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ABSTRACT
This paper presents a review of past studies on sei whales in order to describe stock structure hypotheses for the species in the North Pacific. A number of evidence obtained from different kinds of the analyses using mark-recapture, sighting, catch history, and genetic data shed light on patterns of distribution and migration of the sei whales, facilitating the hypothesis development. The mark-recapture data indicated that whales from the same breeding area distribute widely in the feeding area over almost the entire North Pacific. Although historical catch data from commercial whaling era had shown heterogeneous distribution of the sei whales, genetic evidence indicated no temporal and spatial genetic differences among the whales obtained from the entire North Pacific. The heterogeneous catch distribution appeared to reflect non-random operations of the commercial whaling as well as patchy distribution of their prey species. Overall, based on the series of the available evidence we propose a single stock hypothesis for sei whales in the North Pacific.

INTRODUCTION
In order to investigate current status of whale stocks in a given oceanic region, the Scientific Committee of the International Whaling Commission (IWC/SC) conducts 'in-depth assessments' of the target species. The IWC/SC defined an in-depth assessment (IDA; formerly, comprehensive assessment) as an in-depth evaluation of the present status of whale stocks in the light of management objectives and procedures. IDA examines current stock size, recent population trends, carrying capacity and productivity under the plausible stock structure hypothesis. An evaluation of the status also requires knowledge of the pre-exploitation abundance of the populations that is obtained using population dynamics models in conjunction with the historic catch record (Donovan, 1989). IDA is generally undertaken prior to a Revised Management Procedure (RMP) *Implementation* process.

The sei whale, *Balaenoptera borealis*, is a large baleen whale species inhabiting in all of the major open oceans (Masaki, 1976; Horwood, 1987; Rice, 1998), and was one of the major targets of commercial whaling worldwide (Horwood, 1987). In the western North Pacific off Japanese coast, sei whales were subjected to commercial whaling for a long time until 1975 when it was ended (Horwood, 1987). Period of main exploitation was from 1963 to 1973 in North Pacific (Allen, 1980), but catches over a few hundreds of sei whales per year were counted throughout the commercial whaling era (Horwood, 2002). The previous assessment in the IWC/SC performed by Tillman (1977) revealed, with tentatively assuming a single stock in the North Pacific, that the North Pacific sei whales had undergone substantial decline (approximately 20%) from 42,000 in 1963 to 8,600 in 1974 due to exploitation by the intensive pelagic whaling. Since then, not only a number of new data from the North Pacific sei whales has been accumulated, but a number of new analytical approaches for genetics, abundance, and population modelling have been developed. The IWC/SC recommended in 2014 that the in-depth assessment of the North Pacific sei whales should begin in 2015.

Among all of the required information, understanding of stock structure in the region is essential for successful IDA. Similar to the typical baleen whale species, sei whales have been believed to undergo seasonal movement from winter breeding grounds in low latitude to summer feeding grounds in high latitude, and this migration pattern of sei whales in conjunction with other geographic, biological, and ecological factors could result in spatial and temporal separations of the sei whales, i.e., stocks (Horwood, 1987; Wada and Numachi, 1991). Past studies, however, have provided very limited information on the stock structure of the North Pacific sei whales, and thus no conclusive evidence has been presented (reviewed by Donovan, 1991). A stock is defined as a randomly mating group of organisms that shares same demographic parameters and is genetically discrete from other stocks. In order to find the stock structure, the definition indicates us to extrapolate any patterns of migration, distribution, genetic differentiation as well as some biological characteristics for sei whales in the studied area.

In this paper, we review and examine several data obtained from current and past studies on the North Pacific sei whales to develop the stock structure hypothesis of the species in the North Pacific for successful IDA.

Questions to be addressed relevant to the North Pacific sei whale stock structure are:
1. where they are in winter and in summer, and what they are doing,
2. whether or not they conduct seasonal migrations between breeding and feeding grounds,
3. how straight they migrate north from the breeding grounds, or otherwise, how far they head northwest or northeast direction,
4. how strong they have fidelity to the same breeding and/or feeding grounds,

The format of this paper roughly followed reports of the past IDA for other species.

