

Estimation of prey consumption by cetaceans in the western North Pacific- Update to Hunt et al. (2000)

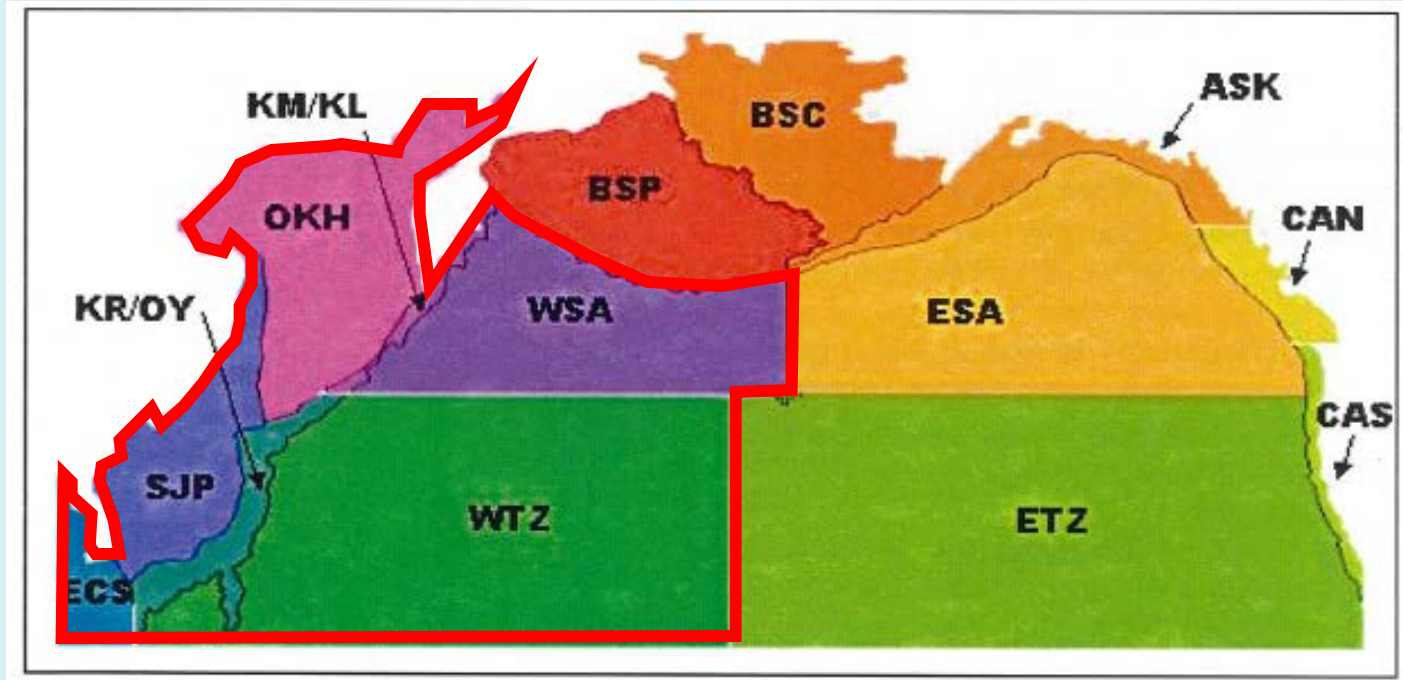
(PICES / S12)

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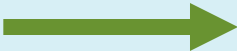

Outline of PICES region



Hunt *et al.* 2000

135 species of sea birds, 47 species of marine mammals

Update issues

- **Up-dating PICES Scientific Report 14 on prey consumption by marine mammals in the western North Pacific.**
- **1) Abundance**
 **JARPNII (Japan), Domestic sighting (Japan),
Several surveys**
- **2) Prey composition**
 **JARPNII, Estimation by several references**
- **3) Days of occupancy**
 **122 days (June – September)**
- **4) Prey consumption**
 **1) +2) +3)**

Estimation of daily prey consumption

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

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

- $a=317$ for toothed whales, 192 for baleen whales, 372 for otariid seals and 200 for phocid seals.

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)

→ **Uncertainty of several prey consumption model**

Comprehensive review of the estimates of consumption

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

Estimation of daily prey consumption

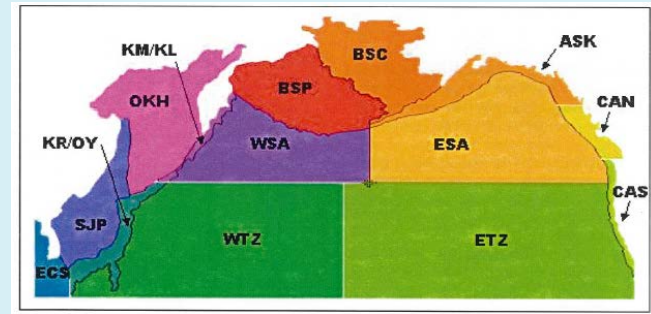
***E* : Caloric value of prey species (KJ per kg)**

