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Distribution pattern of minke whales based on sighting data during the JARPN 1994-1999

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ABSTRACT

To investigate stock identity, distribution pattern is one of the useful information to estimate stock structure or their stock boundaries. Based on the JARPN 1994-1999 sighting data, we analyzed distribution pattern of minke whale sightings from April to September. While minke whales were widely distributed north of 40 ° N between the Japanese coast and eastern boundary of the sub-area 9 (170 ° E) from May to August (the surface temperature was ranged from 3 ° C to 26 ° C). The main distribution areas moved northward from 38 ° N to 45 ° N from May to July in the Pacific sub-areas, which coincide with the northward seasonal migration of the species. To compare minke whale distribution with other large whales, blue, fin, sei, humpback and northern right whales were mainly sighted north of 40 ° N in sub-area 9. Bryde's whales were mainly sighted in the eastern part of sub-area 7. Sperm whales were widely distributed in the Pacific sub-areas. Distribution pattern of minke whales expanding widely and continuously from coastal waters to offshore waters was not observed for other whales. A viewpoint of stock identity of minke whales, we could not find hiatus in the distribution, suggesting two stocks in the Pacific sub-areas.

INTRODUCTION

The JARPN (Japanese Whale Research Program under special permit in the western part of North Pacific) was designed with the aim to elucidate the stock structure in the western North Pacific minke whale. To investigate these stock identities, distribution pattern is one of the useful information to estimate stock structure or their boundaries.

The JARPN had been conducted the systematic whale sighting survey with the sampling activity from 1994-1999 seasons. The sighting information tied up with sampling activity was accumulated through the JARPN. The JARPN covered 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. Details of the outline of the JARPN surveys were reviewed by Fujise (2000a). In this paper, we examined the minke whale distribution pattern using the JARPN sighting data to estimate stock structure or their stock boundaries.

MATERIAL AND METHODS

Sighting procedure

The sighting procedure was not largely changed during the JARPN 1994-1999 surveys with some minor changes of the sighting procedure, which were reviewed by Fujise (2000a). 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 sighting. The sighting activity was continued if weather permitted during daytime from 30 minutes after sunrise to 30 minutes before the sunset.

Survey mode

Searching was conducted under closing mode. Furthermore, two survey modes were adopted as **NSC** (Normal Search **C**losing, 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 under the normal weather conditions defined as visibility of 2 n.miles or more and wind velocity 4 or below. The **NSS** (BS) was under the unfavorable conditions defined as except the BC mode, but under which, the collection of whale samples was possible.

Cruise track (Main survey and SMS)

The **Main survey**, the billiard method by means of fixed angle of reflection using line transect method in 1994 survey, the zigzag-shaped track line was established from north to south to cover survey area after 1995 survey. Furthermore, the 'Special Monitoring Survey (**SMS**)' was adopted in area where the density of minke whales was expected to be high in order to take sample of minke 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. To improve the estimation of the distance to the school and the angle from the bow, the training was conducted in the early time 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. Surface temperatures were recorded by each whale sighting.

RESULTS

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

Table. 1 shows the large whale sightings in the JARPN 1994-1999. Minke whale was dominant species through baleen whales in the JARPN research area. Fig.1 shows all minke whale sighting positions with search effort in the JARPN 1994-1999. According to this, minke whales were widely and continuously distributed in sub-area 11, northern part of sub-areas 7, 8, and 9 from coastal area to off shore area until 170° E longitude, although the 200 n.miles EEZ of the foreign countries such as northern and central parts of the Okhotsk Sea and eastern part of the Kurile Islands were not covered. There is no hiatus in the minke whale distribution pattern in the research area.

Northward migration pattern of minke whales

Fig. 2 shows the monthly changes of the minke whale distributions with the search effort from April to September. In the offshore area (sub-area 9), most of minke whales tended to be sighted around 38-39° N in May, sighted around 39-41° N in June and 40 -45° N in July and August. In the coastal side (sub-area 7 and western part of sub-area 8), most of this species were sighted in around 39-40° N in May, sighted around 40 -43° N in June and 41-43° N in July. Especially in western half of sub-area 7, most of this species were sighted in north of 41° N in June. Thus it seems that northward migration in coastal areas is ahead by almost one-month in comparison to that in offshore area (sub-area 9). Although large-scale overview, the main distribution areas of minke whales were moved northward from 38° N to 45° N from May to July in Pacific sub-areas, which coincided with previous large-scale distribution pattern (5° x 5° square analyses) by Miyashita *et.* al. (1995) and with estimation of feeding migration routes of the species in western North Pacific by Hatanaka and Miyashita (1997).

Surface temperature of minke whale sighting position and their dominant prey species

Table.3 shows the relationship between the surface temperature of minke whale sighted, main distribution area (latitudinal concentration area in each sub-area) of minke whales and their prey species in each sub-area. Although, the surface temperatures were ranged from 3° C to 26° C, there were some clear concentration range of the surface temperature in each sub-area. As the season turns, their range of the surface temperatures were moved gradually to high in sub-areas 11 and 7, slowly in sub-area 8 and 9.

Distributions of the other large whales

Search efforts and sighting positions of large whales are shown in Fig. 3. Blue, fin, sei, humpback and northern right whales tended to be sighted in offshore area rather than coastal area. Especially, most of blue whales were sighted in sub-area 9 (39 schools and 60 individuals, MSS: Mean School Size of primary sightings: 1.85). Fin whales were mainly sighted in sub-areas 8 and 9 of which distribution patterns were similar to blue whale distributions (75 schools and 110 individual, MSS: 1.43). Sei whales were mainly sighted in sub-area 8 and 9 (119 schools and 180 individuals, MSS: 1.59), and tended to be distributed in the southern part of these sub-areas. Bryde's whales were sighted in the eastern boundary of sub-area 7 (41 schools and 49 individuals, MSS: 1.19). It seems that the JARPN surveys did not cover the main distribution area of the species. Humpback whales were mainly sighted in northern part of the Pacific sub-areas (54 schools and 83 individuals, MSS: 1.19). Northern right whales were most rarely sighted throughout the surveys (9 schools and 13 individuals, MSS: 1.42). Sperm whales were widely distributed in each sub-area except sub-area 11 (1,191 schools and 1,711 individuals, MSS: 1.49). Solitary schools were 82 % of this species. Most of plural schools were sighted in sub-area 7.

