Distribution pattern of whale species sighted in the Antarctic based on JARPA and JARPAII sighting surveys (1987/88 to 2008/09)

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ABSTRACT

This paper analyzed the distribution pattern of the Density Index of Whales (DIW: individuals / 100 n.miles) for blue, fin, sei, Antarctic minke, humpback, southern right, sperm, southern bottlenose, unidentified beaked (*Ziphiidae*) and killer whales in the Antarctic based on JARPA (1987/88-2004/05) and JARPA II (2005/06-2008/09) sighting data. A total of 353,134 n.miles was surveyed in Areas IIIE, IV, V and VIW, south of 60°S.

Species	All Areas (IIIE, IV, V and VIW; south of 60S, 35E-145W)						Order of
	Sch.	Ind.	Calf	Mss	DIS	DIW	DIW
Blue whale	286	495	11	1.73	0.081	0.140	8
Fin whale	1,268	5,209	20	4.11	0.359	1.475	5
Sei whale	36	59	0	1.64	0.010	0.017	10
Antarctic minek whale	25,507	69,076	1	2.71	7.223	19.561	1
Humpback whale	10,036	18,770	137	1.87	2.842	5.315	3
Southern right whale	235	298	6	1.27	0.067	0.084	9
Sperm whale	3,810	3,926	0	1.03	1.079	1.112	6
Southern bottlenosed whale	1,666	3,045	3	1.83	0.472	0.862	7
Unid beaked whales	3,175	5,457	3	1.72	0.899	1.545	4
Killer whale	1,472	20,569	59	13.97	0.417	5.825	2

Among the 10 species, Antarctic minke whales were most frequently sighted, followed by killer, humpback, unidentified beaked, fin, sperm, southern bottlenose, blue, southern right and sei whales in the DIW order. Maps of the DIW on a 1° X 1° square are also provided, using all primary efforts and sightings data. These maps are more detailed compared to those of the JSV worldwide map which used a 5° X 5° square for each species. These large amounts of data collected by JARPA and JARPAII including the current maps will contribute to investigating habitat utilization of each species and provide more useful information for whale management in the Antarctic and Antarctic marine ecosystem.

KEYWORDS: ANTARCTIC, SURVEY VESSEL, DISTRIBUTION, BLUE WHALE, FIN WHALE, SEI WHALE, HUMPBACK WHALE, SOUTHERN RIGHT WHALE, SPERM WHALE, SOUTHERN BOTTLENOSE WHALE, BEAKED WHALES, KILLER WHALE,

INTRODUCTION

One of the main sources of sighting data for assessing the population status of whale species in the Antarctic is the JARPA (Japanese Whale Research Program under Special Permit in the Antarctic), which was conducted between 1987/88 and 2004/05, and its second phase JARPAII.

As for whale distribution analyses, the sighting data collected during JARPA have been used for blue whales (Branch *et al*., 2004) and other large whale species (Kishino *et al*., 1991; Kasamatsu *et al*., 2000; Matsuoka *et al*., 2003b, 2011, Murase *et al*., 2002, 2014). The main objective of this paper is to study the geographical distribution pattern for the main whale species sighted in Antarctic Areas IIIE, IV, V and VIW by JARPA and JARPAII sighting surveys. One of

the features of JARPA and JARPAII is that, unlike the IDCR (International Decade for Cetacean Research)-SOWER (Southern Ocean Whale and Ecosystem Research) programmes (Matsuoka *et al*., 2003a, Murase *et al*., 2005), surveys have been repeated in the same area and in the same months every second season over a long period. Current distribution maps are more detailed by each Area compared to those of the IDCR/SOWER maps which had covered the area only three times for each set of circumpolar data on whales. Therefore the JARPAII surveys facilitate the extent of detailed local distribution of whales.

MATERIAL AND METHODS

Sighting data used in this analysis

In this paper, we used all JARPA and JARPAII (1987/88-2008/09) systematic sighting survey data (effort and primary sightings) collected by sighting and sampling vessels (SSV) and dedicated sighting vessels (SV). An outline of the sighting survey is as follows:

Sighting procedure

The sighting procedure of JARPA II (2005/06-2008/09) was not largely changed during the JARPA surveys with some minor changes to the sighting procedure, which were reviewed by Nishiwaki *et al*. (2014). The research vessels were equipped with barrels, where three top men conducted sighting observation. On the upper bridge, a captain, a gunner, a helmsman and a researcher also conducted the sighting. The sighting activity continued if weather permitted during the daytime from 30 minutes after sunrise to 30 minutes before sunset.

Survey modes

Searching was conducted under closing and passing modes. (Hakamada *et al*., 2006, 2014a). These modes were under normal weather conditions defined as having minke visibility of 2 n.miles or more and wind speed under 20 knots in the northern strata (under 25 knot in the southern strata) (Nshiwaki *et al*. 2014).

Confirmation of the sightings

When a school of a cetacean species appearing to be minke whales or another large cetacean was sighted in the research area, the ship closed on the school immediately in order to identify the species, estimate the school size and get other biological information (number of calves, estimated body length etc.). To improve the estimation of the distance to the school and the angle from the bow, training was conducted in the early portion of each cruise by each vessel. Distance was estimated by referring to the scale of the binoculars, and angle was also estimated referring to the angle board. Surface temperatures were recorded in each whale sighting.

Density Index of whales

The Density Index of Whales (DIW) was calculated by each Lat.1°× Long.1°grid squares using the primary searching effort (n.miles) and the number of whales sighted in each square by each species.

RESULTS AND DISCUSSIONS

Primary searching efforts

A total of 353,134 n.miles was surveyed in south of 60^{o}S in Areas IIIE, IV, V and VIW between 1989/90 and 2008/09 seasons. Figures 1a and 1b show the research area and distribution of the primary searching effort (n,miles), respectively. The research area was covered completely during the surveys.

Distribution pattern of whales

Tables 1a and 1b show the summary of the primary sightings in the JARPA and JARPAII (1987/88-2008/09) for baleen whales and toothed whales, respectively. Table 2 shows the summary of the number of calves, observed mean school size and Density Index of Whales (DIW: number of the primary sightings of individuals / 100 n.miles) in the research

area. Figures 2a to 2d show the maps of the DIW of blue, fin, sei, Antarctic minke, dwarf minke, humpback, southern right, sperm, southern bottlenose, unidentified beaked (*Ziphiidae*) and killer whales by each Lat.1°× Long.1°grid squares. Figure 3 shows the monthly change in the density index of these species, except for a small number of sighting species of sei, dwarf minke and unidentified beaked whales.