- Benthic invertebrates 4 KJ/g
- Crustacean zooplankton 4 KJ/g
- Small cephalopods 3.5 KJ/g
- Large cephalopods 4 KJ/g
- Epipelagic fishes (e.g. mackerel) 7 KJ/g
- Mesopelagic fishes (e.g. Myctophids) 7 KJ/g
- Miscellaneous 5 KJ/g
- Marine mammals 7 KJ/g

Food utilization efficiency of marine mammals :

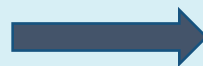
75%

Sea of Japan (SJP)



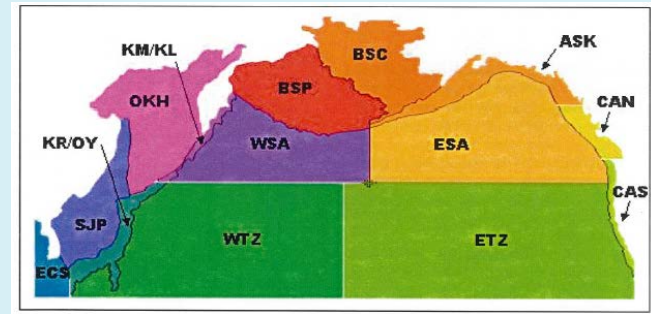
Species	Summer (June-September: 122days)				Mean body mass (kg)	Individual allometric daily energy requirement (1,000 KJ)	Summer energy requirements (1,000 KJ)	References
	Abundance	Code	Residency	Occupancy				
Common minke whale	1,900+	L	Jun-Sep	231,800+	6,566	586.0	135,834,800+	Miyashita <i>et al.</i> (1995)
Fin whale	+		Jun-Sep		55,590	2,908.3	+	
Pygmy sperm whale	+		Jun-Sep		140	54.0	+	
Dwarf sperm whale	+		Jun-Sep		140	54.0	+	
Finless porpoise	+		Jun-Sep		41	21.5	+	
Pacific white-sided dolphin	+		Jun-Sep		79	35.1	+	
Risso's dolphin	+		Jun-Sep		224	76.8	+	
Common bottlenose dolphin	+		Jun-Sep		188	67.3	+	
Common dolphin*1	+		Jun-Sep		80	35.2	+	
False killer whale	+		Jun-Sep		578	156.4	+	
Killer whale	+		Jun-Sep		2,280	437.6	+	
Baird's beaked whale	1,600+		Jun-Sep		3,484	601.7	117,451,840+	Miyashita pers comm.
Ziphiidae	+		Jun-Sep		??		+	
Steller sea lion	+		?		198	82.0	+	
Northern fur seal	+		?		28	18.8	+	
Spotted seal	+		?		43	14.2	+	
						Total	253,286,640	

2 species



2 species

Sea of Japan (SJP)



(1000s tons)

- Benthic invertebrates 3.7
- Crustacean zooplankton 29.4
- Small cephalopods 12.6
- Large cephalopods 9.2
- Epipelagic fishes (*e.g.* mackerel) 9.9
- Mesopelagic fishes (*e.g.* Myctophids) 2.1
- Miscellaneous 6.2
- Marine mammals 0.0

Hunt *et al.* 2000

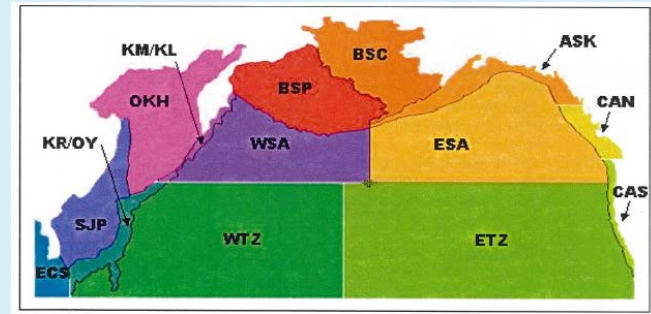
2 species

73.0

2 species

73.0 (1000s) metric tone

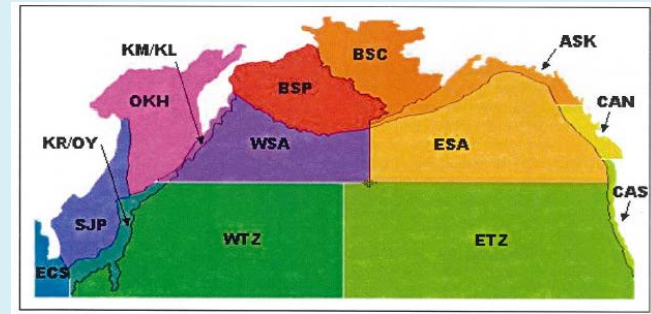
Sea of Okhotsk (OKH)