DISCUSSION

Distribution pattern of minke whales

Distribution pattern of minke whales which expanding widely and continuously from coastal waters to offshore waters was not observed for other species. The continuous distribution pattern of the species was also suggested by previous distribution pattern obtained by the JSV sighting data (Miyashita *et.* al., 1995). Watanabe *et* al., (2000) examined the oceanographic conditions using data which collected by the JARPN surveys. They estimated that longitudinal extension and continuously distribution pattern of the oceanographic conditions in the western North Pacific. The continuously distribution pattern of minke whales also estimated by the distribution pattern of their prey species such as zooplankton, squid and fish (Tamura and Fujise, 2000). Further, there was a variation of almost one-month earlier in the northward migration of minke whales in the coastal sub-areas in comparison to that in offshore sub-areas. This maybe caused the following things; one is there were latitudinal gradient of the geographical distribution of the surface temperature in the Pacific sub-areas, other is there were yearly changes of the rising trend of surface temperatures. Watanabe *et* al. also reported that there were some yearly changes of the oceanographic conditions in the Pacific sub-areas. Further examinations are required for large-scale seasonal and yearly variations of oceanographic condition in the Pacific sub-areas, and for large-scale distribution patterns of their prey species.

A viewpoint of stock identity of minke whale, we could not find hiatus in the distribution pattern, suggesting two stocks in the Pacific sub-areas.

Further survey requirements in the Russian 200 n.miles EEZ

The latest sighting data of the Russian 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 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 for seasonal distribution of minke and other large whales in future studies.

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Table 1. Summary of the sighting surveys in the JARPN 1994-1999.

Year	Period	Sub-area	Vessels	Searching distance (n.miles)	Minke whale Primary Sch.	Ind.	Minke whale Secondary * Sch.	Ind.
1994	5 July - 7 Sep	9	T18, T25	7,414.8	30	31	17	17
	1-4 July	Trans.1	T18, T25	265.3	0	0	0	0
	8-11 Sep.	Trans.2	T18, T25	246.5	2	2	0	0
1995	13 June - 22 Aug.	9	K01, T18, T25	11,914.1	89	90	41	43
	9-12 June	Trans.1	K01, T18, T25	94.8	0	0	0	0
	23-28 Aug.	Trans.2	K01, T18, T25	1,265.4	1	1	0	0
1996	16 July - 13 Aug.,8-13 Sep.	8	K01, T18, T25	5,752.5	24	24	6	6
	7-15 July, 24 Aug.- 7 Sep.	7	K01, T18, T25	5,037.6	26	26	32	32
	15-22 Aug.	11	K01, T18, T25	1,299.6	44	45	19	19
	-	Trans.1	K01, T18, T25	0.0	0	0	0	0
	14 Sep.	Trans.2	K01, T18, T25	0.0	0	0	0	0
1997	6 May - 19 June	9	K01, T18, T25	8,281.7	60	64	28	28
	22- 27 June	7	K01, T18, T25	1,277.6	2	2	0	0
	28 June - 14 July	8	K01, T18, T25	2,625.8	24	26	20	20
	15 May - 1July	9	KS2	3,093.8	1	1	0	0
	1-8 July	8	KS2	327.9	2	2	0	0
	2-5 May	Trans.1	K01, T18, T25	541.0	1	1	0	0
	15-16 July	Trans.2	K01, T18, T25	16.1	0	0	0	0
	9-14 May	Trans.1	KS2	131.4	0	0	0	0
	8-11 July	Trans.2	KS2	124.1	0	0	0	0
1998	2 May - 13 June	7, 8	K01, T18, T25	4,984.1	69	71	80	88
	26 April - 12 May **	7	KS2	1,258.9	0	0	0	0
	18 May - 21 July	8	KS2	1,503.6	13	14	2	3
	-	Trans.1	K01, T18, T25	0.0	0	0	0	0
	15-18 June	Trans.2	K01, T18, T25	0.0	0	0	0	0
	24-25 April	Trans.1	KS2	0.0	0	0	0	0
	22-Jul	Trans.2	KS2	0.0	0	0	0	0
1999	19 June - 3 July	7	YS1, K01, T25	1,629.9	39	42	36	38
	6-15 July	11	YS1, K01, T25	1,230.3	57	61	41	44
	9-29 June	7	KS2	1,379.7	38	45	22	22
	9-23 July	11	KS2	595.2	26	27	20	23
	8-Jun	Trans.1	KS2	0.0	0	0	0	0
	-	Trans.2	KS2	0.0	0	0	0	0
	16-17 June	Trans.1	K01, T18, T25	444.0	7	7	1	1
	16-18 July	Trans.2	K01, T18, T25	436.4	0	0	0	0

K01: Kyo-maru No.1
T18: Toshi-maru No.18
T25: Toshi-maru No.25
YS1: Yushin-maru
KS2: Kyosin-maru No.2 (Dedicated sighting vessel)
Trans.1: From home port to researeh area.
Trans.2: From research area to home port.

* : excluded 18 schools of minke whale sighted by the researeh base Nissin-Maru.
** : 13- 17 May, transit to Shiogama, and transit from Siogama to research area.

Table. 2. Summary of the whale sightings in the JARPN 1994-1999.

Sub-area	11				7				8				9				Trans.1				Trans.2				Total			
	Pry.		Sec.		Pry.		Sec.		Pry.		Sec.		Pry.		Sec.		Pry.		Sec.		Pry.		Sec.		Prymary		Secondary	
Species	Sch.	Ind.	Sch.	Ind.	Sch.	Ind.	Sch.	Ind.	Sch.	Ind.	Sch.	Ind.	Sch.	Ind.	Sch.	Ind.	Sch.	Ind.	Sch.	Ind.	Sch.	Ind.	Sch.	Ind.	Sch.	Ind.	Sch.	Ind.
Minke whale	127	133	80	86	157	168	134	141	80	84	64	68	180	186	86	88	8	8	1	1	3	3	0	0	555	582	365	384
Blue whale	0	0	0	0	0	0	0	0	3	5	0	0	18	33	17	20	0	0	0	0	0	0	1	2	21	38	18	22
Fin whale	2	2	1	1	5	6	1	1	15	23	0	0	47	67	3	8	0	0	0	0	1	2	0	0	70	100	5	10
Sei whale	2	2	6	6	7	8	0	0	10	13	5	7	72	122	16	21	0	0	0	0	1	1	0	0	92	146	27	34
Bryde's whale	0	0	0	0	34	40	4	5	0	0	0	0	1	1	0	0	0	0	1	1	1	2	0	0	36	43	5	6
Humpback whale	0	0	0	0	8	10	1	1	2	2	2	2	34	54	6	13	1	1	0	0	0	0	0	0	45	67	9	16
Right whale	0	0	0	0	4	6	0	0	0	0	0	0	3	4	2	3	0	0	0	0	0	0	0	0	7	10	2	3
Sperm whale	1	1	0	0	189	464	47	74	303	390	64	90	492	578	79	84	6	10	2	7	6	11	2	2	997	1,454	194	257

Trans. 1: Home port to research area

Trans. 2: From research area to home port

Exclude 18 schools of minke whale sighted by the Research base Nissin-Maru.