MARKING OF WHALES

Whale marking experiments by the use of Discovery-type tags were conducted by Japanese Government from 1949 to 1973 in the North Pacific (Fig. 1). The experiments were attempted mainly from scouting boats in the whaling grounds during whaling operation. Some experiments were conducted from chartered catcher boats outside the whaling grounds as well as in the off-season. Total of 564 sei whales were successfully marked, and among them 99 whales were recaptured. The data dug out evidence of the both short- and long-distance migrations within the feeding grounds as well as between the feeding and breeding grounds. More details in the pattern of distribution and migration were described below.

Satellite tagging experiments were conducted for sei whales during JARPNII (second phase of the Japanese whale research program under special permit in the North Pacific), but no successful result has been obtained (e.g., Matsuoka *et al*., 2008; Tamura *et al*., 2009). During the 2007JARPNII survey, although one satellite telemetry tag was attached for a sei whale, its position data was not received successfully (Matsuoka *et al*., 2008). During the 2008JARPNII survey, although four sei whales were targeted for attaching satellite tags, no tag attachment was achieved at all (Tamura *et al*., 2009).

DISTRIBUTION AND MIGRATION

Winter distribution

First of all, as shown elsewhere, almost all of the data for the North Pacific sei whales were obtained during summer in the feeding grounds. The data from the winter season described here is thus quite invaluable.

Japan conducted sighting survey with the tagging experiments in winter seven times from 1971/72 season to 1978 (Ohsumi and Masaki, 1973). Only the two surveys, 1971/72 and 1972/73, sighted sei whales (Figs.2 and 3). The 1971/72 survey was conducted from Jan. 16 to Feb. 16 in 1972 and the 1972/73 survey was conducted from Feb.1 to Mar. 21 in 1973, a little longer than the previous year. Because of the longer research period total survey distance (10,278 miles) of the 1972/73 survey was approximately twice of that (5,007 miles) of the 1971/72 survey. Another difference between the two surveys was that the 1971/72 survey covered a little more southern water than the 1972/73 survey did, while the 1972/73 survey covered more eastern waters than the 1971/72 survey.

During the two surveys, 78 sei whales of 29 schools were found, and approximately 40% of them were singles. All but one group (15°41’N) were found in the area between 20°N and 30°N, and all whales were found in the area between 140°E and 160°W. The most of the whales were sighted at 24°C (20 -27°C). The recorded water temperature in winter was higher than that in summer (in general less than 20°C) (Fujise *et al*, 2004). Five schools were consisted of mother-calf (18%): four were pair schools and one was a group of five whales. All of mother-calf pairs was sighted in February. These findings suggests that the area between 20°N and 30°N in winter is a part of their breeding areas.

Ohsumi and Masaki (1973) observed that a single whale excreted plumes of liquid brown feces while it was chased by a ship. This observation suggests that sei whales feed at the breeding area in winter.

Summer distribution

a) Catch distribution

Longitudinal frequency distribution of commercial catches was summarized by Masaki (1976) shown as Fig 4 of this paper. It is important to note that the heterogeneous distribution of the sei whales along the longitude shown in the figure is due to regulation of the commercial whaling. The sei whale commercial whaling was divided into the pelagic and coastal whaling at 159°E in Japan by the law issued by the government to protect coastal whaling. No whale catch was recorded from 150°E to 159°E because 150°E was the farthest distance at which the coastal whaling catcher boats were able to bring back the whales taken without putrefaction of whale's internal organs. Therefore the gap of commercial catches was entirely caused by the artificial reason and didn't indicate existence of biologically separated stocks. It should also be noted that commercial catch positions cannot be considered as representative samples as the catches were non-random. Nevertheless, Masaki (1976) suggested the separation of the North Pacific sei whales into three stocks based

on heterogeneous distribution of catch positions as the catches aggregated within the areas west of 174°W, between 174°W and 155°W, and east of 155°W.