Blue whale

Blue whale was ranked 8th in the DIW among the 10 species sighted in the research area (Table 2). They were widely distributed in the research area not only in the northern stratum but also the southern stratum. High density values of this species were observed in Areas IIIE (between 45°E and 65°E) (Figure 2a). They were rarely found within the Prydz Bay. They were sighted within the Ross Sea between 70°S and 77°S. A total of 286 schools (495 individuals) were sighted with 11 calves south of 60°S (Table 2). Observed mean school size was 1.73 (individuals). The DIW of this species was 0.140 during the whole season and were almost stable from December to March (Table 2 and Figure 3).

Two subspecies of blue whales exist in the Southern Hemisphere: the Antarctic (or true) blue whale (*Balaenoptera musculus intermedia*) and the pygmy blue whale (*B. m. brevicauda*) (Machintosh, 1966, Ichihara, 1966, Rice, 1998). A complete review of spatial and seasonal distribution, densities and movements of blue whales is provided by Branch *et al*. (2007a, 2007b). This study indicated that there is little evidence that pygmy blue whales migrate into high latitudes of the Antarctic. Less than 1% of the records south of 52°S were of this subspecies. There is no current evidence of a population structure in Antarctic blue whales. The latest abundance of this species (south of 60°S, 35°E-145°W) was 1,223 whales (CV=0.345) in 2007/08 + 2008/09 seasons and the abundance trend was 8.2 % (95%CI: 3.9%, 12.5%) between 1995/96 and 2008/09 for combined Areas IIIE+ IV+V+VIW based on JARPAII data (Matsuoka and Hakamada, 2014). There is a need for the continued monitoring of the abundance and abundance trends of this species, especially because they provide an excellent opportunity to improve our understanding of the dynamics of baleen whale populations recovering from low levels.

Fin whale

Fin whale was ranked 5th in the DIW among the 10 species sighted in the research area. A total of 1,268 schools (5,209 individuals) were sighted with 20 calves (Table 2). Observed mean school size was 4.11 (individuals). Distribution of this species was more frequently encountered in Areas V and VIW than Areas IIIE and IV in both northern and southern strata. High density areas were observed in Areas IIIE (between 55°E and 65°E), VW (between 140°E and 160°E) and VE (between 163°E and 170°W) (Figure 2a). The DIW of this species was 1.475 during the whole season and was increasing from December to March (Figure 3).

In the summer feeding grounds in the Antarctic, fin whales can be found year-round, but a higher density is found from November to May (Kasamatsu *et al*., 1996; Mackintosh, 1966). Whales can be found as far south as 65-70°S, but the majority of the population seems to be north of 60°S (Miyashita *et al*., 1995). Catches occurred throughout the Antarctic, but the majority of whales (~73%) were taken in the IWC Management Areas II and III. Sighting data suggests that spatial distribution varies across ocean basins (Kasamatsu *et al*., 1996).

Sei whale

Sei whales were the most rare species sighted in the research area. A total of 36 schools (59 individuals) were sighted with no calves south of 60°S in the Antarctic (Table 2). Observed mean school size was 1.64 (individuals). Distribution of this species was limited more in Areas V and VIW than Areas IIIE and IV in both northern stratums (Figure 2a). The DIW of this species was 0.017 during the whole season.

In the summer, sei whales do not venture into higher latitude waters near the Antarctic continent as much as some other baleen whales (Horwood, 1987; Miyashita *et al*., 1995). The majority of the population can be found between 40°S and 60°S, usually north of the Antarctic Convergence. Juveniles are found further north than mature individuals. Occurrence

in low latitude wintering grounds has been recorded from March to December, but abundance peaks from June/July to August/September (Horwood, 1987). In late spring and summer, abundance peaks in November between 30°S and 50°S. As the season progresses, relatively more whales are observed south of 40°S and abundance between 50°S and 60°S increases consistently until March (Horwood, 1987). Present results of this paper support these studies.

Antarctic minke whale

This species was most frequently sighted throughout the surveys. A total of 25,507 schools (69,076 individuals) were sighted with no calves south of 60°S in the Antarctic (Table 2). Observed mean school size was 2.71 (individuals). High density areas were observed around the entire ice-edge, especially the Ross Sea and Prydz Bay (Figure 2b). The DIW of this species was higher than other species (19.561) during the whole season and was increasing from December to February and decreasing to March (Figure 3).

In the austral summer, the majority of Antarctic minke whales congregate in the Southern Ocean, with greatest densities close to and within the pack ice, and lower densities with increasing distance from the ice (Kasamatsu *et al*. 2000, Hakamada 2014a), including some north of 60°S. Antarctic minke whales are noticeably well adapted to living within the ice (Ainley *et al*., 2007), but the exact proportion of Antarctic minke whales found within the pack ice, and in polynyas, is currently a source of great debate. It is possible that a large proportion of the population is found within the pack ice, out of reach of ship-based sighting surveys (Murase *et al*., 2005, 2014; Shimada and Kato, 2007).

Dwarf minke whale

The distribution area of this species was limited in the research area. There are two separated areas between 120°E and 147°E, and between 165°E and 170°W, respectively in the northern stratum (mainly between 60°S and 63°S), where the south of Australia and New Zealand (Figure 2b). The dwarf minke whale has a white band on the flipper that distinguishes it from the Antarctic minke whale, but was only fairly recently identified as separate from Antarctic minke whales (Best, 1985). Based on available information, only a small percentage of minke whales in the Antarctic (south of 60°S) are dwarf minke whales. For example, in the IDCR/SOWER surveys from 1993/94–1997/98, only 0.2% of the identified sightings were dwarf minke whales (2 out of 906). No formal analysis has been conducted but it is probable that less than 1% of the minke whales south of 60°S are dwarf minke whales (Branch & Butterworth, 2001).

Humpback whale

Humpback whale was ranked 3rd among the 10 species sighted in the research area. A total of 10,036 schools (18,770 individuals) were sighted with 137 calves (Table 2). Observed mean school size was 1.87 (individuals). They were widely distributed in the research area in both northern and southern stratum. They were rarely found within the Prydz Bay and the Ross Sea and there were no sightings south of 73°S. High density values of this species were observed between 85°E and 110°E (Figure 2b). The DIW of this species was 5.315 during the whole season and was increasing from December to February and decreasing to March (Figure 3).

