Day after sea ice melt index in IDCR/SOWER CPII and CPIII

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ABSTRACT

Day after sea ice melt index in IDCR/SOWER CPII and CPIII was prepared using sighting effort data and sea ice data derived by satellite. Sighting effort data were divided into 1 km segments. Days after sea ice melt were calculated for each 1 km segment. The results suggested that timing of the surveys in relation to timing of sea ice melt was varied in both regions and years. The day after sea ice melt index will be used as one of the environmental variables in future studies to account for reasons of difference of abundance estimate of Antarctic minke whales between CPII and CPIII.

INTRODUCTION

The International Whaling Commission (IWC) conducted sighting surveys for assessing the abundance of the Antarctic minke whale (*Balaenoptera bonaerensis*) from 1978/79 to 2009/10 in the Antarctic in austral summer (Matsuoka *et al.*, 2003 for review). The names of the cruises were firstly the International Decade of Cetacean Research programme (IDCR, from 1978/79 to 1995/96) and then the Southern Ocean Whale and Ecosystem Research programme (SOWER, from 1996/97 to 2009/10). These cruises covered three circumpolar surveys for the purpose of comprehensive assessments: 1978/79-1983/84 (first circumpolar, CPI), 1984/85-1990/91 (second circumpolar, CPII) and 1991/92-2003/2004 (third circumpolar, CPIII). Abundance estimates based on the IWC standard method revealed that an appreciable difference of abundance between CPII and CPIII (Branch and Butterworth, 2001; Branch, 2006). The reasons of the difference have been investigated by the Scientific Committee of the IWC (IWC/SC) since 2001 (IWC, 2002a) but conclusion has not been reached.

As pagophilic (ice-loving) species, Antarctic minke whales are mainly distributed along ice edge (Kasamatsu, *et al.*, 2000; Murase, *et al.*, 2002) as well as in the south of ice edge (Kelly, *et al.*, 2009). However, high densities of Antarctic minke whales were occasionally observed in the waters far from ice edge. For example, high density of Antarctic minke whales was observed in EN stratum of Area II in CPII. Correlation between environmental factors (sea surface temperature and distance from the ice edge) and the high density of Antarctic minke whales in the offshore was investigated but no clear relationship was found (Kasamatsu *et al.* 1998). The effect of timing of sea ice melt on distribution pattern of minke whales was discussed in the 60th IWC/SC (IWC, 2009). Preliminary examination revealed the qualitative relationship between timing of sea ice melt and density of Antarctic minke whales in Area II (Murase and Ensor, 2009). Preparation of the timing of sea ice melt index for the entire time series of CPII and CPIII was recommended in the 61st IWC/SC (IWC, 2010). In this paper, day after sea ice melt index in IDCR/SOWER CPII and CPIII is presented. This exercise was conducted based on the recommendation of the 62nd IWC/SC (IWC, 2011).

MATERIALS AND METHODS

Sighting effort data prepared as a standard data (Burt, 2004) were used in this analysis. Sighting effort data were separated in 1 km segments. Because more than one survey was conducted in same longitudinal sector in CPIII, survey-once option described in Branch (2005) was used in this paper. Satellite derived daily sea ice data, Bootstrap Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I (Comiso, 1999) from 1978 to 2004 was used in the analysis. The data was provided by the National Snow and Ice Data Center (NSIDC, US). Sea ice observation using the satellite passive microwave sensors was started with the launch of Scanning Multichannel Microwave Radiometer (SMMR) on Nimbus-7 in 1978. The sensor was changed to Special Sensor Microwave/Imager (SSM/I) in 1987 and the data collection is still on going. The data were collected every other day for the SMMR whereas those were collected every day for the SSM/I. Sea ice concentration is expressed as percentage of area covered by sea ice in every 25km×25 km grid cell. Sea ice concentrations more than 15% was considered as grid cells with sea ice as in the cases of other studies (Bjøgo, et al., 1997; Hanna, 2001; Zwally, et al., 2002). (Bjøgo, et al., 1997; Hanna, 2001; Zwally, et al., 2002). Therefore, grid cells with more than 15% sea ice concentrations were used in this analysis. The original data was in the NSIDC polar stereographic projection. Nearest sea ice data corresponding to the center positions of segmented sighting effort data were used to

calculate days after sea ice melt. Number of days were counted from the survey date of each segmented sighting effort until encountering the day with more than 15% sea ice concentrations.

RESULTS AND DISCUSSION

Summaries of sighting effort distance (km) by days after sea ice melt in each 5º longitudinal sector in the IWC management areas in CPII and CPIII is shown in Tables 1-6. Spatial distribution patterns of sighting effort in terms of days after sea ice melt are shown in Fig. 1-6. The results suggested that timing of survey in terms of timing of sea ice melt was varied in both regions and years. The day after sea ice melt index will be used as one of the environmental variables in future studies to account for reasons of difference of abundance estimate of Antarctic minke whales between CPII and CPIII.

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Table 1. Summary of sighting effort distance (km) by days after sea ice melt in each 5º longitudinal sector in Area I in CPII and CPIII.

