Distribution pattern of sperm whales in the Western North Pacific based on sighting survey data of the JARPN/JARPNII between 1994 and 2004

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ABSTRACT

This paper reports distribution pattern of sperm whale (*Physeter macrocephalus*) in the Western North Pacific based on sighting data during JARPN and JARPN II between 1994 and 2004. Research area was set in the IWC/management sub-areas 7, 8 and 9 between Japanese coast and 170° E (north of 35° N) exclude foreign EEZ. Research period was from April to September. Total effort was 138,908 n.miles and 2,571 sperm whale schools (4,852 individuals) were observed in the research area during the surveys. The Density Index (no. of whales / 100 n.miles, by lat. 1°x long. 1° square) was calculated for distribution pattern of each year and month in each sub-area. Sperm whales were widely distributed in the whole research area. The DIs were 4.96, 3.07 and 2.49 in sub-areas 7, 8 and 9, respectively. High whale density areas were observed in coastal region in May and were observed in the near the Emperor Sea-mount in offshore region in September. Sea surface temperature of the sighting positions ranged from 5.0 – 27.0 ° C. Solitaly large male sperm whales were mainly observed in sub-area 9 from July to August. Mean school sizes gradually decrease from sub-area 7 to sub-area 9. Most solitaly animals were observed in the waters north of 40° N. Mean school sizes were 3.00, 2.74, 2.40, 1.70, 1.43, 1.85 and 1.89 from April to September, respectively. The main distribution areas moved northward from 40 ° N to 45 ° N from May to September in the sub-areas 8 and 9, and this phenomenon coincides with the northward seasonal migration of the species. Further monitoring survey such as large-scale and long term line transect surveys will contribute for the sperm whale population management in the Western North Pacific.

KEY WORDS: WESTERN NORTH PACIFIC, SURVEY-VESSEL, DISTRIBUTION, SPERM WHALE

INTRODUCTION

The JARPN (Japanese Whale Research Program under Special Permit in the Western part of North Pacific) was designed with the aim mainly to elucidate the stock structure in the western North Pacific minke whale. It had been conducted the systematic whale sighting survey for all cetacean species with the sampling activity from 1994-1999 seasons. The JARPNII have been conducted since 2000 season to study the feeding ecology of minke, Bryde's, sperm and Sei whales, to study oceanic contamination in whales and to clarify the stock structure of whales in the western North Pacific. The sighting information tied up with sampling activity was accumulated through the JARPN and JARPNII. It covered the Pacific waters north of 35 ° N in sub-areas 7, 8 and 9 except the 200 n.miles EEZ of foreign countries (Fig. 1). In the Sea of Okhotsk, it covered only sub-area 11 also except the Russian EEZ. Details of the outline of the JARPN and JARPNII surveys were reviewed by Fujise *et al.*, (2000 and 2003).

It is well known that, in the western parts of North Pacific, sperm whales frequently occur in waters off Sanriku to Kurile coasts, where continental slope or edge of trench exist and in pelagic zone of middle latitudes around 30°N (Kato, 1995). Kato and Miyashita (1998) estimated population abundance of sperm whales to be 102,000 (CV= 0.155) in west of 180° under assumption of g(0) =0.32 (CV=0.11) and they also noted an encounter rate increasing at 11% per annum from 1987 to 1996. In JARPN (1994-1999) surveys, this

species were widely distributed in sub-areas 7, 8 and 9, further solitary schools were 82 % of this species. Most of plural schools were sighted in sub-area 7 (Matsuoka *et al.*, 2000). In this paper, we examined the sperm whale distribution pattern using the JARPN and JARPNII sighting data to investigate distribution pattern and monthly change of the Density Index in the sub-areas 7, 8 and 9.

MATERIAL AND METHODS

Sighting procedure

The sighting procedure was not largely changed from the JARPN (1994-1999) to the JARPNII (2000-2004) surveys with some minor changes of the sighting procedure (Fujise *et al.*, 2003). The research vessels equipped with barrel, where three top men conducted sighting observation. On the upper bridge, a captain, a gunner, a helmsman and a researcher also conducted the whale sightings. The sighting activity continues if weather condition was permitted during daytime from 60 minutes after sunrise to 60 minutes before the sunset.

Survey mode

Searching was conducted under closing mode. Furthermore, two survey modes were adopted as NSC (Normal Search Closing, effort code was BC) mode and NSS (Normal Search closing with Special, effort code was BS) modes by taking into consideration of the sea condition at the time of the searching. The NSC (BC) mode was under the normal weather conditions defined as visibility of 2 n.miles or more and wind scale 4 or below. The NSS (BS) was conducted under the unfavorable conditions defined except the BC mode, but under which, the collection of whale samples was possible.

Confirmation of the whale school

When a cetacean school of which species seemed to be large cetaceans was sighted in the research area, the ship closed to the school immediately in order to identify the species, estimate the school size and get other biological informations (for example; body length). To improve the estimation of the distance to the school and the angle from the bow, the training was conducted in the early period of each cruise by each vessel. Distance was estimated by referring the scale in the binocular and angle was also estimated referring the angle board.

Research vessels

Kyo-Maru No.1, Toshi-Maru No.25, Toshi-Maru No.18 operated for the surveys from 1994 to 1998 survey. *Kyosin-Maru No.2* has been engaged since 1996 survey. *Yusin-Maru* operated from 1999 survey as the replacement of *Toshi-Maru No.18. Yusin-Maru No.2* operated from 2002 survey as the replacement of *Toshi-Maru No.25.*

The Density Index (DI)

The Density Index (number of primary sightings of whales (individuals) / 100 n.miles, by lat. 1°x long. 1° square) of sperm whale distribution in the research sub-area was calculated by month.

Bottom topography

The depth of the sea where each sperm whales were sighted was calculated using the Marine Explore (ME) by the Enviroment Simulation Labolatory Co., Ltd (http://www.esl.co.jp).

Monthly sea surface temperature

Monthly mean sea surface temperature data was calcurated by the PO.DAAC Ocean ESIP Tool (POET). This interface was developed by Ocean ESIP, a member of the Earth Science Information Partner Federation, under contract to NASA.

RESULTS AND DISCUSSIONS

Distribution pattern

Fig.1. shows the research area (sub-area 7, 8 and 9) of JARPN (1994-1999) and JARPNII(2000-2004) in the Western North Pacific. Fig.2. shows distribution of the search effort by each Lat.1°× Long.1°square. The research area was covered almost uniformly during 1994 to 2004 surveys. Fig. 3 shows the all sighting position of the primary sightings of sperm whales during 1994-2004, including transit surveys with bottom topography. They tended to concentrate in the coastal region (sub-area 7) and northern part of the sub-areas 8 and 9. Fig. 4 shows the map of the DIW of sperm whales during 1994-2004, including transit surveys. High whale density areas were observed in each sub-area between 35°N and 40°N. Maximum value of the DIW was 30.2 (individuals / 100 n.miles). Fig. 5 shows the search effort distribution and sighting position of the primary sightings of sperm whales by each survey. Sperm whales were widely distributed in the sub-areas 7, 8 and 9 from the Japanese coastal region to off shore region. High density areas were observed in coastal region in May and were observed near the Emperor Sea-mount in offshore region of sub-area 9 in September. Sea surface temperature of the sighting positions ranged from 5.0 – 27.0 ° C.