Sightings data from both the IDCR/SOWER circumpolar cruises suggested that whales were encountered more frequently at 20-40°E, 80°E-100°E and 150°E-180°E (Branch, 2011). A current map of this species suggested that humpback whales are encountered more frequently at 80°E-100°E than 20-40°E and 50°E-180°E because of its high productivity area (see Discussions). In that area between 80°E and 100°E, large scale distribution changes were observed (Matsuoka *et al*., 2011, Murase *et al*., 2014, Hakamada *et al*. 2014b). It was considered that oceanographic conditions have changed this area as an effect of the Regime Shift in the Global Sea-Surface temperatures in relation to El Nino-Southern Oscillation Events (Watanabe *et al*., 2014, Naganobu *et al*., 2014). It will be further investigated in the future.

Southern right whale

A total of 235 schools (298 individuals) were sighted with 6 calves (Table 2). The distribution area of this species was limited in the research area between 80°E and 135°E south of Western Australia (Figure 2c). The DIW of this species was 0.084 during the whole season and was increasing from December to March (Figure 3). After breeding in winter in relatively warm waters, near continental or island coastlines, southern right whales migrate in summer to feed in colder waters, but generally not as far south as other baleen whales. They appear to occur near the subtropical convergence in summer (January to March) at around 40°-50°S (Ohsumi & Kasamatsu, 1985), but there are records of animals much further south (e.g. around 60°S-65°S south of Australia (Bannister *et al*., 1999, 2008). The present map of this species supported these studies. The population estimate for the coastal area of Western Australia was 2,400 in 2006 (Bannister, 2008). A current estimate in Area IV south of 60°S is 1,557 individuals (95% CI, 871-2,783) in the 2007/08 season based on JARPAII data. The abundance trend was not significant for this species because they were mainly distributed in the area north of 60°S.

Sperm whale

Sperm whale was ranked 6th among the 10 species sighted in the research area. A total of 3,810 schools (3,926 individuals) were sighted without any calves (Table 2). Solitary schools (large male) were 96.5%, and the observed mean school size was 1.03. They were widely distributed in the research area. High density values of sperm whales were observed in Area IV (between 70°E and 100°E) and Area V (between 170°E and 170°W, in mouth of the Ross Sea (Figure 2c). They tended to be concentrated on the Antarctic continental slope, the southern Kerguelen Plateau, and around the mouth of the Ross Sea, where the most frequent depth was between 1,000m and 4,000m. They were rarely found within the Prydz Bay and the Ross Sea (Figure 2c). There were no sightings south of 74°S in the Ross Sea. The DIW of this species was 1.112 during the whole season and was decreasing from December to March (Figure 3).

Southern bottlenose whales

Southern bottlenose whale was ranked 7th among the 10 species sighted in the research area. A total of 1,666 schools (3,045 individuals) were sighted with 3 calves (Table 1). They were widely distributed in the research area and were rarely sighted within the Prydz Bay and the Ross Sea. High density values of this whale were observed between 85°E and 130°E (Figure 2c). Observed mean school size was 1.83 individuals. The DIW of this species was 0.862 during the whole season and was decreasing from December to March (Figure 3).

Unidentified beaked whales

Unidentified beaked whales was ranked 4th among the 10 species sighted in the research area. A total of 3,175 schools (5,457 individuals) were sighted with 3 calves (Table 1). These sightings were recorded as unidentified species but confirmed as beaked whales. These "unidentified beaked whales" included possibly southern bottlenose whales (*Hyperoodon planifrons*), Arnoux's beaked whales (*Berardius arnuxii*), strap-toothed whales (*Mesoplodon layardii*) and Grey's beaked whales (*M. grayi*). The distribution pattern of unidentified beaked whales was consistent with that of southern bottlenose whales (Figure 2d). If they were identified on the species level, they recorded their species codes. But these records were not used in this paper because the number of records was very small.

Killer whale

Killer whale was ranked 2nd among the 10 species sighted in the research area. A total of 1,472 schools (20,569 individuals) were sighted with 59 calves (Table 2). Observed mean school size was 13.97 individuals. The DIW of this species was 5.825 during the whole season (Table 2). They were widely distributed in the research area and sighted more in the southern stratum than the northern stratum. High density areas were observed within the Prydz Bay and the Ross Sea (Figure 2d).

High productivity in the meander of the southern boundary of ACC

From the viewpoint of large scale whale distributions, Area IV was more highly concentrated between 80° E and 110° E (south of 60° S) than in other parts of the research area. This area was characterized by a large meander (rise to 61° S

and slow-moving down to 63° S) of the southern boundary of the ACC which seemed to be formed by a large scale up-welling with nutritious bottom waters resulting from the bottom shape of the southern Kerguelen Plateau (Watanabe *et al*., 2006, 2014, Naganobu *et al*., 2014). The BROKE, Australian Antarctic survey, indicated the possibility of the occurrence of a large-scale upwelling between 80°E and 100° E (Bindoff *et. al*, 2000). In the JARPA 1999/2000 cruise, a high density of *Euphausiids* was reported between 100 °E and 120° E (Murase *et al*., 2002). Humpback, southern right, large male sperm and southern bottlenose whales used this longitudinal section between 80° E and 100° E as their key feeding area from December to March. It is further necessary to investigate the relationship between oceanographic conditions and whale distribution shifts such as the effect of the Regime Shift on the Global Sea-Surface temperatures in relation to El Nino-Southern Oscillation Events (Matsuoka *et al.*, 2003b, Watanabe *et al*. 2014, Naganobu *et al*., 2006, 2014). It will be further investigated in the future.

Large data set for Antarctic ecosystem studies

In this paper, low and middle latitude survey data and other species data including Arnoux's beaked whale, long-finned pilot whale, hourglass dolphin and spectacled porpoise was not used. These large sets of data from JARPA and JARPAII surveys including the results of this paper will contribute to investigating habitat utilization and contribute to baleen whale management in the Antarctic Ocean and further investigation of Antarctic marine ecosystems. JARPAII continues to provide more useful information regarding the recovery management of whale stocks including blue whales. It is regrettable that the recent two sighting surveys had to be cancelled due to unscrupulous, obstructive actions by an anti-whaling group.

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Table 1a. Summary of baleen whales mainly sighted in Areas IIIE, IV, V and IV (south of 60S, 35E-145W) during the JARPA and JARPAII (1987/88-2008/09).