Days after ice melt	Area I												Total
	CPII (1989/1990)												
	120W-115W	115W-110W	110W-105W	105W-100W	100W-95W	95W-90W	90W-85W	85W-80W	80W-75W	75W-70W	70W-65W	65W-60W	
0-9	73	89	109		149	19	41	110	129			26	745
10-19	159	57	79	47	40	295	51	25	56				810
20-29	116	61	121	187	178	49	158	99	9	91			1,068
30-39	31	76	307	69	96	74	13						666
40-49	36	42	6	141					4				228
50-59	108	83	88	283	193	210	85	207	296	49			1,602
60≤	86	56	256	150	216	341	343	355	584	570	1,287	702	4,947
Total	609	465	967	876	872	988	692	796	1,077	710	1,287	728	10,065

Days after ice melt	Area I												Total
	CPIII (2000/2001)		CPIII (1993/1994)						CPIII (1999/2000)				
	120W-115W	115W-110W	110W-105W	105W-100W	100W-95W	95W-90W	90W-85W	85W-80W	80W-75W	75W-70W	70W-65W	65W-60W	
0-9	112	83	219	52	12		63	84	60	2			688
10-19	34	45	176	386	24								664
20-29	84	182	137	191	257	62		39	47	20			1,018
30-39	3	64		56	288	88	42	20		28			589
40-49	66					18	196	196	44				520
50-59	144	95		94	70	165	83	44	61		44		801
60≤	606	868	527	188	523	332	685	748	1,075	730	781	514	7,577
Total	1,050	1,337	1,059	967	1,174	666	1,069	1,130	1,288	780	825	514	11,857

Table 2. Summary of sighting effort distance (km) by days after sea ice melt in each 5º longitudinal sector in Area II in CPII and CPIII.

Days after ice melt	Area II												Total
	CPII (1986/1987)												
	60W-55W	55W-50W	50W-45W	45W-40W	40W-35W	35W-30W	30W-25W	25W-20W	20W-15W	15W-10W	10W-5W	5W-0	
0-9	88	121				2	31	584	38			47	911
10-19	43	37		47	294	375	726	1,076	966	163	59		3,785
20-29	19			119	376	316	179	372	367	558	9	101	2,415
30-39	97			430	221	103	9	161	289	797	652	34	2,793
40-49	46			78	7			56		26	454	369	1,036
50-59	57	10		39							18	562	685
60≤	48	521	619	123									1,311
Total	398	688	619	835	898	797	945	2,249	1,659	1,544	1,192	1,113	12,936

Days after ice melt	Area II												Total
	CPIII (1997/1998)							CPIII (1996/1997)					
	60W-55W	55W-50W	50W-45W	45W-40W	40W-35W	35W-30W	30W-25W	25W-20W	20W-15W	15W-10W	10W-5W	5W-0	
0-9					48				120		43	27	238
10-19		85	63	121	397	17			33		46	31	793
20-29	11	133	2	16	810	499	5		166	340	133	175	2,290
30-39		50		54	153	671	538	15	452	296	110	395	2,735
40-49	7			172		30	637	564	375	477	841	248	3,351
50-59	34	15	136	119			69	346	238	47		38	1,041
60≤	329	142	307					188					965
Total	380	425	507	482	1,407	1,216	1,250	1,112	1,385	1,161	1,174	913	11,413

Table 3. Summary of sighting effort distance (km) by days after sea ice melt in each 5º longitudinal sector in Area III in CPII and CPIII. Note that satellite sea ice data were not available between 30ºE and 70ºE in CPII.

Days after ice melt	Area III													Total
	CPII (1987/1988)													
	0-5E	5E-10E	10E-15E	15E-20E	20E-25E	25E-30E	30E-35E	35E-40E	40E-45E	45E-50E	50E-55E	55E-60E	60E-65E	65E-70E	
0-9							NA								0
10-19															0
20-29															0
30-39						84									84
40-49		43	374	503	578	775									2,274
50-59	142	391	118	130											782
60≤															0
Total	142	434	491	634	578	860									3,140

Days after ice melt	Area III														Total
	CPIII (1992/1993)								CPIII (1994/1995)						
	0-5E	5E-10E	10E-15E	15E-20E	20E-25E	25E-30E	30E-35E	35E-40E	40E-45E	45E-50E	50E-55E	55E-60E	60E-65E	65E-70E	
0-9	22		55	63	22	19		55	132	100	59	70	34	49	680
10-19	623	17	287	1,120	658	33	6	82	119	68	149	83	8	35	3,289
20-29	525	680	622	487	359	1,197	434	123	177	36		17	106	236	5,001
30-39	10	243	81		307	182	594	413	172	100	17	125	190	48	2,481
40-49						70	23	178	237	323	179	116	37	20	1,183
50-59								60	64	262	138	87	26	145	781
60≤									8	8	224	305	541	414	1,501
Total	1,180	940	1,044	1,670	1,346	1,502	1,058	912	910	897	765	803	941	949	14,917

Table 4. Summary of sighting effort distance (km) by days after sea ice melt in each 5º longitudinal sector in Area IV in CPII and CPIII.