Catch positions of sei whales in summer recorded in IWC summary catch database Version 4.0 (Allison, 2008) are shown in Fig. 5. Animals caught by JARPNII from 2002 to 2006 are included in addition to commercial catches. Longitudinal coverage of JARPNII is between 140°E to 170°E. The catch positions of JARPNII fulfilled the artificial gap overserved in Fig. 4. Catch position continued from coastal area of Japan to California and no longitudinal distribution gap was found. Some of catches shown in Fig. 5 include Bryde's whales because sei and Bryde's whales were not separated in the Japanese catch statistics before 1955 (Omura, 1959). Interpretation of Fig.5 needs special care on this point. It should be noted number of commercial catches of Bryde's and sei whales in the database were already corrected (IWC, 1996) while catch positions has not been corrected.

b) *Movements (mark-recapture)*

Masaki (1976) examined east-west movement of the sei whales using the mark-recapture data obtained during the past commercial whaling period (Fig.6). Although Masaki (1976) basically only emphasized that most of whales were marked and recaptured within each of the three areas with several cases of the cross-area movements, the patterns displayed from the solid lines and the dashed ones actually give us quite different, yet very important, implications on the sei whale's migration behavior. The dashed lines represented by the whales marked and recaptured in the same season indicated that the distance of the east-west movement within the feeding grounds appeared to be short. On the other hand, the solid line represented by the whales marked and recaptured later in the different years indicates that, in after years, some migrated back to the same areas in the feeding grounds while others to very different areas in the feeding grounds. Why they chose to go west or east seems unlikely under any predilections.

In addition, Fig.7 shows actual movements of sei whales marked in 1951 to 1972, and recaptured in the coastal area of Japan in 1959 to 1975. Among them, five of eight animals recaptured in the coastal whaling ground were marked in the offshore areas far from the coastal whaling ground (east of 150°E) These instances indicated the clear evidence of the interchange of animals between the coastal and offshore areas in the catch distributions observed in Fig.5.

c) Sightings

During the commercial whaling operations, systematic sighting surveys by Japan were carried out from scouting boats in the North Pacific from 1965 to 1973. Masaki (1976) showed that, using the density data represented as the number of whales sighted per 100 miles of the scouting distance, the sei whale abundance in the northern areas of the whole North Pacific changed by month as it was high in June and July while low in April-May and August-September (Fig.8). The author inferred that the main group of the North Pacific sei whales appeared to arrive at the feeding grounds by June and July each year, and begin southward migration from August and September.

Sighting positions of sei whales in JARPNII (2000-2007) (Murase *et al.*, 2009) and POWER (2010-2012) (Murase *et al.*, 2013) and estimated probability of occurrence of sei whales by using these data are shown in Fig. 9. Again, as in the cases of catch positions (Fig. 5), there is no obvious gap of distribution of sei whales although probabilities of occurrence near the coast of Japan are relatively low. Although two strandings of sei whales have been reported at Tokyo bay in 2013 and 2014 (see more details in ICR stranding database available at the ICR homepage), no bycaught sei whales from seine net fisheries has been reported since the Japanese DNA registration was mandated in July of 2001.

Abundance estimates from JARPNII (2002-2007) (Hakamada *et al*., 2009) and POWER (2010-2012) Hakamada *et al*., 2015) were 7,744 and 33,725 individuals, respectively. Total number of animals in JARPNII and POWER survey area is 41,469 animals.

There is an impression that number of sightings in recent sighting surveys in both along the coast of Japan and United States (Barlow and Forney, 2007) is low in comparison with number of commercial catches. It can be hypothesized that sei whales are not occupied all available areas for them as the current population level is still lower than pre-exploitation level. This aspect should be investigated in parallel with population dynamics studies which will conducted in the light of this in-depth assessment. In addition, both climatic and biological regime shifts have occurred in the North Pacific Ocean (Hare, 2000; Mantua, 2004; Overland *et al.*, 2008; Yatsu *et al.*, 2013). The regime shift might cause shift in distribution of sei whales although it is difficult to test this hypothesis at this stage.

Seasonal Migration (North- South)
Understanding of pattern of the whale's north-south migration is important to develop the stock structure hypothesis because it may directly show evidence of the multiple stocks inferred from the number of separate breeding areas. The migration pattern may reflect the whale's ability of the fidelity to the same breeding area. This section, therefore, dig a little bit deeper into the mark-recapture experiments conducted in winter.

During the 1971/72 and 1972/73 surveys in low latitude already described above, 63 of the sighted 78 sei whales were tagged using Japanese discovery-type tags. Table 1 shows records of the sighting and tagging by the schools in the 1971/72 survey (The data from the 1972/73 survey was not available while writing this paper). Fourteen schools were targeted for the tagging experiments, and 46 individuals were tagged. Except one case (eight tagged over 13), all individuals in the schools were successfully tagged.