No.	Season	Effort (n.miles)	Blue whale			Fin whale			Sei whale			Ant. minke whale			Humpback whale			S. right whale		
			sch.	ind.	calf	sch.	ind.	calf	sch.	ind.	calf	sch.	ind.	calf	sch.	ind.	calf	sch.	ind.	calf
1	1987/88	8,860.6	0	0	0	3	3	0	1	1	0	237	719	0	35	76	0	1	1	0
2	1988/89	10,806.7	2	3	0	7	16	0	0	0	0	353	768	0	1	2	0	0	0	0
3	1989/90	16,423.2	5	9	0	5	20	0	0	0	0	758	1,968	0	121	210	11	2	2	0
4	1990/91	14,660.0	4	6	0	33	67	0	0	0	0	740	1,713	0	58	90	0	0	0	0
5	1991/92	17,844.1	3	3	0	8	34	0	2	2	0	597	2,030	0	177	321	7	26	30	0
6	1992/93	13,924.9	7	9	0	15	27	1	2	4	0	1,024	3,228	0	28	56	5	3	4	0
7	1993/94	17,957.3	5	9	0	9	26	0	0	0	0	688	1,619	0	133	220	1	11	14	0
8	1994/95	14,047.7	13	20	1	73	241	1	2	5	0	823	2,453	0	131	228	9	0	0	0
9	1995/96	21,466.7	9	16	0	60	214	1	0	0	0	887	2,008	0	325	562	10	8	8	0
10	1996/97	17,783.2	7	9	0	37	82	1	1	1	0	853	2,610	0	114	200	3	0	0	0
11	1997/98	21,594.4	16	25	0	18	57	0	0	0	0	672	1,373	0	577	1,122	2	34	37	0
12	1998/99	8,066.5	4	7	1	45	222	1	0	0	0	826	2,665	0	106	203	7	0	0	0
13	1999/2000	16,341.5	25	53	2	66	356	3	0	0	0	1,507	6,581	0	661	1,269	5	3	3	0
14	2000/01	20,421.3	10	18	0	114	374	0	7	13	0	1,907	4,949	0	191	341	3	2	2	0
15	2001/02	19,767.4	17	26	1	143	983	2	1	2	0	1,867	4,374	0	1219	2,387	5	15	22	1
16	2002/03	18,126.2	5	10	0	52	216	0	8	14	0	2,420	6,531	0	145	228	4	0	0	0
17	2003/04	19,287.4	32	61	0	109	446	0	0	0	0	1,092	3,250	0	1690	3,134	5	1	2	1
18	2004/05	18,486.7	12	16	0	49	118	1	1	1	0	1,663	4,278	0	197	336	2	2	2	0
19	2005/06	16,372.7	24	38	2	188	748	1	2	3	0	1,657	4,375	0	1702	3,200	22	53	73	4
20	2006/07	11,968.8	7	12	1	37	253	0	0	0	0	969	2,169	0	160	283	13	0	0	0
21	2007/08	14,575.3	43	84	1	48	134	4	2	2	0	823	1,702	0	1314	2,536	7	72	96	0
22	2008/09	14,351.4	14	28	1	109	440	2	5	7	0	1,870	4,668	0	339	587	8	0	0	0
-	Total	353,134	264	462	10	1,228	5,077	18	34	55	0	24,233	66,031	0	9,424	17,591	129	233	296	6

Table. 1b. Summary of toothed whales mainly sighted in Areas IIIE, IV, V and IV (south of 60°S, 35°E-145°W) during the JARPA and JARPAII (1987/88-2008/09).

No.	Season	Effort (n.miles)	Sperm whale			S. bottlenose whale			Unid. beaked whales			Killer whale		
			sch.	ind.	calf	sch.	ind.	calf	sch.	ind.	calf	sch.	ind.	calf
1	1987/88	8,860.6	6	6	0	3	5	0	87	218	0	20	194	0
2	1988/89	10,806.7	81	91	0	2	4	0	65	143	0	31	189	0
3	1989/90	16,423.2	204	215	0	23	46	0	281	514	0	69	859	0
4	1990/91	14,660.0	175	188	0	13	26	0	241	421	1	32	870	2
5	1991/92	17,844.1	225	233	0	29	51	0	181	304	1	53	805	0
6	1992/93	13,924.9	105	108	0	10	19	0	202	361	0	82	1,130	0
7	1993/94	17,957.3	321	336	0	145	243	0	205	337	0	56	399	1
8	1994/95	14,047.7	133	135	0	74	146	1	168	263	0	35	281	1
9	1995/96	21,466.7	341	352	0	137	273	1	161	284	0	109	1,282	1
10	1996/97	17,783.2	121	128	0	75	128	0	78	144	1	50	539	4
11	1997/98	21,594.4	295	302	0	222	409	0	197	338	0	82	931	9
12	1998/99	8,066.5	49	50	0	23	53	0	35	54	0	35	409	5
13	1999/2000	16,341.5	195	204	0	138	251	0	110	188	0	109	2,011	7
14	2000/01	20,421.3	100	106	0	72	121	0	173	272	0	72	1,471	2
15	2001/02	19,767.4	269	272	0	126	226	0	134	205	0	79	939	0
16	2002/03	18,126.2	128	129	0	97	168	0	113	154	0	63	953	0
17	2003/04	19,287.4	222	223	0	154	274	0	208	338	0	120	1,348	0
18	2004/05	18,486.7	105	108	0	44	78	0	89	159	0	78	1,472	3
19	2005/06	16,372.7	181	182	0	88	179	0	135	244	0	100	1,563	3
20	2006/07	11,968.8	63	63	0	51	80	0	66	88	0	44	394	0
21	2007/08	14,575.3	280	280	0	79	157	1	102	155	0	62	790	0
22	2008/09	14,351.4	75	76	0	32	61	0	77	140	0	38	788	14
-	Total	353,134.0	3,674	3,787	0	1,637	2,998	3	3,108	5,324	3	1,419	19,617	52

Table. 2. Summary of the main species sightings during the JARPA and JARPAII (1987/88-2008/09). Sch.: Number of the primary sightings of schools. Ind.: Number of the primary sightings of individuals. Calf: Number of calves including Individuals. Mss: mean school size (Ind. / Sch.). DIS: Density Index (schools / 100 n.miles). DIW: Density Index (individuals / 100 n.miles).

