Distribution of blue (*Balaenoptera musculus*), fin (*B. physalus*), humpback (*Megaptera novaeangliae*) and north pacific right (*Eubalaena japonica)* whales in the western North Pacific based on JARPN and JARPNII surveys (1994 to 2014)

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ABSTRACT

We report here the Density Index (DI: individuals / 100 n.miles) and monthly distribution pattern of blue, fin, humpback and North Pacific right whales from May to September in the western North Pacific based on JARPN and JARPNII (1994-2014) sighting data. A total of 269,728.1 n.miles were surveyed. Among four species, fin whales were most frequently sighted, and next were blue, humpback and right whales in order. Monthly maps of the DI by 1°X 1°square are provided, using all primary effort and sightings data. Northward migration patterns of whales were observed for these species. Blue whales were mainly distributed north of 35°N and east of 157°E (374 schools and 508 individuals; Mean schools size (Mss) was 1.36 individuals including 23 mother and calf pairs). The DI of this species was 0.19. A high density area was observed north of 45°N between 157°E-170°E. Surface temperature (ST) ranged from 3.0 °C to 25.8° C. Fin whales were mainly sighted between 150°E and 170°E (799 schools and 1,125 individuals; Mss: 1.41, including 37 mother and calf pairs). Distribution patterns were similar to blue whales. DI of this species was 0.42. A high density area was observed north of 45°N. The ST ranged from 2.9 °C to 26.9°C. Humpback whales were mainly distributed north of 37°N (492 schools and 685 individuals; Mss: 1.39, including 42 mother and calf pairs). DI was 0.25. The ST ranged from 2.8 °C to 24.1°C. Right whale was the rarest baleen whale species sighted in the research area. They were mainly distributed north of 40°N (48 sch. and 68 ind.; Mss: 1.42, including 9 mother and calf pairs). The DI was 0.03. Surface temperature ranged from 2.7 °C to 17.0°C. Based on the additional data during 2008 to 2014, distribution pattern of these species during May to August are more obvious and this new information will contribute to marine ecosystem studies in the western North Pacific where information has been lacking since the cessation of commercial whaling. Further continuation of the systematic sighting surveys including in foreign EEZ areas are required to improve information on seasonal distribution of baleen whales.

KEY WORDS: PACIFIC OCEAN, SURVEY VESSEL, DISTRIBUTION, BLUE WHALE, FIN WHALE, HUMPBACK WHALE, RIGHT WHALE

INTRODUCTION

The JARPNII (Japanese Whale Research Program under special permit in the western part of North Pacific-Phase II) was designed with the aim to elucidate the a) feeding ecology and ecosystem studies, b) Monitoring environmental pollutant in cetaceans and the marine ecosystem, c) Stock structure of large whales (Common minke, Bryde's, sei and sperm whales).

The JARPN (1994-1999) and JARPNII (2000-2014, ongoing) have conducted systematic whale sighting surveys with and without the sampling activity. Research area of the JARPN and JARPNII is the Pacific waters north of 35°N in sub-areas 7, 8 and 9 except the 200 n.miles EEZ of foreign countries. In the Sea of Okhotsk, it covered only sub-area 11 also except the Russian EEZ. All whale species sighted are recorded during the sighting surveys. Details of the outline of the JARPN and JARPNII surveys were reviewed by Fujise (2000), Tamura *et al*. (2009) and Kiwada *et al.*, (2009). Sighting data by JARPN and JARPNII (1994-2007) for blue (*Balaenoptera musculus*), fin (*B. physalus*), humpback (*B. musculus*), North Pacific right (*Eubalaena japonica*) and common minke whales (*B. acutorostrata*) were reported to the JARPNII review meetings which were held by the IWC/SC in 2000 and 2009 (Matsuoka *et al*., 2000, Okamura *et al.*, 2001, Matsuoka *et al.*, 2009). In this paper, we examined the blue, fin, humpback and right whale distribution patterns including new JARPNII sighting data (from 2008 to 2014).

MATERIAL AND METHODS

Sighting data used in this analysis

In this paper, we used all JARPN (1994-1999) and JARPNII (2000-2014) systematic sighting survey data (effort and primary sightings) collected by sighting and sampling vessel (SSV) and dedicated sighting vessel (SV). Outline of sighting survey are followings;

Sighting procedure

The sighting procedure of JARPNII (2008-2014) was not significantly changed during the JARPN (1994-1999) and JARPNII surveys (2000-2007) with some minor changes of the sighting procedure, which were reviewed by Bando *et al*. (2016: SC/F16/JR4) and Matsuoka *et al*. (2016: SC/F16/JR9). The research vessels were equipped with a barrel, where three top men conducted sighting observations. On the upper bridge, a captain, a gunner, a helmsman and a researcher also conducted the sightings. The sighting activity was continued if weather permitted during daytime from 30 minutes after sunrise to 30 minutes before the sunset.

Survey modes

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 the sea condition at the time of the searching. The NSC (BC) mode was conducted under the normal weather conditions defined as visibility of 2 n.miles or more and wind velocity 4 or below. The NSS (BS) was conducted under the unfavorable conditions defined as except the BC mode, but under which, the collection of whale samples was possible (Tamura *et al*., 2009, Bando *et al*., 2016: SC/F16/JR9). Searching was conducted using two survey modes (closing (ASP) and passing (NSP) modes) by the dedicated sighting vessel (SV) (Kiwada *et al*. 2009, Matsuoka *et al*. 2016: SC/F16/JR2).