Table. 3. Outline of the main distribution area of minke whales (MDA), surface temperature of their sighting position (WT) and their dominant prey species (DPS) by each sub-area and month in the JARPN 1994-1999.

Sea	Southern Okhotsk sea			Western North Pacific								
Sub-area	11			7			8			9		
Longitude	142°E - 145°30E			Japanese coast - 150°E			150E - 157°E			157E - 170°E		
Depth (m)	< 250m			200-4000m <			4000 m <			4000 m <		
	MDA	WT	DPS	MDA	WT	DPS	MDA	WT	DPS	MDA	WT	DPS
May	-	-	-	39-40°N *	7-10°C	Ja	39-40°N	11°C	Ja	38-40°N	10-12°C	Ja
June	-	-	-	41-43°N **	9°C, 15°C	Ja	40-41°N	10-11°C	Ja	38-41°N	11-12°C	Ja
July	44-45°30N	11-13°C	Kr	-	-	-	41-43°N	9-10°C	Ps	40-45°N	11-13°C	Ps
Aug.	44-45°30N	15-17°C	Kr	41-43°N **	15-17°C	Ps	-	-	-	42-47°N	13-14°C	Ps
Sep.	-	-	-	-	-	-	-	-	-	-	-	-

MDA: Main distribution area (latitude(°N)).
WT: Range of surface temperature of minke whale sighting position.
DPS: Dominant prey speeies (Tamura and Fujise, 2000).

Kr: Krill
Ja.: Japanese anchovy
Ps: Pacifie saury

* eastern part of sub-area 7.
** Coastal area of sub-area 7 (Do-to)

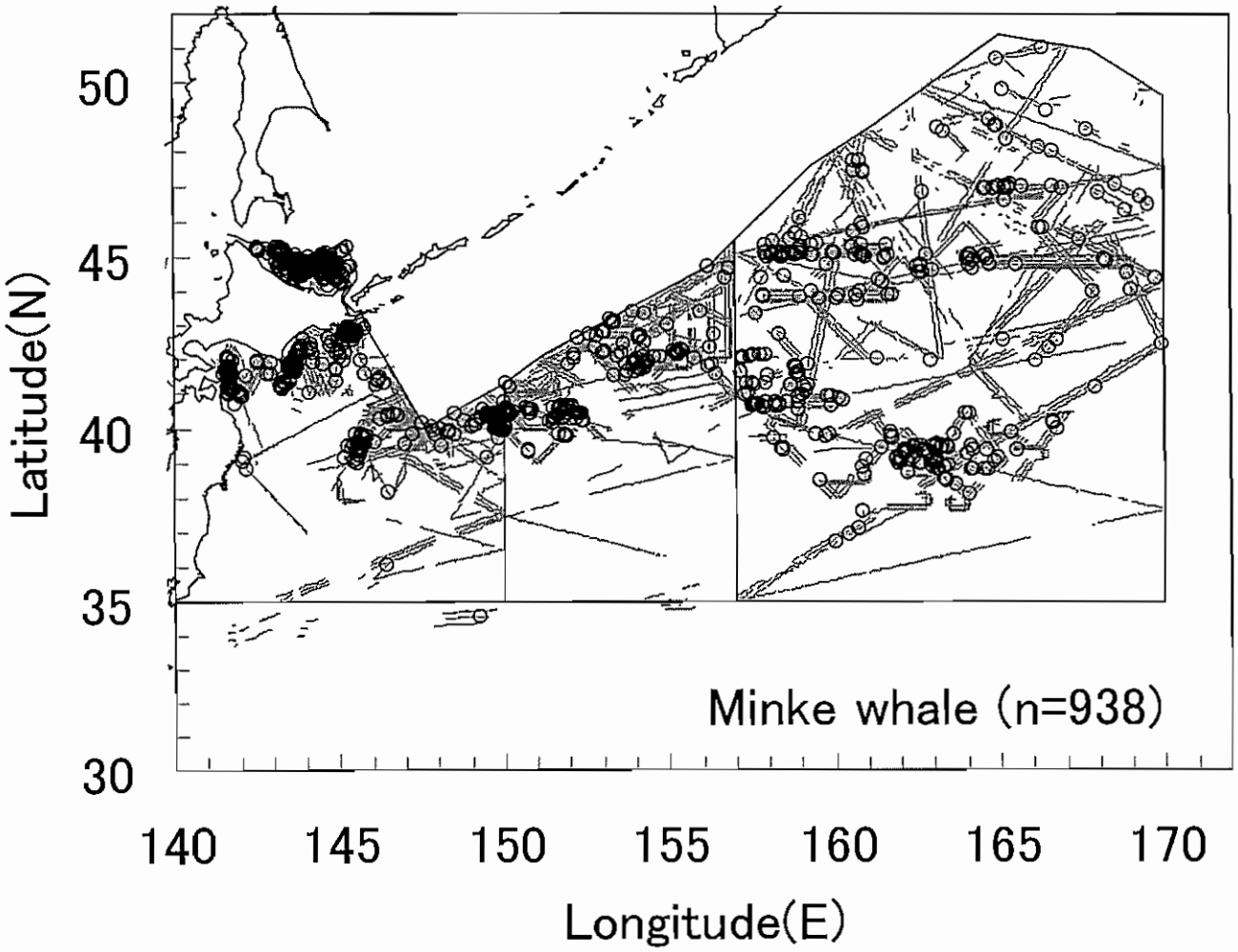

Fig.1. Search effort and sighting position of minke whales in the JARPN 1994-1999 (All sightings).

