Abundance and Distribution of Sperm and Beaked Whales in the Antarctic Areas IV and V

-Preliminary Report-

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Abstract

Current abundance and the distributions of large male sperm whales (*Physeter catodon*) and beaked whales (family Ziphiidae) in the Antarctic Areas IV and V (longitude 70° E-160° W and latitude south of 60° S) were studied using the sightings data derived from the JARPA cruises during 1989/90-1995/96. Uncorrected abundance estimates of large male sperm whale and beaked whales during four seasons (1989/90-95/96) in Area IV are 2,946 (c.v.=0.20) to 4,289 (c.v.=0.28) and 6,343 (c.v.=0.29) to 11,780 (c.v.=0.31), respectively. Those in Area V during three seasons (1990/91-94/95) are 2,207 (c.v.=0.23) to 3,148 (c.v.=0.32) and 17,597 (c.v.=0.40) to 31,021 (c.v.=0.40), respectively. Corrected abundance estimates (corrected by g(0)) of large male sperm whales in Areas IV and V are estimated to be 9,206 (c.v.=0.23) to 13,403 (c.v.=0.30) and 6,897 (c.v.=0.25) to 9,837 (c.v.=0.34) whales, and those of beaked whales are 23,490 (c.v.=0.31) to 43,630 (c.v.=0.33) and 65,174 (c.v.=0.42) to 114,892 (c.v.=0.42) whales, respectively. Maximum biomass of these species in Areas IV and V are calculated to be 367,000 and 270,000 tons (large male sperm whales), 196,000 and 517,000 tons (beaked whales), respectively.

Introduction

The Japanese Whale Research Programme under special permit in the Antarctic (JARPA) has been carried out in a consistent way every year in Areas IV and V. The sighting surveys are conducted to obtain information on the abundance and distribution of minke and other species in the Antarctic Areas IV and V during the Austral summer

season.

Although the target species of the JARPA programme is minke whales, information on distribution and abundance of other major whale species (such as blue, fin, humpback, sperm and beaked whales) are important to understand for not only the position and role of minke whales in the whale community but also the Antarctic marine ecosystem. Information on current status of toothed whales is limited although the toothed whales are on the highest trophic level in the Antarctic marine ecosystem (Kasamatsu and Joyce,1995). In addition, biological results of beaked whales were introduced using 1987/88-92/93 JARPA data (Ohsumi *et* al., 1994)

This paper reports current abundance of sperm and beaked whales in Areas IV and V (longitude between 70° E-160° W and latitude south of 60° S). Abundance of baleen whales except minke whales has been reported previously (Nishiwaki *et* al.,1997).

Material and Methods

Sighting surveys

Unique sighting procedures to collect unbiased data have been introduced in the JARPA including (1)the trackline was designed in order to cover the whole area uniformly, (2) the line transect procedure sampled the schools proportionally to the densities encountered, (3) all the schools sighted were recorded, (4) searches were conducted only in wind speed 20 knot or less for northern strata and 25 knot or less in the southern strata. Details of the sighting procedures were given in the Review of the sighting survey in the JARPA (Nishiwaki *et* al.,1997).

Research area covered

The area from 60° S to the ice-edge in the Areas IV(70° E-130° E) and V(130° E-170° W) was covered. Research area were divided into two strata: 60° S latitude line to the line of 45 n.miles from the ice-edge, and ice-edge to 45 n.miles from the ice-edge line (Fig.1).

Design of the trackline

The sawtooth type was adopted to account for the wider area of coverage. The starting point of the sawtooth trackline was randomly selected from 1 n.mile intervals on the lines. The following trackline legs were systematically set on the ice-edge and on the locus of the 45n.miles from the ice-edge (southern stratum), and the 45 n.miles from the 60° S latitude line (northern stratum). Total searching distance for each season was calculated by strata (Table.1).

Sighting data

Total number of the primary sightings of sperm and beaked whales, in which school size was confirmed, were used in this analyses (Table.1,2). The sighting data of beaked whales are included southern bottlenose whale, strap-toothed whale, Arnoux's beaked whale, unidentified *Mesoplodon* species and Ziphiid whales in this study. However, most of the beaked whales is suggested to be southern bottlenose whale (Kasamatsu and Joyce, 1995).

Abundance estimates

The sighting surveys of JARPA have been conducted using only the normal closing mode(NSC). For all schools sighted during the searching effort, species were identified and the number of individuals counted. In this paper, abundance were estimated by the usual line transect method (Burnham *et* al.,1980; Buckland *et* al.,1993). Let g(y) denote the probability that a school of whales is detected at y n.miles in perpendicular distance from the trackline. g(y) is called a detection curve. The effective search half-width "$\hat{w}$" is obtained by $\hat{w} = \int_0^c g(y)\, dy$, where c>0 indicates the limiting perpendicular distance of the schools sighted and adopted for the analysis (Kishino *et* al.,1991). In this analysis, c=1.5 n.miles for beaked whales and 3.0 n.miles for sperm whales were applied.

Effective search half-width ($\hat{w}$)

The use of the following hazard rate model (hazard rate model; (Hayes and Buckland, 1983, Buckland, 1985,1987) is considered.

$$g(y) = 1 - \exp[-(y/a)^{1-b}]$$

Here, a and b are the free parameters to be estimated. The multinominal distribution defined by the probabilities of the sub-intervals of the perpendicular distance obtained from the normalized detection function $f(y) = g(y) / \int_0^c g(y')\, dy'$ was fitted to the distribution of the numbers of sightings in the sub-intervals of the perpendicular distance. Under the assumption that all whales on the trackline should be detected, i.e., g(0) = 1, and estimate of $\hat{w}$ is obtained by $\hat{w} = 1/\widehat{f(0)}$, where $\widehat{f(0)}$ denotes the fitted value of $f(0)$. Table.1 and 2 show the effective search half width of each strata.