Days after ice melt	Area IV												Total
	CPII (1988/1989)												
	70E-75E	75E-80E	80E-85E	85E-90E	90E-95E	95E-100E	100E-105E	105E-110E	110E-115E	115E-120E	120E-125E	125E-130E	
0-9	140	208	163	306	56	139	226	204	194	189	136		1,961
10-19	422	35	81	105	112	88	8	70	51	28			1,000
20-29	728	260	49	88	274	269	79	29	33	42	7		1,857
30-39	163	297	68	344	257	25	85	38		31	8		1,315
40-49	89	292	248		151	121	134	50	17	48	18		1,168
50-59	137	266	208	143	25	69	24	75	51	131	41		1,171
60≤					42	82	196	496	668	545	297	95	2,421
Total	1,679	1,357	815	986	916	794	752	963	1,014	1,014	507	95	10,894

Days after ice melt	Area IV												Total
	CPIII (1994/1995)		CPIII (1998/1999)										
	70E-75E	75E-80E	80E-85E	85E-90E	90E-95E	95E-100E	100E-105E	105E-110E	110E-115E	115E-120E	120E-125E	125E-130E	
0-9	35		144	69	65	87	134	95	126	51	64	82	953
10-19		21	100			75	24			87	96	38	441
20-29	76	116	8		2		121	85		40	18	18	485
30-39	251	55	63	128	34	93	14	11		33	63	41	786
40-49	239	137	90	36	24		60	84			54	45	768
50-59	329	83	194	189	127		9	48		35	59	55	1,127
60≤	429	919	138	179	518	402	339	352	536	521	540	542	5,416
Total	1,359	1,331	738	600	770	657	702	675	663	766	894	821	9,976

Table 5. Summary of sighting effort distance (km) by days after sea ice melt in each 5º longitudinal sector in Area V in CPII and CPIII.

Days after ice melt	Area V															Total
	CPII (1985/1986)															
	130E-135E	135E-140E	140E-145E	145E-150E	150E-155E	155E-160E	160E-165E	165E-170E	170E-175E	175E-180	180-175W	175W-170W	170W-165W	165W-160W	160W-155W	
0-9		115		197	34		88	307	68	27	30	199	40	2		1,108
10-19					23	78	465	19	366			84	95			1,131
20-29		4		100	167	332	106	133	338	92	97	254	128			1,753
30-39			12	7	17	89	196	121	137	154	175	61	26			996
40-49		36	16	30	33	44	82	217	289	364	619	169	5	93		1,998
50-59			142	111	203	161	14	50	54	568	551	71	23	77		2,026
60≤	52	123	253	835	743	359	540	397	650	653	431	702	209	230		6,178
Total	52	278	424	1,280	1,221	1,064	1,492	1,245	1,904	1,858	1,903	1,541	527	402	0	15,189

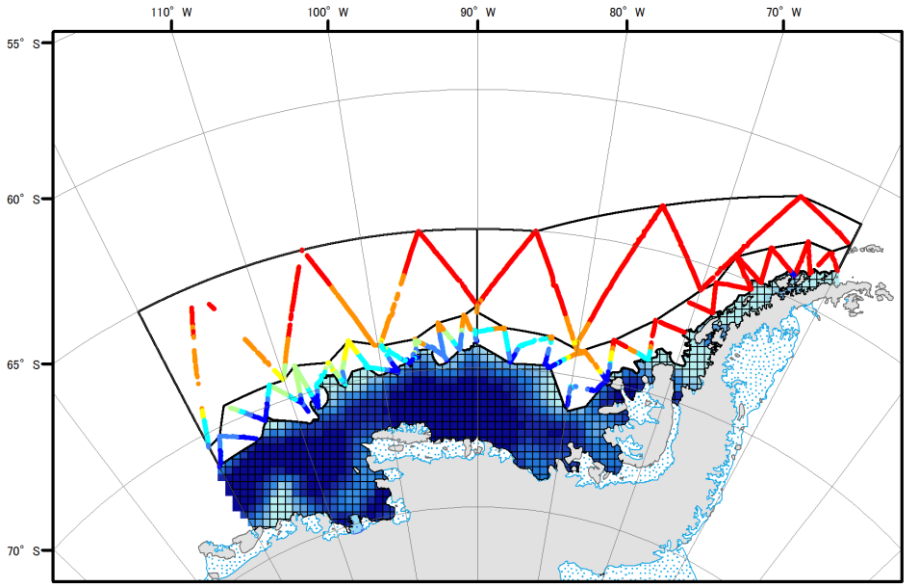
Days after ice melt	Area V															Total
	CPIII (2001/2002)				CPIII (2002/2003)				CPIII (2003/2004)							
	130E-135E	135E-140E	140E-145E	145E-150E	150E-155E	155E-160E	160E-165E	165E-170E	170E-175E	175E-180	180-175W	175W-170W	170W-165W	165W-160W	160W-155W	
0-9	10	62		77	113	175	114	278	141	200	126	304	132	30	31	1,794
10-19	278	55		16	21		47	401	93	106	85	163	132	15	7	1,418
20-29		185		20	0	34	184	94	125	342	226	232		34	1	1,478
30-39	119	111	262		72	79	34	254	116	528	508	153	135			2,371
40-49	19	135	117		20	93	87	44	311	200	212	53	21	107		1,418
50-59		127	44	19	173	26	1	48	467		104	404		118		1,533
60≤	441	302	356	776	379	386	115	327	489	471	474	544		33		5,092
Total	868	978	780	908	777	793	582	1,446	1,742	1,846	1,736	1,853	420	337	39	15,104

Table 6. Summary of sighting effort distance (km) by days after sea ice melt in each 5º longitudinal sector in Area VI in CPII and CPIII.