Cruise track (Main survey and SMS)

For the Main survey, the zigzag-shaped track line was established to cover the survey area. Furthermore, the 'Special Monitoring Survey (SMS)' was adopted in area where the density of whales was expected to be high in order to take samples of whales efficiently. The vessels conducted the sighting surveys 6 and 4 n.miles away from each other in the Main survey and the SMS survey, respectively.

Confirmation of the sightings

When the cetacean school of which species seemed to be minke whales or other 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 information (number of calf, 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 part of each cruise by each vessel. Distance

was estimated by referring to the scale in the binoculars and angle was estimated referring the angle board. Surface temperatures were recorded by each whale sighting.

RESULTS AND DISCUSSIONS

Primary searching efforts

A total of 269,728.1 n.miles were surveyed mainly in the sub-areas 7, 8 and 9 between 1994 and 2014. Figures 1a and 1b show the research area and the primary searching effort (n.mile) of JARPN and JARPNII by Lat.1°× Long.1°square. Research area was covered completely during the surveys.

Distribution pattern of whales in sub-areas 7, 8 and 9

Table 1 shows the summary of all the primary whale sightings in the JARPN and JARPNII during 1994 to 2014. Table 2 shows the summary of primary whale sightings in the sub-areas 7, 8 and 9. Figures 1a and 1b show the distribution of the density index (number of the primary sightings of individuals / 100 n.miles) using primary searching efforts and number of primary sightings (individuals) of blue, fin, humpback and right whales in the research area between 1994 and 2014. Figures 2a, 2b, 2c and 2d show the monthly change in the density index for these species during the surveys.

Northward migration pattern of whales

Figures 2a, 2b, 2c and 2d show the monthly changes of the whale distributions with the search effort from May to September. As a whole, the main distribution areas of blue, fin, humpback and North Pacific right whales moved northward from 35ºN to 45ºN from May to August in Pacific sub-areas, which coincided with the previous large-scale distribution pattern reported by Miyashita *et al*. (1995).

Blue whale

Blue whales were mainly distributed north of 35ºN in the sub-areas 8 and 9 from May to September (374 schools and 508 individuals). Density index of this species was 0.19 (DIW: individuals / 100 n.miles) during the surveys. Mean schools size was 1.36 individuals including 23 mother and calf pairs (Table 1). A high density area was observed north of 45ºN in sub-area 9. Surface temperature was ranged from 3.0ºC to 25.8ºC. A northward migration pattern of whales was observed. The main distribution areas from 35ºN to 40ºN during May to June moved northward to north of 40ºN during July to August in the sub-areas 8 and 9.

Blue whales were previously caught around the rim of the Western North Pacific. In summer they concentrated along the edge of the continental shelf and along the south side of the Aleutian Archipelago. There was a distribution gap between sub-areas 7 and 9 for this species using previous catch data in summer (Nishiwaki, 1966). However, JARPNII data show that there is no gap between sub-areas 7 and 9. The previous gap may have been caused by regulation of the whaling operations between coastal (land base type) and offshore (mother ship type) whaling. Further, according to the JSV sighting data collected between 1966 and 1990, blue whales were not sighted in sub-areas 7, 8 and 9 in June. On the other hand, this species was widely distributed in these sub-areas in June between 1994 and 2014.

Fin whale

Fin whales were most frequently sighted compared to blue, humpback and right whales. This species was mainly sighted in sub-areas 8 and 9 of which distribution patterns were similar to blue whale distributions. This species was mainly distributed north of 37ºN in the sub-areas 7, 8 and 9 from May to September (799 schools and 1,125 individuals). The DIW of this species was 0.42. Mean schools size was 1.41 individuals including 37 mother and calf pairs (Table 1). A high density area was observed north of 45ºN in sub-area 9. Surface temperature was ranged from 2.9ºC to 26.9ºC. A northward migration pattern of whales was observed. The main distribution areas from 35ºN to 40ºN during May to June moved northward to north of 40ºN during July to August in the sub-areas 8 and 9.

Fin whales were widely distributed in summer in the Western North Pacific and were previously caught along the outer shelf and south of the Aleutian Islands. A distribution gap between sub-areas 7 and 9 was previously observed for this species in summer (Nishiwaki, 1966). However, present results show that there is no gap observed between sub-areas 7 and 9. This species was widely distributed in these sub-areas between 1994 and 2017.

Humpback whale

Humpback whales were mainly distributed north of 37°N in the sub-areas 7, 8 and 9 from May to September (492 schools and 685 individuals). The DIW of this species was 0.25. Mean schools size was 1.39 individuals including 42 mother and calf pairs (Table 1). High density areas were observed north of 35°N in the sub-areas 7 and 8, and north of 45°N in the sub-area 9. Surface temperature was ranged from 2.8°C to 24.1°C. A northward migration pattern of whales was observed. The main distribution areas from 37°N to 43°N in the sub-area 7 during May to June moved northward to north of 45°N during July to August in the sub-areas 8 and 9.

Present results confirm that distribution pattern of this species is similar to the previous knowledge on distribution pattern. However, new information shows that, although humpback whales were not sighted in sub-areas 7 and 8 in May and June by the JSV sighting data (1966-1990), this species was widely distributed in these sub-areas in May and June between 1994 and 2014.