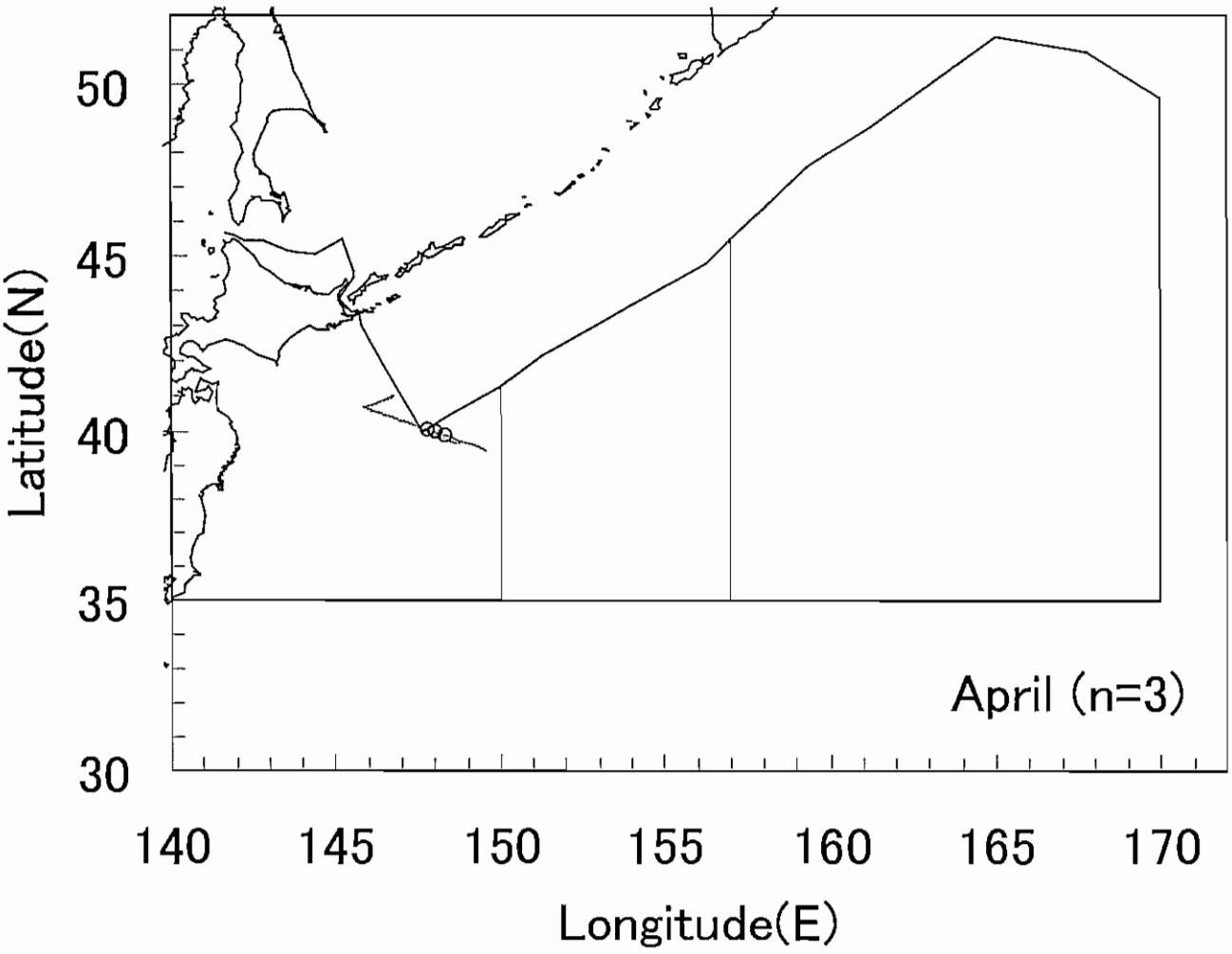

Fig.2. Search effort and sighting position of minke whales in the JARPN 1994-1999. (April).