Mean school size ($\bar{s}$)

The mean school size of each stratum is estimated using the primary schools seen within a perpendicular distance of one n.mile from the trackline. All schools used for this calculation are primary sightings with identified species and confirmed school size during closing mode.

Variance estimates for $\widehat{P}$

Variance calculations for abundance estimates ($\widehat{P}$) in each stratum make use of the following formula (Kishino *et* al.,1991);

$$[\text{c.v.}(\widehat{P})]^2 = [\text{c.v.}(\widehat{n/L})]^2 + [\text{c.v.}(\widehat{f(0)})]^2 + [\text{c.v.}(\bar{s})]^2 \quad \text{----------(3)}$$

Probability of an animal being seen on the trackline, g(0), and corrected abundance

Abundance estimates based on the line transect model could be substantially underestimated for the long-diving species such as sperm and beaked whales if the probability of an animal being seen on the trackline, g(0), is not considered. In this paper, we use the g(0) values of 0.32 (cv=0.11) for sperm and 0.27 (cv=0.04) for beaked whales (Kasamatsu and Joyce, 1995) to obtain the corrected abundance.

Results and Discussion

Distribution of large male sperm whale and beaked whales from previous surveys

The geographical positions of large male sperm whale and beaked whale schools from primary and secondary sighting during 1989/90-1995/96 JARPA seasons were plotted in Fig. 2 and 3.

The distribution of sperm whales in Areas IV and V were widely distributed every year. There was a high density area between 70° E-100° E. They were rarely found within the Prydz Bay and the Ross Sea. There was no sighting in the south of 73° S in the Ross Sea. It should be noted that large male sperm whales migrating in the Antarctic water (including our research areas) must be single large male sperm whales.

Beaked whales also widely distributed in Areas IV and V . They were also rarely found within the Prydz Bay and the Ross Sea except some sighting in south of 75° S in the Ross Sea.

Four species of beaked whales were reported by the JARPA surveys. They are the Arnoux's beaked whale (*Berardius arnuxii*), southern bottlenose whale (*Hyperoodon planifrons*), strap-toothed whale (*Mesoplodon layardii*) and Gray's beaked whale (*M. grayi*), in addition to unidentified *Mesoplodon* and Ziphiid whales. According to the

sighting records in previous surveys, southern bottlenose whales were distributed widely in the open sea of the research area. Their distribution pattern was consistent with that of unidentified beaked whales. Although there were few sighting records of Arnoux's beaked whales, they were found around the pack-ice edge line and in the southern bottom of the Ross Sea. Distributions of *Mesoplodon* species in the research area are not still clear because there were quite few sighting records.

Uncorrected abundance estimates

Total searching distances, covered area, the search half-width ($\hat{w}$), and number of schools, individuals and uncorrected abundance estimates($\hat{P}$) are shown in Tables 1 and 2. Total uncorrected abundance estimates in each season in each Areas are summarized in Table 3.

Abundance estimates of sperm whales in Area IV ranged from 2,946 (c.v.=0.20) to 4,289 (c.v.=0.28) individuals. Those in Area V ranged from 2,207 (c.v.=0.23) to 3,148 (c.v.=0.32) individuals. Abundance estimates of beaked whales in Area IV ranged from 6,343 (c.v.=0.29) to 11,780 (c.v.=0.31), and those in Area V ranged 17,597 (c.v.=0.40) to 31,021 (c.v.=0.40).

Possible under-surveying of higher density areas of minke whales in the JARPA cruises has been noted (IWC ,1997). The effect of this on the abundance estimations of sperm and beaked whales has not been examined in this paper.

Corrected abundance estimates and biomass

The corrected abundance estimates of male sperm whales ranged from 9,206 (c.v.=0.23) to 13,403 (c.v.=0.30) in Area IV and 6,897 (c.v.=0.25) to 9,838 (c.v.=0.34) in Area V. Those of beaked whales ranged from 23,490 (c.v.=0.31) to 43,630 (c.v.=0.33) in Area IV and 65,174 (c.v.=0.42) to 114,892 (c.v.=0.42) in Area V, respectively.

Biomass of each species were estimated using the mean body weight of sperm (27.4 tones) (Lockyer, 1981), beaked whales-southern bottlenose whale (4.5 tons)(Zemskii and Budylenko, 1970) in this paper. Estimated biomass for sperm and beaked whales in each Area were 254,000 to 367,000 tons (Area Ⅳ), 189,000 to 270,000 tons (Area Ⅴ), 106,000 to 196,000 tons (Area Ⅳ) and 293,000 to 517,000 tons (Area Ⅴ), respectively (Table.4). It should be noted that the biomass of the sperm whales calculated could be underestimated because the estimated weight of the sperm whale (27.4 tons) does not include the body fluid.

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Table. 1 Abundance estimate of large male sperm whale in Areas IV and V.
w is the effective search half-width of schools. n is the number of shools. Ind. is the number of whales sighted.
s is the estimated mean school size. *P* is abundance estimation.

