# Prey consumption and feeding habits of three baleen whale species in the western North Pacific

(PICES / W3)

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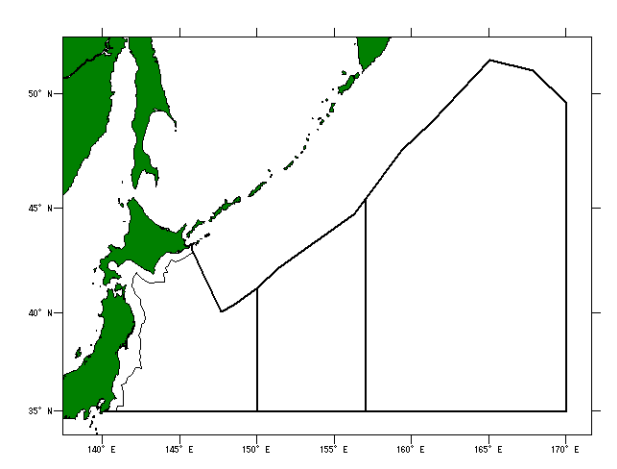
# Outline of JARPN II -1-




**Research area**
**: From 140E to 170E**

**Research period**
**: From May to September**

**Research objectives**

1. Feeding ecology of whales and ecosystem studies

2. Monitoring environmental pollutants in cetaceans and the marine ecosystem

3. Stock structure

# Outline of JARPN II -2-

## Common minke whale (*Balaenoptera acutorostrata*)

Body length 7 m
Body weight 5 t

**220 inds./year**

## Sei whale (*Balaenoptera borealis*)

Body length 14 m
Body weight 22 t

**100 inds./year**

## Bryde's whale (*Balaenoptera edeni*)

Body length 13 m
Body weight 16 t

**50 inds./year**

## Sperm whale (*Physeter macrocephalus*)

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

**10 inds./year**

# Outline of JARPN II -3-

**Measurement of body weight**

**Identification of stomach contents**

**Sampling of stomach contents**

**Measurement of stomach contents**

The relative prey composition (%) by weight of each prey species

$$(RW)\ RW = (W_i / W_{all}) \times 100$$

$W_i$ = the weight of contents containing prey group *i*

$W_{all}$ = the total weight of contents analyzed.

# Prey species of baleen whale species

**Copepods** (*Neocalanus spp.*)

**Krill** (*Euphausia pacifica*)

**Japanese anchovy** (*Engraulis japonicus*)

**Chub mackerel** (*Scomber japonicus*)

**Pacific saury** (*Colorabis saira*)

**Japanese flying squid** (*Tadarodes pacificus*)

**Minke whale**

**Sei whale**

**Bryde's whale**

**# Differences in feeding habits among three baleen whale species**

**→ Minke whale — Higher trophic level prey (Flying squid)**

**Sei whale — Lower trophic level prey (Copepods, Krill)**

**Bryde's whale — Lower trophic level prey (Krill, Japanese anchovy)**

# Prey species of sperm whales

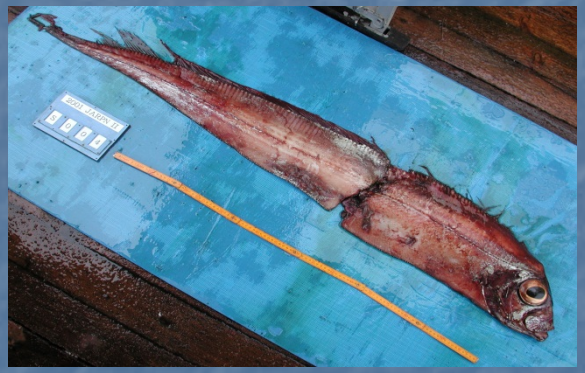
**Deep-Sea /epipelagic squids**

*Onykia robusta* (ML 130cm)


*Taningia danae* (ML 65cm)


Beaks of neon flying squid

**Mesopelagic /bottom fish**



*Trachipterus trachypterus* (SL 158cm)