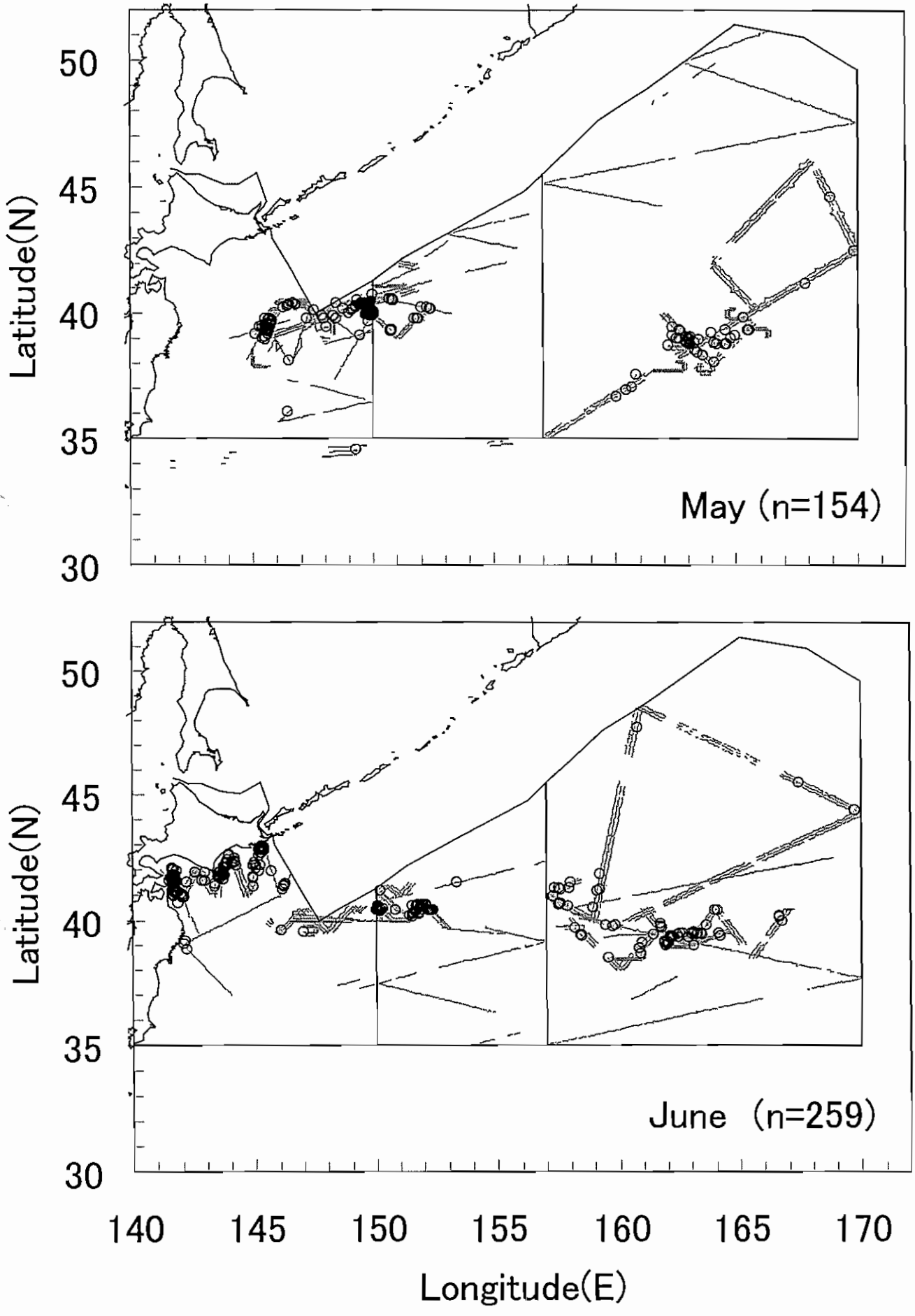

Fig.2. Search effort and sighting position of minke whales in the JARPN 1994-1999. (Upper: May, lower: June).

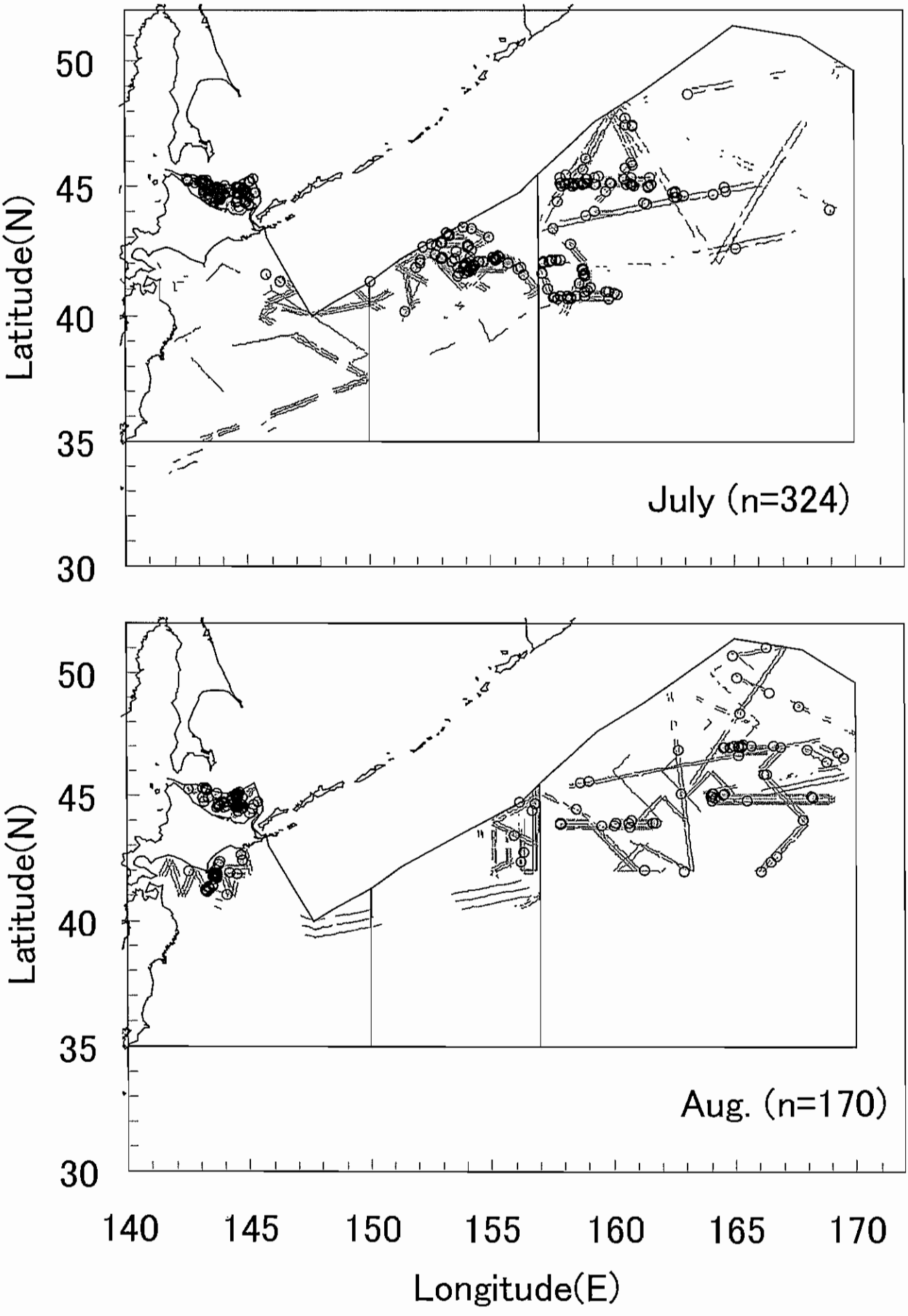

Fig.2. Search effort and sighting position of minke whales in the JARPN 1994-1999. (Upper: July, lower: August)