Species	Summer (June-September)				Mean body mass (kg)	Individual allometric daily energy requirement (KJ)	Summer energy requirements (1000 KJ)	References
	Abundance	Code	Residency	Occupancy				
Northern Pacific right whale	922	L	Jun-Sep	112,484	24,069	1,552.3	174,608,913	Miyashita and Kato (1998)
Bowhead whale	+		Jun-Sep	+	31,506	3,136.3	+	
Gray whale	< 200	BG	Jun-Sep	24,400	19,600	1,330.7	32,469,080	
Common minke whale	19,209	L	Jul-Sep	1,767,228	6,566	586.0	1,035,595,608	Buckland <i>et al</i> (1993)
Fin whale	+		Jun-Sep	+	55,590	2,908.3	+	
Humpback whale	+		Jun-Sep	+	30,408	1,849.7	+	
White whale	+		Jul-Sep	+	303	96.3	+	
Harbor porpoise	+		Jun-Sep	+	31	17.4	+	
Dall's porpoise	554,000	L	Jul-Sep	50,968,000	62	29.3	1,493,362,400	Kato <i>et al.</i> (1997)
Pacific white-sided dolphin	+		Jun-Oct	+	79	35.1	+	
Killer whale	+		Jun-Sep	+	2,280	437.6	+	
Baird's beaked whale	660	L	Jul-Sep	80,520	3,484	601.7	48,448,884	Miyashita and Kato (1992)
Ziphiidae	+		?	+	??		+	
Steller sea lion	1,500	C	Jun-Sep	183,000	198	82.0	15,006,000	Loughlin <i>et al</i> (1982)
Northern fur seal	56,000	?	Jun-Sep	6,832,000	28	18.8	128,441,600	NPFSC (1984)
Spotted seal	130,000	S?	Jun-Sep	15,860,000	43	14.2	225,212,000	Popov (1982)
Bearded seal	200,000	S?	Jun-Sep	24,400,000	200	44.4	1,083,360,000	Popov (1982)
Ringed seal	86,500	S	Jun-Sep	10,553,000	43	14.2	149,852,600	Popov (1982)
Ribbon seal	130,000	S?	Jun-Sep	15,860,000	71	20.5	325,130,000	Popov (1982)
						Total	4,711,487,085	

11 species  13 species

Sea of Okhotsk (OKH)

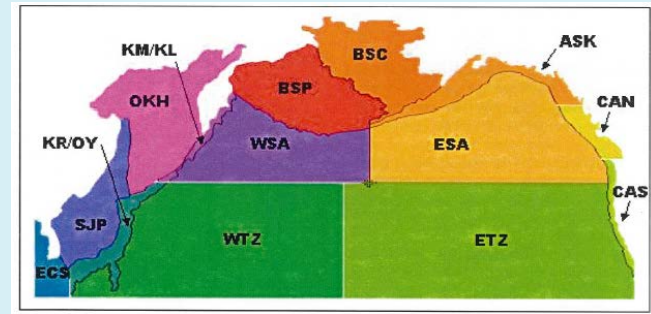


	(1000s tons)
• Benthic invertebrates	279.0
• Crustacean zooplankton	663.8
• Small cephalopods	146.5
• Large cephalopods	52.5
• Epipelagic fishes (<i>e.g.</i> mackerel)	140.3
• Mesopelagic fishes (<i>e.g.</i> Myctophids)	47.8
• Miscellaneous	213.5
• Marine mammals	0.1

Hunt *et al.* 2000 11 species 1,324.4

13 species 1,543.4 (1000s) metric tone

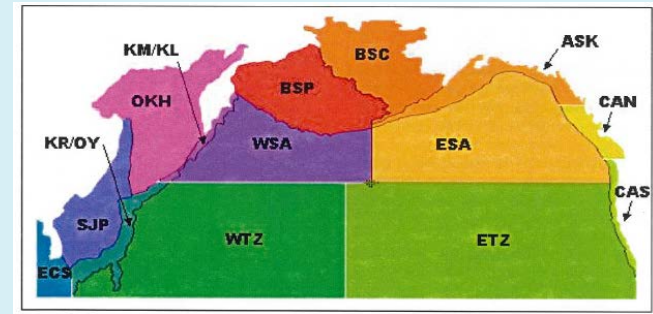
Kuroshio/Oyashio Region (KR/OY)