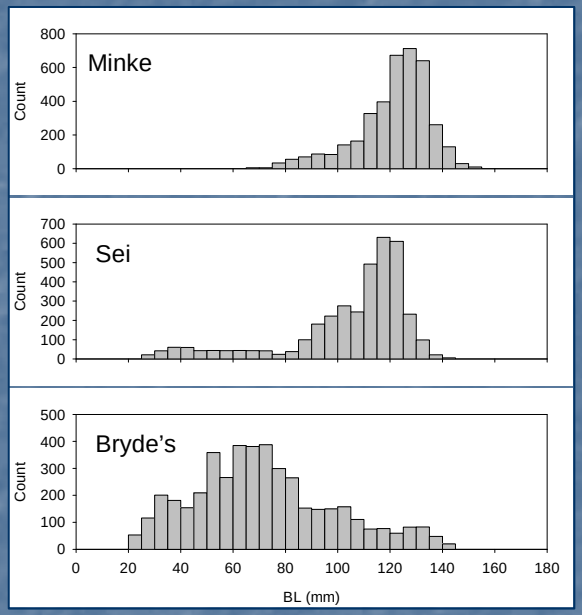
*Himantolophus groenlandicus* (SL 23cm)

Otholis of walleye pollock

**# Main prey species were deep-sea / epipelagic squids and mesopelagic / bottom fishes**

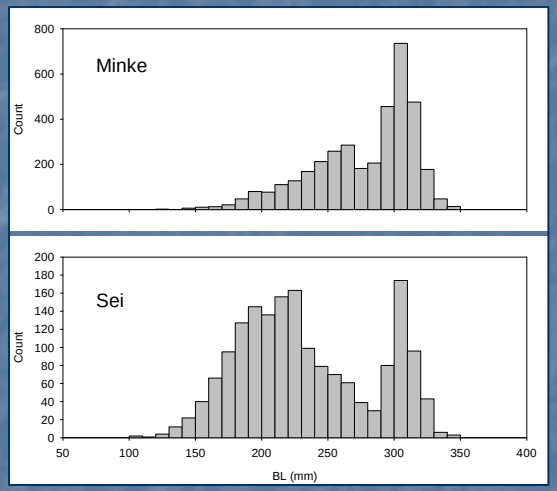
# Prey sizes consumed by baleen whales

**Japanese anchovy**



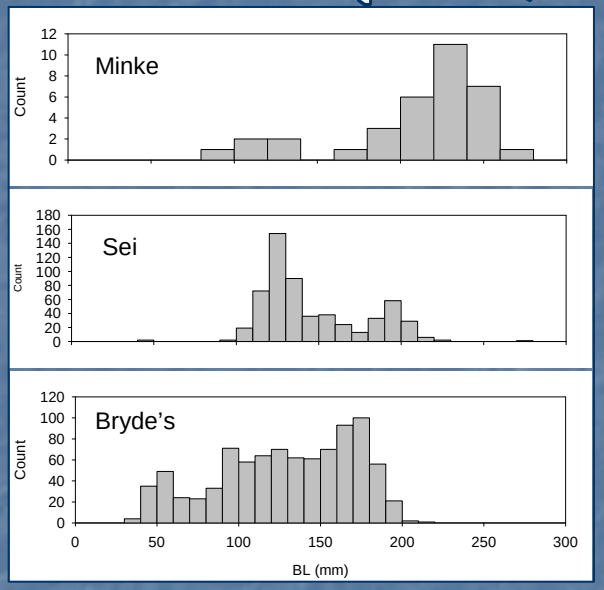

**Minke ≧ Sei > Bryde's**

**Pacific saury**




**Minke > Sei**

**Mackerels**

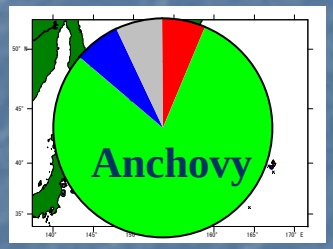
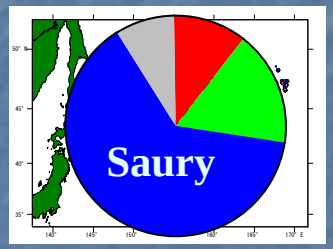
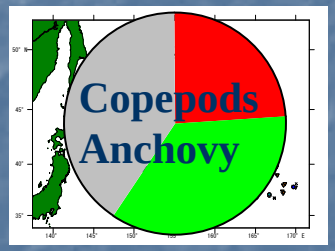
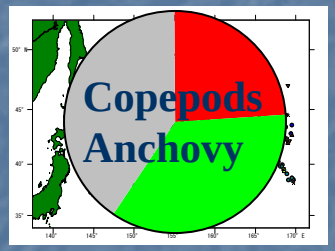
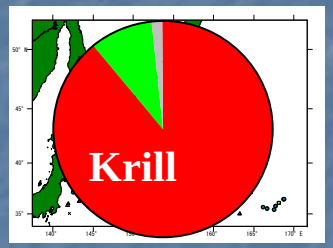
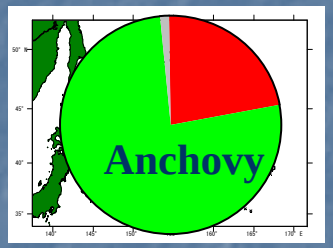



**Minke > Sei ≧ Bryde's**

→ **Differences of prey sizes among three baleen whale species**

→ **The minke whale fed on bigger prey species**

# Seasonal and geographical change of prey species

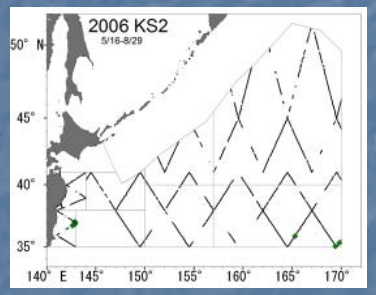