Days after ice melt	Area VI										Total
	CPII (1990/1991)										
	170W-165W	165W-160W	160W-155W	155W-150W	150W-145W	145W-140W	140W-135W	135W-130W	130W-125W	125W-120W	
0-9	186	135	24				47		31		423
10-19	36	19	59	91	106		209		18		537
20-29		15	14	4			76		139	15	263
30-39	20	4	213	180	118	59	168	147	48		958
40-49	125	81	348	41	164	231	109	77		165	1,342
50-59	13		176	30	1	256	49	125		92	742
60≤	450	468	28	106	253	217	476	40		96	2,134
Total	830	722	862	453	642	764	1,134	388	236	368	6,399

Days after ice melt	Area VI										Total
	CPIII (1995/1996)						CPIII (2000/2001)				
	170W-165W	165W-160W	160W-155W	155W-150W	150W-145W	145W-140W	140W-135W	135W-130W	130W-125W	125W-120W	
0-9	6	122		51	27		20	5	2	43	277
10-19	5	144	301	322	444	85	247	154	40		1,742
20-29	244	160	509	270	97	192	84	223	309	188	2,276
30-39	193	277	70	123	108	63	77	105	55		1,070
40-49	48	282	119	49	127	12	65		44	97	842
50-59	23			29	27	12	144	127	156	56	575
60≤	180	261	301	325	209	171	217	276	204	785	2,930
Total	700	1,247	1,300	1,169	1,038	535	854	889	811	1,169	9,712

Area I CPII (1989/90)



Area I CPIII (1993/94, 1999/00, 2000/01)

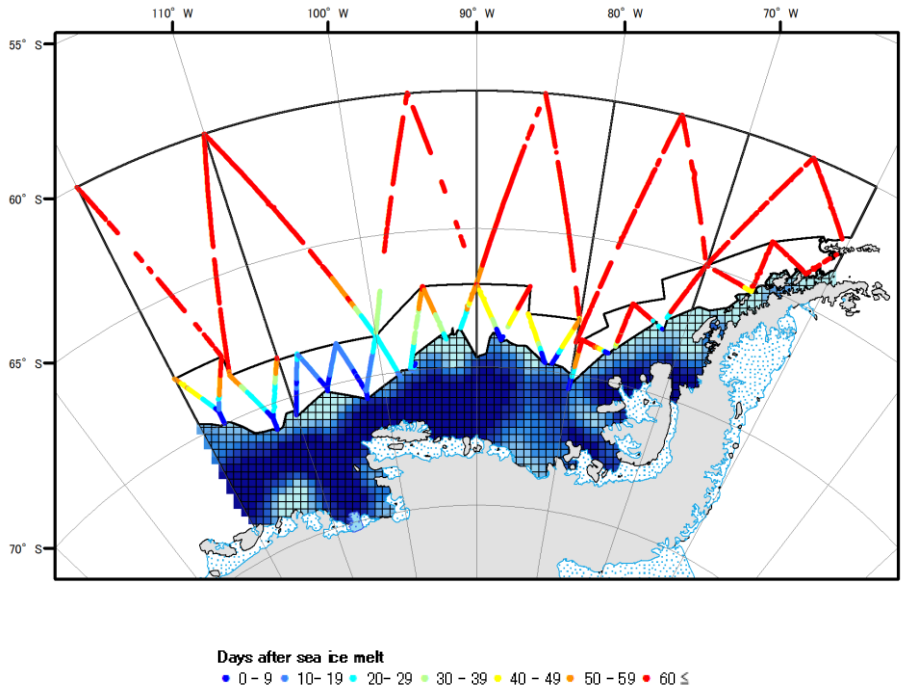
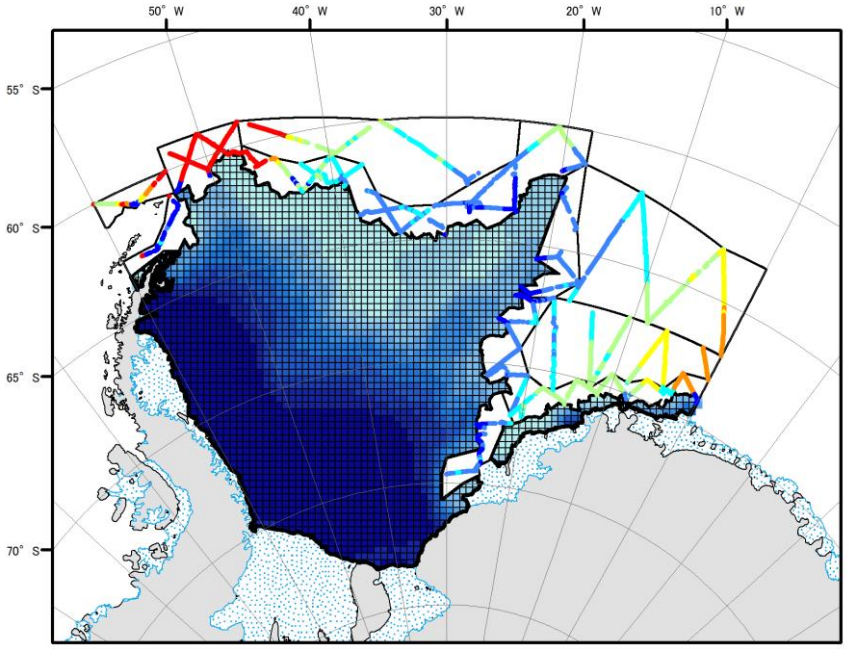


Fig. 1. Spatial distribution patterns of the sighting survey efforts in terms of days after sea ice melt in Area I in CPII (top) and CPIII (bottom).