Table 2 then shows records of the tagged and recovered locations by the individuals that were taken by the commercial whaling. Total of the 26 tags were recovered, which was 41% of the total tags. Among these tags, 22 tags from 9 males and 13 females were confirmed their tagged and recovered locations by the whales' catch records. The locations of these 22 cases in the North Pacific were illustrated in Fig.10. Those whales tagged in the low latitude area (15N to 24N; 143E to 166 W) between January and March were recaptured in the northern area (35N to 48N; 143E to 155W) between May and August. As explained above, the tagging experiments were conducted to the whales in the same schools, so that the records were able to trace the differences in the migration directions among the individuals in the same schools (i.e., #11989-#11998; #12013-#12028; #12066-#12076; #12003-#12031-#12050; #12101-#12139; #12114-#12129). The results showed that the tagged whales from the same schools migrated together quite closely to the north area in some cases and to the different areas in other cases. For instance, a pair (#12013-#12028) was recovered at the same day at the quite similar position, while a trio (#12003-#12031-#12050) was recovered from the quite different positions.

The migration route uncovered by #12050 shed light on an important implication for stock structure of the North Pacific sei whale. This whale was tagged in the east longitude area (21.39N/151.21E) and then was caught at the west longitude area (48.02N/141.00W) next year. This result indicated not only that sei whales did not always migrate straight north but that whales migrating from the same breeding ground distributed quite widely in the feeding ground.

An additional important observation from the experiments was the migration of #11963 that also showed the direct evidence of the whales from the different part of the breeding ground mixing in the same feeding ground. Although most of the whales, with a few exceptions, were tagged at the water around the

150E, the #11963 was tagged at 179.10E. Still, they were recovered at very similar area of the feeding grounds around 40N/170E.

Overall, these results from the tag-recapture experiments provide us several important facts that should answer the questions initially raised in this paper: the North Pacific sei whales stay in the areas around 20°N in winter, conduct south-north migration for breeding and feeding, stay in the areas around 40N in summer for feeding. While conducting the seasonal migration, some sei whales migrate rather northwest or northeast direction than straight north. The whales from different breeding areas mix in the same area of the feeding grounds and this type of the mixing could occur anywhere in the North Pacific.

One thing still to be clarified is the fidelity of the whales to the same breeding grounds. That is, although whales from the same breeding area or simply any single whales can migrate to the different part of the feeding ground every years, we are unsure whether or not they migrate back to the same breeding ground repeatedly. In this case, we still could find evidence of multiple stocks in the North Pacific because of some degree of reproductive isolation. This can be tested using another approaches, such as genetics.

GENETICS

A pioneer genetic work of Wada and Numachi (1991) looked at genetic variation at allozyme loci in samples of the North Pacific sei whales collected in the area east of 160°E. These authors were unable to detect evidence of temporal and spatial genetic heterogeneity in the samples, suggesting existence of only a single stock in the area. Unfortunately, lack of the genetic heterogeneity in the samples collected from such a wide area could have been resulted from low resolution power of the genetic marker due to the characteristics of the marker themselves as well as the number of the marker used (only three polymorphic allozyme loci). The allozyme method tend to show low level of genetic variation because it can detect the genetic variation at a small portion of all genes, it cannot detect genetic changes that do not alter the amino acid, and the rate of allozyme mutation is low (Avise, 1994).

Such limitation was overcome using hypervariable microsatellite loci. Kanda *et al*. (2006) utilized genetic variations at 17 hypervariable microsatellite markers in the 2002 and 2003 JARPNII samples of sei whales from the western North Pacific for describing their genetic characteristics. Genetic analysis of a total of 89 whales found high level of genetic diversity within the samples, while no evidence of genetic heterogeneity between the samples. Even with highly variable microsatellite markers, Kanda *et al*. (2006) also reached the same conclusion to Wada and Numachi (1991). The sizes and geographic origins of the samples were still rather limited, however.