Mean school size

Table 1 shows the number of schools and individuals from 1994 to 2004 by each sub-area. 872 schools (2,493 individuals, mean school size; 2.86) were observed in sub-area 7, 556 schools (800 individuals, mean school size; 1.44) were observed in sub-area 8, 1,143 schools (1,559 individuals, mean school size; 1.36) were observed in sub-area 9, respectively. Most of plural schools were sighted in sub-area 7. Average of the mean school sizes were 3.00, 2.74, 2.40, 1.70, 1.43, 1.85 and 1.89, respectively from May to September in the research area (Table 2). Mean school size decreases from sub-area 7 to sub-area 9 (Fig.6). Solitary schools occupied 55 % of this species in sub-area 7, 84% in sub-area 8 and 88 % in sub-area 9. Most solitaly animals were observed in the waters north of 45 ° N (Fig.7). Fig. 8 shows the relationship between the mean school size of sperm whale and Sea Surface Temperature (SST) which recorded for each school sighted in 1994-2004. Mean school sizes were changed when the SST of the sighting positions was lower than 17 ° C. Fig. 9 shows the relationship between the mean school size and estimated body length of sperm whale in 1994-2004. Mean school sizes were changed when the estimated body length was more than 15 meters. The large male solitaly animals which were estimated as body length over 15 meters were mainly distributed in sub-area 9 in the northern part of the research area (Fig.10).

Monthly and yearly change of the density index (DI)

Fig. 11 shows the sighting position of sperm whales and bottom topography in 1994-2004 by month. Fig. 12 shows the map of the DIW of sperm whales during 1994-2004, including transit surveys. Maximum values of the DIWs were 46.4, 90.3, 58.3, 62.9, 48.5 and 77.9 during April to September. Fig. 13 shows the yearly change of the DIW using efforts and number of primary sightings of sperm whales in the research sub-area (north of 35°N) between 1994 and 2004 surveys. The DIWs of sperm whales were estimated to increase gradually from 1994 to 2004 especially in sub-area 7. Fig. 14 shows the monthly searching effort between 1994 and 2004 surveys. Fig. 15 shows monthly change of the DIW using efforts and number of primary sightings of sperm whales in the research sub-area (north of 35°N) between 1994 and 2004 surveys. The DIW of sperm whales increase from May to September in sub-area 9, and decrease from May to September in sub-areas 7 and 8.

Northward migration pattern of sperm whales

Fig. 16 shows the relationship between the monthly mean SST distributions and sperm whale distribution from May to September in 2002. Contour interval is 5°C. To examin this relationship, we plotted sighting points of sperm whales on the SST map of each month. In the offshore region, sighting positions show a concentration in the Subarctic Boundary region around 40°N from May to July. In July, another concentration is found around 45°N. Sighting points were widely distributed in the Western Subarctic Gyre region north of 40°N in August.

The close relationship between warming of the area in July and the start of the northward shift of sighting points is seen in sub-areas 8 and 9. From large-scale overview, the main distribution areas of sperm whales were moved northward from 40 ° N to 45 ° N from May to July in Pacific sub-areas, which coincide with previous large-scale distribution pattern (Miyashita *et. al.* 1995).

Requirement of the international cooperation research in the foreign EEZ

Because of the latitudinal limitation of the research area by the foreign EEZ in the northern part of the sub-areas 7 and 8, decrease of monthly DIWs in these sub-areas may indicate northward migration pattern of this species from May to September. The latest sighting data of the Russian EEZ in the Sea of Okhotsk and the east of Kurile Islands during July and August were reported by Buckland *et al.*, (1992) using Japanese whale sighting survey data conducted by the National Research Institute of Far Seas Fisheries in Japan. Further surveys in May, June and September are required to improve the seasonal distribution of sperm and other large whales in future studies.

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Table 1. Summary of the primary sightings of sperm whales in the JARPN & JARPNII from 1994 to 2004 by each sub-area. MSS: mean school size. DIW: Density Index of whales (number of whales / 100 n.miles).

Year	sub-area 7				sub-area 8				sub-area 9				total			
	Sch.	Ind.	MSS	DIW	Sch.	Ind.	MSS	DIW	Sch.	Ind.	MSS	DIW	Sch.	Ind.	MSS	DIW
1994	1	2	2.00	1.83	0	0	0.00	0.00	132	149	1.13	1.99	133	151	1.14	1.96
1995	1	1	1.00	0.20	3	7	2.33	1.53	240	274	1.14	2.30	244	282	1.16	2.19
1996	92	214	2.33	4.25	204	250	1.23	4.35	1	1	1.00	8.77	297	465	1.57	4.31
1997	17	27	1.59	1.71	89	121	1.36	3.79	94	118	1.26	1.06	200	266	1.33	1.67
1998	74	212	2.86	5.10	34	61	1.79	1.70	0	0	0.00	0.00	108	273	2.53	3.52
1999	17	24	1.41	0.75	0	0	0.00	0.00	0	0	0.00	0.00	17	24	1.41	0.75
2000	93	246	2.65	2.92	9	9	1.00	7.53	60	72	1.20	4.27	162	327	2.02	3.19
2001	121	569	4.70	5.89	51	71	1.39	3.14	97	112	1.15	1.83	269	752	2.80	4.17
2002	180	418	2.32	6.57	48	60	1.25	1.43	83	91	1.10	1.68	311	569	1.83	3.56
2003	199	632	3.18	7.46	83	163	1.96	3.69	177	275	1.55	3.57	459	1,070	2.33	5.20
2004	77	148	1.92	5.37	35	58	1.66	2.90	259	467	1.80	4.21	371	673	1.81	4.24
total	872	2,493	2.86	4.96	556	800	1.44	3.07	1,143	1,559	1.36	2.49	2,571	4,852	1.89	3.49

Table 2. Summary of the primary sightings of sperm whales in the JARPN & JARPNII from 1994 to 2004 by each month (from May to September). MSS: mean school size. DIW: Density Index of whales (number of whales / 100 n.miles).

Month	sub-area 7				sub-area 8				sub-area 9				total			
	Sch.	Ind.	MSS	DIW	Sch.	Ind.	MSS	DIW	Sch.	Ind.	MSS	DIW	Sch.	Ind.	MSS	DIW
APR	17	51	3.00	3.40	0	0	0.00	0.00	0	0	0.00	0.00	17	51	3.00	3.40
MAY	206	733	3.56	6.17	60	115	1.92	3.00	70	74	1.06	1.15	336	922	2.74	4.16
JUN	176	589	3.35	5.10	96	170	1.77	2.61	144	240	1.67	1.71	416	999	2.40	3.11
JUL	97	311	3.21	4.86	250	340	1.36	4.19	309	466	1.51	2.21	656	1,117	1.70	3.13
AUG	194	484	2.49	4.33	96	109	1.14	2.37	561	624	1.11	3.36	851	1,217	1.43	3.55
SEP	182	325	1.79	4.19	54	66	1.22	2.22	59	155	2.63	6.28	295	546	1.85	4.14
total	872	2,493	2.86	4.96	556	800	1.44	3.07	1,143	1,559	1.36	2.49	2,571	4,852	1.89	3.49

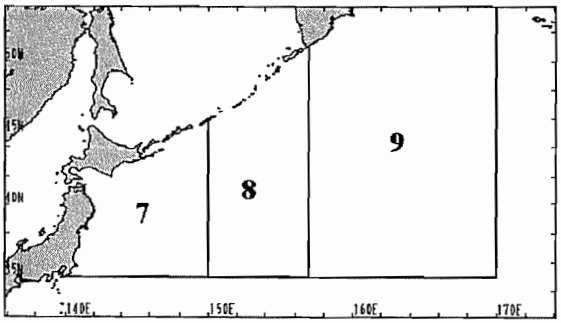


Fig.1. Research area of JARPN& JARPNII from 1994 to 2004 in the Western North Pacific(Sub-areas 7, 8 and 9). Sub-areas was used in the IST of Nprth Pacific Minke whales by IWC/SC.

