A size-based cascade in the Pacific subtropical pelagic ecosystem: observations and theory

Jeffrey J. Polovina and Phoebe A. Woodworth-Jefcoats
Pacific Islands Fisheries Science Center
NOAA Fisheries, Honolulu, HI
Hawaii-based pelagic longline fishery

2010: 127 vessels, Ex-vessel value US$ 83 million

Total Effort of the Hawaii-based longline fishery 1990 - 2005

Hooks (x10^6)
Annual CPUE for individual species/groups with significant linear trends
Top: High CPUEs
Bottom: Low CPUEs

Fishing mortality in Central and Western Pacific for 1990-2010 increased by 4-5 fold for yellowfin and bigeye tunas
<table>
<thead>
<tr>
<th>Species</th>
<th>% Change in CPUE from Linear Fit over 16 yr period</th>
<th>Mean Wt (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue Marlin</td>
<td>-80.30</td>
<td>224.0</td>
</tr>
<tr>
<td>Blue Shark</td>
<td>-59.18</td>
<td>106.4</td>
</tr>
<tr>
<td>Striped Marlin</td>
<td>-79.63</td>
<td>93.5</td>
</tr>
<tr>
<td>Shortbill Spearfish</td>
<td>-67.03</td>
<td>75.7</td>
</tr>
<tr>
<td>Opah</td>
<td>-65.36</td>
<td>30.2</td>
</tr>
<tr>
<td>Bigeye</td>
<td>-33.77</td>
<td>22.5</td>
</tr>
<tr>
<td>Oceanic White-tip</td>
<td>-110.37</td>
<td>19.0</td>
</tr>
<tr>
<td>Albacore</td>
<td>-114.37</td>
<td>17.1</td>
</tr>
<tr>
<td>Escolars</td>
<td>194.5</td>
<td>12.1</td>
</tr>
<tr>
<td>Lancetfish</td>
<td>35.3</td>
<td>7.1</td>
</tr>
<tr>
<td>Snake Mackerel</td>
<td>240.8</td>
<td>0.8</td>
</tr>
</tbody>
</table>
Lancetfish (*Alepisaurus ferox*)

Escolar, walu, (*Lepidocybium flavobrunneum*)

Snake mackerel (*Gempylus serpens*)
**Small fishes**: 8 Fishes with mean weight $< 15$ kg

- Skipjack: 7.92 kg
- Escolars: 12.12 kg
- Mahi: 7.44 kg
- Great barracuda: 5.92 kg

**Large fishes**: 14 Fishes with mean weight $\geq 15$ kg

- Yellowfin: 33.5 kg
- Albacore: 17.14 kg
- Unid. tuna: 23.89 kg
- Bigeye: 22.50 kg
- Swordfish: 41.97 kg
- Striped marlin: 93.49 kg
- Blue marlin: 224.03 kg

- Shortbill spearfish: 93.49 kg
- Wahoo: 16.38 kg
- Opah: 30.17 kg
- Oceanic White-tip: 18.96 kg
- Bigeye thresher: 23.91 kg
- Shortfin mako: 48.27 kg
- Blue shark: 106.42 kg
Observed and GAM fitted CPUE

<table>
<thead>
<tr>
<th></th>
<th>Intercept</th>
<th>year</th>
<th>Hooks set</th>
<th>longitude</th>
<th>latitude</th>
<th>sst</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catch (&lt;15kg)</td>
<td>0.9676</td>
<td>0.0265</td>
<td>&lt;2×10^{-16}</td>
<td>&lt;2×10^{-16}</td>
<td>&lt;2×10^{-16}</td>
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</tr>
<tr>
<td>Catch (≥15kg)</td>
<td>&lt;2×10^{-16}</td>
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</tbody>
</table>

Fish Less Than 15 kg

Fish Greater Than 15 kg

Annual Mean Catch / Annual Mean Effort (#/1,000 hrs)

Year
Size-based model

Assumes size-based predation, and size-specific growth and mortality are functions of food availability and SST

**Input:** monthly plankton size spectrum and SST

**Output:** monthly population size spectrum

Size of entry to fishery 1 kg (1 – 15 kg: F = 0.25F) and size full selective by gear is 15 kg.
GAM standardized fishery CPUE

Size-based model
Nature of the Size-Based Cascade in Subtropical Pelagic Ecosystem

Model estimated percent change in size frequency distribution for various levels of fishing mortality relative to the unfished population. Size of entry to fishery 1 kg (1 – 15 kg: \( F = 0.25F \)) and size of full selectivity 15 kg.
Nature of the Size-Based Cascade in Subtropical Pelagic Ecosystem

Model estimated percent change in size frequency distribution for various levels of fishing mortality relative to the unfished population. Size of entry to fishery 1 kg and size of full selectivity 1 kg.
Percent of fish > 15 kg in catch from fishery data

Change in catch and number of fish > 15 kg from size-based model as a function of F
Summary

• A size-based model captures temporal dynamics of subtropical pelagic ecosystem suggesting the system may be regulated largely by size-based predation.

• The reach of a size-based cascade is limited – for example, a decline in the abundance of fishes larger than 15 kg results in an increase in abundance of animals from 15 to 0.1 kg but with minimal further cascading to sizes smaller than 0.1 kg.

• When a size-based cascade occurs, fishery data alone underestimates fishing impacts on ecosystem size structure.