Area II CPII (1986/87)



Area II CPIII (1996/97, 1997/98)

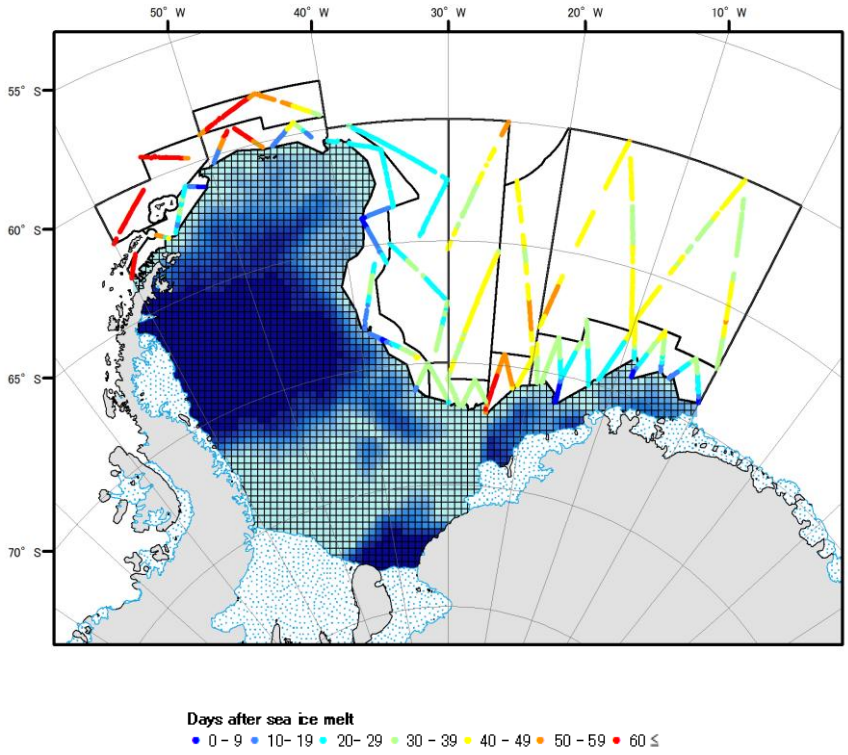
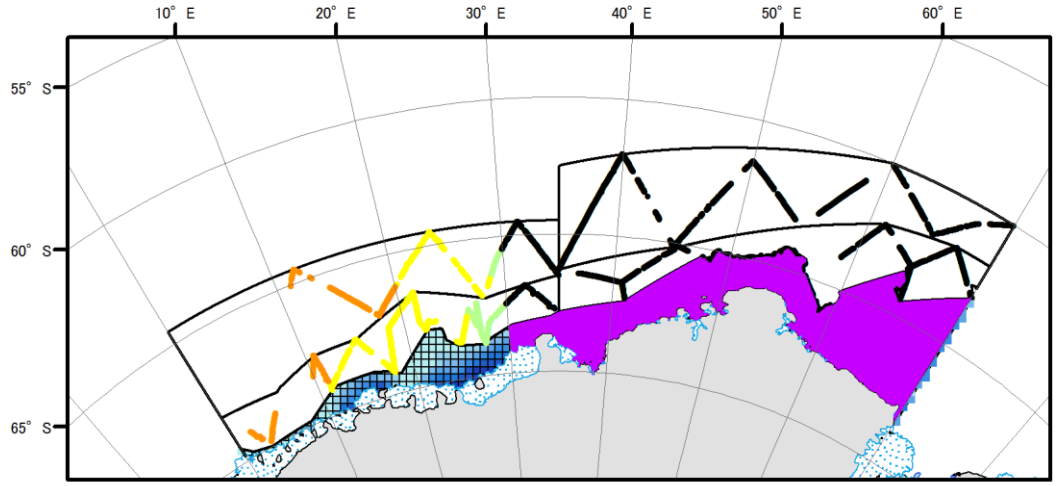


Fig. 2. Spatial distribution patterns of the sighting survey efforts in terms of days after sea ice melt in Area II in CPII (top) and CPIII (bottom).