The most comprehensive studies conducted so far were those presented at the previous JARPNII Review workshop in 2009 (Kanda *et al*. 2009) as well as presented at the recent IWC/SC (Kanda *et al*. 2013). Kanda *et al*. (2009) analyzed genetic variation at 17 microsatellite loci and 487 bp of mitochondrial DNA (mtDNA) control region sequences in the JARPNII samples (N=489) from 2002 to 2007 in the area between 143°E and 170°E as well as in the commercial whaling samples (N=301) from 1972 and 1973 conducted in the area between 165°E and 139°W to describe their stock structure in the North Pacific. No evidence of genetic differences within as well as between the JARPNII and commercial whaling samples was found. Both females and males showed same pattern of the stock structure. Sequencing and phylogenetic analysis of the mtDNA control region also showed no evidence of the genetic heterogeneity in the JARPNII samples as well as no spatially or temporally unique phylogenetic clusters. Addition of the 400 more sei whales from the 2004-2007 JARPNII surveys for the genetic analyses did not change the results observed in Kanda *et al*. (2006) that used only the 2002 and 2003 JARPNII samples.

Kanda *et al*. (2013) examined genetic variations at 14 microsatellite loci in the North Pacific sei whales' biopsy samples obtained from the IWC-POWER (the International Whaling Commission/Pacific Ocean Whale and Ecosystem Research; hereafter, POWER) cruises that surveyed 170°E - 170°W area of the central North Pacific in 2010 (N=13), 170°W - 150°W area of the central North Pacific in 2011 (N=29), and 150°W - 135°W area of the eastern North Pacific in 2012 (N=35). The observed POWER data was analyzed with previously reported genetic data in the Kanda *et al*. (2009) that allowed the authors to detect temporal (40 years apart between the POWER and commercial whaling data) and spatial (143°E to 135°W area divided into western, central, and eastern) genetic differences of the North Pacific sei whales (Fig.11). The results showed no evidence of the temporal genetic differences between the recent POWER and past commercial whaling samples collected from the same area and no evidence of the spatial genetic differences among the western, central, and eastern samples.

SUMMARY

Stock Structure Hypothesis

With regard to stock structure hypothesis, on the basis of the observations obtained from analyzing sighting, tagging, and catch history data mentioned so far above, Masaki (1976) firstly proposed the existence of three stocks of sei whales with the stock boundaries at 174°W and 155°W in the North Pacific. Heterogeneous distributions of sei whales observed from the catch history and marking data could reflect patchy distributions of the genetically different stocks. It is important to note, however, that this mark-recapture data was largely influenced by the operation of commercial whaling because the takes of the whales by the commercial whaling were not necessarily in a random fashion. Alternately, non-random distribution of the whales could simply reveal their feeding aggregations that do not necessary indicate existence of multiple stocks. It is known that oceanographic environment (e.g., limit of Kuroshio extension, flow pattern of Alaska gyre, etc.) and oceanic geography (Emperor Seamount Chain) influence distributions and variety of prey species around the 174°W and 155°W (e.g., Kawamura, 1982; Bakun, 2006; Gregr and Bodtker, 2007; Murase *et al*., 2009), limiting east-west movement of sei whales in the feeding ground.

Tracking the north-south movement of the whales using the winter tagging experiments should be a very strong means of describing the pattern of the migration between breeding and feeding grounds. The past winter tagging experiments shown above strongly suggests whales tagged at the similar as well as different positions in the lower latitudinal waters mixed well in the higher latitudinal waters. Similarly, the summer tagging experiments during the commercial whaling operation indicate that same single whales do not necessarily come back to the same feeding areas every year, and that whales from the same school observed at the lower latitudinal waters migrated to the different areas in the feeding grounds.

It still remains unclear from the field observations that the sei whales migrate back to either the same or different wintering areas every time in the North Pacific. Genetic results favor the former, because no evidence of temporal and spatial genetic differences was detected among samples. In conclusion, based on the current knowledge described above, the most plausible stock structure hypothesis is that a single stock of sei whales exists in the North Pacific.

Prieto *et al*. (2012) conducted a bibliometric analysis of the literatures on the sei whale in the North Atlantic to review the species' distribution, movements, stock structure, feeding, reproduction, abundance, acoustic, mortality and threats. In regard to the stock structure, the IWC separated the North Atlantic into three management areas for the sei whales based on the statistical reason as well as the historical catch data (Donovan, 1991). However, biological evidence of stock separation was limited. In fact, no evidence of genetic heterogeneity was obtained among the samples from these areas (Danielsdottir, 1991). Recent satellite telemetry study (see also Prieto *et al*., 2014) suggested that the migration patterns of the North Atlantic sei whales may be more complex than it has been previously assumed. The authors indicated that it is still unclear whether the North Atlantic sei whales constitute multiple stocks or a panmictic stock.