Species	Summer (June-September)				Mean body mass (kg)	Individual allometric daily energy requirement (1,000 KJ)	Summer energy requirements (1,000 KJ)	References
	Abundance	Code	Residency	Occupancy				
Northern Pacific right whale	+		Jun-Sep.	+	24,069	1,552.3	+	
Gray whale	+		Jun-Sep	+	19,600	1,330.7	+	
Common minke whale	+		Jul-Sep	+	6,566	586.0	+	
Sei whale	+		Jun-Sep	+	16,811	1,186.0	+	
Bryde's whale	58+	L	Jun-Sep	7,076+	16,945	1,193.1	8,422,376+	Kishino <i>et al</i> (1997)
Blue whale	+		Jun-Sep	+	102,736	4,609.8	+	
Fin whale	+		Jun-Sep	+	55,590	2,908.3	+	
Humpback whale	+		Jun-Sep	+	30,408	1,849.7	+	
Sperm whale	1,137+	L	Jun-Sep	138,714+	26,939	2,788.9	292,062,327+	Kato <i>et al</i> (1997)
Pygmy sperm whale	+		Jun-Sep	+	140	54.0	+	
Dwarf sperm whale	+		Jun-Sep	+	140	54.0	+	
Harbor porpoise	+		Jun-Sep	+	31	17.4	+	
Finless porpoise	+		Jun-Sep	+	41	21.5	+	
Dall's porpoise	+		Jun-Sep	+	62	29.3	+	
Rough-toothed dolphin	+		Jun-Sep	+	92	39.4	+	
Pacific white-sided dolphin	50,818	L	Jun-Sep	6,199,796	79	35.1	217,612,840	Kato <i>et al</i> (1997)
Risso's dolphin	+		Jun-Sep	+	224	76.8	+	
Common bottlenose dolphin	+		Jun-Sep	+	188	67.3	+	
Pantropical spotted dolphin	+		Jun-Sep	+	65	30.0	+	
Spinner dolphin	+		Jun-Sep	+	41	21.5	+	
Common dolphin*1	+		Jun-Sep	+	80	35.2	+	
Fraser's dolphin	+		Jun-Sep	+	95	40.4	+	
Northern right whale dolphin	+		Jun-Sep	+	105	43.6	+	
Pygmy killer whale	+		Jun-Sep	+	177	64.4	+	
False killer whale	+		Jun-Sep	+	578	156.4	+	
Killer whale	+		Jun-Sep	+	2,280	437.6	+	
Long-finned pilot whale	5,300	L	Jun-Sep	646,600	643	169.4	109,534,040	Miyashita (1993a)
Short-finned pilot whale	53,000	L	Jun-Sep	6,466,000	643	169.4	1,095,340,400	Miyashita (1993a)
Baird's beaked whale	4,200	L	Jun-Aug	386,400	3,484	601.7	232,496,880	Miyashita and Kato (1994)
Ziphiidae	+		Jun-Sep	+	??		+	
Steller sea lion	+		Jun-Sep	+	198	82.0	+	
Northern fur seal	+		Jun-Sep	+	28	18.8	+	
Harbor seal	+		Jun-Sep	+	60	18.0	+	
Spotted seal	+		Jun-Sep	+	43	14.2	+	
					Total	1,947,046,487		

6 species ➔ 17 species

Kuroshio/Oyashio Region (KR/OY)



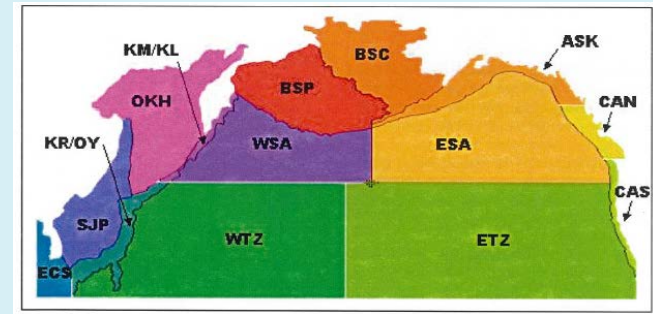
(1000s tons)

- Benthic invertebrates 81.2
- Crustacean zooplankton 0.6
- Small cephalopods 794.0
- Large cephalopods 681.3
- Epipelagic fishes (e.g. mackerel) 107.3
- Mesopelagic fishes (e.g. Myctophids) 276.4
- Miscellaneous 409.0
- Marine mammals 0.1

Hunt *et al.* 2000 6 species 532.9

17 species 2,350.1 (1000s) metric tone

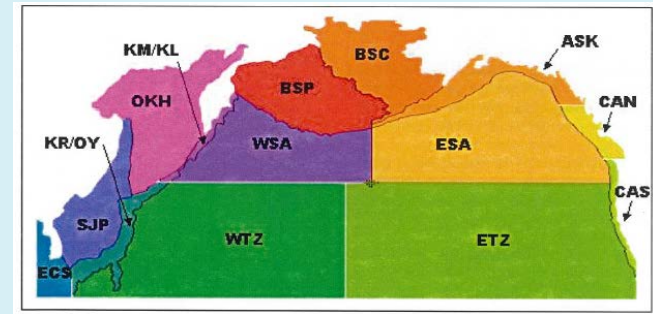
Western Tropical Zone (WTZ)