Area IV

					Sperm whale								
Season	Area	Strata	Dist.	n.mile^2	*w*	cv*w*	n	ind.	cvn	*s*	cv*s*	*P*	cv*P*
1989/90	IV	NW	2,005	218,378	1.56	0.13	85	87	0.32	1.02	0.14	3,027	0.37
	IV	NE	1,789	223,833	1.56	0.13	19	19	0.40	1.00	0.00	762	0.42
	IV	SW	2,523	46,753	0.95	0.21	39	40	0.32	1.04	0.18	396	0.42
	IV	SE	2,622	40,370	0.95	0.21	10	11	0.52	1.00	0.00	81	0.56
	IV	PB	762	34,628	0.95	0.21	1	1	0.86	1.00	0.00	24	0.89
	IV	All										4,289	0.28
1991/92	IV	NW	2,486	258,237	2.08	0.04	65	69	0.22	1.08	0.24	1,753	0.33
	IV	NE	2,178	223,666	2.08	0.04	12	12	0.33	1.00	0.00	296	0.33
	IV	SW	2,162	38,978	1.33	0.09	86	86	0.22	1.00	0.00	583	0.24
	IV	SE	2,949	34,871	1.33	0.09	52	53	0.24	1.00	0.00	231	0.26
	IV	PB	630	27,733	1.33	0.09	5	9	0.37	1.00	0.00	83	0.38
	IV	All										2,946	0.20
1993/94	IV	NW	3,500	230,748	1.69	0.12	91	95	0.17	1.04	0.18	1,846	0.28
	IV	NE	3,177	161,376	1.69	0.12	21	23	0.41	1.17	0.29	369	0.52
	IV	SW	2,391	35,428	1.75	0.11	82	83	0.29	1.02	0.14	354	0.34
	IV	SE	611	40,813	1.75	0.11	42	43	0.26	1.04	0.17	834	0.33
	IV	PB	1,042	35,196	1.75	0.11	0	0	0.00	0.00	0.00	0	0.11
	IV	All										3,403	0.18
1995/96	IV	NW	3,513	217,044	0.97	0.19	52	55	0.32	1.03	0.15	1,706	0.40
	IV	NE	2,982	228,383	0.97	0.19	9	9	0.40	1.00	0.00	355	0.44
	IV	SW	1,601	33,433	1.15	0.18	75	78	0.25	1.02	0.14	695	0.34
	IV	SE	2,125	29,932	1.15	0.18	29	29	0.37	1.00	0.00	178	0.41
	IV	PB	1,295	27,929	1.15	0.18	5	5	0.75	1.00	0.00	47	0.77
	IV	All										2,980	0.25

Area V

					Sperm whale								
Season	Area	Strata	Dist.	n.mile^2	*w*	cv*w*	n	ind.	cvn	*s*	cv*s*	*P*	cv*P*
1990/91	V	NW	2,648	256,089	1.64	0.08	5	5	0.49	1.00	0.00	147	0.50
	V	NE	4,069	347,440	1.64	0.08	13	14	0.33	1.00	0.00	338	0.34
	V	SW	1,830	69,915	1.64	0.08	35	37	0.26	1.05	0.20	428	0.34
	V	SE	1,672	208,511	1.64	0.08	34	36	0.36	1.00	0.00	1,293	0.37
	V	All										2,207	0.23
1992/93	V	NW	2,255	332,682	0.94	0.29	4	4	0.42	1.00	0.00	314	0.51
	V	NE	1,439	290,526	0.94	0.29	4	4	0.36	1.00	0.00	430	0.46
	V	SW	1,891	43,572	0.94	0.29	17	18	0.46	1.00	0.00	208	0.54
	V	SE	1,517	180,745	0.94	0.29	33	34	0.27	1.05	0.20	2,196	0.44
	V	All										3,148	0.32
1994/95	V	NW	2,957	189,310	1.12	0.21	5	5	0.48	1.00	0.00	143	0.52
	V	NE	2,529	303,617	1.12	0.21	35	35	0.2	1.00	0.00	1,876	0.29
	V	SW	359	45,685	1.12	0.21	7	7	0.56	1.00	0.00	398	0.60
	V	SE	598	175,421	1.12	0.21	5	5	0.45	1.00	0.00	655	0.50
	V	All										3,071	0.22

Table. 2 Abundance estimate of beaked whales in Areas IV and V.

w is the effective search half-width of schools. n is the number of shools. Ind. is the number of whales sighted. *s* is the estimated mean school size. *P* is abundance estimation.

Area IV

					beaked whales								
Season	Area	Strata	Dist.	n.mile^2	*w*	cv*w*	n	ind.	cv*n*	*s*	cv*s*	*P*	cv*P*
1989/90	IV	NW	2,005	218,378	0.56	0.17	37	53	0.22	1.41	0.49	5,073	0.56
	IV	NE	1,789	223,833	0.56	0.17	14	19	0.27	1.36	0.33	2,127	0.46
	IV	SW	2,523	46,753	0.50	0.21	41	61	0.14	1.49	0.55	1,132	0.61
	IV	SE	2,622	40,370	0.50	0.21	55	114	0.16	2.08	0.51	1,761	0.57
	IV	PB	762	34,628	0.50	0.21	2	4	0.83	2.00	0.55	182	1.02
	IV	All										10,276	0.32
1991/92	IV	NW	2,486	258,237	0.53	0.19	45	72	0.15	1.63	0.48	7,188	0.54
	IV	NE	2,178	223,666	0.53	0.19	15	23	0.26	1.38	0.33	2,005	0.46
	IV	SW	2,162	38,978	0.74	0.16	41	66	0.24	1.58	0.79	789	0.84
	IV	SE	2,949	34,871	0.74	0.16	79	138	0.17	1.68	0.53	1,060	0.58
	IV	PB	630	27,733	0.74	0.16	0	0	0.00	0.00	0.00	0	0.16
	IV	All										11,043	0.37
1993/94	IV	NW	3,500	230,748	0.61	0.29	57	91	0.17	1.53	0.45	4,713	0.56
	IV	NE	3,177	161,376	0.61	0.29	53	92	0.17	1.70	0.51	3,751	0.61
	IV	SW	2,391	35,428	1.01	0.13	77	135	0.24	1.79	0.57	1,011	0.63
	IV	SE	611	40,813	1.01	0.13	31	57	0.17	1.89	0.37	1,937	0.43
	IV	PB	1,042	35,196	1.01	0.13	13	22	0.93	1.69	0.55	367	1.09
	IV	All										11,780	0.31
1995/96	IV	NW	3,513	217,044	0.96	0.09	27	41	0.23	1.54	0.51	1,338	0.57
	IV	NE	2,982	228,383	0.96	0.09	44	75	0.17	1.71	0.41	3,001	0.45
	IV	SW	1,601	33,433	1.16	0.07	94	197	0.14	2.14	0.49	1,811	0.51
	IV	SE	2,125	29,932	1.16	0.07	15	31	0.31	1.92	0.59	175	0.67
	IV	PB	1,295	27,929	1.16	0.07	2	2	0.92	1.00	0.00	19	0.92
	IV	All										6,343	0.29