| | Early (May-June) | Late (July-Sept.) | Early (May-June) | Late (July-Sept.) |
|---|---|---|---|---|
| Minke whale |  |  | Anchovy → | Saury |
| Sei whale |  |  | Copepods<br>Anchovy → | Copepods<br>Anchovy |
| Bryde's whale |  |  | Krill → | Anchovy |

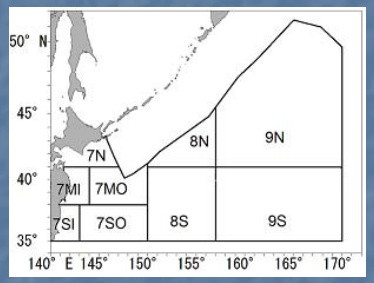
*Coastal area (East off Hokkaido): Walleye pollock, Common squid


→ **Japanese anchovy is most important prey species**

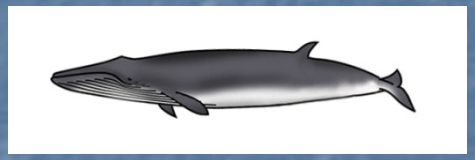
# Estimation of the numbers of whales distributed

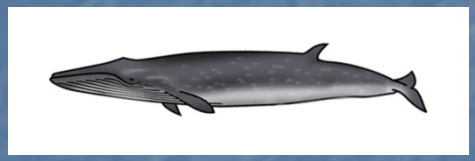
Sighting survey
(2002-2007)

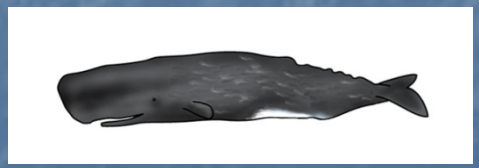



| | Early (May-June) | Late (July-Sept.) |
|---|---|---|
| **Common minke whale** | **7,338** (CV 0.71) | **2,976** (CV 0.52) |
| **Sei whale** | **7,744** (CV 0.27) | **5,406** (CV 0.30) |
| **Bryde's whale** | **1,677** (CV 0.89) | **9,797** (CV 0.31) |
| **Sperm whale** | **15,929** (CV 0.44) | **20,292** (CV 0.41) |