Area III CPII (1987/88)



Area III CPIII (1992/93, 1994/95)

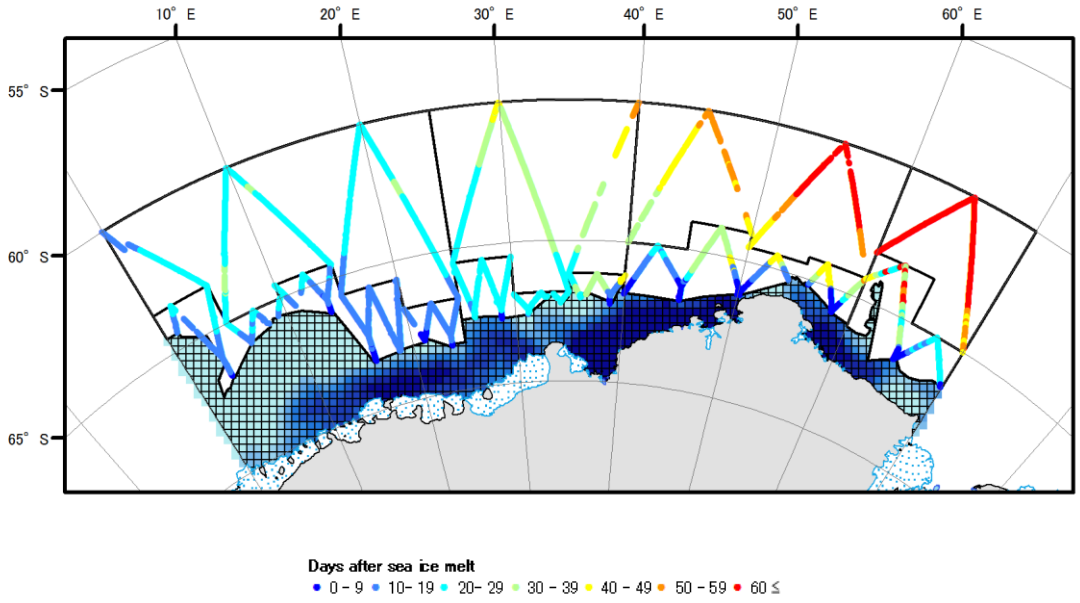
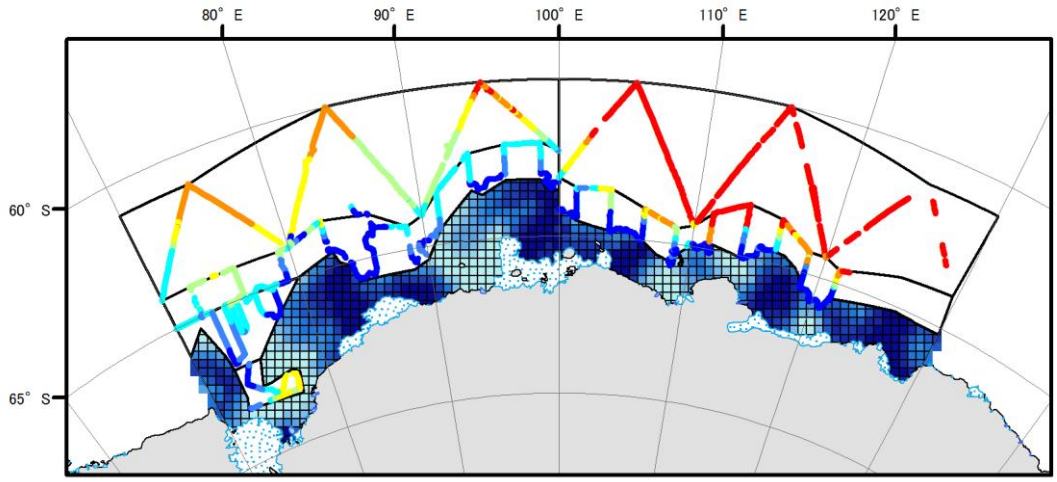


Fig. 3. Spatial distribution patterns of the sighting survey efforts in terms of days after sea ice melt in Area III in CPII (top) and CPIII (bottom). Note that satellite sea ice data were not available between 30ºE and 70ºE in CPII (purple area in the top).

Area IV CPII (1988/89)



Area IV CPIII (1994/95, 1998/99)