Species	Summer (June-September: 122days)				Mean body mass (kg)	Individual allometric daily energy requirement (1,000 KJ)	Summer energy requirements (1,000 KJ)	References
	Abundance	Code	Residency	Occupancy				
Northern Pacific right whale	+		Jun-Sep	+	24,069	1,552.3	+	
Common minke whale	3,080	L	Jul-Sep	375,760	6,566	586.0	220,195,360	JARPNI
Sei whale	5,086	L	Jun-Sep	620,492	16,811	1,186.0	735,903,512	JARPNI
Bryde's whale	15,422	L	Jun-Sep	1,881,484	16,945	1,193.1	2,244,798,560	POWER/JARPNI: Area 1W
Blue whale	+		Jun-Sep	+	102,736	4,609.8	+	
Fin whale	+		Jun-Sep	+	55,590	2,908.3	+	
Humpback whale	+		Jun-Sep	+	30,408	1,849.7	+	
Sperm whale	17,128+	L	Jun-Sep	2,089,616+	26,939	2,788.9	5,827,730,062+	Kato <i>et al.</i> (1997)
Pygmy sperm whale	+		Jun-Sep	+	140	54.0	+	
Dwarf sperm whale	+		Jun-Sep	+	140	54.0	+	
Dall's porpoise	1,925,000	D/S	Jun-Sep	234,850,000	62	29.3	6,881,105,000	Kato and Miyazaki (1986)
Rough-toothed dolphin	+		Jun-Sep	+	92	39.4	+	
Pacific white-sided dolphin	1,000,000	L	Jun-Sep	122,000,000	79	35.1	4,282,200,000	Miyashita (1992)
Risso's dolphin	93,000	L/D	Jun-Sep	11,346,000	224	76.8	871,372,800	Miyashita (1993a)
Common bottlenose dolphin	156,000	L	Jun-Sep	19,032,000	188	67.3	1,280,853,600	Miyashita (1993b)
Pantropical spotted dolphin	438,000	L	Jun-Sep	53,436,000	65	30.0	1,603,080,000	Miyashita (1993a)
Spinner dolphin	+		Jun-Sep	+	41	21.5	+	
Striped dolphin	568,000	L	Jun-Sep	69,296,000	116	46.9	3,249,982,400	Miyashita (1993a)
Common dolphin*1	+		Jun-Sep	+	80	35.2	+	
Fraser's dolphin	+		Jun-Sep	+	95	40.4	+	
Northern right whale dolphin	740,000	L/D	Jun-Sep	90,280,000	105	43.6	3,936,208,000	Miyashita (1992)
Pygmy killer whale	+		Jun-Sep	+	177	64.4	+	
False killer whale	+		Jun-Sep	+	578	156.4	+	
Killer whale	+		Jun-Sep	+	2,280	437.6	+	
Short-finned pilot whale -N type	5,300	L	Jun-Sep	646,600	643	169.4	109,534,040	Anon, 1992
Short-finned pilot whale -S type	32,753	L	Jun-Sep	3,995,866	643	169.4	676,899,700	Kanaji (unpublished)
Ziphiidae			Jun-Sep		??			
1: Combined estimation for areas WTZ+WSA+ESA+ETZ								
2: Combined estimation for areas WTZ+KR/OY								
					Total		26,092,132,973	

10 species → 13 species

Western Tropical Zone (WTZ)



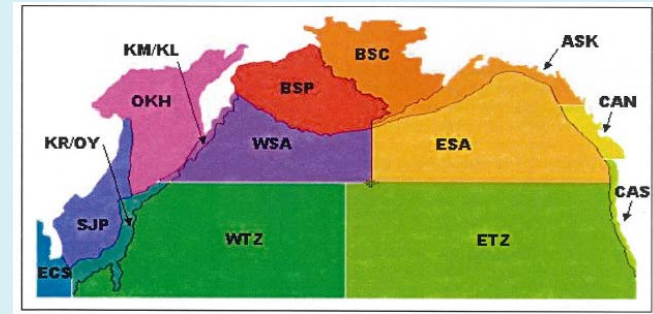
(1000s tons)

- Benthic invertebrates 183.4
- Crustacean zooplankton 275.0
- Small cephalopods 3,181.3
- Large cephalopods 2,296.9
- Epipelagic fishes (*e.g.* mackerel) 1,069.2
- Mesopelagic fishes (*e.g.* Myctophids) 930.2
- Miscellaneous 1,281.8
- Marine mammals 0.0

Hunt *et al.* 2000 10 species 6,395.1

13 species 9,217.8 (1000s) metric tone

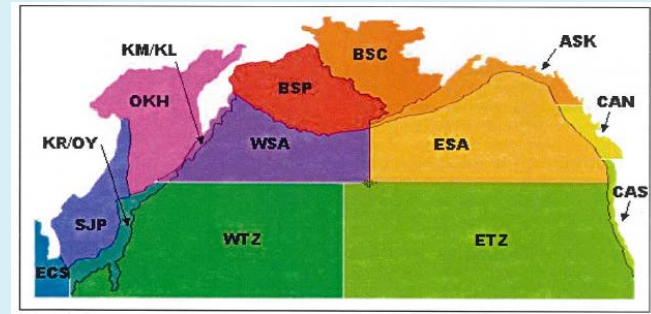
Western Subarctic (WSA)



