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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Back ground

- 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

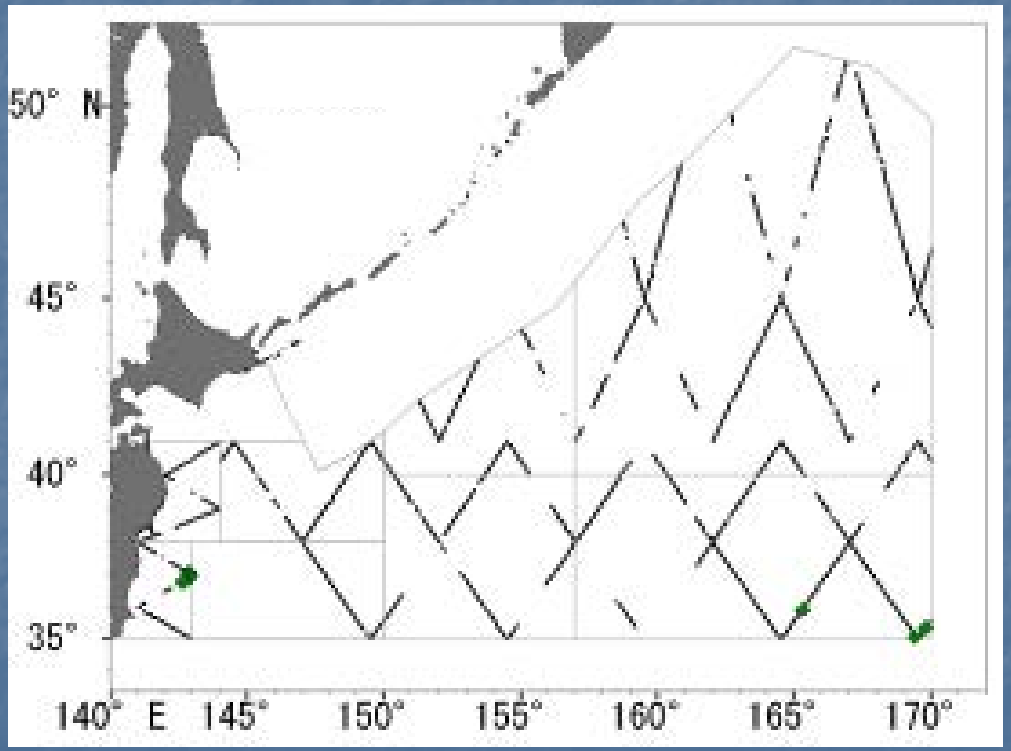
Body length 13 m
Body weight 16 t

Sperm whale

Body length
Male: 15m, Female: 11m
Body weight
Male: 40t , Female: 18t

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) $D = 4.186aM^{0.75}$; $F = D / E$

Perez *et al*. (1990)
* PICES 2000

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

(b) $D = 863.6M^{0.783}$; $F = D / E$

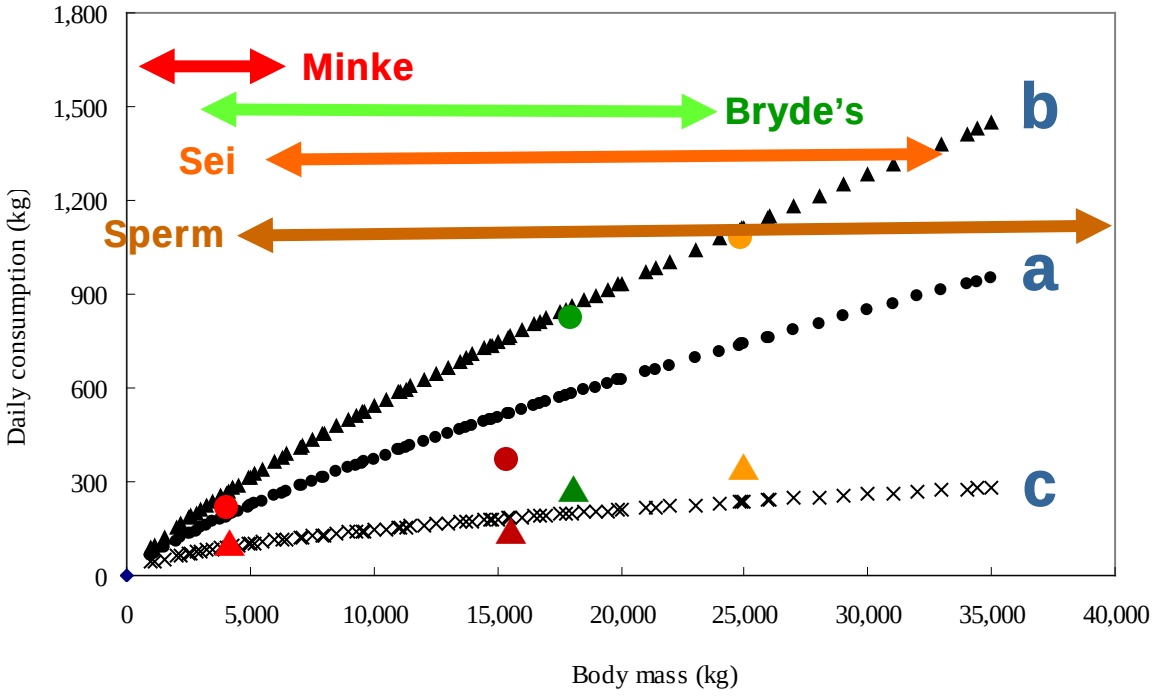
Sigurjónsson and Víkingsson (1997)