Area V

					beaked whales								
Season	Area	Strata	Dist.	n.mile^2	*w*	cv*w*	n	ind.	cv*n*	*s*	cv*s*	*P*	cv*P*
1990/91	V	NW	2,648	256,089	0.30	0.24	45	89	0.22	1.98	0.62	14,361	0.70
	V	NE	4,069	347,440	0.30	0.24	69	98	0.16	1.43	0.43	14,042	0.52
	V	SW	1,830	69,915	0.76	0.11	52	99	0.18	1.94	0.60	2,536	0.64
	V	SE	1,672	208,511	0.76	0.11	1	1	0.97	1.00	0.00	82	0.98
	V	All										31,021	0.40
1992/93	V	NW	2,255	332,682	0.34	0.28	17	26	0.23	1.53	0.38	5,643	0.53
	V	NE	1,439	290,526	0.34	0.28	22	31	0.15	1.38	0.46	9,014	0.56
	V	SW	1,891	43,572	0.51	0.38	34	66	0.35	1.93	1.13	1,482	1.24
	V	SE	1,517	180,745	0.51	0.38	15	34	0.33	2.38	0.92	4,170	1.05
	V	All										20,310	0.37
1994/95	V	NW	2,957	189,310	0.53	0.18	30	43	0.25	1.43	0.49	2,591	0.58
	V	NE	2,529	303,617	0.53	0.18	72	136	0.17	1.59	0.46	12,966	0.52
	V	SW	359	45,685	1.16	0.09	12	14	0.39	1.18	0.31	777	0.51
	V	SE	598	175,421	1.16	0.09	3	10	0.49	3.33	0.99	1,263	1.11
	V	All										17,597	0.40

Table. 3 Corrected abundance estimates and biomass of large male sperm whale and beaked whales in Areas IV and V.

Estimates g(0) are 0.32(cv=0.11) for sperm whale and 0.27(cv=0.04) for beaked whales(Kasamatsu and Joyce, 1995). The mean body weight of sperm whales (27.4 tonnes, Lockyer 1981) and beaked whales (4.5 tonnes, Zemskii & Budylenko 1970). (see text).

Sperm whale

Area IV	*P*	cv*P*	corrected abundance	cv	biomass
1989/90	4,289	0.28	13,403	0.30	367,000
1991/92	2,946	0.20	9,206	0.23	252,000
1993/94	3,403	0.18	10,634	0.21	291,000
1995/96	2,980	0.25	9,313	0.27	255,000

Area V	*P*	cv*P*	corrected abundance	cv	biomass
1990/91	2,207	0.23	6,897	0.25	189,000
1992/93	3,148	0.32	9,838	0.34	270,000
1994/95	3,071	0.22	9,597	0.25	263,000
–	–	–	–	–	–

Beaked whales

Area IV	*P*	cv*P*	corrected abundance	cv	biomass
1989/90	10,276	0.32	38,060	0.34	171,000
1991/92	11,043	0.37	40,900	0.39	184,000
1993/94	11,780	0.31	43,630	0.33	196,000
1995/96	6,343	0.29	23,490	0.31	106,000

Area V	*P*	cv*P*	corrected abundance	cv	biomass
1990/91	31,021	0.40	114,892	0.42	517,000
1992/93	20,310	0.37	75,222	0.39	339,000
1994/95	17,597	0.40	65,174	0.42	293,000
–	–	–	–	–	–