Species	All Areas (IIIE, IV, V and VIW; south of 60S, 35E-145W)						Order of	Dec.	Jan.	Feb.	Mar.
	Sch.	Ind.	Calf	Mss	DIS	DIW*	DIW*	DIW	DIW	DIW	DIW
Blue whale	286	495	11	1.73	0.081	0.140	8	0.281	0.092	0.101	0.102
Fin whale	1,268	5,209	20	4.11	0.359	1.475	5	1.323	0.794	1.760	3.059
Sei whale	36	59	0	1.64	0.010	0.017	10	0.002	0.004	0.020	0.044
Antarctic minek whale	25,507	69,076	0	2.71	7.223	19.561	1	10.173	14.301	33.331	19.436
Humpback whale	10,036	18,770	137	1.87	2.842	5.315	3	3.425	4.842	7.337	6.708
Southern right whale	235	298	6	1.27	0.067	0.084	9	0.001	0.014	0.156	0.292
Sperm whale	3,810	3,926	0	1.03	1.079	1.112	6	1.500	1.272	0.992	0.292
Southern bottlenosed whale	1,666	3,045	3	1.83	0.472	0.862	7	0.932	0.974	0.787	0.570
Unid beaked whale	3,175	5,457	3	1.72	0.899	1.545	4	1.864	1.594	1.123	1.209
Killer whale	1,472	20,569	59	13.97	0.417	5.825	2	1.935	5.692	9.303	6.624

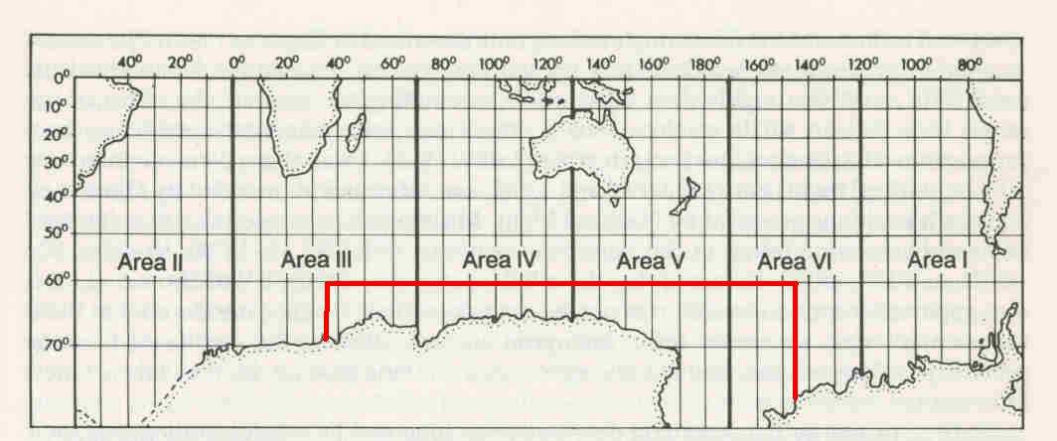

Figure 1a. The IWC Antarctic Areas for the management of baleen whales (except Bryde's whale) and research area of the JARPA and JARPAII surveys between 35°E and 145°W (colored). Area III east (IIIE: 35 °E-70°E), Area IV(70°E-130°E), Area V (130°E-170°W) and Area VI west (VIW: 170°W -145°W).

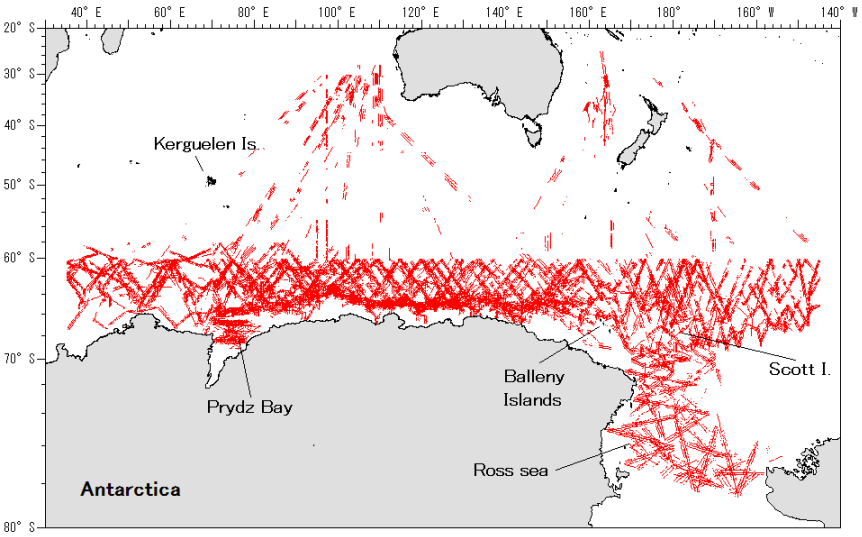

Figure 1b. Map of the searching efforts (red line) in the JARPA1987/88-2004/05 and JARPAII 2005/06-2008/09 seasons, including middle latitude transit sighting survey.