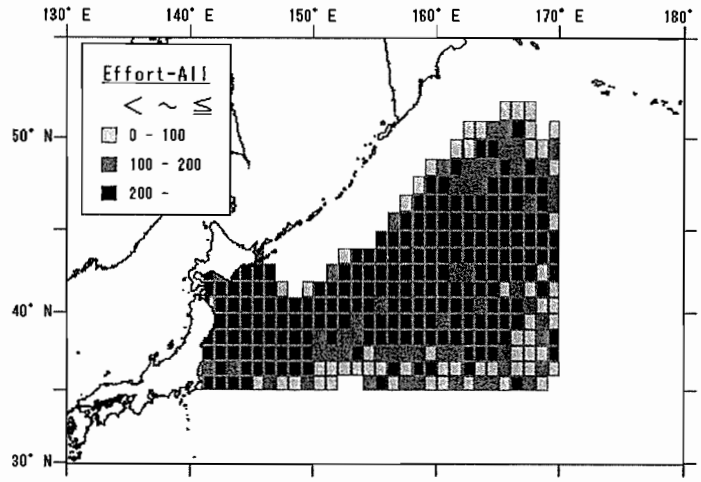


Fig.2. Distribution of the searching effort in the sub-area 7, 8 and 9 during the JARPN & JARPNII from 1994-2004.

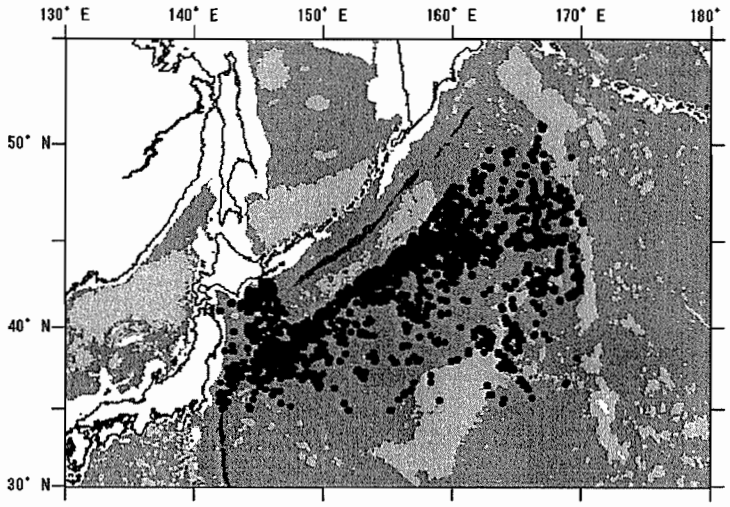


Fig.3. Sighting positions of sperm whales (black circle) in the sub-area 7, 8 and 9 during the JARPN & JARPNII from 1994-2004 with bottom topography. Light grey color show the depth of water less than 5,000 m. Grey color show the depth of water between 5,000 and 7,000 m. Dark grey color show the depth of water over 8,000 m.

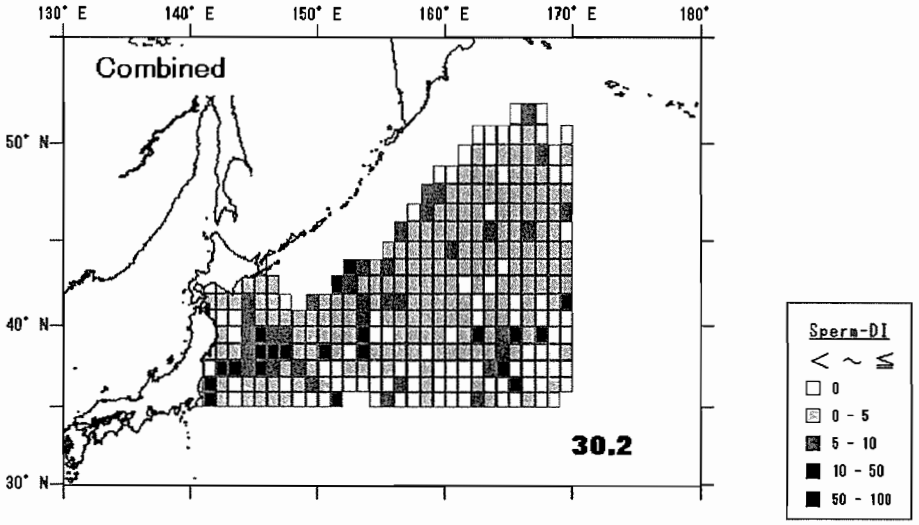


Fig.4. Distribution of the Density Index (DI) of sperm whales (number of primary sightings of whales / 100 n.mile) in the JARPN & JARPNII from 1994-2004. Bold number shows the maximum sighting rate.

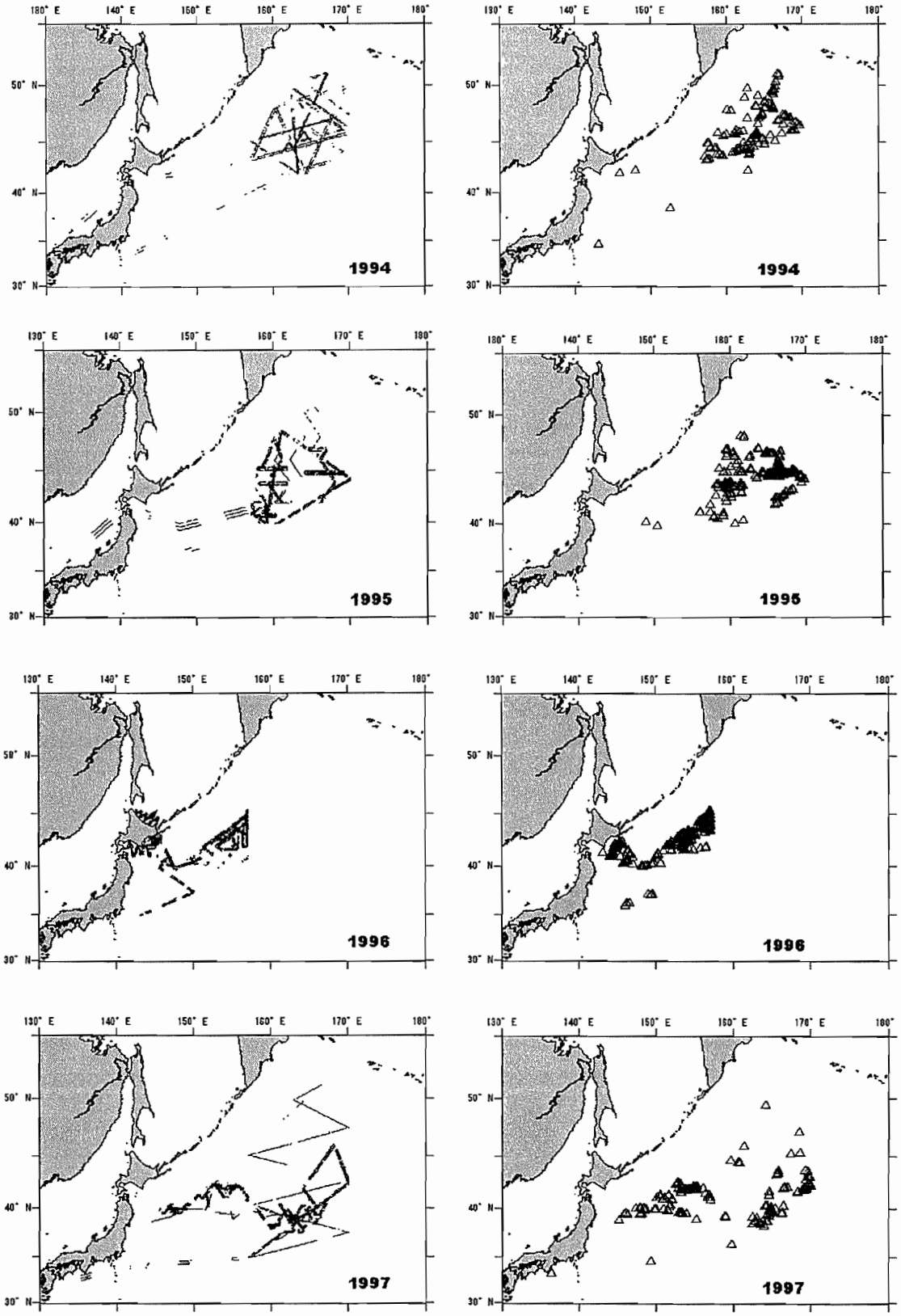


Fig. 5. Search effort and sighting position of sperm whales in the JARPN & JARPNII from 1994-2004.