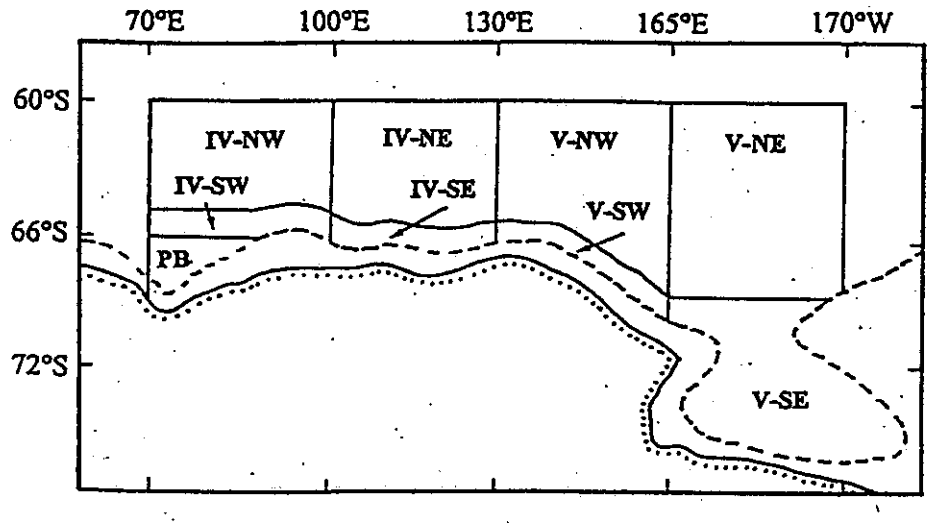
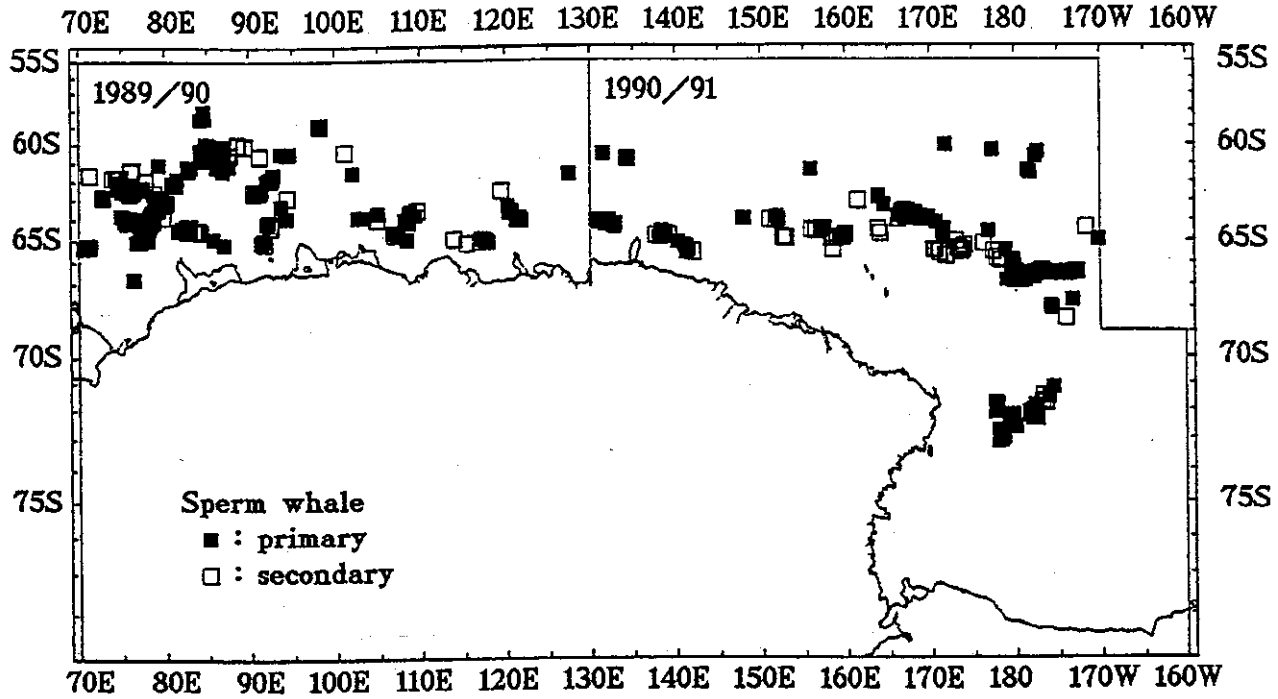


Fig. 1. Separation of sub-areas in Areas IV and V in JARPA.
Solid line with dot : Continental line, broken line : Pack-ice line.
IV : Area IV, V : Area V, NW : West-North, SW : West-South, NE : East-North, SE : East-South, PB : Prydz-Bay.



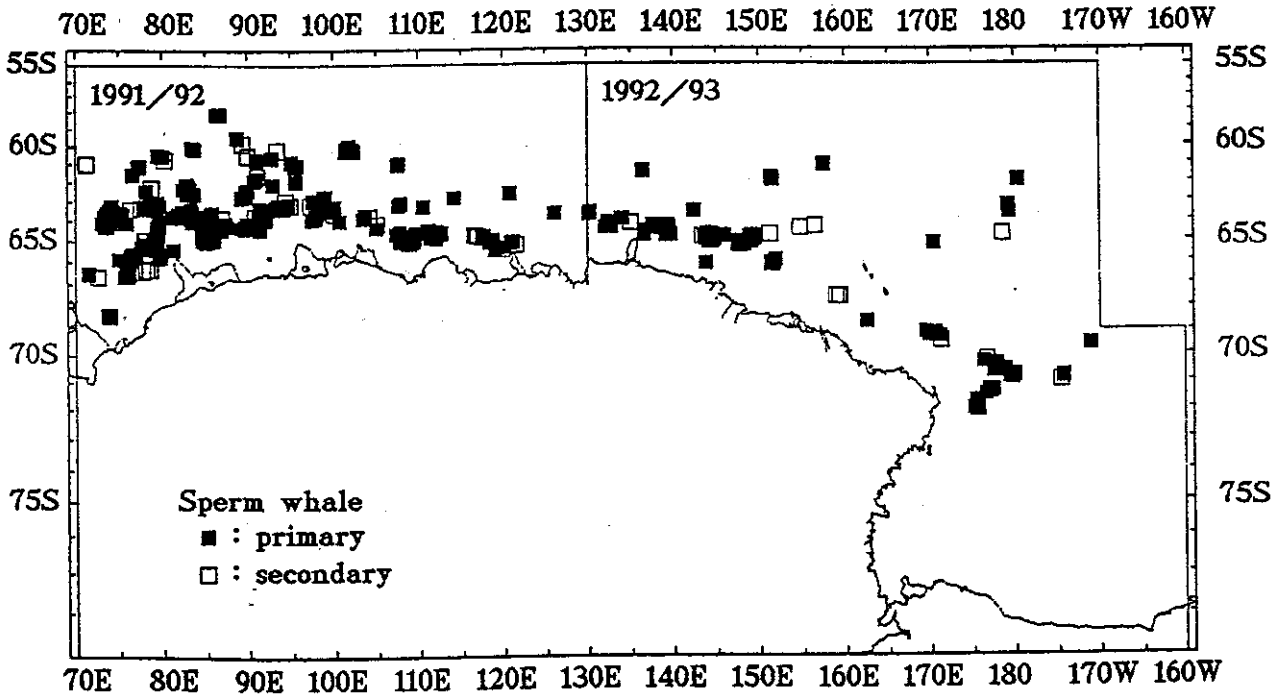
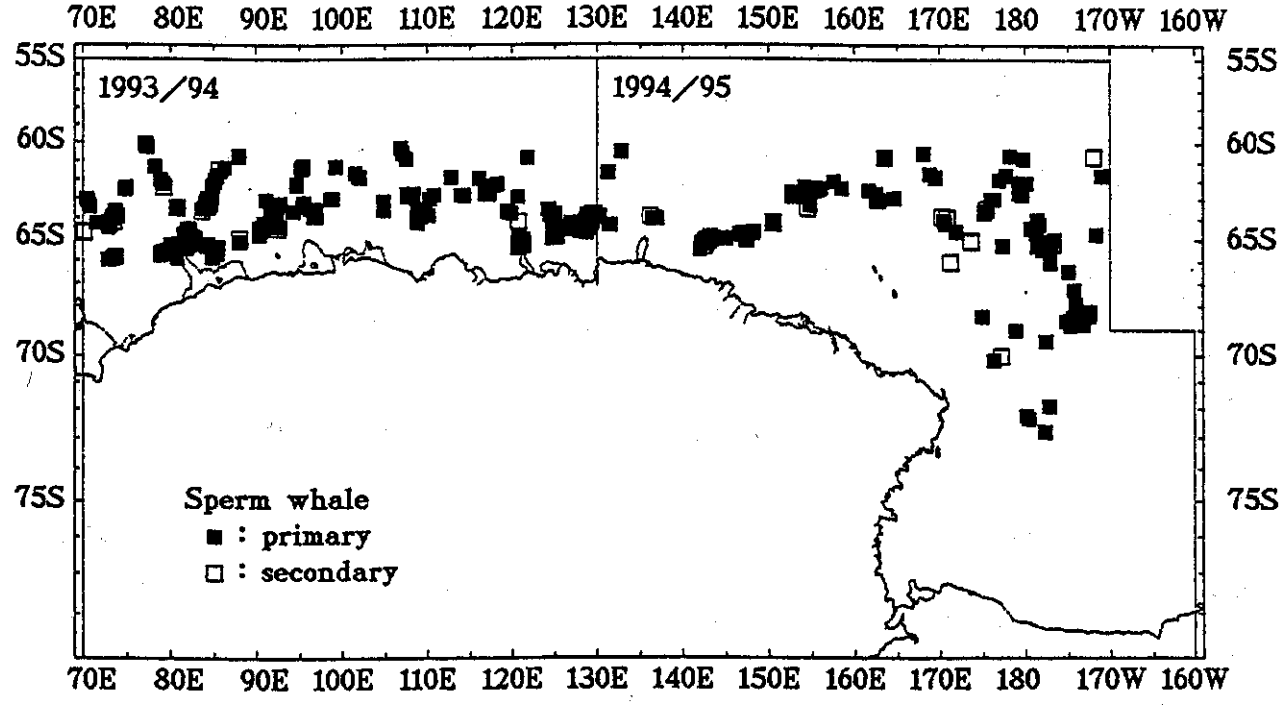