Hakamada *et al.* (2009)

# Estimation of daily prey consumption

(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)

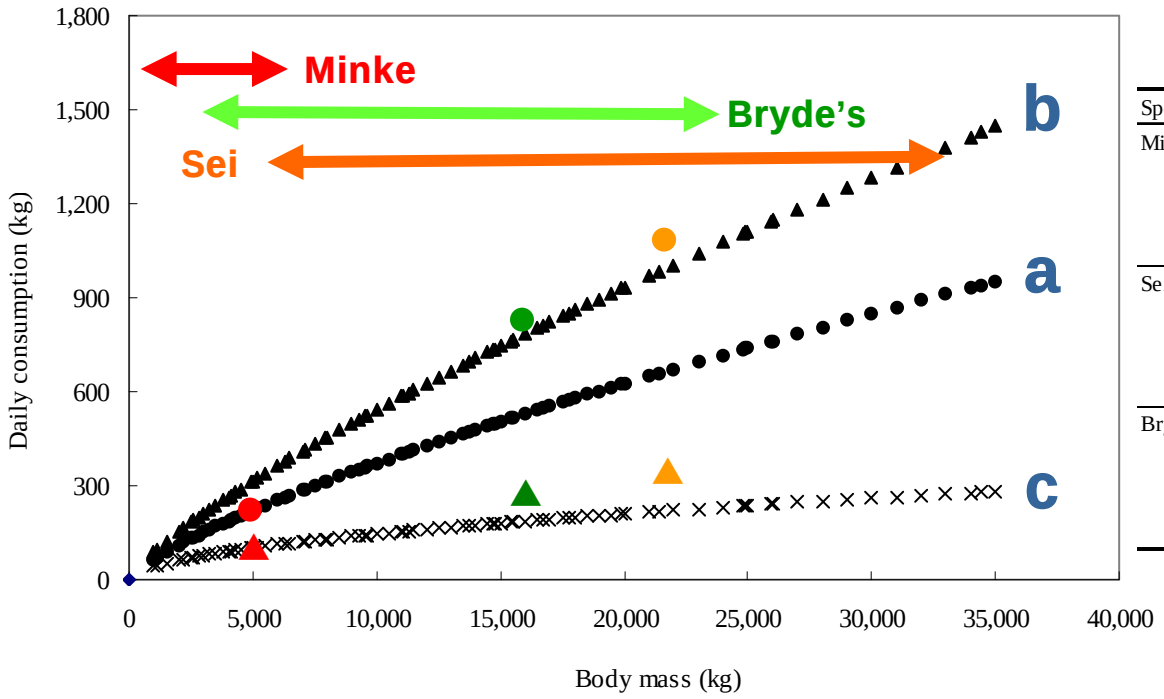
***D*** **: Daily prey consumption (KJ per day)**
***F*** **: Daily prey consumption (kg per day)**
***M*** **: Mean body weight of whales (kg)**
***E*** **: Caloric value of prey species (KJ per kg)**

**Feeding period : 150 days (May to September)**
**→ 2.020 *F***

→ **Uncertainty of several prey consumption model**

**Comprehensive review of the estimates of consumption**
**(Leaper and Lavigne 2007; Tamura *et al*. 2009)**

# Daily prey consumption by three models




**Observed stomach contents**

| Species | Sex maturity | N | Average | S.D. | Max. | Min. |
|---|---|---|---|---|---|---|
| Minke | IM | 10 | 28.47 | 16.78 | 53.96 | 3.80 |
| | MM | 86 | 67.85 | 40.43 | 196.19 | 17.35 |
| | IF | 10 | 40.14 | 36.60 | 105.60 | 9.97 |
| | MF | 11 | 85.10 | 48.96 | 197.60 | 21.45 |
| Sei | IM | 18 | 147.35 | 114.70 | 426.00 | 22.15 |
| | MM | 44 | 220.62 | 156.29 | 694.31 | 11.62 |
| | IF | 13 | 151.82 | 83.92 | 293.60 | 52.90 |
| | MF | 39 | 286.04 | 246.27 | 1,041.90 | 11.98 |
| Bryde's | IM | 24 | 144.21 | 78.44 | 290.00 | 5.55 |
| | MM | 13 | 184.89 | 103.39 | 463.86 | 76.27 |
| | IF | 14 | 156.31 | 93.94 | 272.55 | 7.25 |
| | MF | 26 | 263.31 | 191.19 | 810.45 | 1.25 |