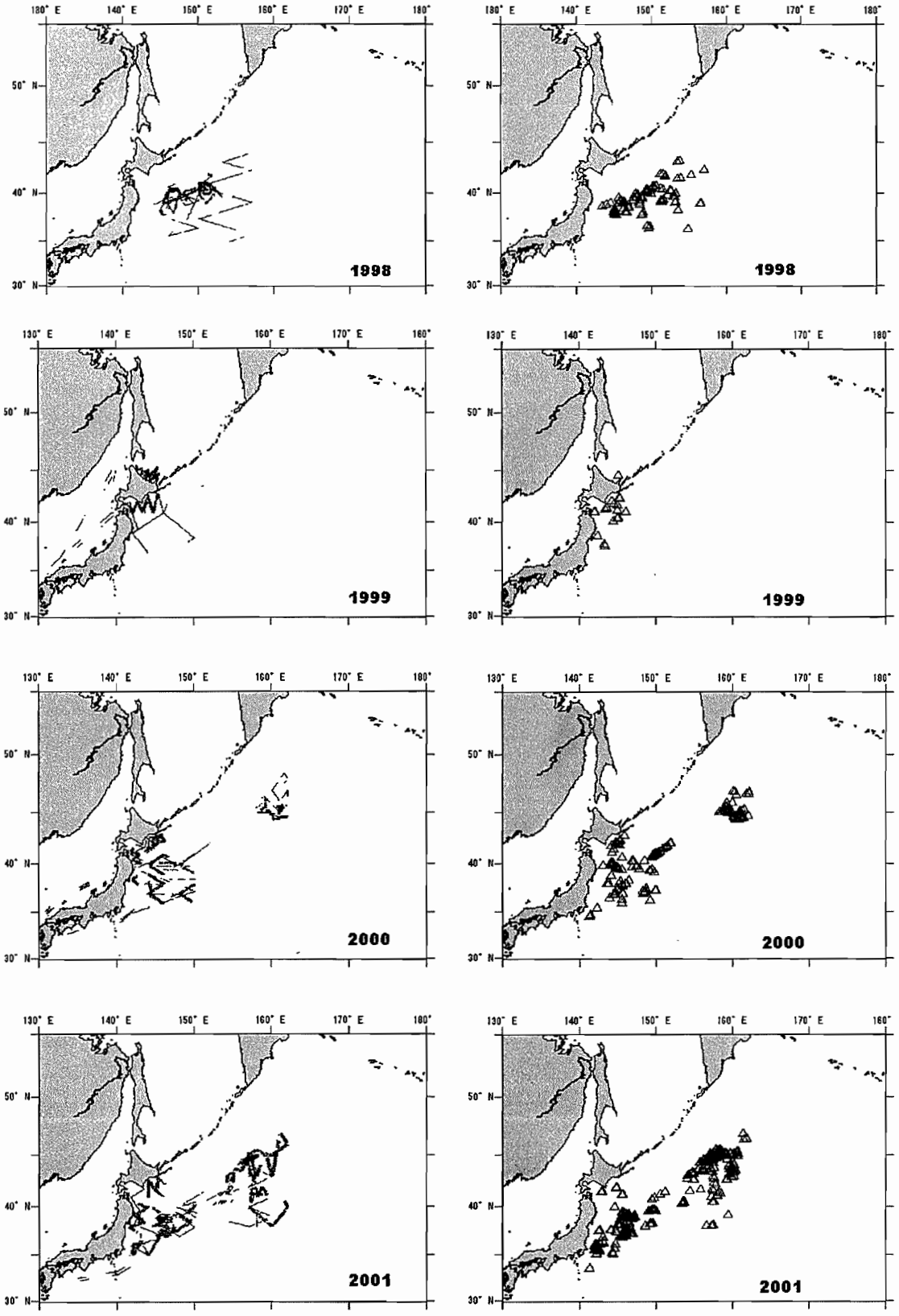
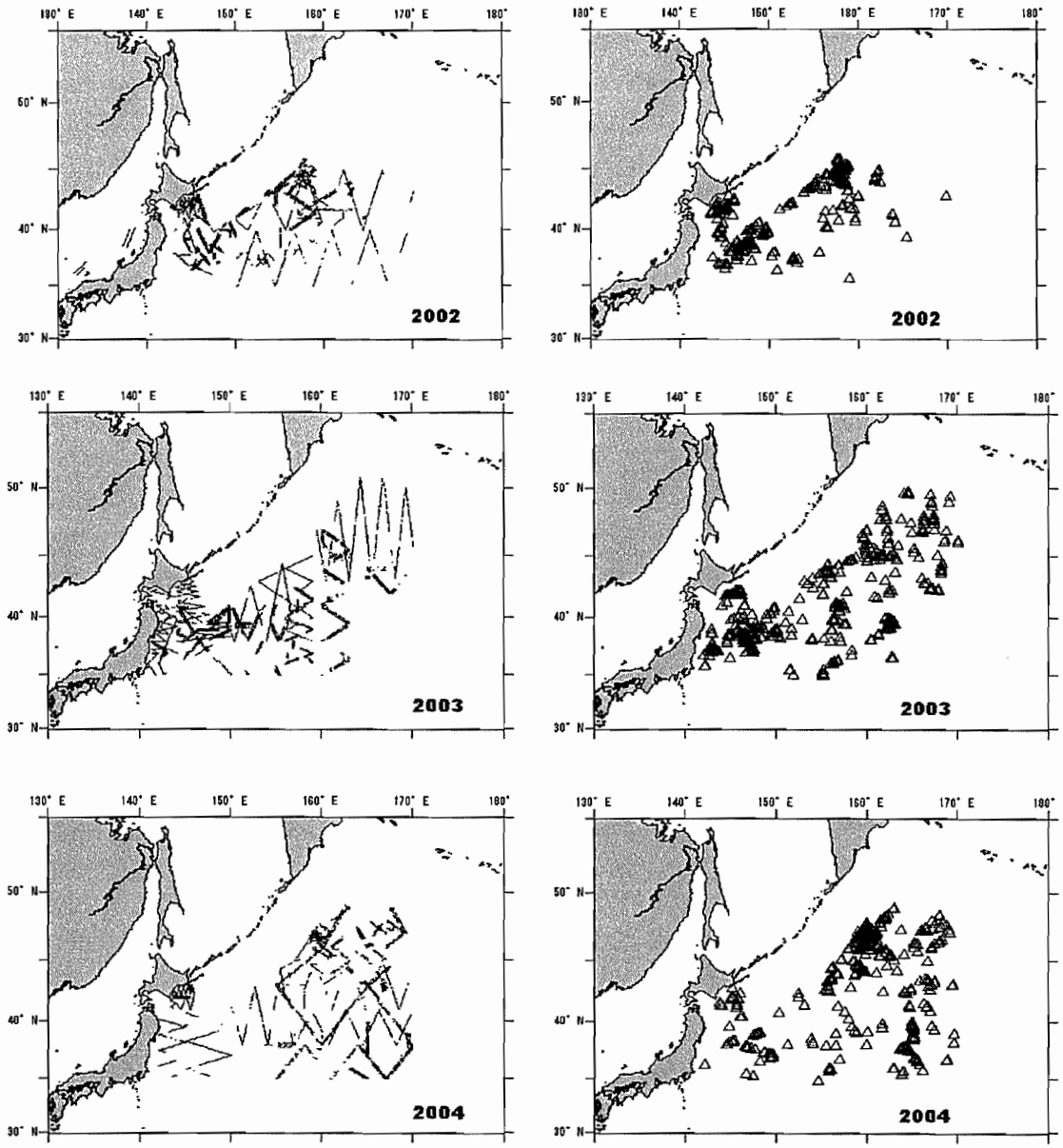


Fig. 5. Continued.