North Pacific right whale

Right whale was most rare baleen whale species sighted in the research area. The DIW of this species was 0.03, which is 13 % of that for blue whales (Table 1). This species was mainly distributed north of 37°N in the sub-areas 7, 8 and 9 from May to September (48 schools and 68 individuals). Mean schools size was 1.42 individuals including 9 mother and calf pairs. Surface temperature was ranged from 2.7°C to 17.0°C. A northward migration pattern of whales was observed. The main distribution area was north of 42°N during July to August in the sub-area 9.

Distribution pattern of this species was reported using catch and JSV data (Omura, 1986, Miyashita and Kato, 1998, Clapham *et al*., 2004), present results confirm existence of this species in the sub-area 7, 8 and 9 during 1994-2014, and distribution pattern is similar to the previous pattern during May to September.

New information and further survey requirements

Distribution information of blue, fin, humpback and right whales in the western North Pacific had been reported using commercial whaling catch data (e.g. Nishiwaki, 1966) and sighting survey data (e.g. JSV data; 5°X 5°square analyses; Miyashita *et al*., 1995). Present information of whale distributions based on the additional new data during 2008 to 2014, provided by JARPN and JARPNII during 1994 to 2014 is valuable as new information for these species. Overall, this information is more detailed than previous data. This new information indicated that sighting areas of these species were expanded compared to the previous information, and will contribute to marine ecosystem studies in the western North Pacific.

The latest sighting data for the foreign 200 n.miles EEZ in the Sea of Okhotsk and the east of Kurile Islands during July and August were reported by Buckland *et al.*, (1992) using sighting data from surveys conducted by the National Research Institute of Far Seas Fisheries in Japan. Further surveys are required to improve our knowledge of the seasonal distribution of baleen whales.

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REFERENCES

Bando, T., Yasunaga, G., Tamura, T, Matsuoka, K., Murase, H., Kishiro, T. and Miyashita, T., 2016. Methodology and survey procedures under the JARPNII -offshore component- during 2008 to 2014 with special emphasis on whale sampling procedures. Paper SC/F16/JR4 presented to the JARPNII special permit expert panel review workshop, Tokyo, February 2016 (unpublished).**pp. [Paper available from the Office of this Journal].

Buckland, S.T., Cattanach, K.L. and Miyashita, T., 1992. Minke whale abundance in the Northwest Pacific and the Okhotsk Sea estimated from 1989 and 1990 sighting surveys. *Rep. Int. Whal. Commn.* 42:387-90.

Clapham, P.J., Good, C., Quinn, S.E., Reeves, R.R., Scarff, J.E. and Brownell, R.L. 2004. Distribution of North Pacific right whales (*Eubalaena japonica*) as shown by 19th and 20th century whaling catch and sighting records. *J. Cetacean Res. Manage.* 6 (1):1-6.

Fujise, Y., 2000. Outline of the research activities under the Japanese Whale Research Program under a special permit in the North Pacific (JARPN) from 1994 to 1999. Document SC/F2K/J8 presented to JARPN Review Meeting, 7-10 February 2000 (unpublished). 30pp. [Paper available from the Office of this Journal].

Kiwada, H., Kumagai, S. and Matsuoka, K., 2009. Methodology and procedure of the dedicated sighting surveys in JARPNII –Offshore and coastal component of Sanriku and Kushiro-. Paper SC/J09/JR2 presented at the JARPNII Review Meeting, 26-30 January 2009 (unpublished). 16pp. [Paper available from the Office of this Journal].

Matsuoka, K., Hakamada, T., Fujise, Y. and Miyashita, T. 2000. Distribution pattern of minke whales based on sighting data during the JARPN 1994-1999. Paper SC/F2K/J16 presented at the JARPN Review Meeting, 7-10 February 2000 (unpublished). 17pp. [Paper available from the Office of this Journal].

Matsuoka, K., Kiwada, H., Fujise, Y. and Miyashita, T., 2009. Distribution of blue (*Balaenoptera musculus*), fin (*B.physalus*), humpback (*Megaptera novaeangliae*) and North Pacific right (*Eubalaena japonica*) whales in the western North Pacific based on JARPN and JARPNII sighting surveys (1994 to 2007). Paper SC/J09/JR35 presented at the JARPNII Review Meeting, 26-30 January 2009 (unpublished). 12pp. [Paper available from the Office of this Journal].

Matsuoka, K., Hakamada, T. and Miyashita, T. 2016. Methodology and procedure of the dedicated sighting surveys in JARPNII - Offshore component -, 2016. Paper SC/F16/JR2 presented to the JARPNII special permit expert panel review workshop, Tokyo, February 2016 (unpublished).**pp. [Paper available from the Office of this Journal].

Miyashita, T., Kato, H. and Kasuya, T. (Eds), 1995. Worldwide Map of Cetacean Distribution based on Japanese Sighting Data (Volume 1). National Research Institute of Far Seas Fisheries, Shimizu, Shizuoka, Japan.140pp.

Miyashita, T., Kato, H. 1998. Recent data on the status of right whales in the NW Pacific Ocean. Paper SC/M98/RW11 presented to the IWC Special Meeting of the Scientific Committee towards a Comprehensive Assessment of Right Whales Worldwide, 16-25 March, Cape Town, South Africa.

Nishiwaki, M., 1966. Distribution and migration of the larger cetaceans in the North pacific as shown by Japanese whaling results. In K.S. Norris, ed., Whales, dolphins, and porpoises. University of California Press, Berkely. CA. pages 171-191.