***E*** **: Caloric value of prey species (KJ per kg) = 5,450 KJ/kg**

**Minke whale** **102 - 315 kg per ind./day**

**Sei whale** **221 – 1,005 kg per ind./day**

**Bryde's whale** **187 - 783 kg per ind./day**

● 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)

# Total prey consumption (tons) during feeding season

**All**

| Prey species | Common minke whale | | | | Sei whale | | | | Bryde's whale | | | | Total (t) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sub-area 7 | Sub-area 8 | Sub-area 9 | Total | Sub-area 7 | Sub-area 8 | Sub-area 9 | Total | Sub-area 7 | Sub-area 8 | Sub-area 9 | Total | |
| Copepods | 0.3 | 9 | 5,887 | 5,897 | 1,347 | 2,794 | 265,100 | 269,241 | 0 | 0 | 0 | 0 | 275,138 |
| Krill | 13,403 | 2,553 | 2,372 | 18,328 | | 91,778 | 136,545 | 228,323 | 62,929 | 29,860 | 10,429 | 103,218 | 349,870 |
| Anchovy | | | | | | | | | | | | | |
| B.L < 80 mm | | | | | | | | | | | 43,007 | 189,330 | 247,946 |
| B.L > 80 mm | 5 | | | | | | | | | | 28,334 | 210,610 | 491,510 |
| Saury | | | | | | | | | | | 0 | 0 | 43,481 |
| Mackerels | | | | | | | | | | | 1,573 | 13,461 | 140,023 |
| Walleye pollock | 1 | | | | | | | | | | 0 | 0 | 15,510 |
| Japanese flying squid | 111 | 120 | 0.2 | 231 | 0 | 6 | 118 | 123 | 0 | 1 | 0 | 1 | 355 |
| Sardine | | | | | | | | | | | 0 | 0 | 809 |
| Pacific pomfret | | | | | | | | | | | 0 | 0 | 296 |
| Salmonids | 0 | 188 | 38 | 226 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 226 |
| Min. armed squid | 0 | 0 | 1,281 | 1,281 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1,281 |
| Attka mackerel | 0 | 0 | 67 | 67 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 67 |
| Oceanic lightfish | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 17,450 | 17,450 | 17,450 |
| Other fish | 26 | 1 | 22 | 48 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 48 |
| Other Squid | 0 | 4 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 |
| **Total** | | | | 145,033 | | | | 904,911 | | | | 534,069 | |
| | | | | | | | | | | **Total consumption** | | **1,584,013** | **t** |

**(Eq-a Perez *et al.* 1990) 1.4 million tons**

**(Eq-b Sigurjónsson and Víkingsson 1997) 1.6 million tons**

**(Eq-c Boyed 2002) 0.3 million tons**

Prey consumption of sperm whales: **0.4 - 2.0 million tons**

# The feeding impact by three baleen whale species on fish

| Prey species | Prey consumption (tons) | | | | Fisheries | | Resources | |
|---|---|---|---|---|---|---|---|---|
| | Minke | Sei | Bryde's | Total | catch (tons) | % | (tons) | % |
| **Equation-1 (Perez *et al*. 1990)** | | | | | | | | |
| Japanese anchovy | | | | | | | 000 | 18.0 |
| Pacific saury | | | | | | | 000 | 5.1 |
| Mackerels | | | | | | | 00 | 2.3 |
| **Equation-2 (Sigurjonsson and Vikingsson 1997)** | | | | | | | | |
| Japanese anchovy | | | | | | | 00 | 16.1 |
| Pacific saury | 28,138 | 16,528 | | 44,666 | 420,000 | 10.6 | 1,010,000 | 4.4 |
| Mackerels | 4,549 | 77,633 | 10,063 | 92,245 | 410,000 | 22.5 | 4,500,000 | 2.0 |
| Japanese anchovy | 15,696 | 63,942 | 106,385 | 186,023 | 330,000 | 57.0 | 4,800,000 | 3.9 |
| Pacific saury | 9,205 | 3,712 | | 12,917 | 420,000 | 3.1 | 1,010,000 | 1.3 |

