Consumption and prey removals by humpback whales (*Megaptera novaeangliae*) near Kodiak Island, Alaska: A revision of previous estimates

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**Abstract:** Models estimating consumption and prey removal by humpback whales (*Megaptera novaeangliae*) off northeastern Kodiak Island, Alaska were revised in light of new information on diet composition and population size. Previous models were based on the assumption that humpback whales foraged on available prey species in proportion to their relative abundance in 2002. Recent analyses of dive profiles and tissue stable isotopes suggest humpback whales are more selective in their prey choice and that previous estimates of consumption may have misrepresented removal of certain species. Analyses of stable carbon and nitrogen isotope ratios of humpback whale skin and dive profiles of acoustically tagged animals suggest juvenile Walleye pollock (*Theragra chalcogramma*) and eulachon (*Ammodytes hexapterus*) do not contribute significantly to regional humpback whale diet as modeled in the previous diet models. Results suggest a diet comprised primarily of euphausiids (*Thysanoessa* spp), capelin (*Mallotus villosus*), and Pacific sand lance (*Pleuragramma spp*) (Thysanoessa hexametra). An estimate of humpback whale abundance for northeastern Kodiak Island was also updated from 2002 (*N* = 157) to 2007 based on photo-identification efforts. Abundance was estimated using two methods: the first applied a growth rate of 10% per year to the previous estimate of abundance (*N* = 253) and the second used the Schmidt maximum likelihood estimator and incorporated all mark-recapture histories between 1999 and 2007 (*N* = 977). Revisions to diet and abundance in the consumption model had significant effects on estimates of prey removal. Total prey removal, previously estimated as 8,834 kg, increased to 17,940 - 69,279 kg using revised models. Estimates of seasonal removal of capelin, Pacific sand lance, and euphausiids increased dramatically, while increases in the consumption of juvenile Walleye pollock were small.

**Introduction:**

Humpback whales are top-level predators and regional prey removal may approach or exceed removals due to commercial fishing.

High levels of consumption can impact distribution and abundance of prey species and structure of marine communities.

Prey removal by the population of humpback whales near Kodiak Island, Alaska (*N* = 157) was previously estimated at nearly 9,000 tons for a 152 day feeding season (Witteveen et al. 2006).

Consumption models were based on the assumption that whales foraged on available prey species in proportion to their relative abundance. Using additional methodologies to explore specific foraging behavior can refine estimates of consumption by accounting for prey selectivity.

Here we use new data on humpback whale foraging obtained through stable isotope analysis of skin samples and analysis of dive profiles to adjust previous estimates of consumption.

**Materials & Methods:**

**Estimates of Abundance:**

- *K_Schmidt* = 157 from Witteveen et al. 2007
- *N_2002*, updated for 2007 based on photo-identification efforts using two methods:
  - A growth rate of 10% per year was applied to the initial estimate
    - *N_2002* = 253
  - The Schmidt likelihood estimator was applied to all mark-recapture histories between 1999 and 2007
    - *N_Schmidt* = 977

**Prey removal**

Estimated based on general energy requirements of humpback whales and the energy content of their prey using the following equations:

\[ E = \frac{aM}{d} \]

where:

- *E* = energy requirement (kcal/day)
- *a* = estimated coefficient for Mysticetans (Sumich 1983)
- *M* = body mass (kg)
- *d* = body length (kg)

- *No. of Days* = 152
- *C* = calculated daily energy requirement (kcal/day)
- *K* = calculated for prey species (kcal/kg)
- *K* = calculated for diet

**Results:**

- Isotopes showed previous estimates of consumption may have overestimated removals of juvenile pollock and eulachon.
- Revised models suggest a stronger reliance on euphausiids, capelin and Pacific sand lance.
- Consumption increased substantially when new diets and new estimates of abundance were applied.

**Table 1:** Total seasonal prey removal (tons) due to humpback whale consumption near Kodiak Island, Alaska

<table>
<thead>
<tr>
<th>Diet</th>
<th>No. of Days</th>
<th><em>N_2002</em></th>
<th><em>N_Schmidt</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>157</td>
<td>253</td>
<td>977</td>
</tr>
<tr>
<td>B</td>
<td>11,133</td>
<td>17,940</td>
<td>69,279</td>
</tr>
<tr>
<td>C</td>
<td>10,855</td>
<td>17,492</td>
<td>67,548</td>
</tr>
</tbody>
</table>

**Materials & Methods:**

- Three diets, A, B, and C, were created for input into consumption models.
- Diet A was based on consumption in proportion to availability (Witteveen et al. 2006).

**Diet composition**

- Diet B was based on analysis of stable carbon (δ13C) and nitrogen (δ15N) isotes of humpback whale skin and potential preys.
- Skin samples were collected using a hollow-tipped biopsy dart fired by a modified 22 rifle.
- Prey were collected during mid-water trawl and hydroacoustic surveys (Witteveen et al. 2006).
- δ13C and δ15N of humpback whale skin and prey species were entered using a mixing model, IsoSource (http://www.epa.gov/oes/diet/models.html).
- IsoSource uses an iterative approach to produce all feasible prey combinations based on isotope values of consumer and prey (Phillips & Gregor 2003).
- Diet C was a simplified version of Diet B.
- The number of species in Diet C was reduced based on
  - Analysis of dive profiles collected through real-time acoustic tags (Witteveen et al. 2006).
  - Minor contribution in initial IsoSource outputs

**Conclusions:**

- A reexamination and revision of previous estimates of prey removal by Kodiak Island humpback whale showed that estimation methods based on consumption in proportion to availability may be inaccurate.
- Analysis of stable isotope ratios and dive profiles suggested that previous estimates likely overestimated the importance of some fish species, including walleye pollock, Pacific herring, and eulachon, while underestimated the importance of zooplankton, capelin, and Pacific sand lance.
- Revisions of abundance estimates also shows how the growth of local humpback whale populations can substantially impact the amount of prey being removed from regional ecosystems and that accurate estimates of abundance are critical in ecosystem models.

**Literature Cited:**


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