(c) $D = 2529.2M^{0.524}$; $F = D / E$

Boyed (2002)

D **: Daily prey consumption (KJ per day)**
F **: Daily prey consumption (kg per day)**
M **: Mean body weight of whales (kg)**
E **: Caloric value of prey species (KJ per kg)**

1. Daily prey consumption models



Observed stomach contents

Minke	Avg.	85.1 kg
	Max.	197.6 kg
Bryde's	Avg.	263.3 kg
	Max.	810.8 kg
Sei	Avg.	286.0 kg
	Max.	1,041.9 kg
Sperm	Avg.	305.8 kg
	Max.	305.8 kg

● a: $D = 1{,}329.9M^{0.75}/E$ (Perez *et al*. 1990)

▲ b: $D = 863.6M^{0.783}/E$ (Sigurjónsson and Víkingsson 1997)

× c: $D = 2{,}529.2M^{0.524}/E$ (Boyed 2002)

If body weight is 25 tons.....

236 ～1,111kg

2. Prey energy

Copepods (*Neocalanus spp.*)	Krill (*Euphausia pacifica*)	Japanese anchovy (*Engraulis japonicus*)	Chub mackerel (*Scomber japonicus*)	Pacific saury (*Colorabis saira*)	Japanese flying squid (*Tadarodes pacificus*)
					
3,850KJ/kg	3,600KJ/kg	5,500KJ/kg ～ 6,400KJ/kg	3,400KJ/kg ～ 6,500KJ/kg	5,200KJ/kg ～ 13,100KJ/kg	3,900KJ/kg ～ 6,600KJ/kg

3,400 ～13,100KJ/kg

5. *r* (the ratio of low/high feeding period)

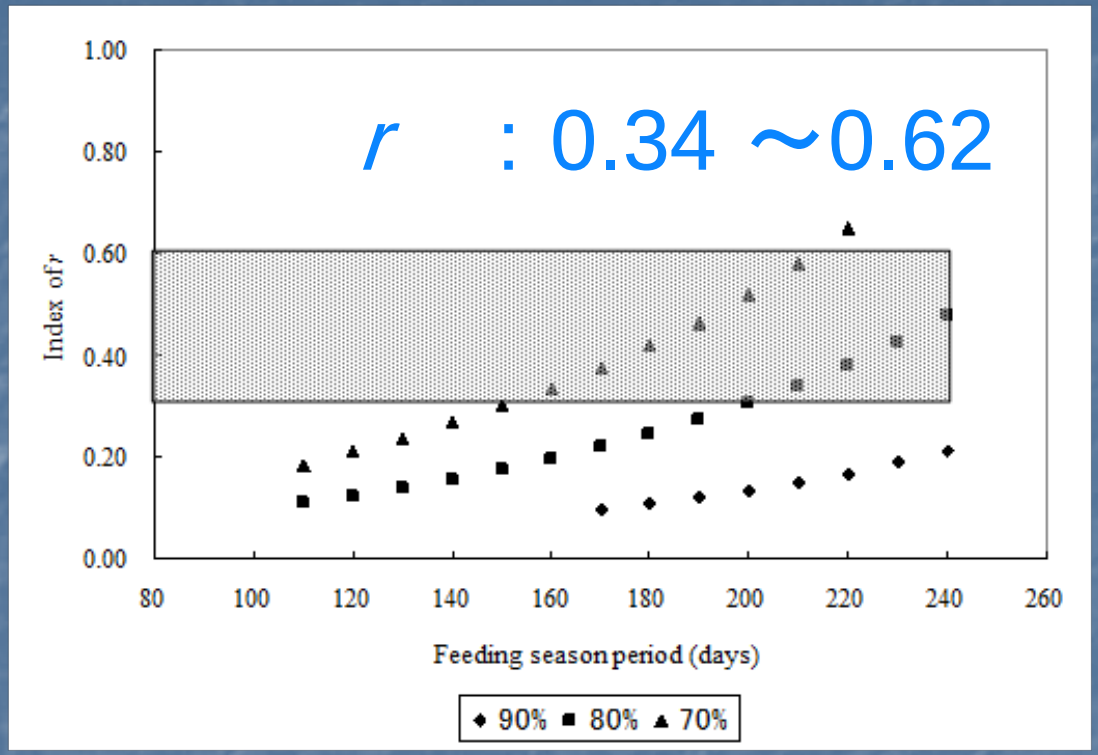
$$r = ((365(1-P)) / (365-HD)) / (365 P / HD))$$

