance (number, size, biomass, etc.). Examples: Shift to smaller sized fish; decrease in abundance, size, or proportional representation of species</td>
</tr>
<tr>
<td>Rare</td>
<td>Evidence of severe human impact. Examples: Truncated geographic ranges; greatly reduced population size; harvesting of pre-reproductive individuals</td>
</tr>
<tr>
<td>Ecologically extinct</td>
<td>Rarely observed and further reduction would have no further environmental effect. Examples: Observation of individual sighting considered worthy of publication; local extinctions</td>
</tr>
<tr>
<td>Globally extinct</td>
<td>No longer in existence. Example: Caribbean monk seal</td>
</tr>
</tbody>
</table>
Table S2. Data matrix for the Florida Keys and Hawaiian islands. The larger data matrix used in this analysis is in the online supplemental material of (S1).

<table>
<thead>
<tr>
<th>Site</th>
<th>Large carnivores</th>
<th>Small carnivores</th>
<th>Large herbivores</th>
<th>Small herbivores</th>
<th>Corals</th>
<th>Seagrass</th>
<th>Suspension feeders</th>
</tr>
</thead>
<tbody>
<tr>
<td>Florida Keys</td>
<td>5</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>NW Hawaii</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>no data</td>
<td>2</td>
</tr>
<tr>
<td>Main Hawaii</td>
<td>5</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>no data</td>
<td>2</td>
</tr>
</tbody>
</table>

Legend: Ecological State
1 pristine
2 abundant/common
3 depleted/uncommon
4 rare
5 ecologically extinct
6 globally extinct
no data: no data exist to evaluate ecosystem state

Table S3. References for data matrix.

<table>
<thead>
<tr>
<th>Site</th>
<th>Large carnivores</th>
<th>Small carnivores</th>
<th>Large herbivores</th>
<th>Small herbivores</th>
<th>Corals</th>
<th>Seagrass</th>
<th>Suspension feeders</th>
</tr>
</thead>
<tbody>
<tr>
<td>Florida Keys</td>
<td>S2–S9</td>
<td>S6–S8</td>
<td>S3, S6, S7, S10, S11</td>
<td>S6, S7, S12</td>
<td>S13</td>
<td>S14, S15</td>
<td>S16, S17</td>
</tr>
<tr>
<td>NW Hawaii</td>
<td>S18–S22</td>
<td>S18, S21, S22</td>
<td>S18–S21</td>
<td>S18, S21, S22</td>
<td>S18, S23</td>
<td>no data</td>
<td>S18</td>
</tr>
<tr>
<td>Main Hawaiian Islands</td>
<td>S18, S21, S22, S24, S25, S18–S21, S22, S24–S28</td>
<td>S18–S21, S18, S21, S22, S24–S28</td>
<td>S18–S21, S18, S21, S22, S24–S28</td>
<td>S18, S27, S29, S30</td>
<td>no data</td>
<td>S18</td>
<td></td>
</tr>
</tbody>
</table>

References and Notes