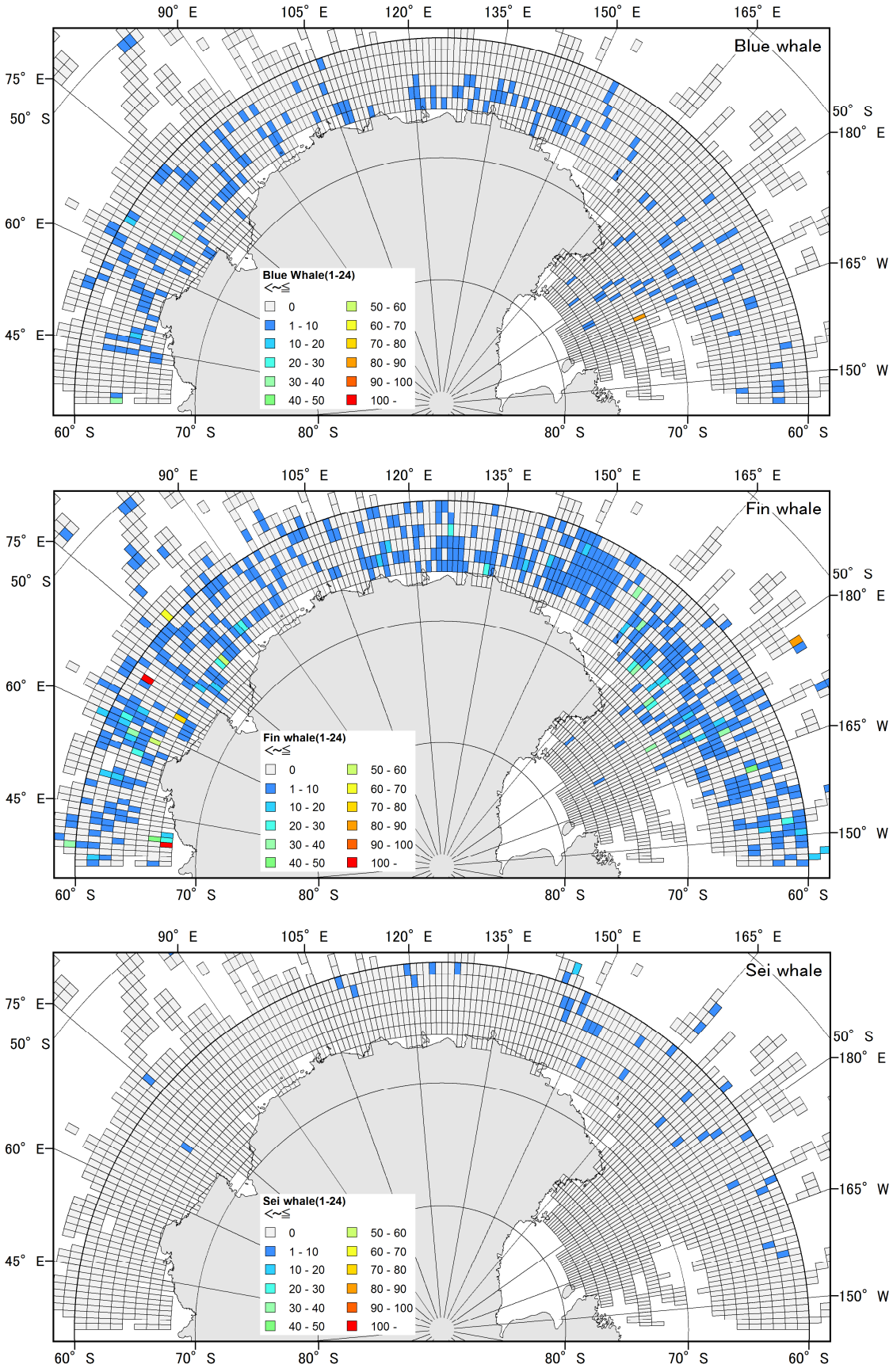

Figure 2a. Distribution of the Density Index (number of primary sightings of individuals / 100 n.miles) of blue (top), fin (middle) and sei (bottom) whales during JARPA and JARPAII (1987/88-2008/09) by Lat.1°× Long.1°square.

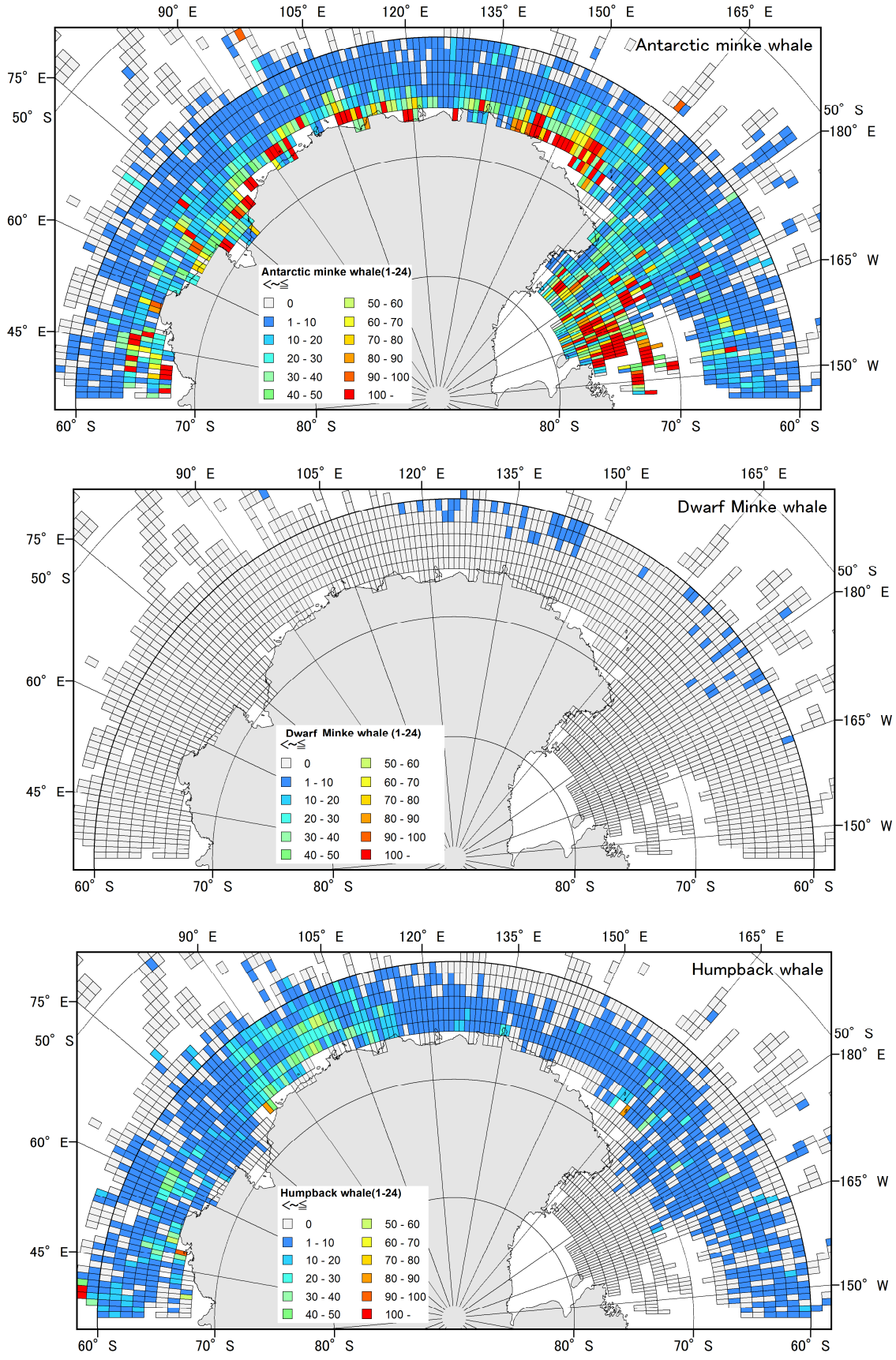

Figure 2b. Distribution of the Density Index (number of primary sightings of individuals / 100 n.miles) of A. minke (top), dwarf minke (middle) and humpback (bottom) whales during JARPA and JARPAII (1987/88-2008/09) by Lat.1°× Long.1°square.