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*Average daily prey consumption

r =0.62, 1.38*Average daily prey consumption

6. Abundance of whales in the research area

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

Results

Daily prey consumption $F = D * r / E$

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)

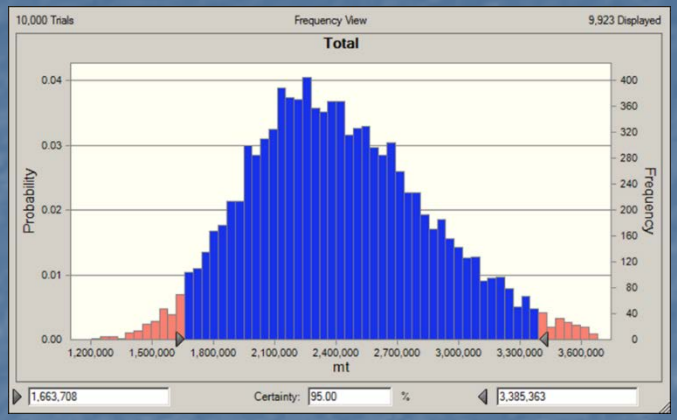
- Seasonal prey consumption (150 days) of four whale species estimated with 10,000 Monte Carlo simulations ….

Seasonal prey consumption $SF = 150 * F$

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

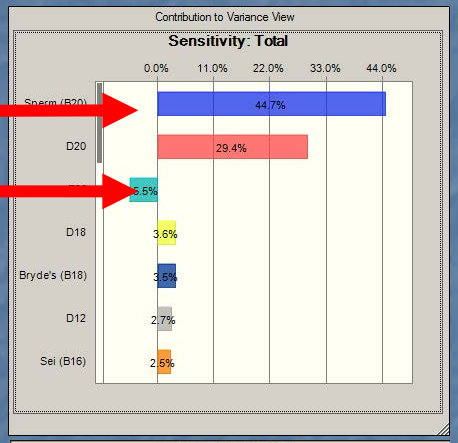
In 2012 PICES, seasonal prey consumption by three baleen whales estimated 0.3-1.6 million mt

Results

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

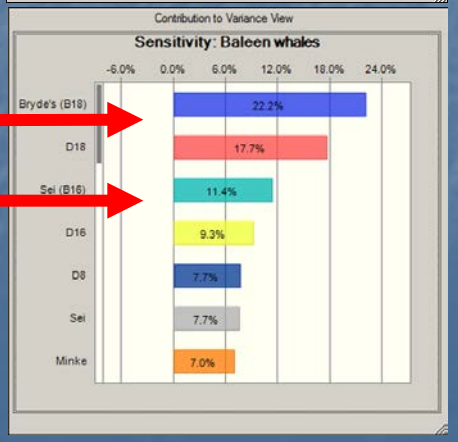
Abundance of sperm whales

Model basal energy (kJ) of sperm whales



Abundance of Bryde's whales

Model basal energy (kJ) of Bryde's whales



Summary

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.