Fig.2a. Geographical positions of primary and secondary sightings of large male sperm whale schools during 1989/90-1992/93 JARPA.



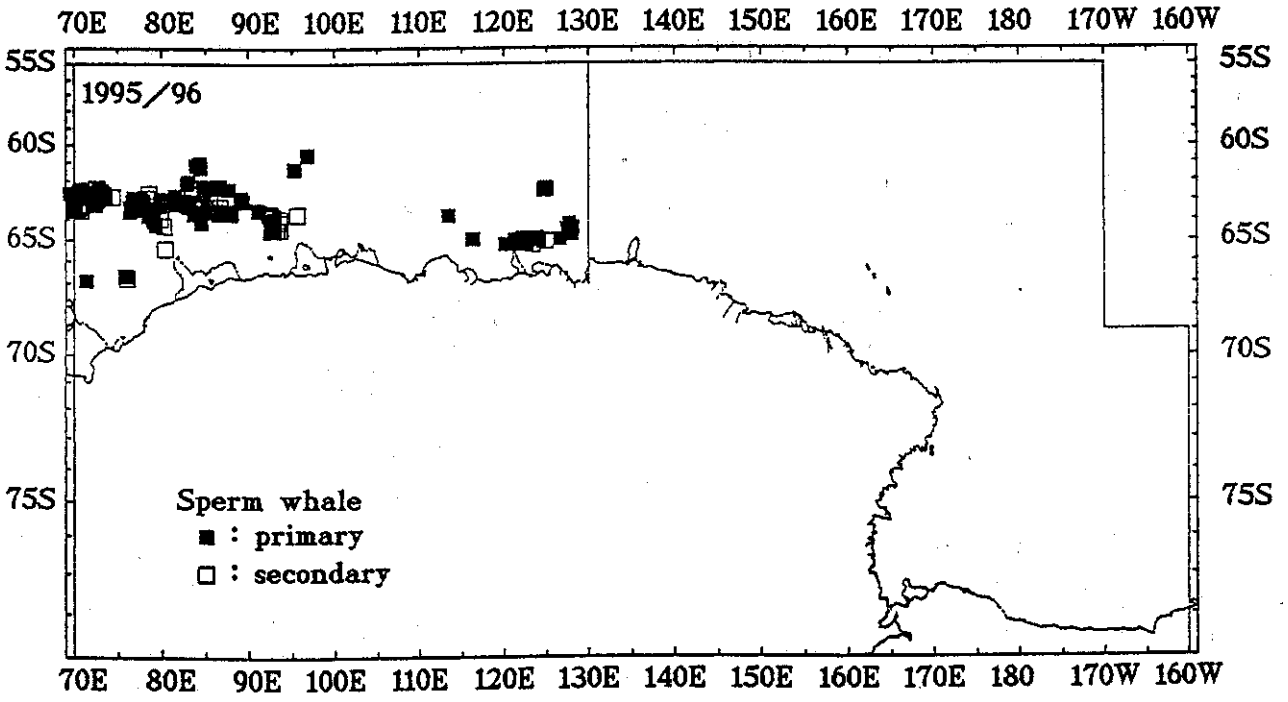
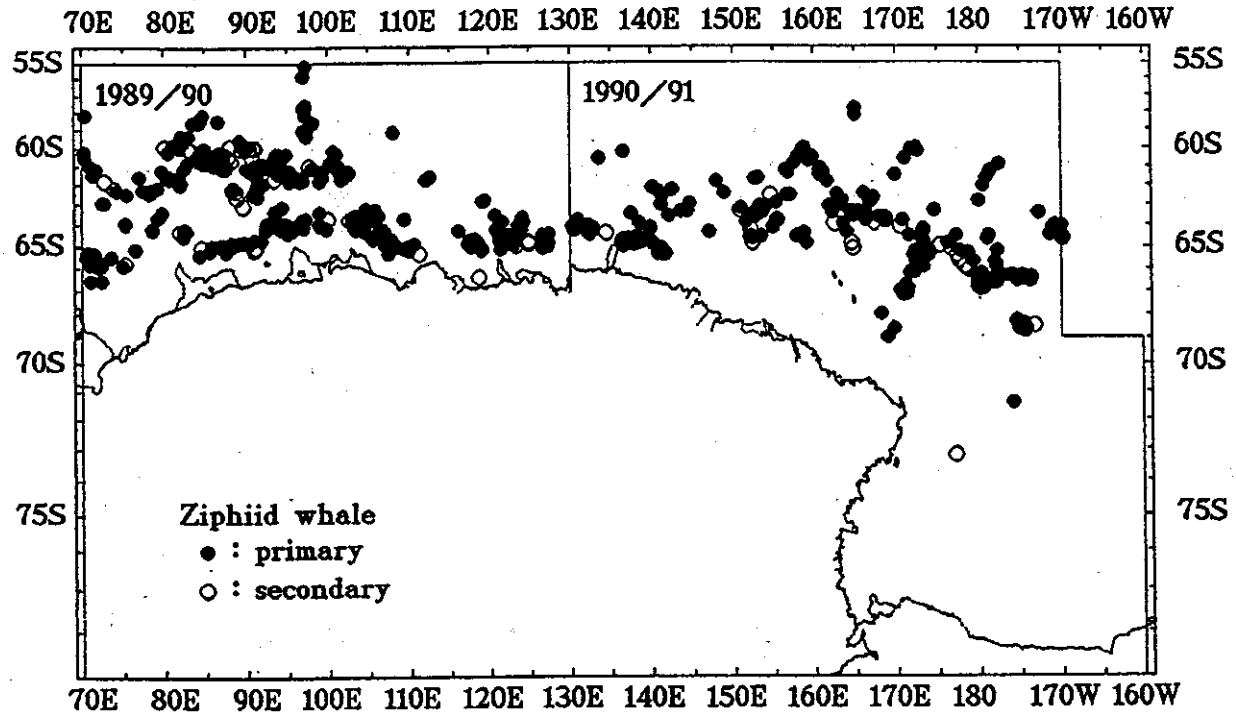