Okamura, H, Matsuoka K, Hakamada T, Okazaki M, and Miyashita, T., 2001. Spatial and temporal structure of the western North Pacific minke whale distribution inferred from JARPN sightings data. *J. Cetacean Res. Manage.* 3(2): 193-200.

Omura, H. 1986. History of right whale catches in the waters around Japan. *Rep. int. Whal. Commn* (special issue) 10:35-41.

Tamura, T., Matsuoka and Fujise, Y., 2009. Methodology and survey procedure under the JARPNII - offshore component- with special emphasis on whale sampling procedures. Paper SC/J09/JR4 presented to the JARPNII Review Workshop, Tokyo, January 2009 (unpublished). 16pp.

Table. 1. Summary of all primary sightings of blue, fin, humpback and North Pacific right whales during the JARPN and JARPNII (1994-2014) including transit surveys to and from the research areas. Sch.: Number of the primary sightings of schools. Ind.: Number of the primary sightings of individuals. Calf: Number of calves including Ind.. Mss: mean school size (Ind. / Sch.). DIS: Density Index (schools / 100 n.miles). DIW: Density Index (individuals / 100 n.miles). WT: Range of surface temperature of the species sighting position.

Species	Western North pacific (all primary sightings)						
	Sch.	Ind.	Calf	Mss	DIS	DIW	WT
Blue whale	374	508	23	1.36	0.14	0.19	3.0 - 25.8ºC
Fin whale	799	1,125	37	1.41	0.30	0.42	2.9 - 26.9ºC
Humpback whale	492	685	42	1.39	0.18	0.25	2.8 - 24.1ºC
N.P. right whale	48	68	9	1.42	0.02	0.03	2.7 - 17.0ºC

Table. 2. Summary of all primary sightings restricted by the sub-areas 7, 8 and 9 during the JARPN and JARPNII (1994-2014).

Sea	Western North pacific					
Sub-area	Sub-area 7		Sub-area 8		Sub-area 9	
Latitude	35N-43N		35N - 45N		35N - 51N	
Longitude	Japanese coast - 150E		150E - 157E		157E - 170E	
Depth (m)	200-4000m<		4000 m <		4000 m <	
Species	Sch.	Ind.	Sch.	Ind.	Sch.	Ind.
Blue whale	20	23	59	77	271	377
Fin whale	93	124	231	323	464	676
Humpback whale	165	225	191	274	148	213
N.P. right whale	7	9	7	9	34	52