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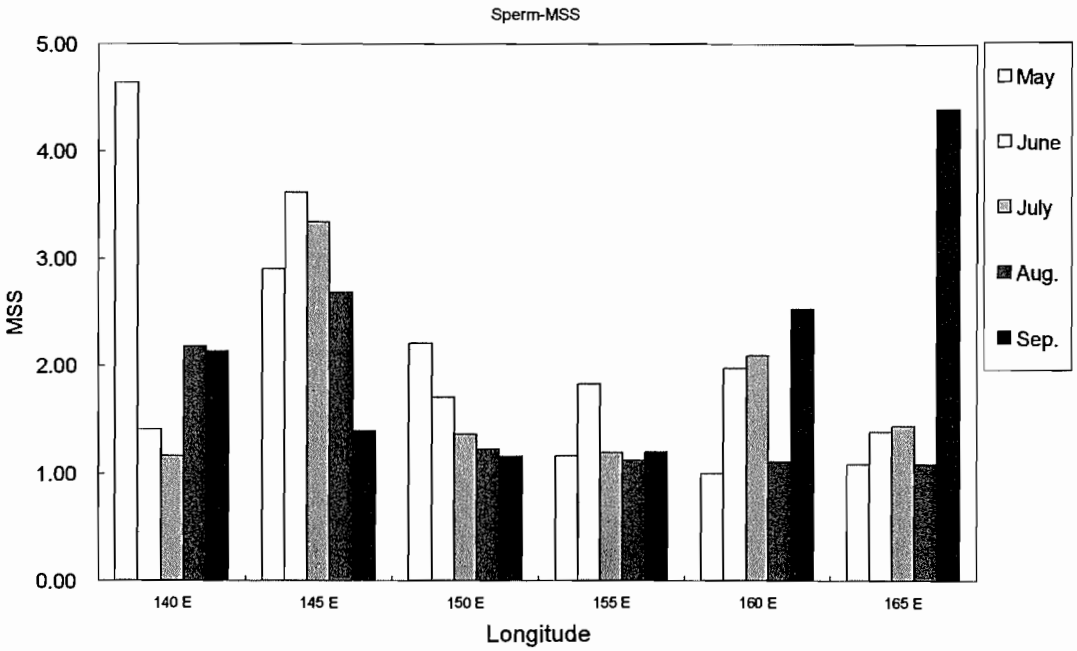

Fig. 6. Relationship between the mean school size of sperm whale and longitude in the JARPN & JARPNII from 1994-2004.

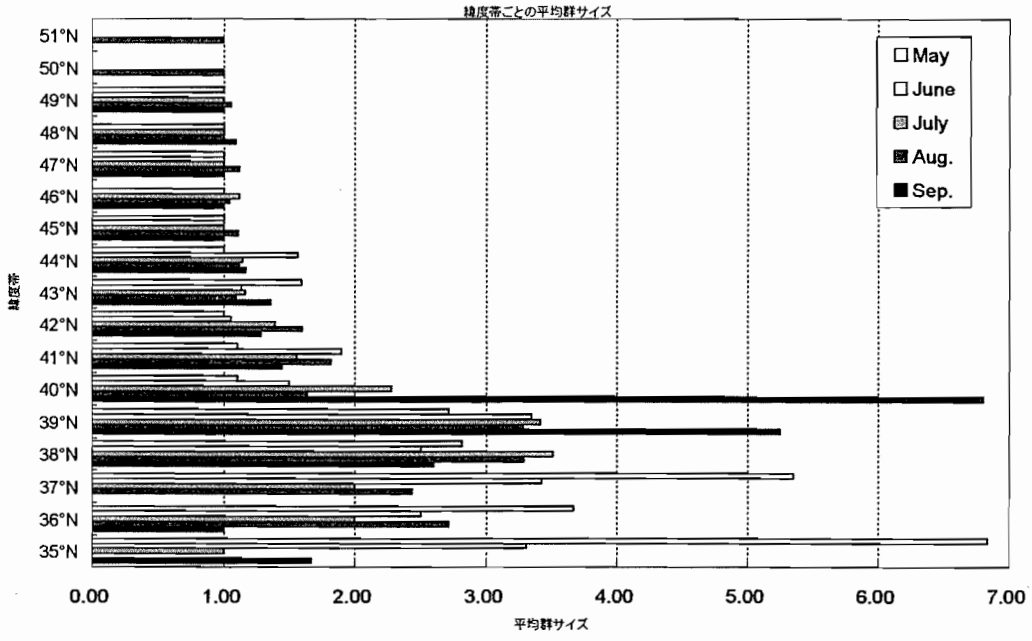

Fig. 7. Relationship between the mean school size of sperm whale and latitude in the JARPN & JARPNII from 1994-2004.

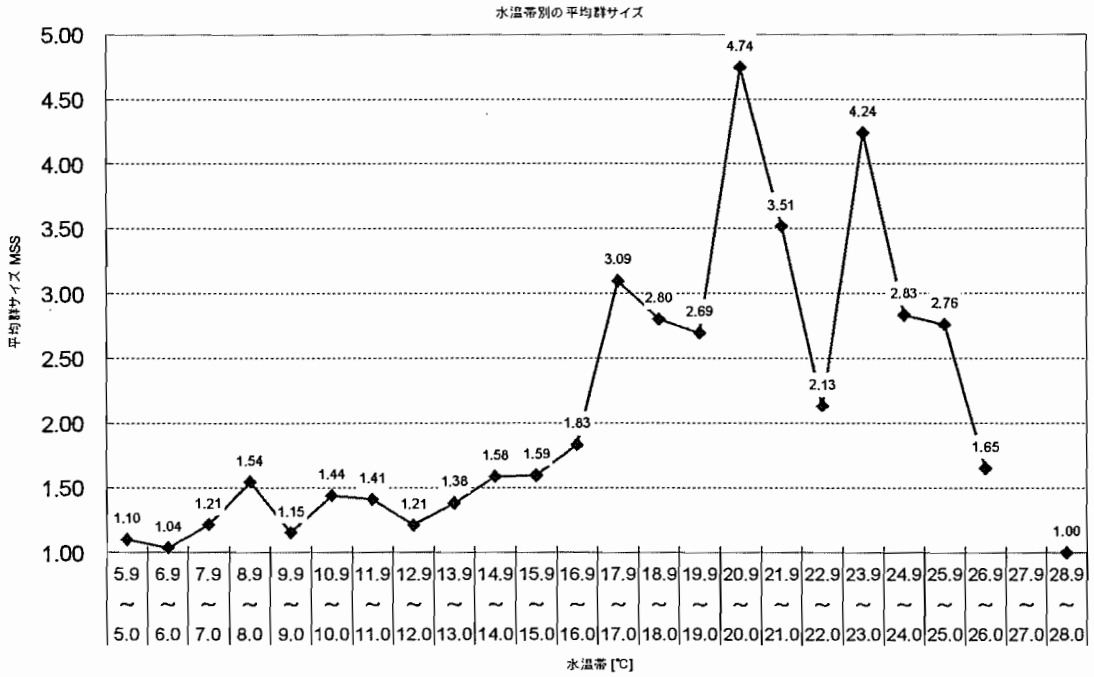

Fig.8. Relationship between the mean school size of sperm whale and Sea Surface Temperature (SST) in the JARPN & JARPNII from 1994-2004.