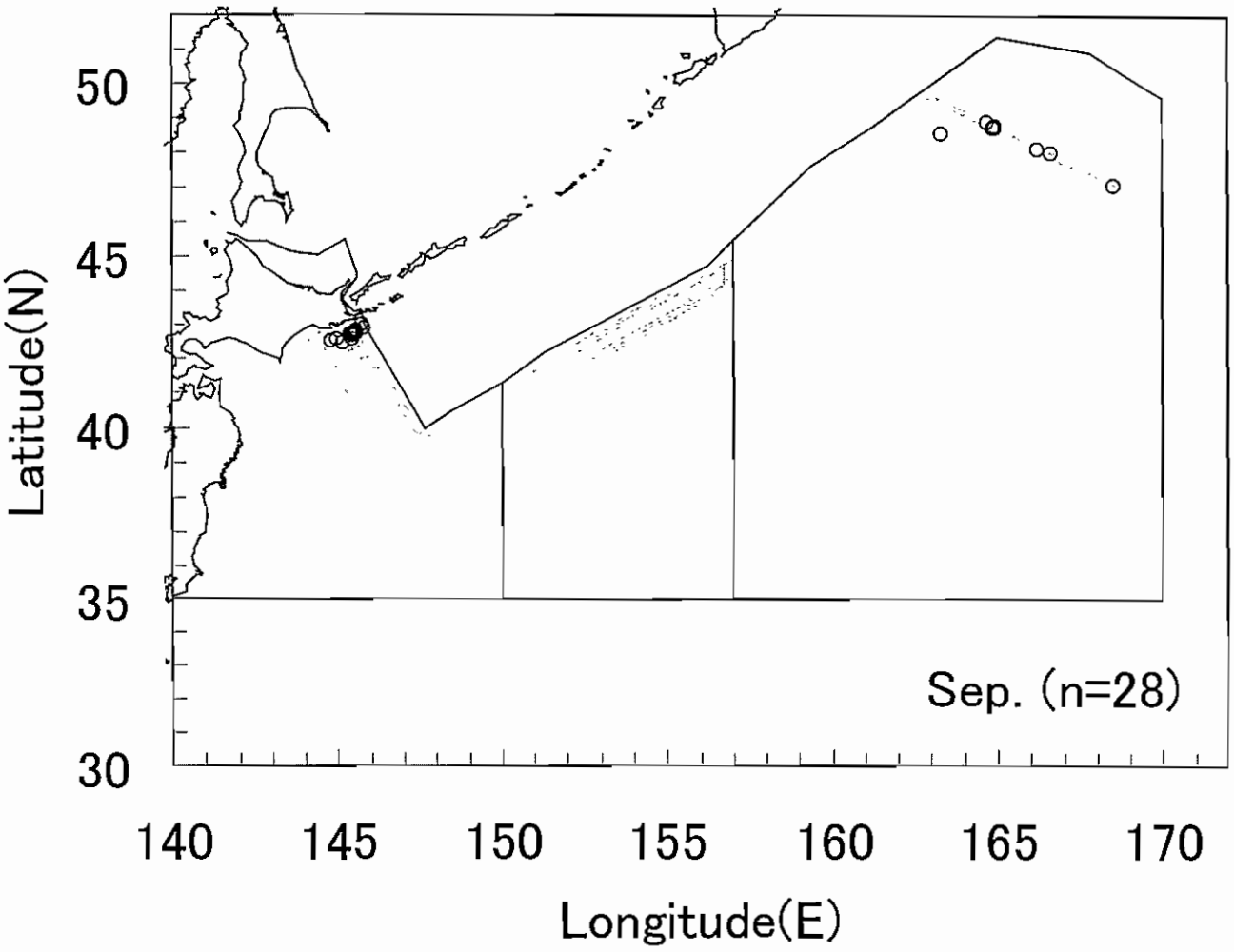

Fig.2. Search effort and sighting position of minke whales in the JARPN 1994-1999. (September).

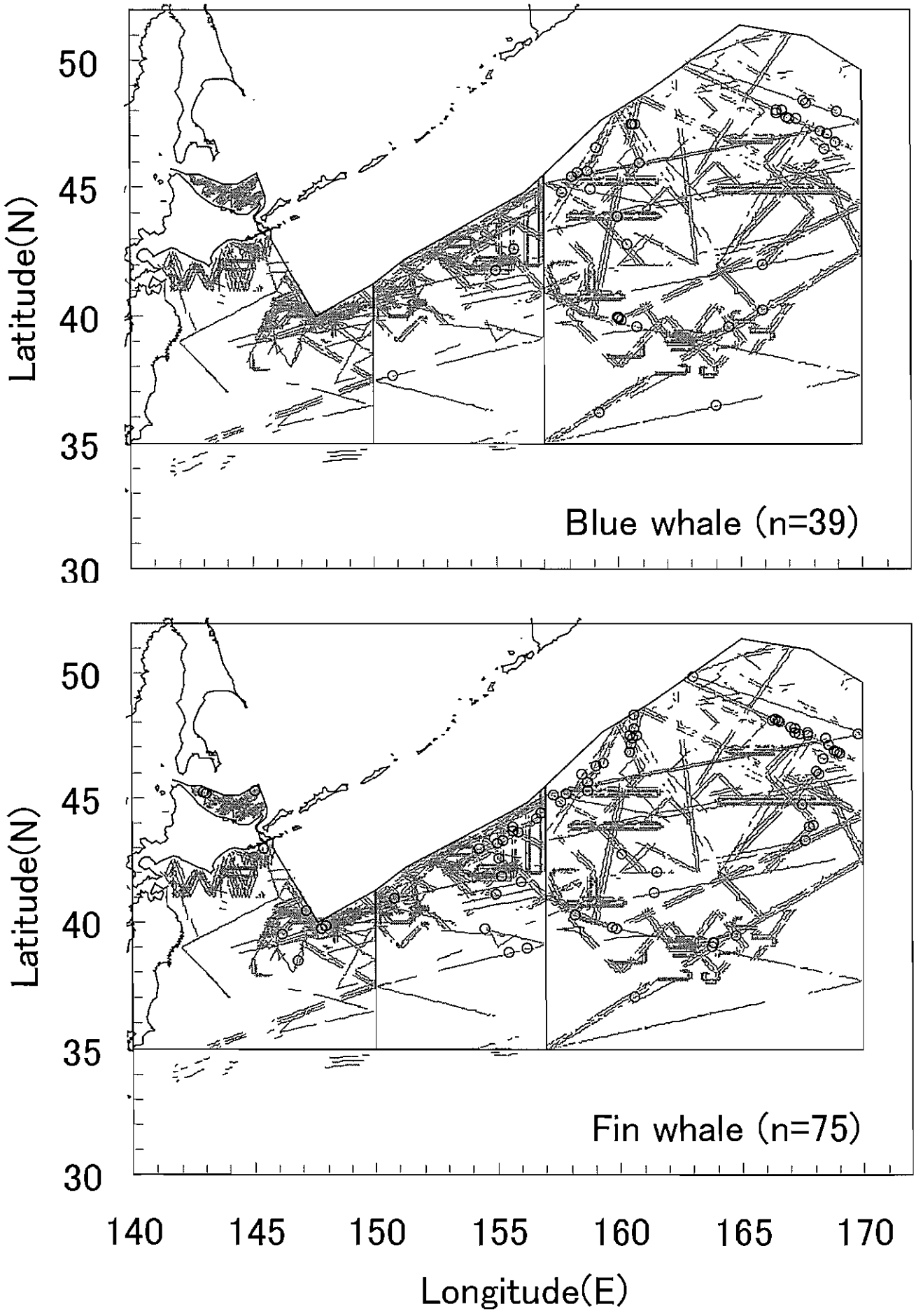

Fig.4. Search effort and sighting position of other large whales in the JARPN 1994-1999. (Upper: blue whale, lower: fin whale).