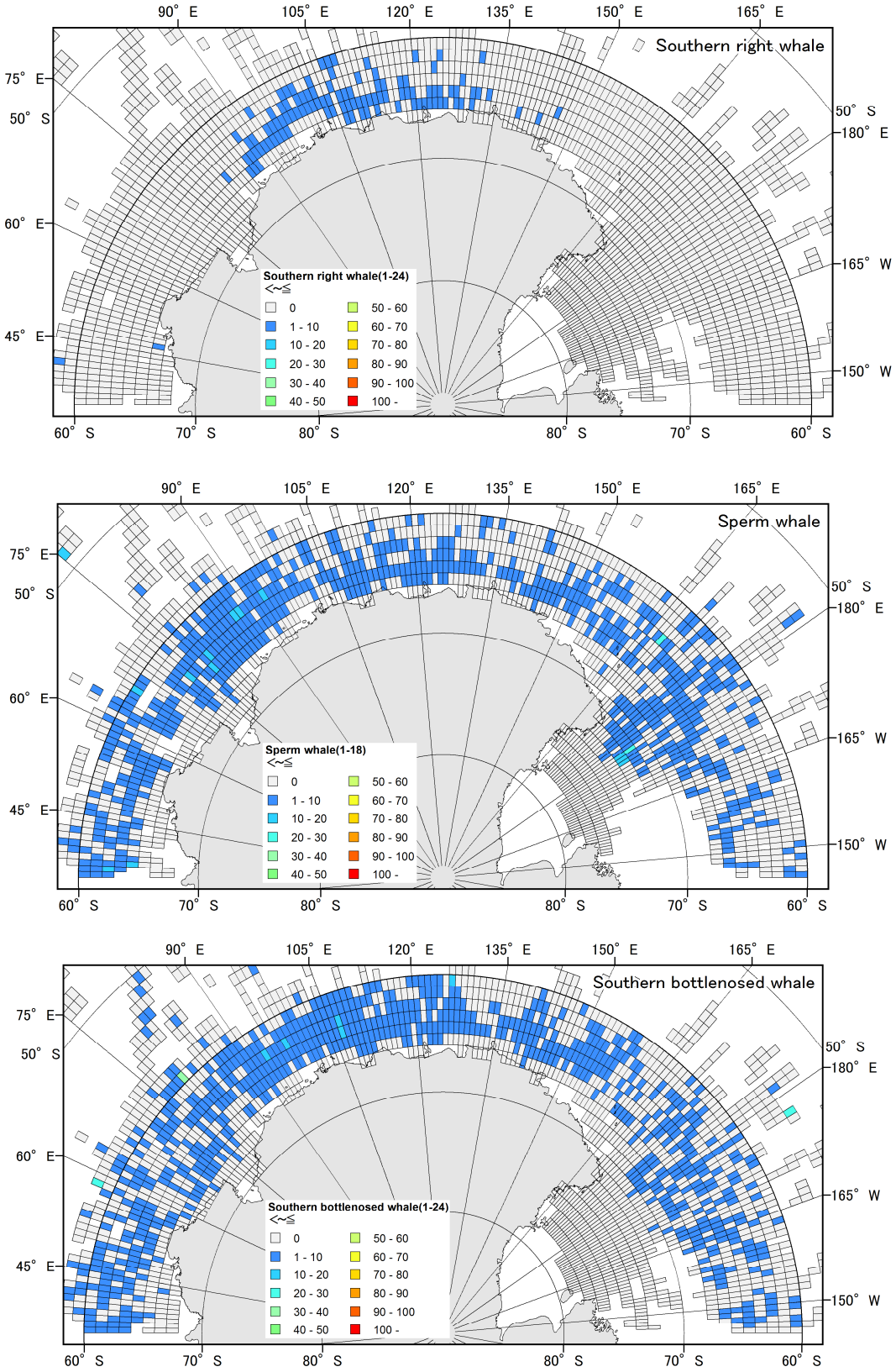

Figure 2c. Distribution of the Density Index (number of primary sightings of individuals / 100 n.miles) of southern right (top), sperm (middle) and southern bottlenose (bottom) whales during JARPA and JARPAII (1987/88-2008/09) by Lat.1°× Long.1°square.