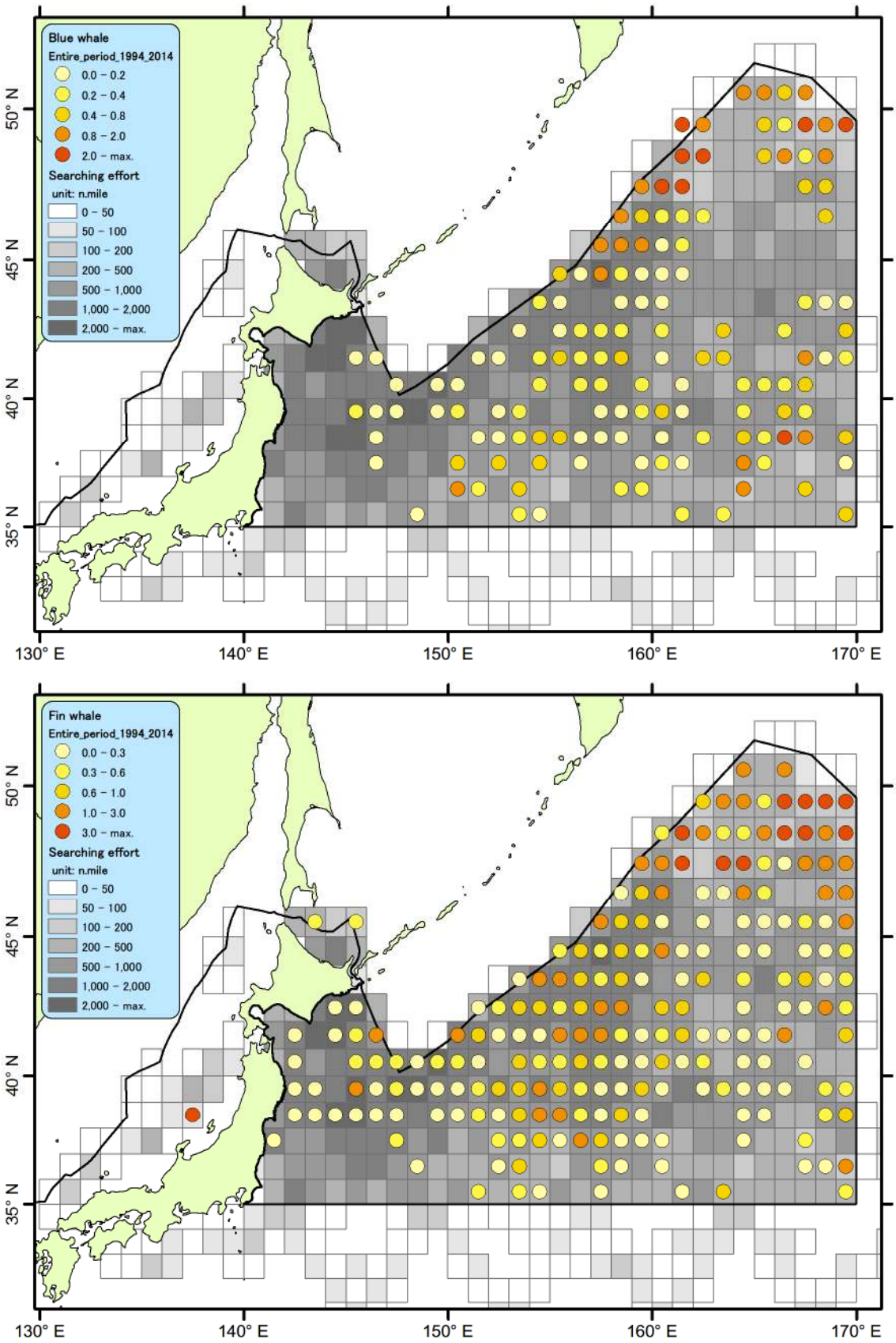

Figure 1a. Distribution of the Density Index (number of primary sightings of individuals / 100 n.mile) of whales during JARPN and JARPNII from 1994 to 2014 surveys by Lat.1°× Long.1°square. Upper: blue whale, Bottom: Fin whale.

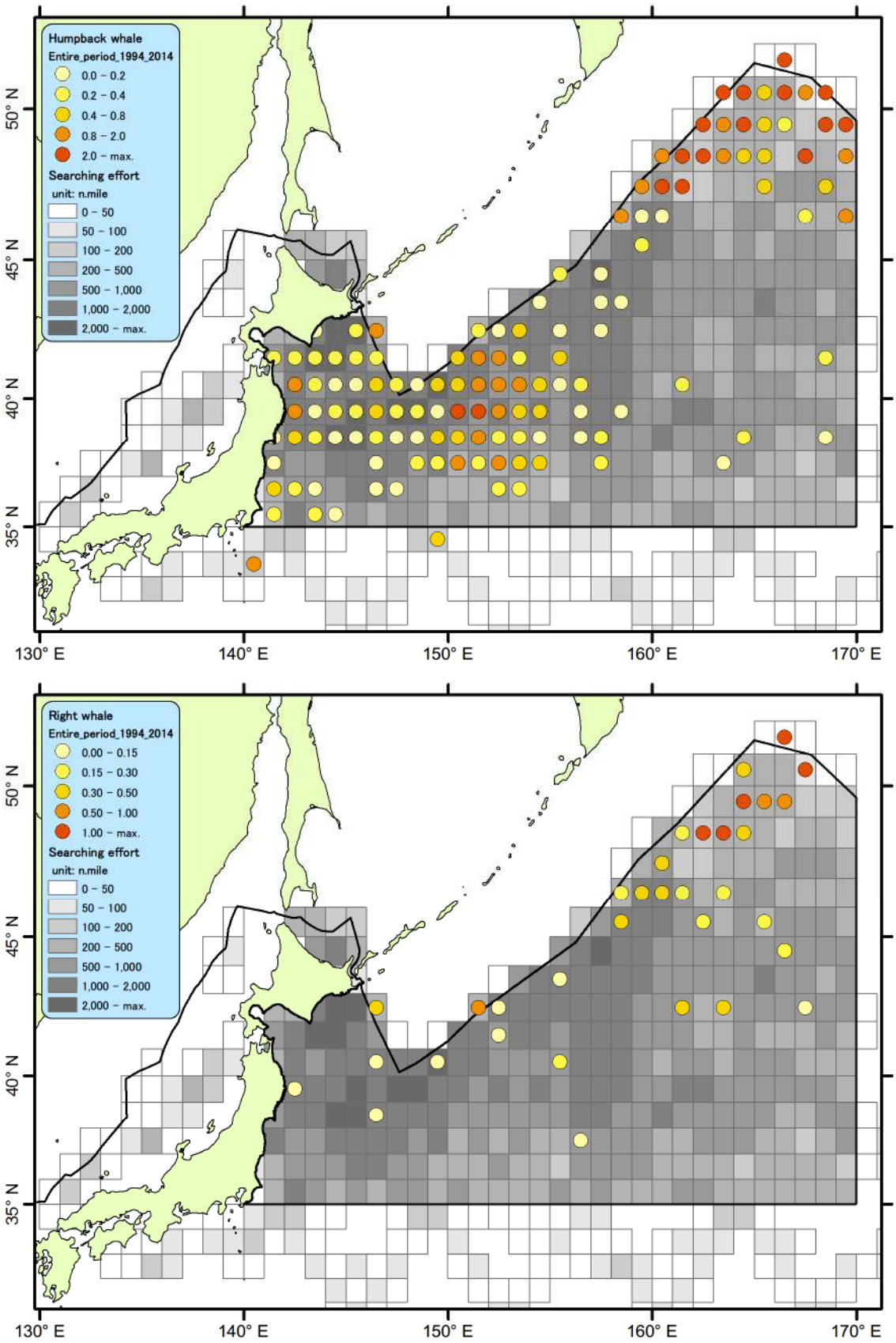

Figure 1b. (continue). Upper: humpback whale, Bottom: North Pacific right whale.