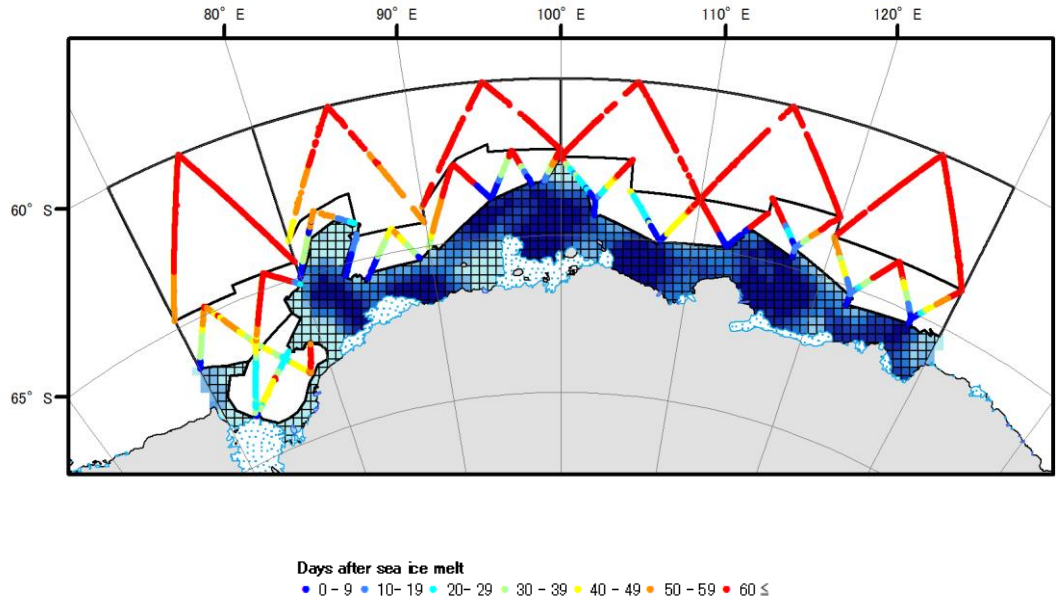
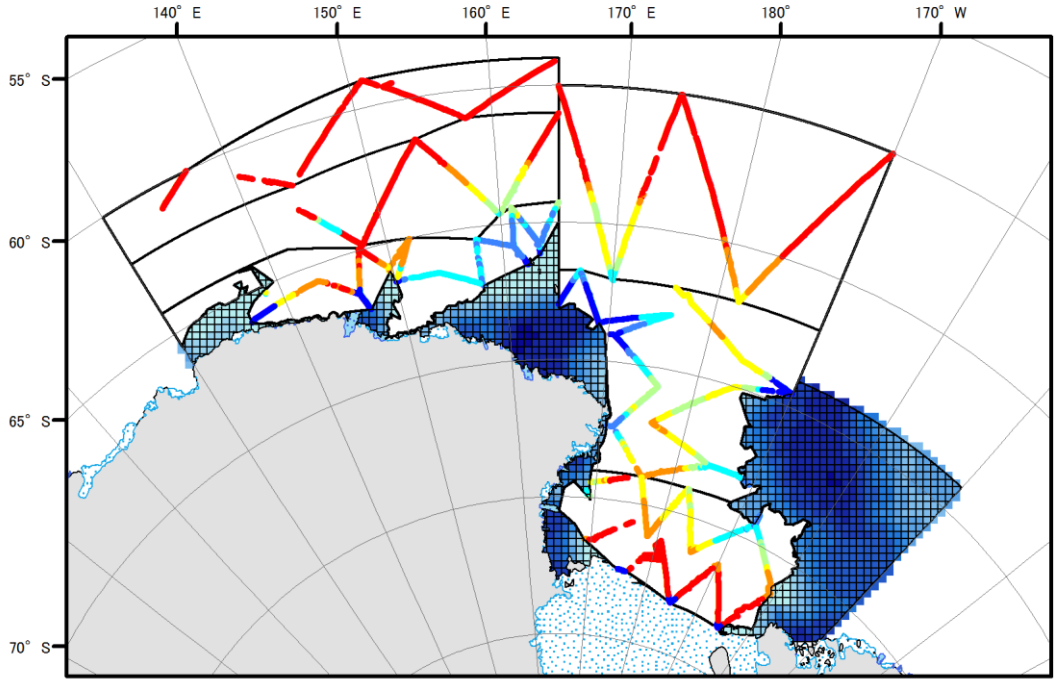


Fig. 4 Spatial distribution patterns of the sighting survey efforts in terms of days after sea ice melt in Area IV in CPII (top) and CPIII (bottom).

Area V CPII (1985/86)



Area V CPIII (2001/02, 2002/03, 2003/04)