Species	Summer (June-September)				Mean body mass (kg)	Individual allometric daily energy requirement (1,000 KJ)	Summer energy requirements (1,000 KJ)	References
	Abundance	Code	Residency	Occupancy				
Northern Pacific right whale	+		Jun-Sept.	+	24,069	1,552.3	+	
Common minke whale	+		Jul-Sep	+	6,566	586.0	+	
Sei whale	+		Jun-Sep	+	16,811	1,186.0	+	
Blue whale	+		Jun-Sep	+	102,736	4,609.8	+	
Fin whale	+		Jun-Sep	+	55,590	2,908.3	+	
Humpback whale	+		Jun-Sep	+	30,408	1,849.7	+	
Sperm whale	2,323+		Jun-Sep	283,406+	26,939	2,788.9	790,390,993+	
Dall's porpoise	+		Jun-Sep	+	62	29.3	+	
Pacific white-sided dolphin	+		Jun-Sep	+	79	35.1	+	
Killer whale	+		Jun-Sep	+	2,280	437.6	+	
Ziphiidae	+		Jun-Sep	+	??		+	
Steller sea lion	+		?	+	198	82.0	+	
Northern fur seal	+		?	+	28	18.8	+	
						Total	790,390,993	

1 species ➔ 1 species

Western Subarctic (WSA)



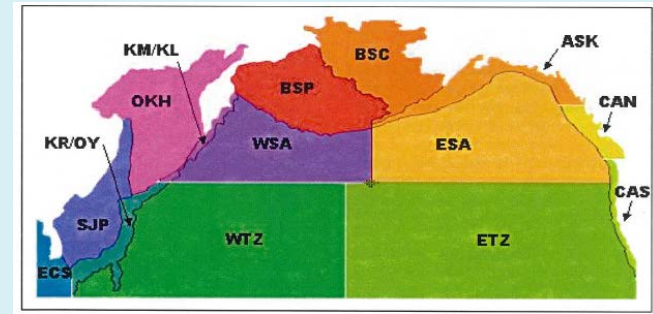
(1000s tons)

- Benthic invertebrates 0.0
- Crustacean zooplankton 0.0
- Small cephalopods 90.3
- Large cephalopods 171.3
- Epipelagic fishes (e.g. mackerel) 0.0
- Mesopelagic fishes (e.g. Myctophids) 0.0
- Miscellaneous 10.5
- Marine mammals 0.0

Hunt *et al.* 2000 1 species 180.3

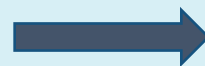
1 species 272.1 (1000s) metric tone

Kurile Islands Region (KM/KL)



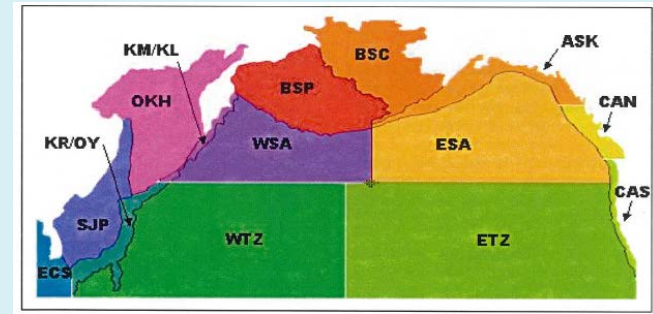
Species	Summer (June-September)				Mean body mass (kg)	Individual allometric daily energy requirement (KJ)	Summer energy requirements (1000 KJ)	References
	Abundance	Code	Residency	Occupancy				
Northern Pacific right whale	+		Jun-Sep.	+	24,069	1,552.3	+	
Gray whale			Jun-Sep		19,600	1,330.7	+	
Common minke whale	5,841	L	Jul-Sep	712,602	6,566	586.0	417,584,772	Kato <i>et al.</i> (1997)
Sei whale			Jun-Sep		16,811	1,186.0	+	
Blue whale			Jun-Sep		102,736	4,609.8	+	
Fin whale			Jun-Sep		55,590	2,908.3	+	
Humpback whale	+		Jun-Sep	+	30,408	1,849.7	+	
Sperm whale	+		Jun-Sep	+	26,939	2,788.9	+	
Harbor porpoise	+		Jun-Sep	+	31	17.4	+	
Dall's porpoise	1,925,000	D/S	Jun-Sep	234,850,000	62	29.3	6,881,105,000	Kato and Miyazaki (1986)
Pacific white-sided dolphin	1,000,000	L	Jun-Sep	122,000,000	79	35.1	4,282,200,000	Miyashita (1992)
Northern right whale dolphin	740,000	L/D	Jun-Sep	90,280,000	105	43.6	3,936,208,000	Miyashita (1992)
Killer whale	+		Jun-Sep	+	2,280	437.6	+	
Baird's beaked whale	+		Jun-Sep	+	3,484	601.7	+	
Ziphiidae	+		Jun-Sep	+	??		+	
Steller sea lion	5,100	C	Jun-Sep	622,200	198	82.0	51,020,400	
Northern fur seal	45,000	C	Jun-Sep	5,490,000	28	18.8	103,212,000	
Harbor seal	3,400	C	Jun-Sep	414,800	60	18.0	7,466,400	
Sea otter	+		Jun-Sep	+	25	24.3	+	
						Total	15,678,796,572	

7 species



13 species

Kurile Islands Region (KM/KL)



(1000s tons)

- Benthic invertebrates 117.5
- Crustacean zooplankton 46.4
- Small cephalopods 1,768.8
- Large cephalopods 599.1
- Epipelagic fishes (*e.g.* mackerel) 565.9
- Mesopelagic fishes (*e.g.* Myctophids) 744.2
- Miscellaneous 648.2
- Marine mammals 0.5

