The Role of Marine Mammals in Marine Ecosystems
-- part I

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SIO 133 – Marine Mammal Biology
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Preface: The Take-Home Message
Sources: *RL Brownell pers. comm. 2012; synthesis by Hewitt and Lipsky 2009

<table>
<thead>
<tr>
<th>Whale Type</th>
<th>Southern Hemisphere</th>
<th>North Pacific</th>
<th>North Atlantic</th>
<th>Total</th>
<th>Mean Body Mass (tons)</th>
<th>Tons of Whale in the Ecosystem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Humpback Whale</td>
<td>56,000</td>
<td>20,000</td>
<td>12,000</td>
<td>88,000</td>
<td>31.8</td>
<td>2,798,400</td>
</tr>
<tr>
<td>Right Whales</td>
<td>12,000</td>
<td>550</td>
<td>450</td>
<td>13,000</td>
<td>53.0</td>
<td>689,000</td>
</tr>
<tr>
<td>Gray Whales</td>
<td>20,000</td>
<td>---</td>
<td>---</td>
<td>20,000</td>
<td>25.0</td>
<td>500,000</td>
</tr>
<tr>
<td>Blue Whales</td>
<td>4,600</td>
<td>2,000</td>
<td>2,000</td>
<td>8,600</td>
<td>69.2</td>
<td>595,120</td>
</tr>
<tr>
<td>Fin Whales</td>
<td>15,000</td>
<td>11,000</td>
<td>37,000</td>
<td>62,000</td>
<td>42.3</td>
<td>2,622,600</td>
</tr>
<tr>
<td>Sei Whales</td>
<td>10,000</td>
<td>10,000</td>
<td>12,400</td>
<td>32,400</td>
<td>19.9</td>
<td>644,760</td>
</tr>
<tr>
<td>Bryde's Whales</td>
<td>50,000</td>
<td>39,000</td>
<td>5,000</td>
<td>94,000</td>
<td>13.2</td>
<td>1,240,800</td>
</tr>
<tr>
<td>Minke Whales</td>
<td>500,000</td>
<td>30,000</td>
<td>185,000</td>
<td>715,000</td>
<td>7.0</td>
<td>5,005,000</td>
</tr>
<tr>
<td>Bowhead Whales</td>
<td>---</td>
<td>12,000</td>
<td>8,000</td>
<td>20,000</td>
<td>80.0</td>
<td>1,600,000</td>
</tr>
</tbody>
</table>

~15.7 million tons of whale in the world’s marine ecosystems
This sheer tonnage implies that marine mammals can play significant roles in marine ecosystems.

- Cetaceans in the California Current are estimated to consume ~12% of the ecosystem’s net primary productivity (Barlow et al. 2008).

- Benthic feeding by gray whales provides habitat for benthic scavengers, prey for seabirds, and mixes sediment, with the potential to alter primary production (Oliver and Slattery 1985, Obst and Hunt 1990, Pilskaln et al. 1998).

- Whale carcasses support 350+ species and can be havens of deep-sea biodiversity (Jones et al. 1998, Smith 2006).

- A decline of sperm whales in the tropical and subtropical Pacific may have resulted in a shift toward ecosystems dominated by squids and tunas (Essington 2006).

- Killer whales may have sequentially depleted marine mammal species in the Bering Sea (Springer et al. 2003).
“The irony is that, although whales have become a symbol of the human capacity for greedy overharvest and a rallying point for environmental activists, we know surprisingly little about their ecological role.”

<table>
<thead>
<tr>
<th>Journal/Timeframe</th>
<th>Total Number of Publications</th>
<th>Number (%) Addressing Whale Ecology, Species Interactions, Effects on Ecosystem Processes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marine Ecology (1999-2003)</td>
<td>106</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Marine Mammal Science (1985-2003)</td>
<td>94 (focused on whales)</td>
<td>17 (18%)</td>
</tr>
</tbody>
</table>

Kareiva et al. 2006
Marine Mammals and Ecosystems: a trophic interactions perspective

- MMs as Consumers
- MMs as Competitors
- MMs as Prey
Marine Mammals as Consumers

“The combination of great abundance, large body size, and endothermic metabolic demands make odontocete and mysticete whales some of the most voracious consumers in the oceans. As such, they have the potential to place extraordinary pressures on marine resources.” (Williams 2006)
When we think of consumers in an ecosystem context, we ask questions like:

- What is eaten?
- How much?
- How does this consumption impact the ecosystem?
Case Study: Cetaceans in the Southern Ocean\textsuperscript{1} Ecosystem

\textsuperscript{1}South of the Polar Front
**Krill**

*E. superba, E. crystallorophias, T. macrura*

“Krill-based ecosystem” in about one quarter of the ~32 million sq. km of the Southern Ocean (Siegel & Loeb 1995)