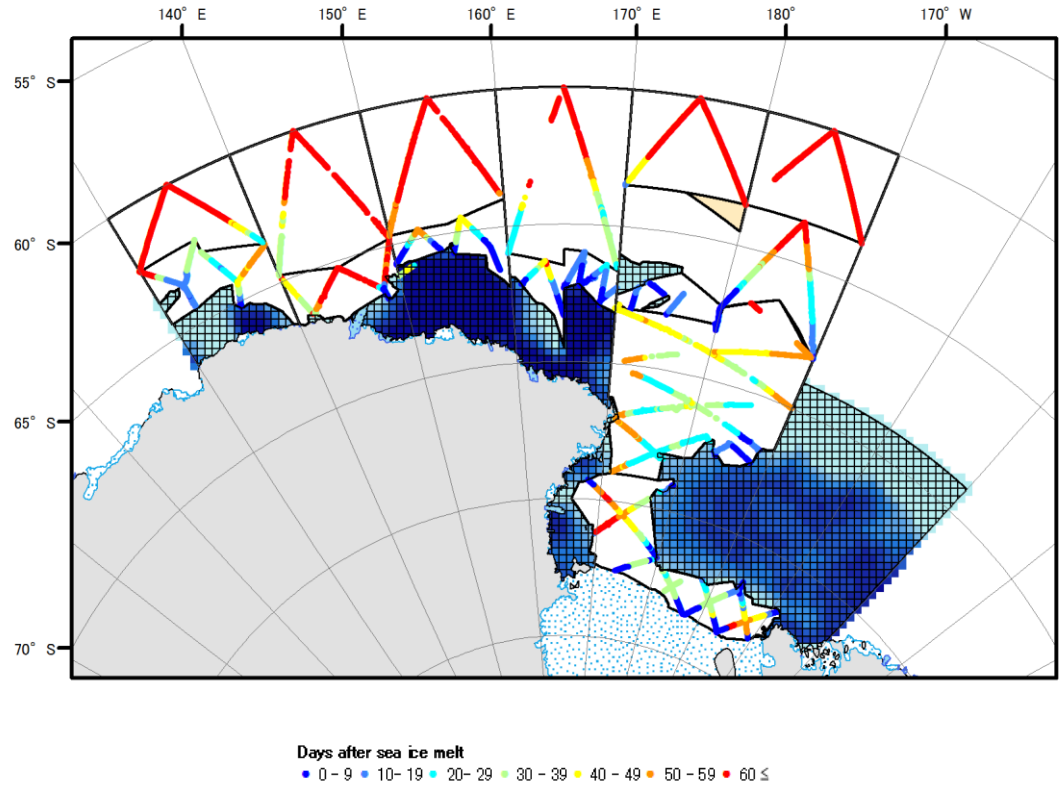
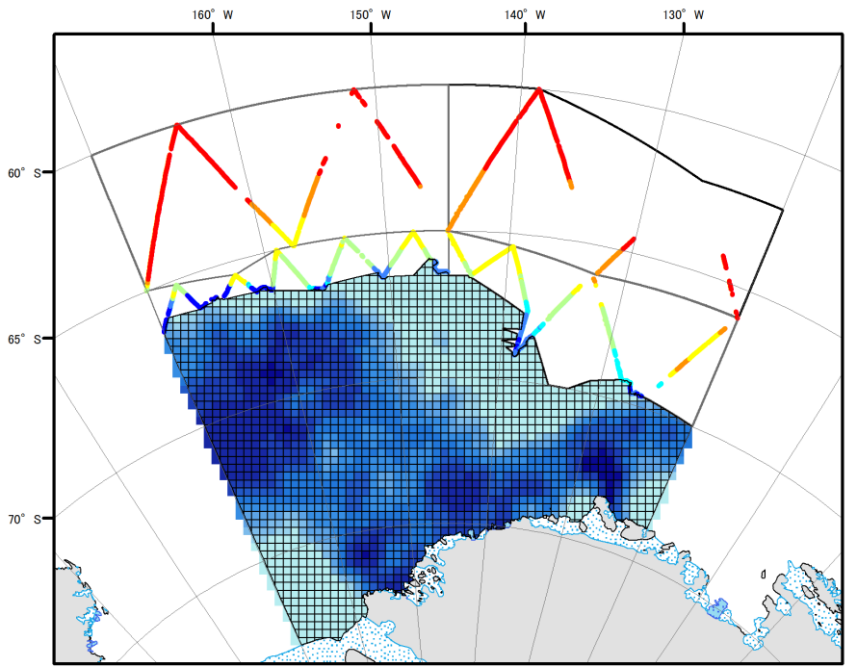


Fig. 5. Spatial distribution patterns of the sighting survey efforts in terms of days after sea ice melt in Area V in CPII (top) and CPIII (bottom).

Area VI CPII (1990/91)



Aera VI CPIII (1995/96, 2000/01)

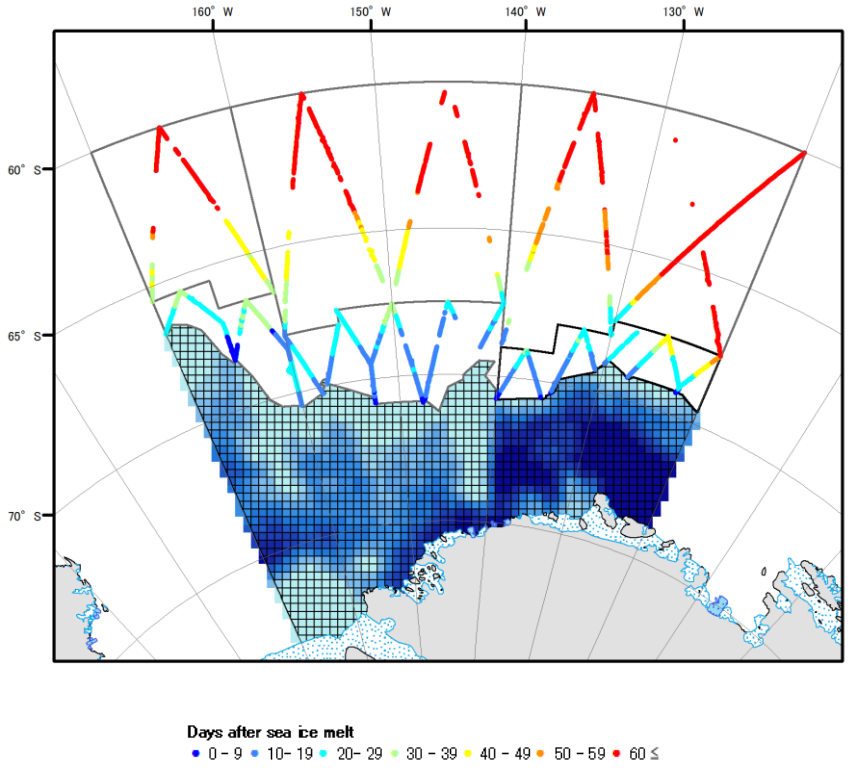


Fig. 6. Spatial distribution patterns of the sighting survey efforts in terms of days after sea ice melt in Area VI in CPII (top) and CPIII (bottom).