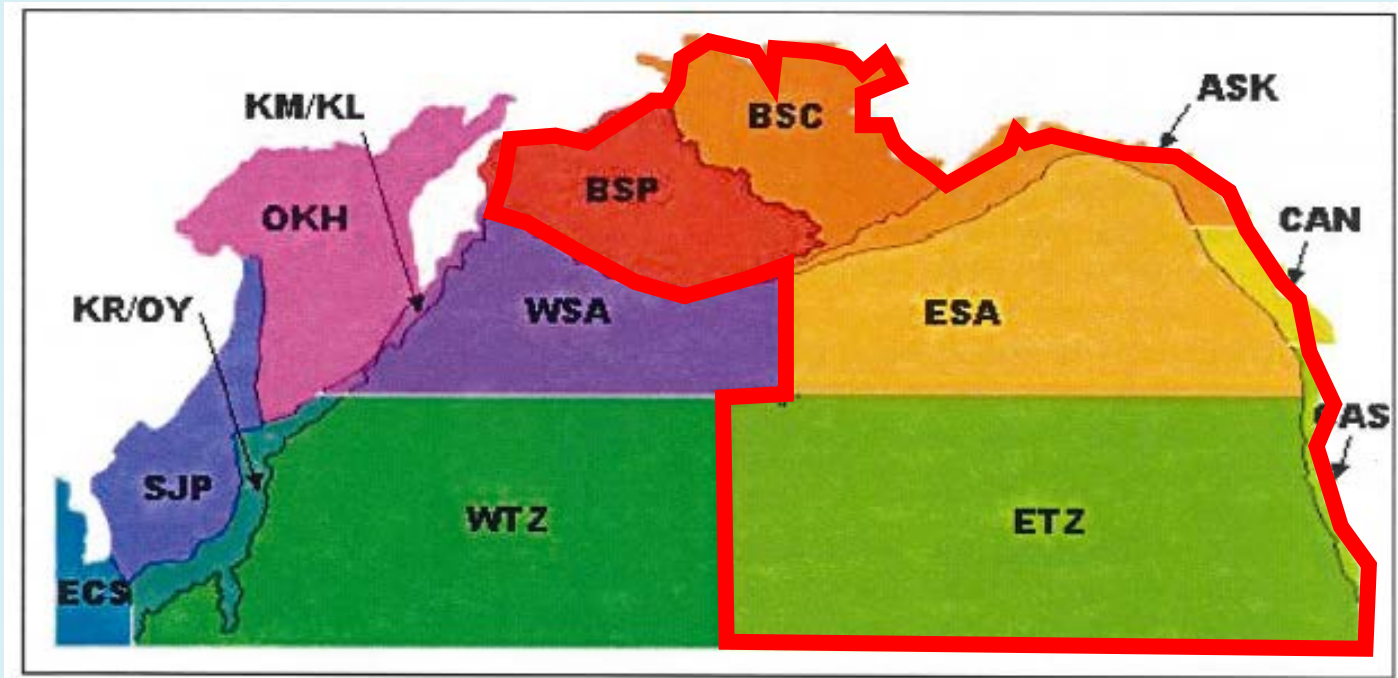
Hunt *et al.* 2000 7 species 4,029.0

13 species 4,489.6 (1000s) metric tone

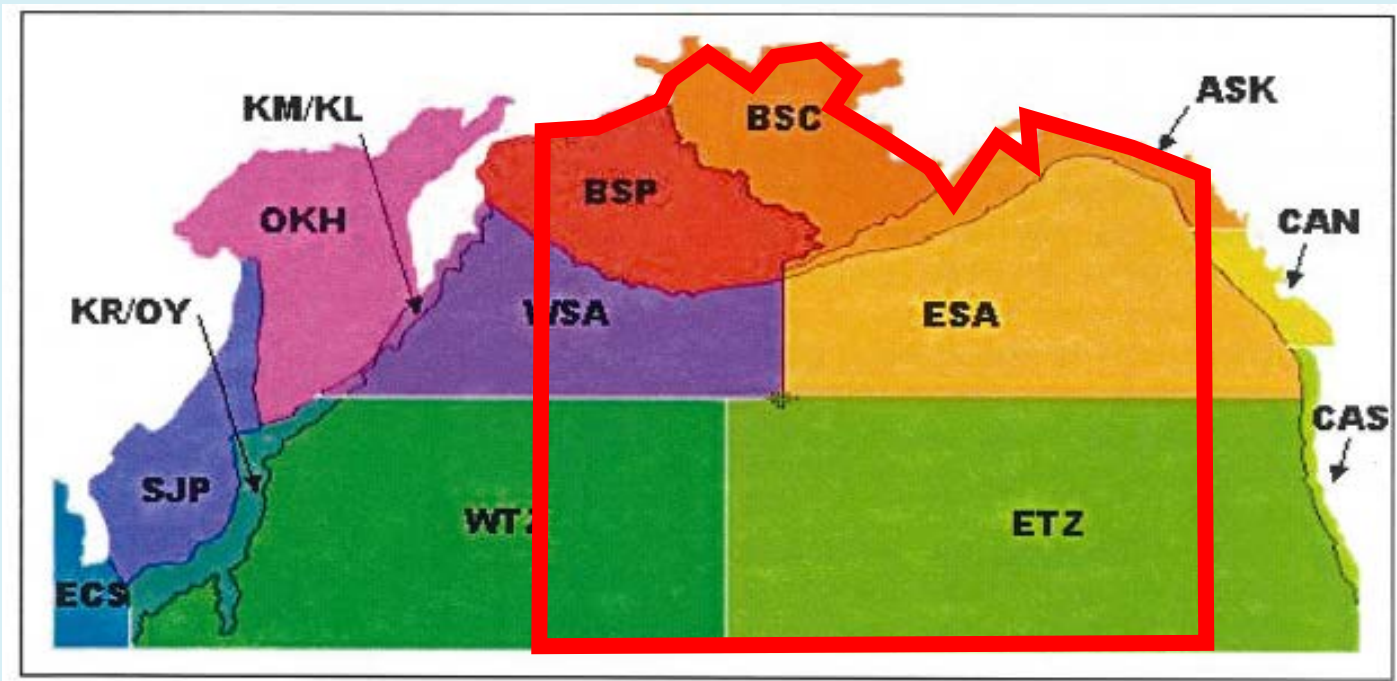
Summary

- The estimation of prey consumption by marine mammals was up-dated in six sub-regions of western part of North Pacific.
- Total prey consumption by marine mammals during feeding season is estimated to 17.9 million tons in six sub regions.