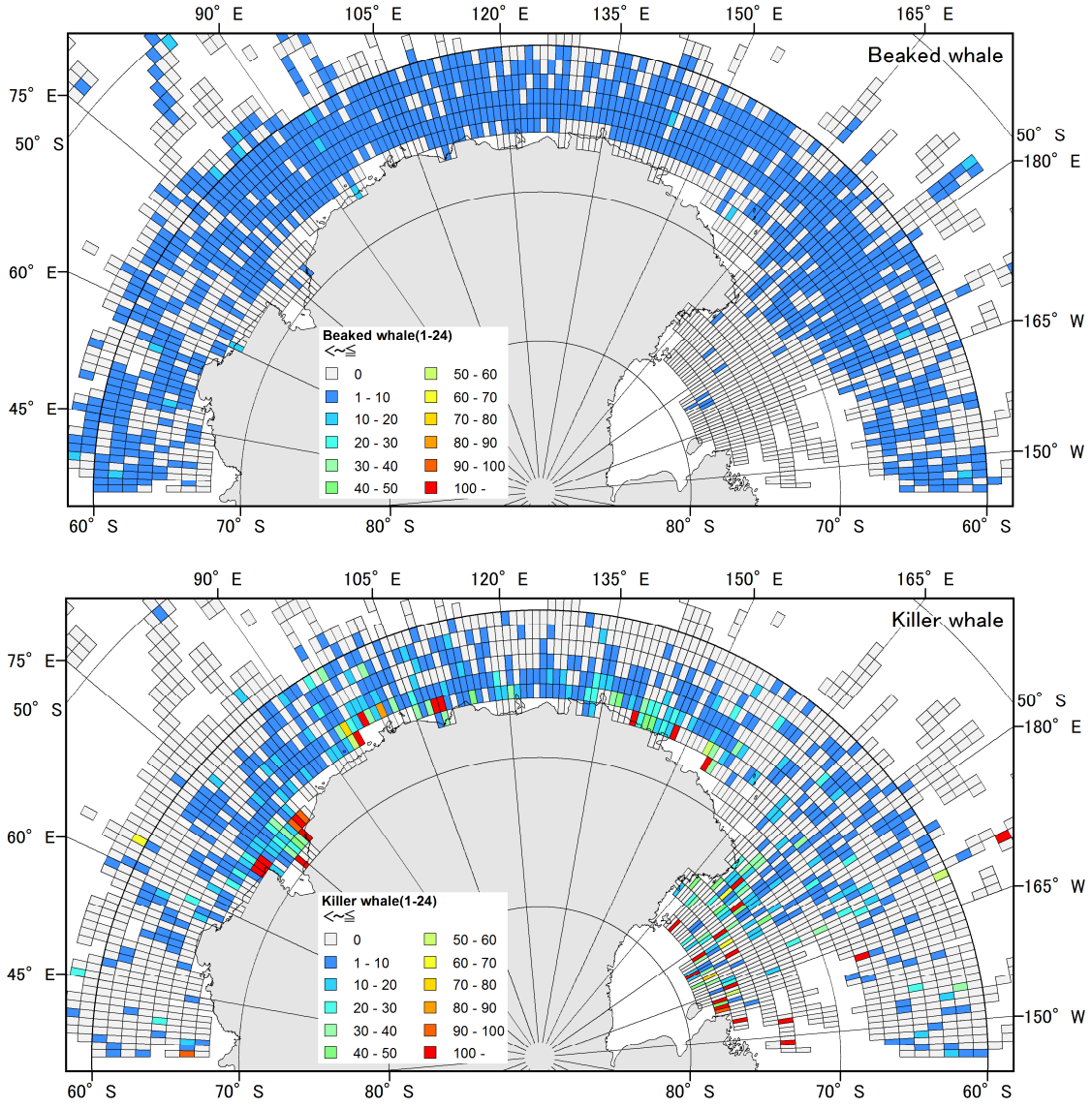

Figure 2d. Distribution of the Density Index (number of primary sightings of individuals / 100 n.miles) of unidentified beaked whales (top) and killer whales (bottom) during JARPA and JARPAII (1987/88-2008/09) by Lat.1°× Long.1°square.

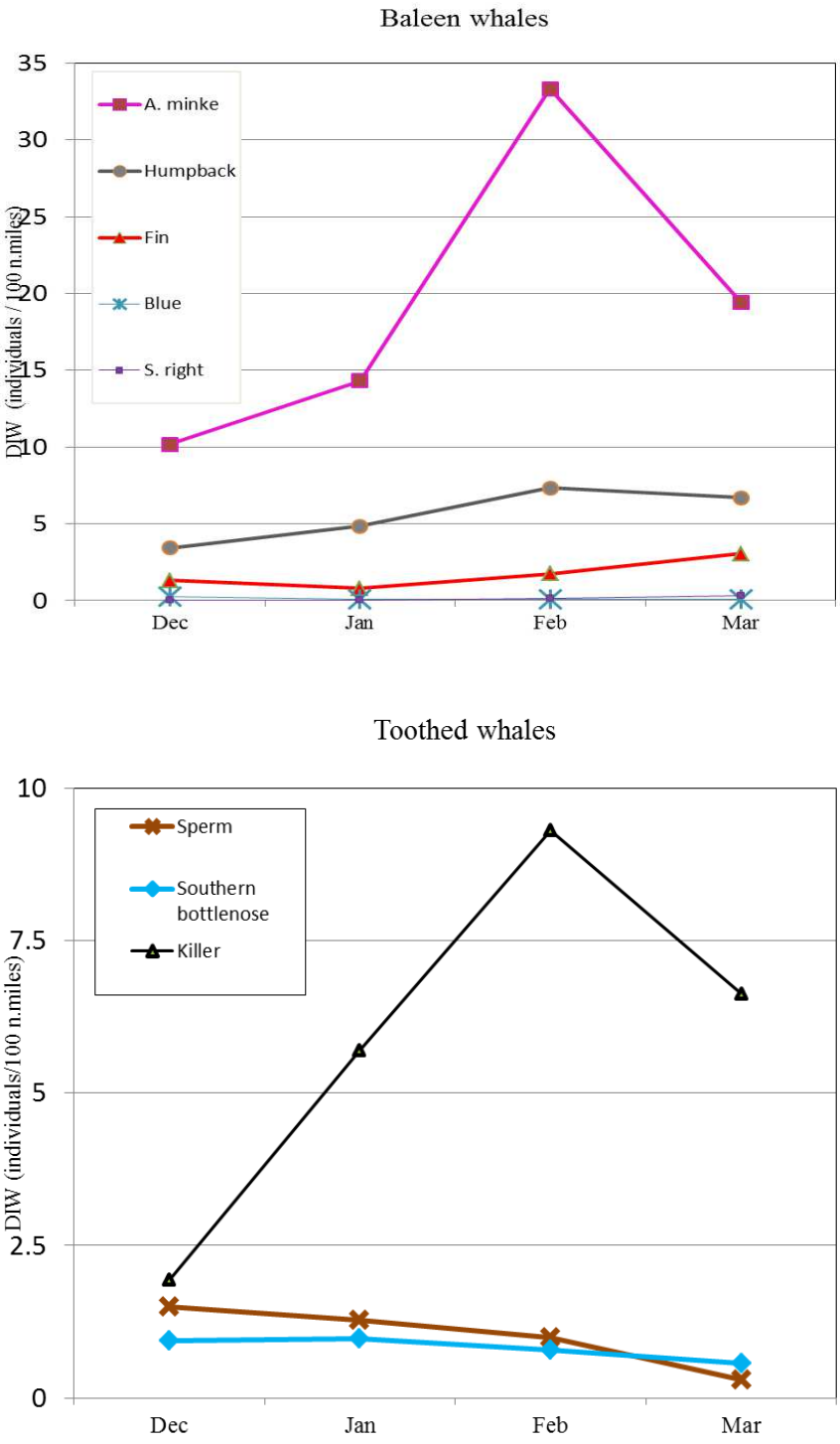

Figure 3. Monthly change of the density index (DIW: individuals / 100 n.miles) for baleen whales (top) and toothed whales (bottom) in the whole research area (Areas IIIE+IV+V+VIW) during JARPA and JARPAII (1987/88-2008/09).