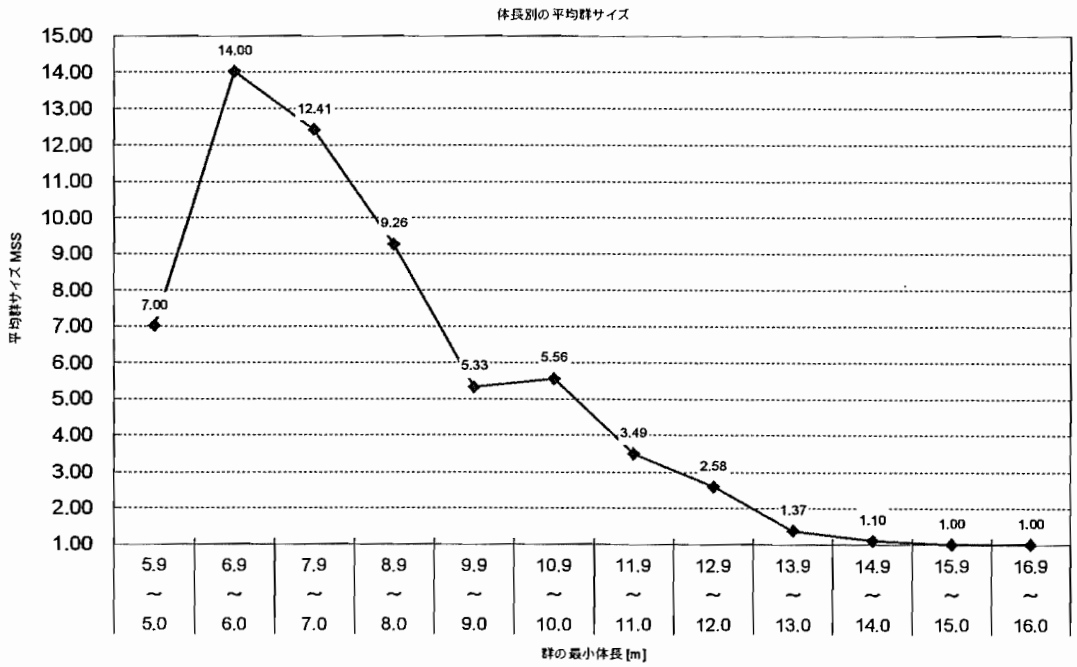

Fig. 9. Relationship between the mean school size and estimated body length of sperm whale in the JARPN & JARPNII from 1994-2004.

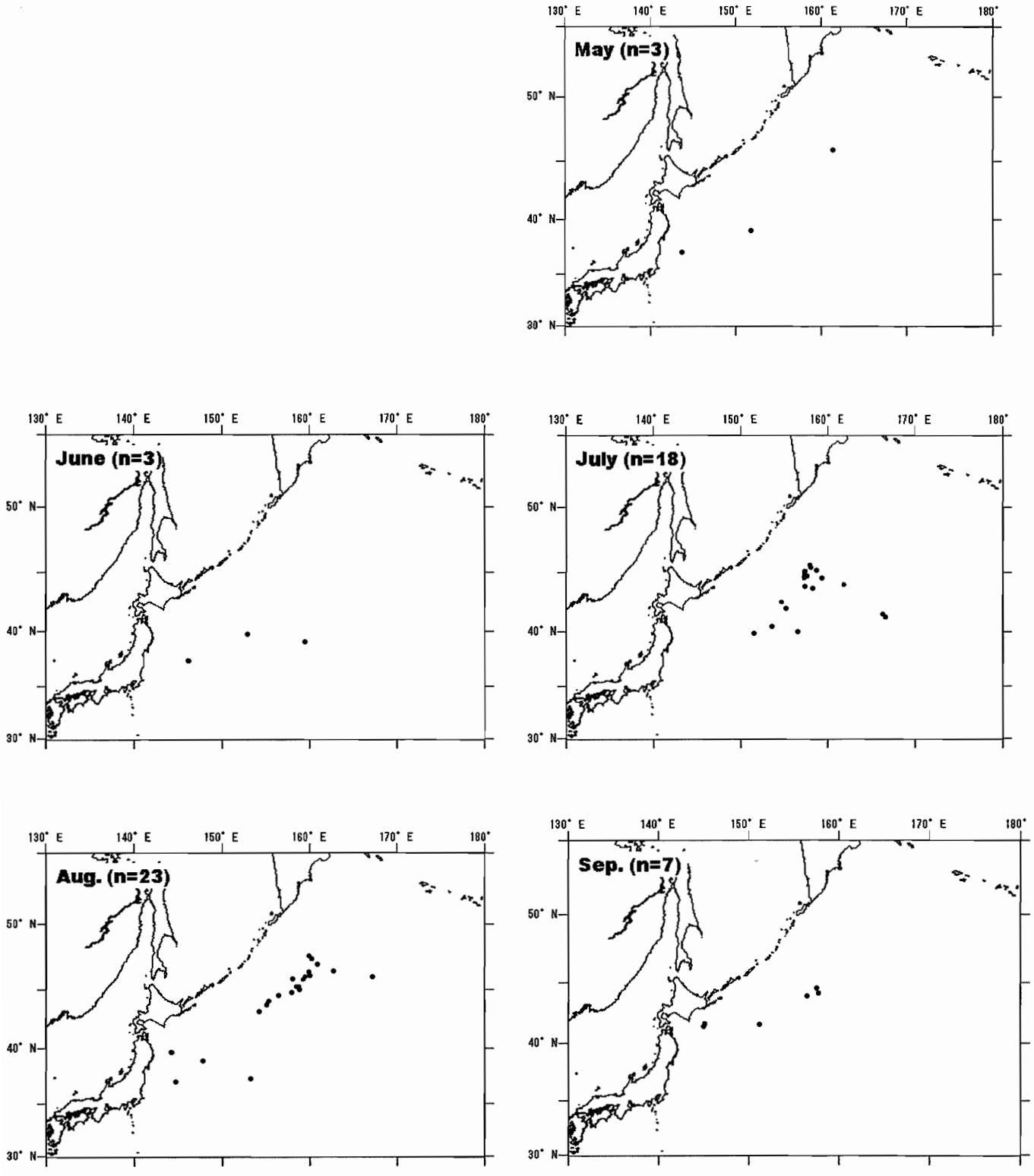

Fig.10. Sighting position of the large male sperm whales, which their estimated body length was over 15meters in the JARPN & JARPNII from 1994-2004 by month.