### How much krill is consumed?

<table>
<thead>
<tr>
<th></th>
<th>Estimated Abundance</th>
<th>Mean Mass (tons)</th>
<th>Ingestion Rate/Day (1,000 kcal)</th>
<th>No. Days Spent Feeding</th>
<th>% Krill in Diet</th>
<th>Total Krill Consumed Annually (millions of tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antarctic Blue Whales</td>
<td>2,300</td>
<td>83</td>
<td>3,708</td>
<td>120</td>
<td>100</td>
<td>1.1</td>
</tr>
<tr>
<td>Fin Whales</td>
<td>15,000</td>
<td>48</td>
<td>2,415</td>
<td>120</td>
<td>100</td>
<td>4.7</td>
</tr>
<tr>
<td>Sei Whales</td>
<td>20,000</td>
<td>17.5</td>
<td>1,096</td>
<td>120</td>
<td>80</td>
<td>2.3</td>
</tr>
<tr>
<td>Humpback Whales</td>
<td>55,000</td>
<td>26.5</td>
<td>1,517</td>
<td>120</td>
<td>100</td>
<td>10.8</td>
</tr>
<tr>
<td>Antarctic Minke Whales</td>
<td>500,000</td>
<td>7</td>
<td>535</td>
<td>120</td>
<td>100</td>
<td>34.5</td>
</tr>
</tbody>
</table>

Sources: RL Brownell pers. comm. 2012; synthesis by Hewitt and Lipsky 2009
~53.4 million tons krill consumed annually by 5 species of whales

• For some perspective, annually:
  – 190 million tons consumed by baleen whales alone prior to commercial exploitation (Laws 1985)
  – 250 million tons consumed by current populations of all krill predators (whales, birds, pinnipeds, fish, squid: Miller and Hampton 1989)

• Despite much careful attention, estimates of krill consumption are invariably associated with a great degree of uncertainty (e.g., Leaper and Lavigne 2007)

• How does this consumption impact the ecosystem?*

  *remember for later: “Marine Mammals as Competitors”
Squid

- Sperm whales
  - 10,000 males (R.L. Brownell, pers. comm. 2012)

- Beaked whales
  - 599,300 Ziphiid whales (almost all *H. planifrons*) in the Southern Ocean (Kasamatsu & Joyce 1995)
  - *H. planifrons* – the most abundant cetacean in the Southern Ocean?

- Killer whales? (Type B)

- How much squid is consumed?*
- How does this consumption impact the ecosystem?*

*Big Unanswered Questions

*Durban & Pitman, unpublished data*
Other Species

• Killer whales as consumers of:

Fish, penguins, seals, whales
Killer Whale Ecotypes in the Southern Ocean

Distinct differences
- Color pattern
- Morphology
- Group Size
- Habitat
- Diet

Pitman et al. 2011 and references therein
Fish - Ross Sea
KWs "Type C"

Krahn et al. 2008
Penguins – Gerlache KWs “Small Type B”

Pitman & Durban 2010

Photo: Justin Hofman
Seals - Pack Ice KW “Large Type B”

Pitman & Durban 2011
Whales – “Type A”  

Pitman & Ensor 2003
How much of these species do killer whales consume?

- ~ 25,000 killer whales in the Southern Ocean (Branch & Butterworth 2001)
- Prey specialization (?)

- What is the distribution and abundance of KW ecotypes?
- How does this consumption impact the ecosystem?
A “back of the envelop calculation”
- Pack Ice Killer Whales (Large Type B) in the Antarctic Peninsula region*

~ 150 seal specialists
  • Length ~ 25ft, Weight ~ 13,000 lbs
  • Average seal taken ~ 450lbs
  • Each KW eats ~ 5% of body wt / day

= 72,000 seals a year *(IF they specialize all the time)*

Weddell Seals are declining

*Durban & Pitman, unpublished data

Remember for later: “Marine Mammals as Prey”
Marine Mammals as Competitors

“...competition from any one species may profoundly affect the population dynamics and carrying capacity of another, either through its effect on their mutual resources or by direct interference.” (Rickleffs 1990)
Case Study: Marine Mammals in the Southern Ocean\textsuperscript{1} Ecosystem

\textsuperscript{1}South of the Polar Front
The “Krill Surplus” Hypothesis – an example of competitive release (?

• > 2 million whales removed from Southern Hemisphere (Clapham and Baker 2006)

• Up to 150 million tons krill/yr unconsumed (Laws 1977)

• Theoretically could support addition of 200-300 million penguins per year (Sladen 1964; Emison 1968)

• Growth in penguin populations attributed to “krill surplus” (Sladen 1964; Emison 1968; Conroy 1975; Croxall and Kirkwood 1979; Croxall et al. 1981; Laws 1985; Rootes 1988)
Antarctic Fur Seals: the best example of competitive release?

- Remarkable recovery from commercial exploitation at South Georgia
- Populations above pre-exploitation levels?

- Range expansion to Signy, South Orkneys, due to population increase

- Numbers 78-94% > than during past 6570 (±60) radiocarbon years – exceeding range of natural variability
Competition for krill is occurring.

- At Anvers Island, there are significant relationships between humpback whale abundance, and penguin foraging success (1993-2001).

- Humpback whales and Adélie Penguins appear to target and share similar spatio-temporal prey resources.

Friedlander et al. 2008
This competition can result in changes in abundance (of predators and prey).

- Penguin population declining
- Interpretation
  - Predators reaching $K$
  - Competition for krill is occurring
  - Fur seals are outcompeting penguins

- At Bird Island, South Georgia, Antarctic fur seals and Macaroni Penguins exploit the same size and population of krill

- % krill in fur seal diet > in penguin diet

Barlow et al. 2002
Competition can result in niche partitioning.

- Near the South Shetland Islands, baleen whales show a krill size-dependent relationship with krill abundance hotspots.

Santora et al. 2010
Reading


Marine Mammals as Prey

“The ecological role of large whales as prey is the most controversial of the three potential food web pathways ...” (Estes et al. 2006)