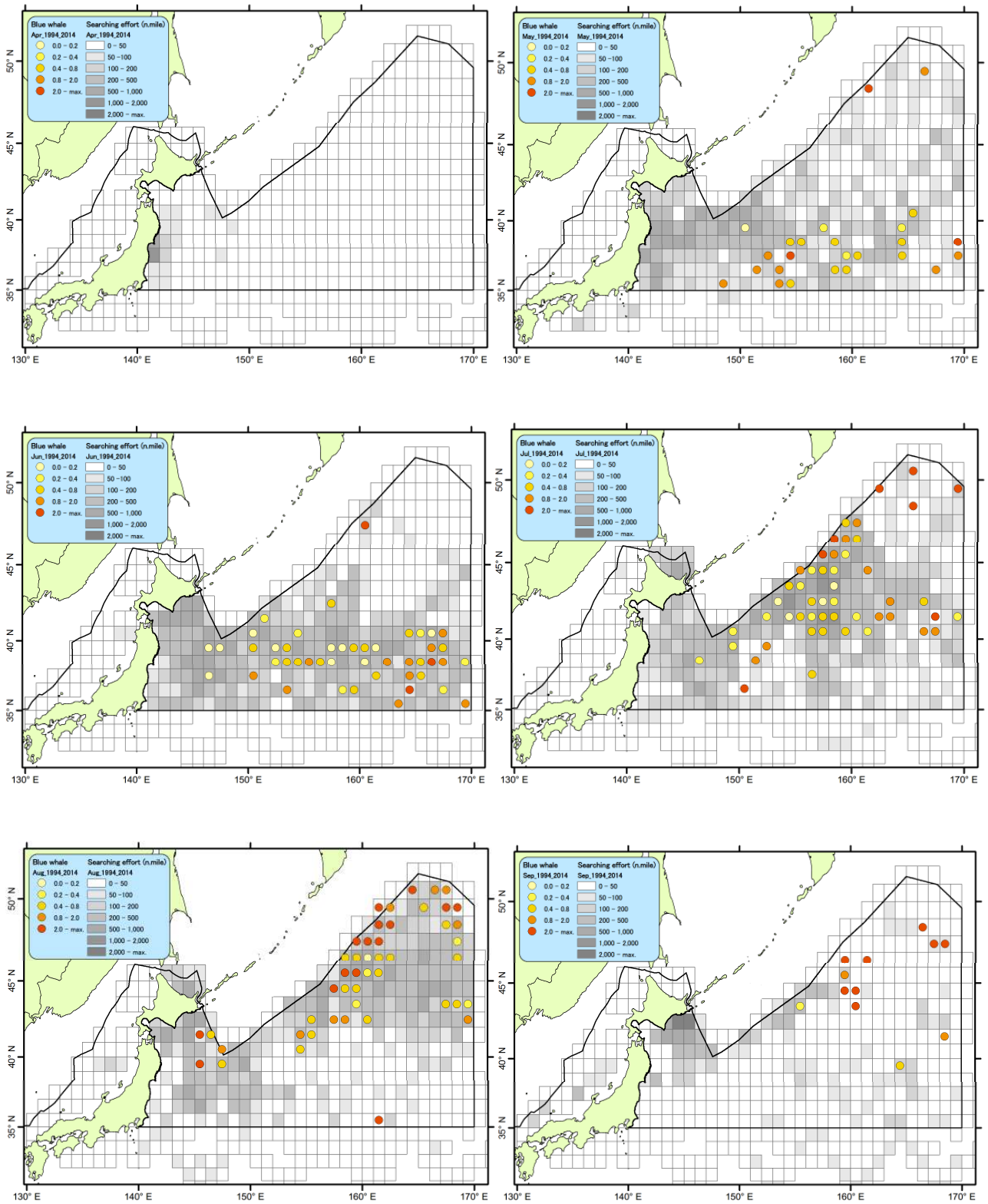

Figure 2a. Monthly change of the Density Index (number of primary sightings of whales / 100 n.mile) of blue whales during JARPN and JARPNII from 1994 to 2014 surveys by Lat.1°× Long.1°square. Top left: April. Top right: May. Middle left: June. Middle right: July. Bottom left: August. Bottom right: Sep.