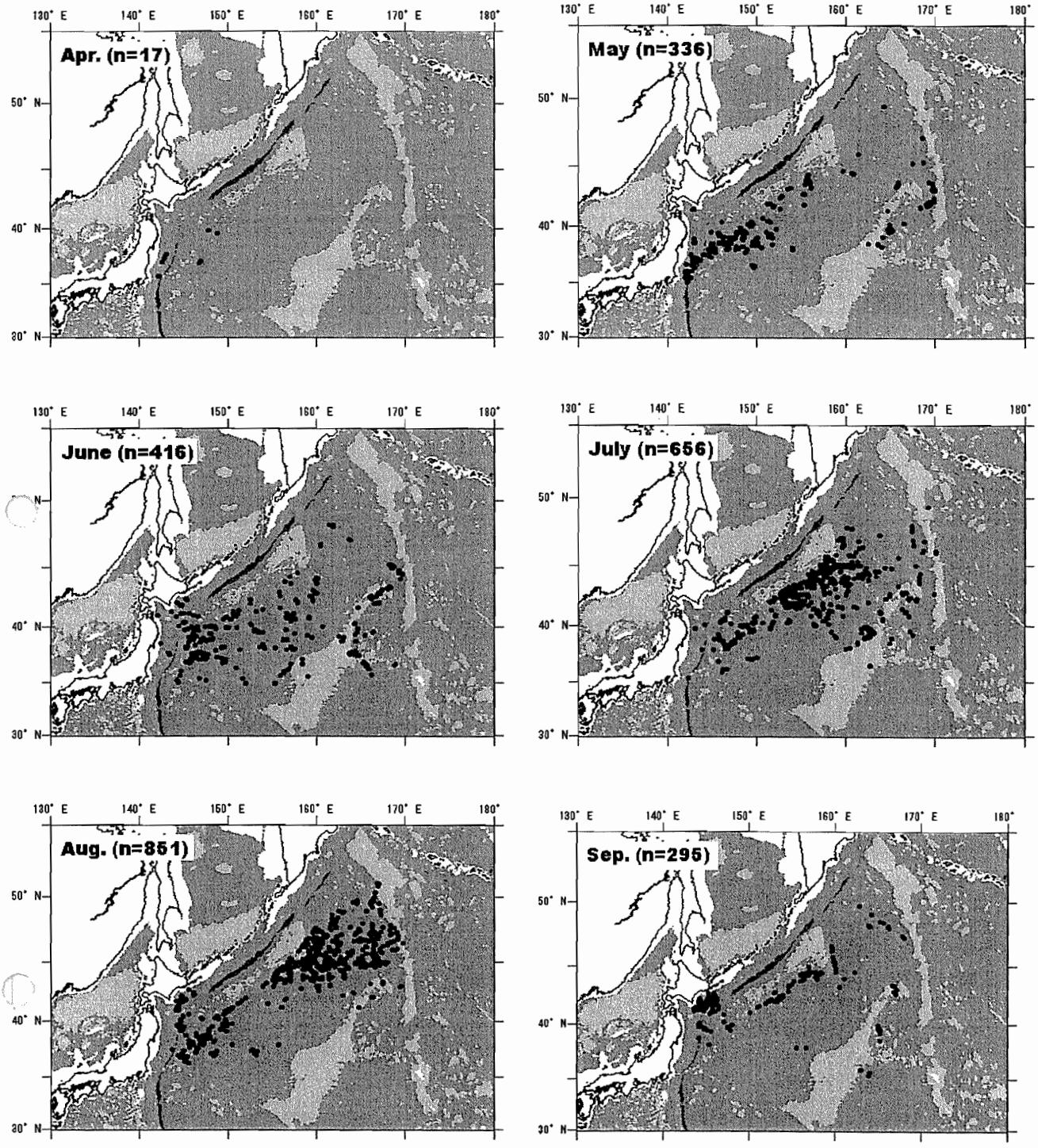

Fig.11. Sighting position of sperm whales and bottom topography in the JARPN & JARPNII from 1994-2004 by month. Light grey color show the depth of water less than 5,000 m. Grey color show the depth of water between 5,000 and 7,000 m. Dark grey color show the depth of water over 8,000 m.

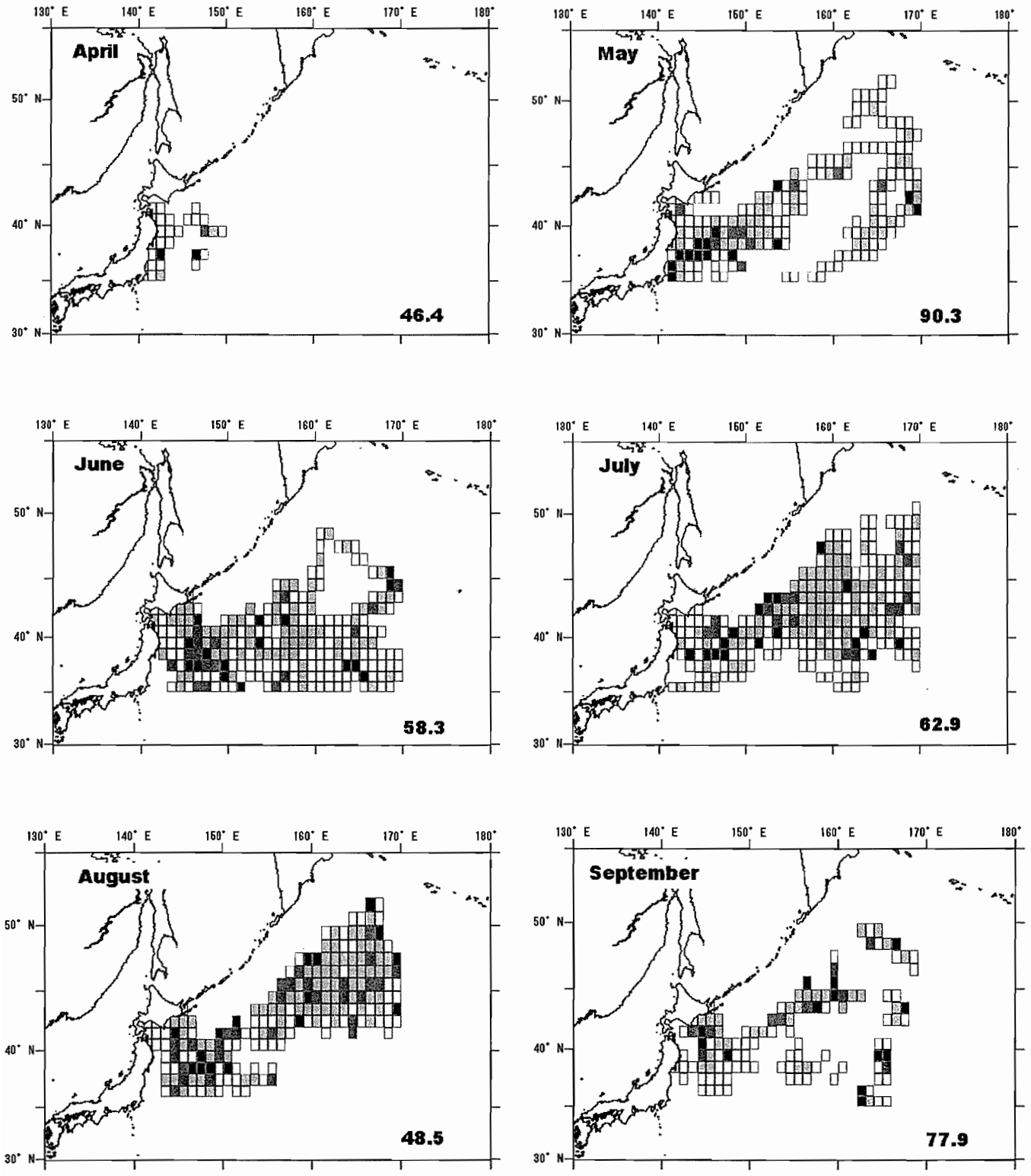

Fig.12. Distribution of the Density Index (DI) of sperm whales (number of primary sightings of whales / 100 n.mile) in the JARPN & JARPNII from 1994-2004. Bold number shows the maximum sighting rate.

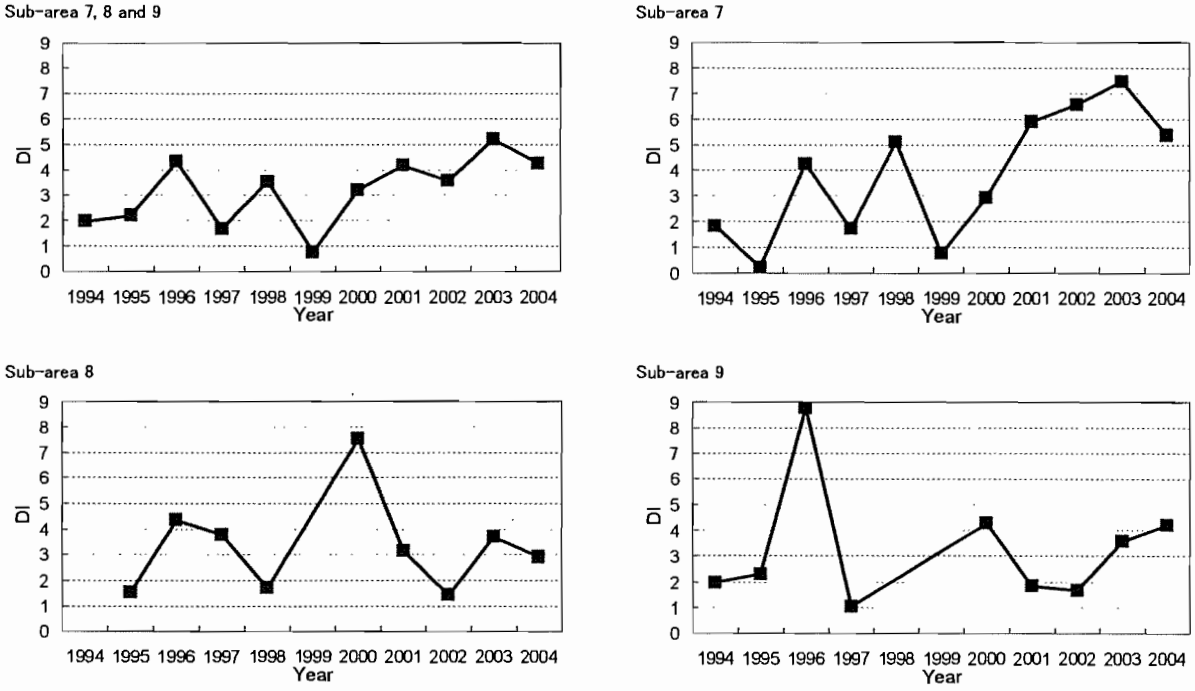

Fig.13. Yearly change of the Density Index (DI) of sperm whales (number of primary sightings of whales / 100 n.mile) in the JARPN & JARPNII from 1994-2004.