**Japanese anchovy 188-865 thousands tons**

**Pacific saury 13- 51 thousands tons**

**Mackerels 21-103 thousands tons**

→ **Japanese anchovy is most important prey among three baleen whales**

→ **There is the possibility of direct interaction between baleen whales and important commercial fisheries such as Japanese anchovy and mackerels**

# Summary of results

## ～ the impact on Japan's fisheries resources ～

- **Differences in feeding habits among three baleen whale species**
- **Differences of prey sizes among three baleen whale species**
- **The smaller minke whale fed on bigger prey species**
- **Japanese anchovy is most important prey among baleen whales**
- **Total prey consumption by three baleen whale species during feeding season is 0.3-1.6 million tons**
- **There is the possibility of direct interaction between baleen whales and important commercial fisheries such as Japanese anchovy and mackerels**

# Future tasks

- **Up-dating PICES Scientific Report 14 on prey consumption by marine birds and mammals in the PICES region**

- **1) Abundance**

  → JARPN II (Japan), POWER sighting (IWC), Domestic sighting (Japan)

- **2) Prey composition**

  → JARPN II, Estimation by some resources

- **3) Days of occupancy**

  → Estimation by some resources

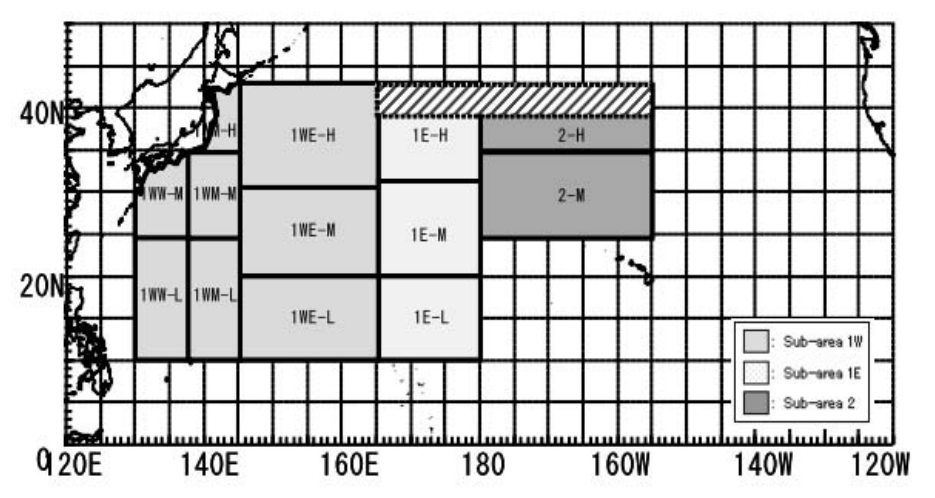
- **4) Prey consumption**

  → 1) +2) +3)