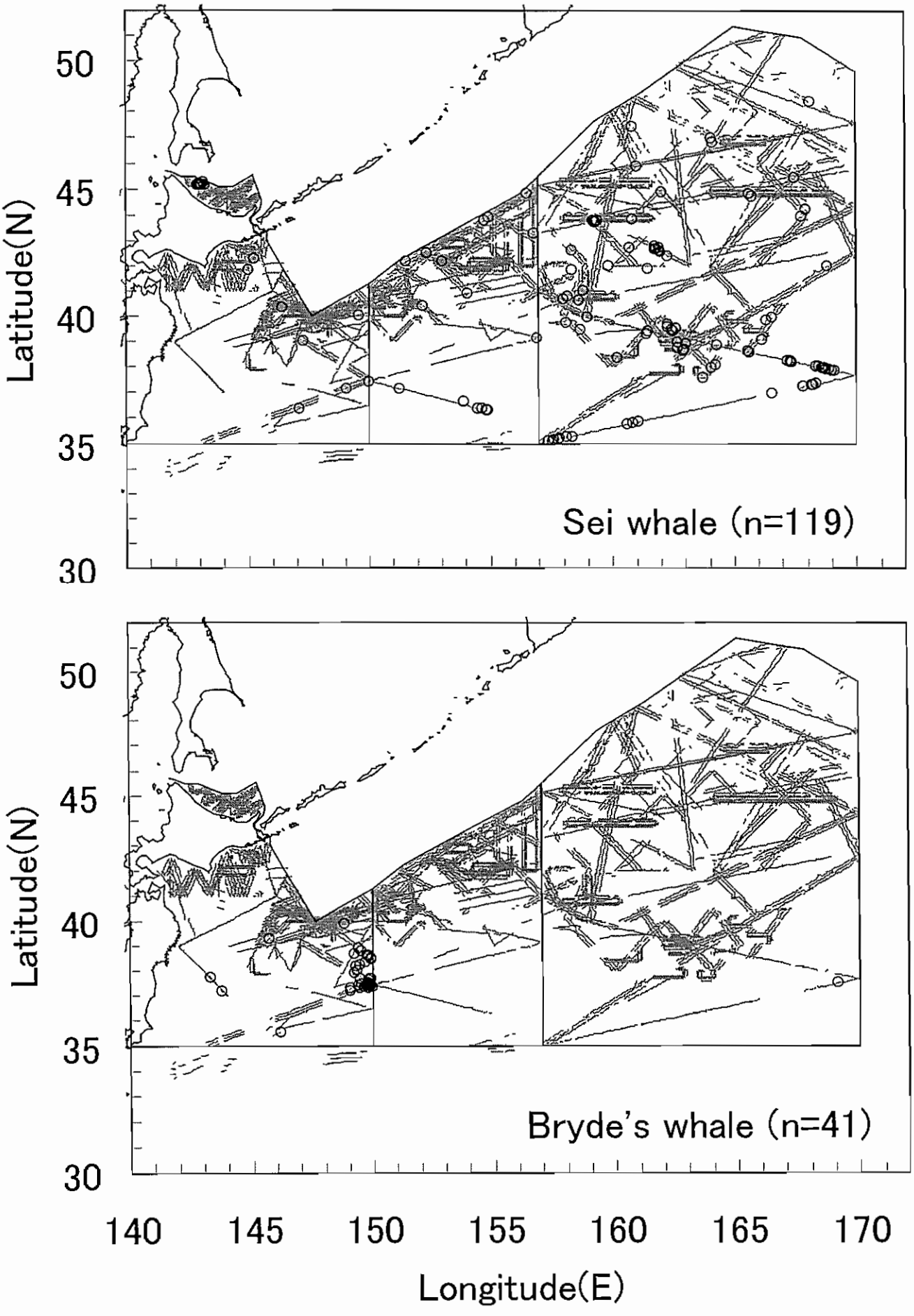

Fig.4. Search effort and sighting position of other large whales in the JARPN 1994-1999. (Upper: sei whale, lower: bryde's whale).