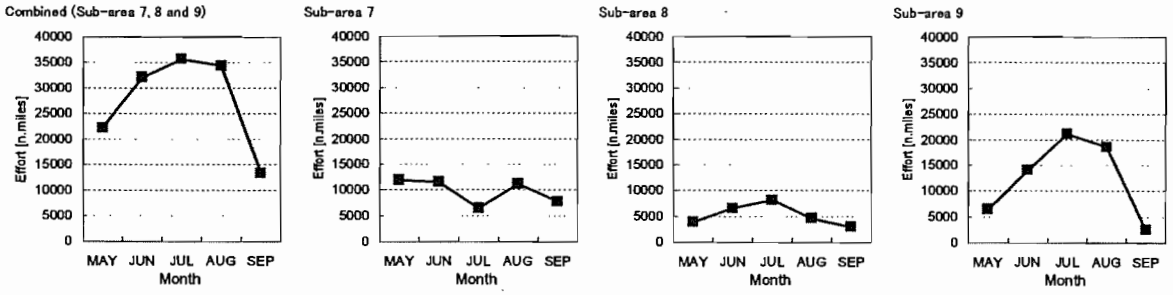

Fig. 14. Monthly change of the searching effort by each sub-area in the JARPN & JARPNII from 1994-2004.

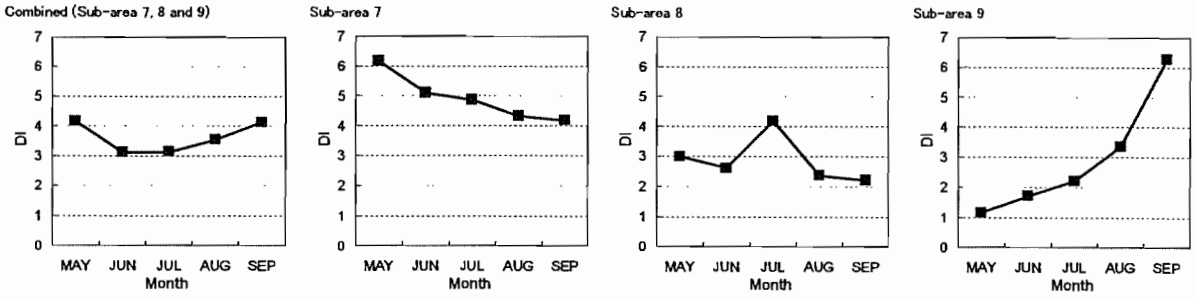

Fig.15. Monthly change of sperm whales DIW by each sub-area in the JARPN & JARPNII from 1994-2004.

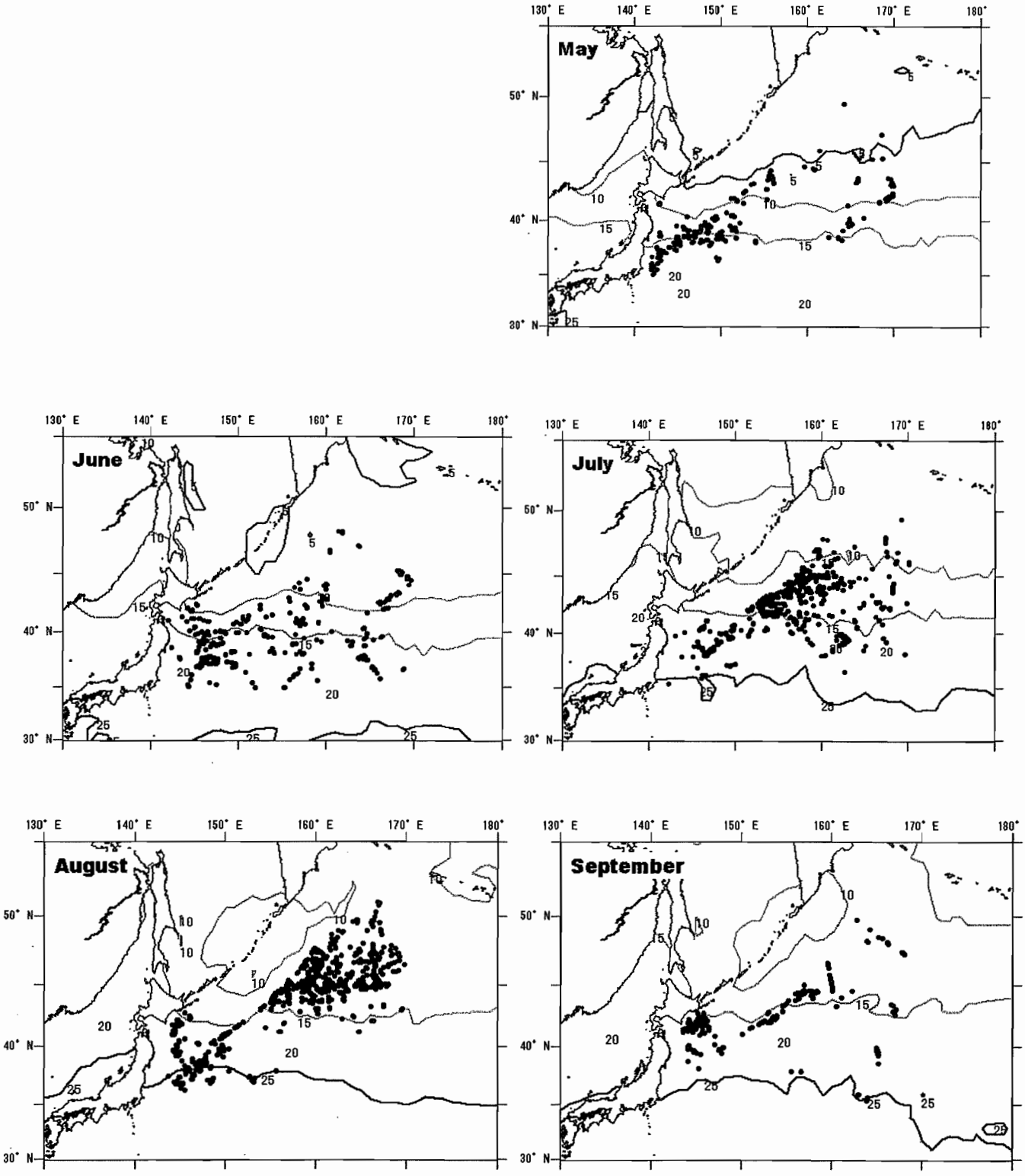

Fig.16. Relationship between the monthly mean sea surface temperature distributions and sperm whale distribution from May to September in 2002. Contour interval is 5°C. Full circle dram on each map indicate the sighting position of sperm whales. Monthly mean sea surface temperature data was calcurated by the PO.DAAC Ocean ESIP Tool (POET). This interface was developed by Ocean ESIP, a member of the Earth Science Information Partner Federation, under contract to NASA.