Fig.2b. Geographical positions of primary and secondary sightings of large male sperm whale schools during 1993/94-1995/96 JARPA.



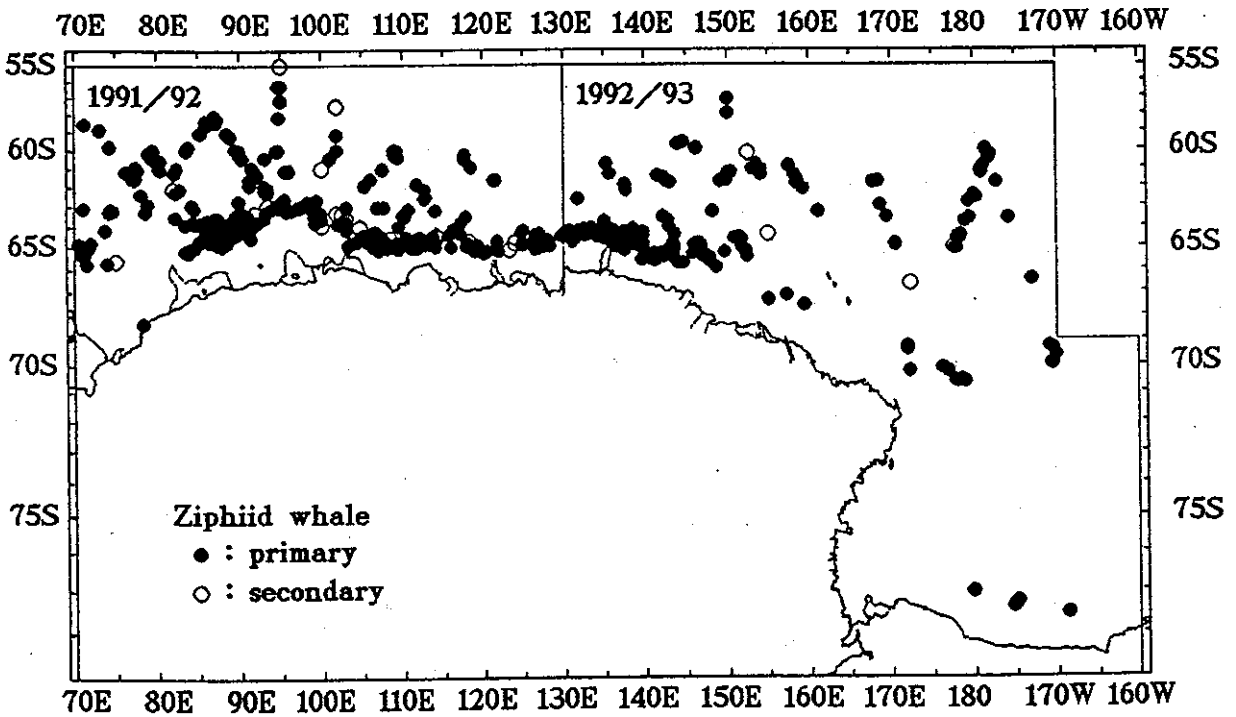
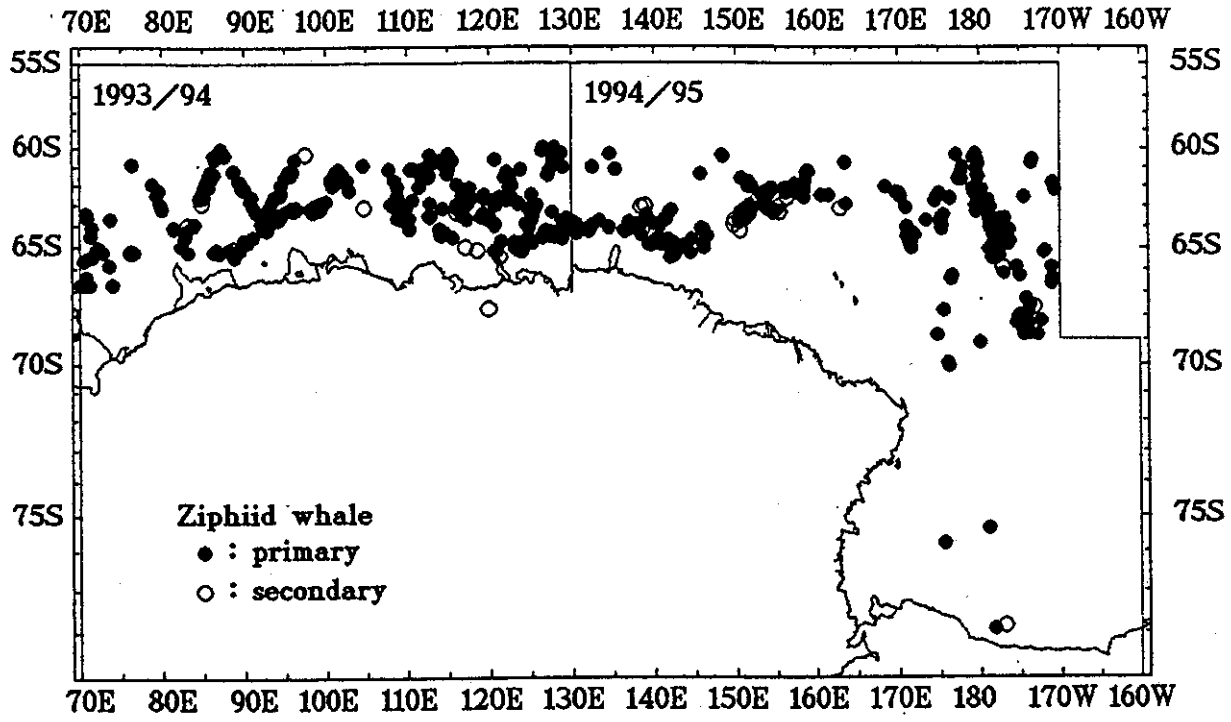


