Estimation of prey consumption by sei, Bryde’s, common minke and sperm whales in the western North Pacific taking into account uncertainties

(PICES / BIO-Paper)

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Background

- It is important to make knowledge available to estimate more precisely annual prey consumption by cetaceans in PICES region (0.3-1.6 million mt 2012 PICES).

Daily prey consumption (Two methods)

A: Theoretical energy requirement calculations

B: Diurnal changes of stomach contents mass
What are the uncertainties of prey consumption model?

1. Daily prey consumption models
2. Prey energy
3. Body weight of whales
4. Assimilation efficiency
5. $r$ (the ratio of low/high feeding period)
6. Abundance of whales in the research area
Objectives

- To estimate the prey consumption of four whale species taking into account uncertainties

**Common minke whale**
- Body length: 7 m
- Body weight: 5 t

**Sei whale**
- Body length: 14 m
- Body weight: 22 t

**Bryde's whale**
- Body length: 13 m
- Body weight: 16 t

**Sperm whale**
- Male: 15 m, Female: 11 m
- Male: 40 t, Female: 18 t
Materials and Methods

- **JARPN II** from May to September in 2000-2012
- Sighting data from survey vessels
- Stomach contents analyses

Track lines in the sighting survey
1. Daily prey consumption models (KJ)

(a) \[ D = 4.186aM^{0.75} \ ; \ F = \frac{D}{E} \]

* a=317 for toothed whales, 192 for baleen whales

(b) \[ D = 863.6M^{0.783} \ ; \ F = \frac{D}{E} \]

(c) \[ D = 2529.2M^{0.524} \ ; \ F = \frac{D}{E} \]

\[ D : \text{Daily prey consumption (KJ per day)} \]
\[ F : \text{Daily prey consumption (kg per day)} \]
\[ M : \text{Mean body weight of whales (kg)} \]
\[ E : \text{Caloric value of prey species (KJ per kg)} \]

Perez et al. (1990)* PICES 2000
Sigurjónsson and Vikingsson (1997)
Boyed (2002)
1. Daily prey consumption models

If body weight is 25 tons......

236 ~ 1,111kg
2. Prey energy

- **Copepods** (Neocalanus spp.)
  - 3,850 KJ/kg
  - 3,600 KJ/kg

- **Krill** (Euphausiapacifica)
  - 5,500 KJ/kg
  - ~
  - 6,400 KJ/kg

- **Japanese anchovy** (Engraulis japonicus)
  - 3,400 KJ/kg
  - ~
  - 6,500 KJ/kg

- **Chub mackerel** (Scomber japonicus)
  - 5,200 KJ/kg
  - ~
  - 13,100 KJ/kg

- **Pacific saury** (Cololabis saira)
  - 3,900 KJ/kg
  - ~
  - 6,600 KJ/kg

**3,400 ~ 13,100 KJ/kg**
5. \( r \) (the ratio of low/high feeding period)

\[
r = \frac{(365(1-P))}{(365-HD)}/\frac{(365P)}{HD}
\]

\( r \) : Ratio of low feeding/high feeding period

\( P \) : Proportion of the annual energy intake ingested in the feeding season

\( HD \) : Number of days of high feeding period
5. $r$ (the ratio of low/high feeding period)

Leaper and Lavigne (2007) and Tamura et al. (2009)

IF feeding period is 150 days,

$r = 0.34, 1.73 \times \text{Average daily prey consumption}$

$r = 0.62, 1.38 \times \text{Average daily prey consumption}$
### 6. Abundance of whales in the research area

<table>
<thead>
<tr>
<th>Whale Type</th>
<th>Early (May – June)</th>
<th>Late (July – Sept.)</th>
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</thead>
<tbody>
<tr>
<td>Common minke whale</td>
<td>7,338 inds.</td>
<td>2,976 inds.</td>
</tr>
<tr>
<td></td>
<td>(95%CI: 2,092-25,774)</td>
<td>(95%CI: 1,146-7,725)</td>
</tr>
<tr>
<td>Sei whale</td>
<td>7,744 inds.</td>
<td>5,406 inds.</td>
</tr>
<tr>
<td></td>
<td>(95%CI: 4,604-13,024)</td>
<td>(95%CI: 3,041-9,611)</td>
</tr>
<tr>
<td>Bryde's whale</td>
<td>1,677 inds.</td>
<td>9,797 inds.</td>
</tr>
<tr>
<td></td>
<td>(95%CI: 374-7,522)</td>
<td>(95%CI: 5,401-17,772)</td>
</tr>
<tr>
<td>Sperm whale</td>
<td>15,929 inds.</td>
<td>20,292 inds.</td>
</tr>
<tr>
<td></td>
<td>(95%CI: 6,936-36,581)</td>
<td>(95%CI: 9,355-44,016)</td>
</tr>
</tbody>
</table>
Results

Daily prey consumption

\[ F = D \times \frac{r}{E} \]

- \( F \): Daily prey consumption (kg per day)
- \( D \): Daily prey consumption based on some models (KJ per day)
- \( r \): Ratio of low/high feeding period
- \( E \): Caloric value of prey species (KJ per kg)

Seasonal prey consumption (150 days) of four whale species estimated with 10,000 Monte Carlo simulations ....

Seasonal prey consumption

\[ SF = 150 \times F \]

- \( SF \): Seasonal prey consumption (kg)
Results

- Seasonal prey consumption (150 days) of four whale species estimated with 10,000 Monte Carlo simulations ....

2,087,916 mt (about 2.1 million mt)
95% CI: 1,663,708 – 3,385,363 mt

Baleen whales (Minke, Sei and Bryde's)

1,122,834 mt (about 1.1 million mt)
95% CI: 792,369 – 1,547,570 mt

In 2012 PICES, seasonal prey consumption by three baleen whales estimated 0.3-1.6 million mt
Results

Major source of uncertainty were the abundance and consumption models of sperm whales and Bryde’s whales....

Abundance of sperm whales
Model basal energy (kJ) of sperm whales

Abundance of Bryde’s whales
Model basal energy (kJ) of Bryde’s whales
Prey consumption of whales in the western North Pacific taking into account uncertainties

- Seasonal prey consumption (150 days) of four whale species in the western North Pacific estimated with 10,000 Monte Carlo simulations is about 2.1 million metric tons.

- Major source of uncertainty in prey consumption estimates were the abundance and consumption models of sperm whales and Bryde’s whales.