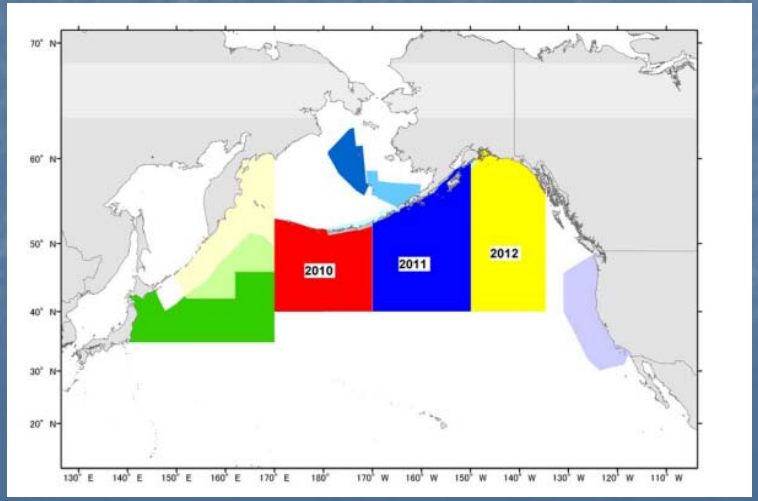
# Up-dating abundance of cetaceans after 2000

| English name | Japanese name | Year | Abundance | Area | Resource |
|---|---|---|---|---|---|
| Humpback whale | ザトウクジラ | 2007 | 10,000 | North Pacific | IWC-web site |
| Gray whale | コククジラ | 2007 | 121 | western North Pacific | IWC-web site |
| Right whale | セミクジラ | 1989-92 | 920 | Okhotsk sea | Miyashita and Kato (1998) |
| Sei whale | イワシクジラ | 2002-03 | 68,000 | North Pacific | Hakamada *et al.* (2004) |
| Common minke whale | ミンククジラ | 1989-1990 | 25,000 | North Pacific-Okhotsk Sea | IWC-web site |
| Bryde's whale | ニタリクジラ | 1998-2002 | 20,501 | western North Pacific | IWC-web site |
| Sperm whale | マッコウクジラ | 1982-1986 | 102,112 | western North Pacific | Kato and Miyashita (1998) |
| Dall's purpose (Truei type) | イシイルカ | 2003-05 | 174,000 | Sea of Japan-Okhotsk Sea | 宮下ほか (2007a) |
| Dall's purpose (Dalli type) | | 2003-05 | 178,000 | North Pacific-Okhotsk Sea | 宮下ほか (2007a) |
| Striped dolphin | スジイルカ | 1983-91 | 517,000 | western North Pacific | Miyashita (1993a) |
| | | 1998-2001 | 504,000 | western North Pacific* | 南川ほか (2007) |
| Pantropical spotted dolphin | マダライルカ | 1983-1991 | 438,000 | western North Pacific | Miyashita (1993a) |
| | | 1998-2001 | 400,000 | western North Pacific | 南川ほか (2007) |
| Bottlenose dolphin | ハンドウイルカ | 1983-1991 | 169,000 | western North Pacific | Miyashita (1993a) |
| | | 1998-2001 | 39,000 | western North Pacific | 南川ほか (2007) |
| Short-finned pilot whale | コビレゴンドウ | 1983-1991 | 54,000 | western North Pacific | Miyashita (1993a) |
| Southern-form | (マゴンドウ) | 1998-2001 | 15,000 | western North Pacific | 南川ほか (2007) |
| False killer whale | オキゴンドウ | 1983-1991 | 17,000 | western North Pacific | Miyashita (1993a) |
| | | 1998-2001 | 40,000 | western North Pacific | 南川ほか (2007) |
| Risso's dolphin | ハナゴンドウ | 1983-1991 | 76,000 | western North Pacific | Miyashita (1993a) |
| | | 1998-2001 | 33,000 | western North Pacific* | 南川ほか (2007) |
| Pacific white-sided dolphin | カマイルカ | 1992-96 | 57,000 | Coastal area around Japan | 宮下ほか (2007b) |
| | | 1987-90 | 988,000 | North Pacific | Miyashita (1993b) |
| Killer whale | シャチ | 1992-96 | 8,300 | North Pacific-Okhotsk Sea | 宮下 (2008) |
| | スナメリ | 2002-04 | 11,000 | Around Japan | Yoshida (2005) |
| Northern right whale dolphin | セミイルカ | 1987-90 | 308,000 | North Pacific | Miyashita (1993b) |

*: Northern part of 30 N degree.




Shimada *et al.* 2008




Kato *et al.* 2011

Thank you for your attention!