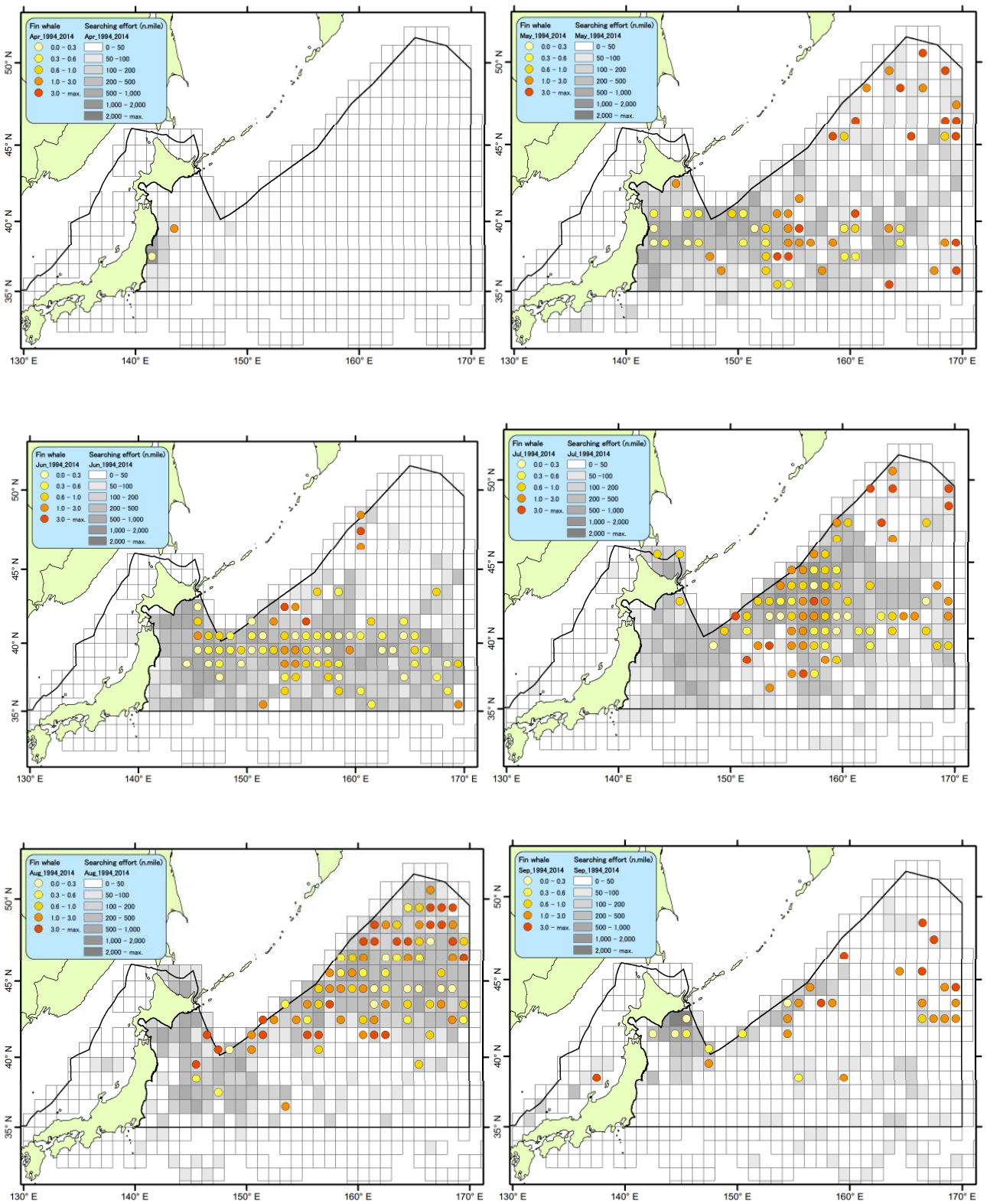

Figure 2b. Monthly change of the Density Index (number of primary sightings of whales / 100 n.mile) of fin whales during JARPN and JARPNII from 1994 to 2014 surveys by Lat.1°× Long.1°square. Top left: April. Top right: May. Middle left: June. Middle right: July. Bottom left: August. Bottom right: Sep.