- More information is needed on the abundance, body weight and prey composition of marine mammals to address a more realistic strategy for fisheries management and the conservation of marine mammals in future.

Future work



IWC/POWER cruises



170E

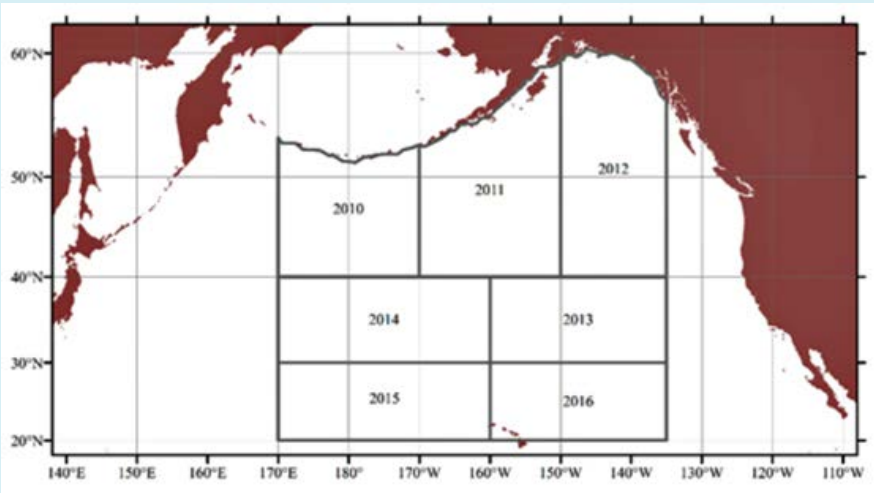
135W

20N

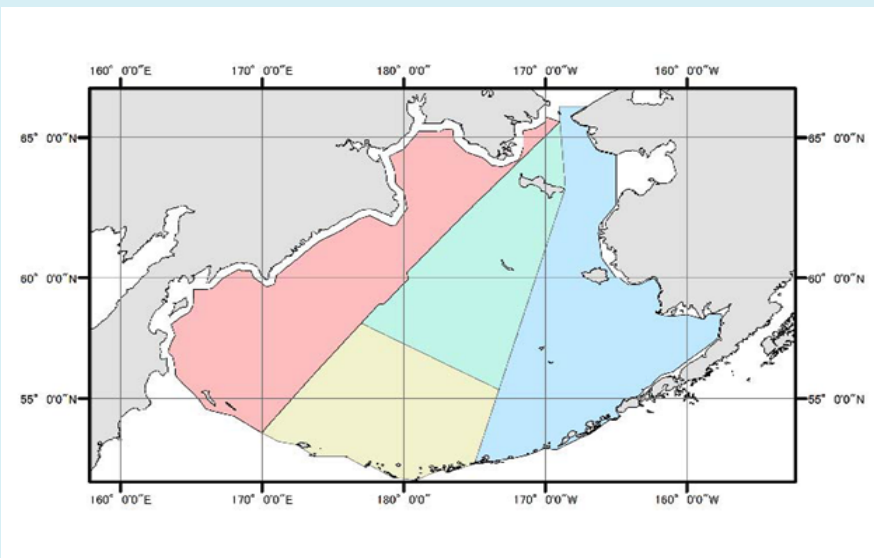
Since 2010

IWC/POWER cruises

2010- 2016



2017- 2019



Thank you for your
attention!

Acknowledgement

Kaoru Hattori
Yoko Goto