Fig.3a. Geographical positions of primary and secondary sightings of Ziphiid whale schools (including southern bottlenose whale) during 1989/90-1992/93 JARPA.



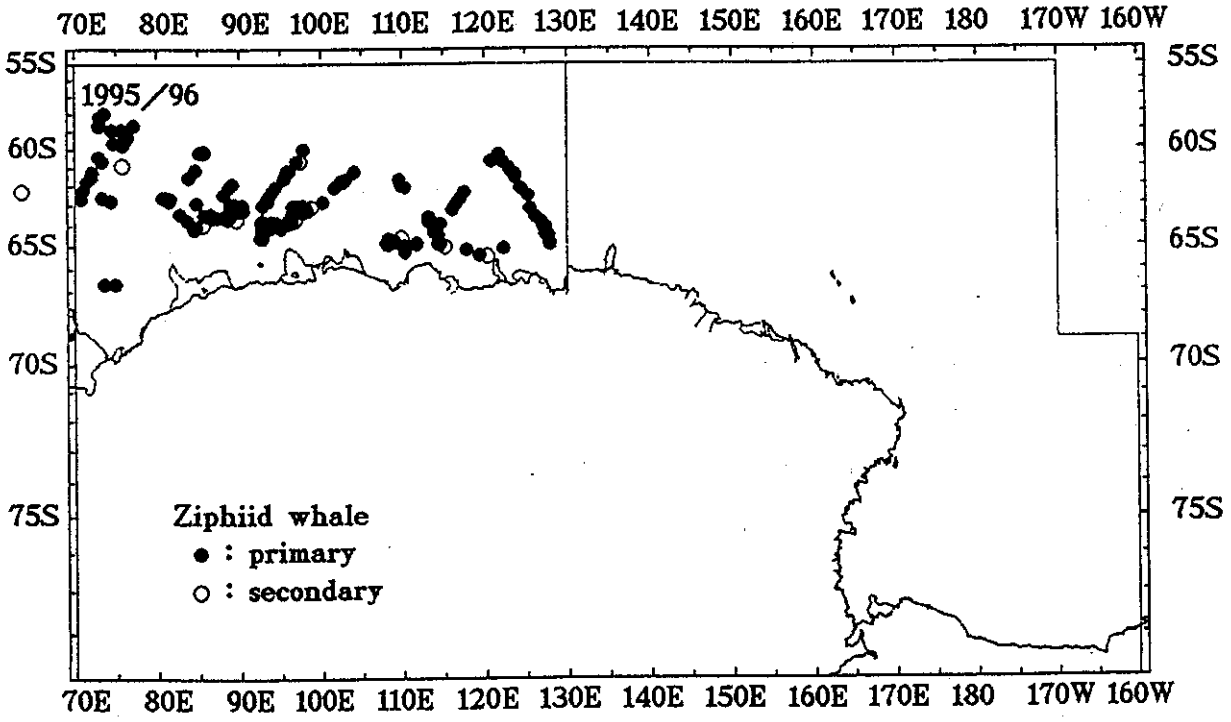


Fig.3b. Geographical positions of primary and secondary sightings of Ziphiid whale schools (including southern bottlenose whale) during 1993/94-1995/96 JARPA.