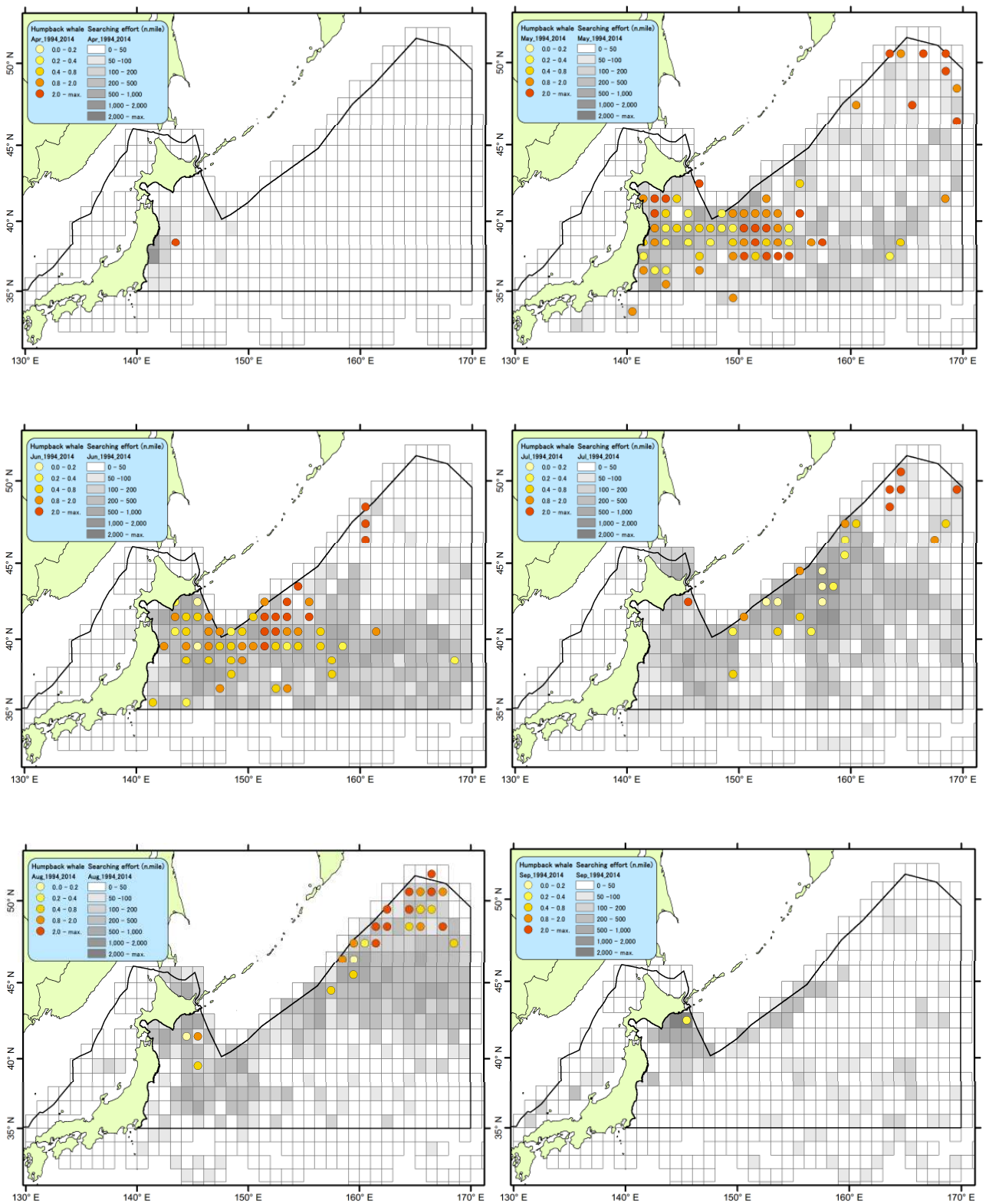

Figure 2c. Monthly change of the Density Index (number of primary sightings of whales / 100 n.mile) of humpback whales during JARPN and JARPNII from 1994 to 2014 surveys by Lat.1°× Long.1°square. Top left: April. Top right: May. Middle left: June. Middle right: July. Bottom left: August. Bottom right: Sep.

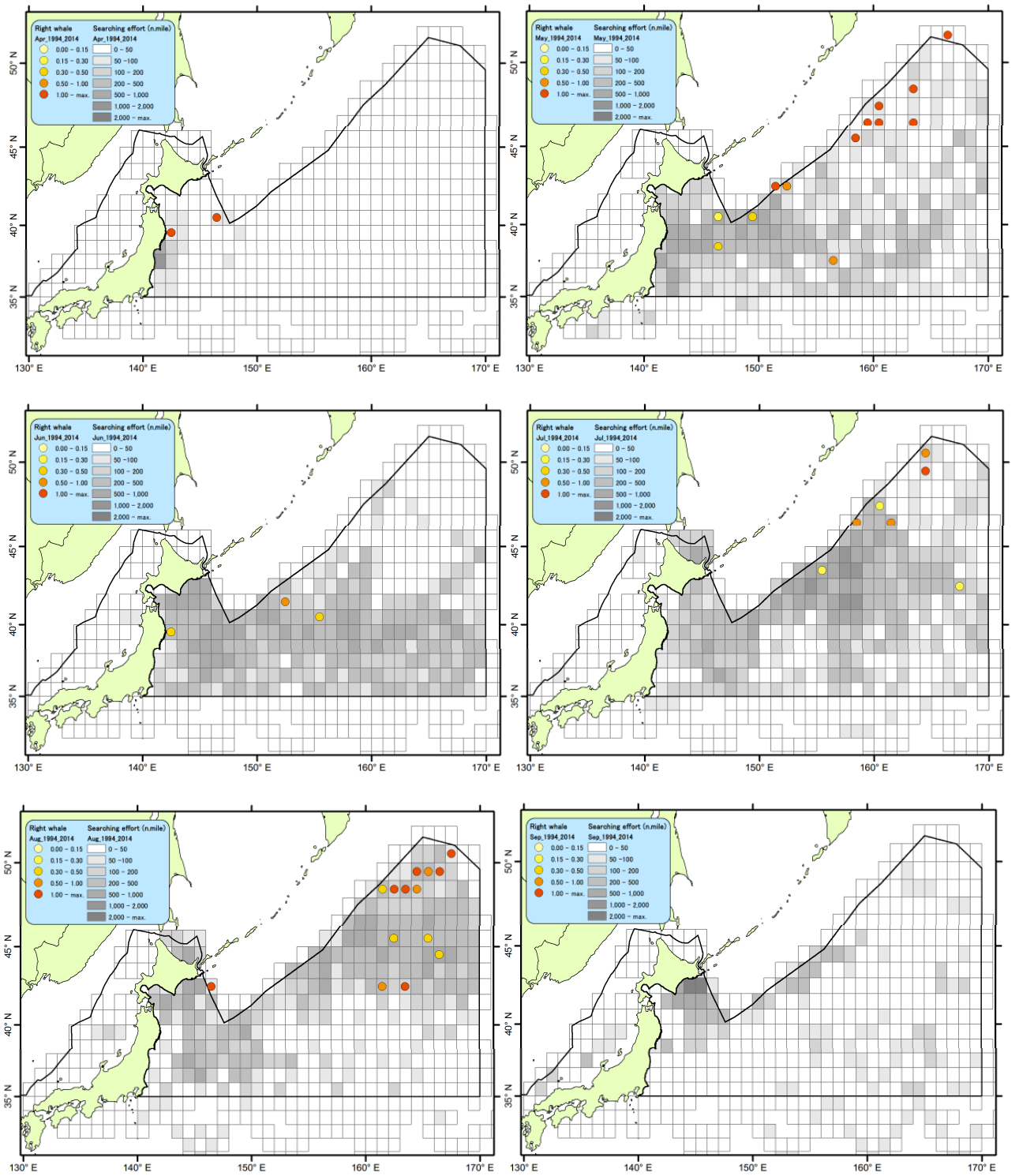

Figure 2d. Monthly change of the Density Index (number of primary sightings of whales / 100 n.mile) of North Pacific right whales during JARPN and JARPNII from 1994 to 2014 surveys by Lat.1°× Long.1°square. Top left: April. Top right: May. Middle left: June. Middle right: July. Bottom left: August. Bottom right: Sep.