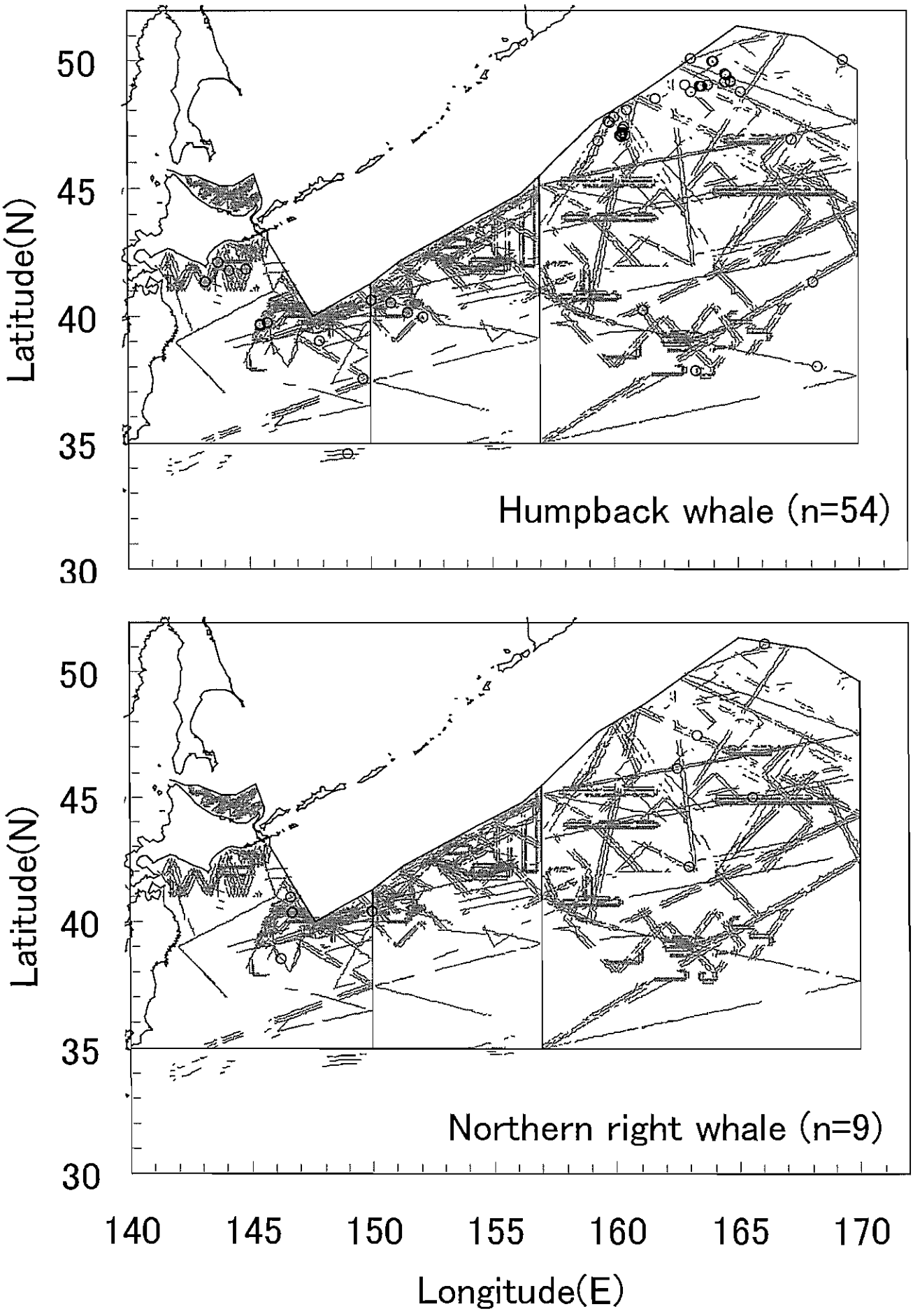

Fig.4. Search effort and sighting position of other large whales in the JARPN 1994-1999. (Upper: humpback whale, lower: northern right whale).

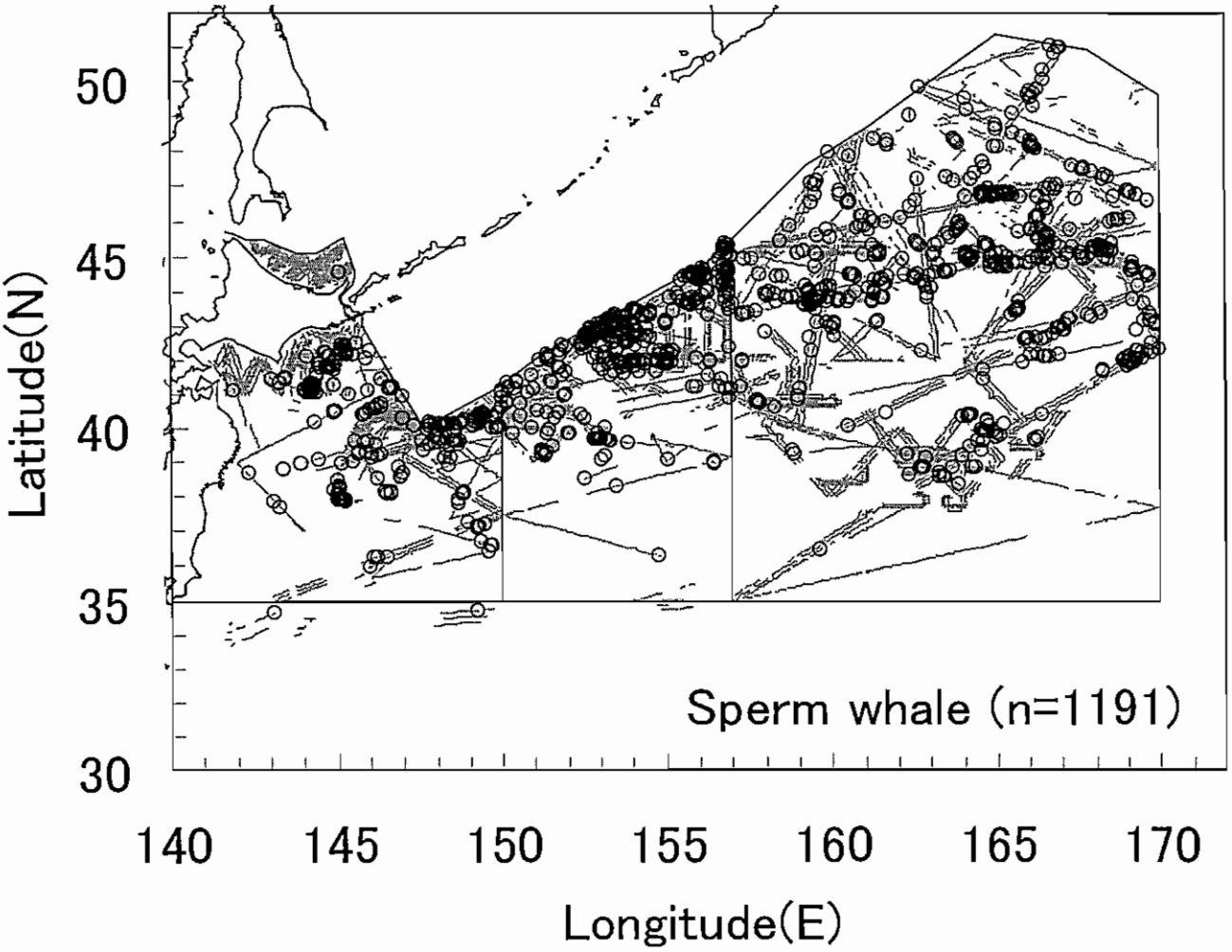

Fig.4. Search effort and sighting position of other large whales in the JARPN 1994-1999. (Sperm whale).