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Table 1. Date, school size (S), position, temperature (T) of sei whales sighted during the 1971/72 survey.

Date	S	Position	T (ºC)	Note
1972/01/26	13	15・41N, 143・00E	27.3	8 tagged
1972/02/05	3	20・41N, 152・12E	25.2	3 tagged
1972/02/06	3	21・37N, 151・26E	28.0	3 tagged
1972/02/06	3	21・39N, 151・22E	28.0	3 tagged
1972/02/06	2	21・42N, 151・36E	26.0	2 tagged (mother and calf)
1972/02/06	2	21・23N, 151・43E	25.7	2 tagged
1972/02/06	2	21・36N, 151・57E	26.0	2 tagged (mother and calf)
1972/02/07	5	23・00N, 151・42E	25.3	5 tagged (incl. mother and calf pair)
1972/02/07	2	23・00N, 151・45E	25.4	2 tagged
1972/02/07	2	23・30N, 151・35E	24.5	2 tagged
1972/02/09	5	23・28N, 147・09E	24.8	5 tagged (incl. mother and calf pair)
1972/02/09	3	23・00N, 147・08E	24.8	3 tagged
1972/02/09	4	23・00N, 147・04E	24.4	4 tagged
1972/02/14	2	23・00N, 151・45E	20.1	2 tagged (mother and calf)

Table 2. Records of the tagged and recaptured sei whales during the winter surveys.

Tag #	Sex	Body length (m)	Date		Position	
			Tagged	Recap.	Tagged	Recap.
11831	F	12.5	72/01/26	72/06/12	15-25N, 143-00E	46-50N, 172-24E
11974	F	13.7	72/02/05	72/06/15	20-41N, 152-12E	35-12N, 177-06E
11986	-	-	72/02/05	72/08/9	20-45N, 152-12E	- -
11989	M	13.0	72/02/06	72/07/23	21-37N, 151-26E	45-15N, 167-13E
11998	M	13.3	72/02/06	72/06/14	21-37N, 151-26E	36-38N, 178-13E
12012	M	14.2	72/02/06	72/07/03	21-36N, 151-57E	38-56N, 174-49E
12013	F	13.4	72/02/07	72/06/03	23-00N, 151-45E	42-05N, 167-19E
12028	M	13.5	72/02/07	72/06/03	23-00N, 151-45E	42-07N, 168-18E
12038	F	14.7	72/02/06	72/07/03	21-36N, 151-57E	38-52N, 174-53E
12066	F	14.0	72/02/09	72/05/24	23-36N, 147-04E	39-23N, 169-44E
12076	M	12.8	72/02/09	72/06/08	23-36N, 147-04E	39-01N, 168-16E
12134	F	12.9	72/02/09	72/06/26	23-28N, 147-09E	40-46N, 175-50E
11952	F	14.0	73/03/02	73/08/21	24-10N, 166-13W	45-00N, 155-42W
12003	M	13.2	72/02/06	73/05/24	21-39N, 151-22E	38-19N, 155-50E
12031	F	14.4	72/02/06	73/06/27	21-39N, 151-22E	42-05N, 170-19E
12050	F	12.3	72/02/06	73/08/07	21-39N, 151-21E	48-02N, 141-00W
12101	-	-	72/02/09	73/06/04	23-28N, 147-09E	- -
12139	F	14.5	72/02/09	73/06/04	23-28N, 147-09E	39-58N, 166-42E
11822	F	13.0	73/03/02	74/08/15	24-09N, 166-09W	43-03N, 163-10W
11842	F	13.5	72/01/26	74/07/10	15-25N, 143-00E	48-31N, 171-32E
11963	F	13.2	73/02/16	74/07/08	20-57N, 179-10E	41-38N, 171-33E
12068	M	12.5	72/02/09	74/07/11	23-36N, 147-04E	48-42N, 176-13E
12114	M	12.7	72/02/07	74,07/04	22-59N, 151-45E	39-07N, 169-44E
12129	-	-	72/02/07	-	22-59N, 151-45E	- -
12858	-	-	73/02/06	-	23-50N, 155-06E	- -
12029	M	12.4	72/02/06	75/05/17	21-42N, 151-36E	34-42N, 143-20E

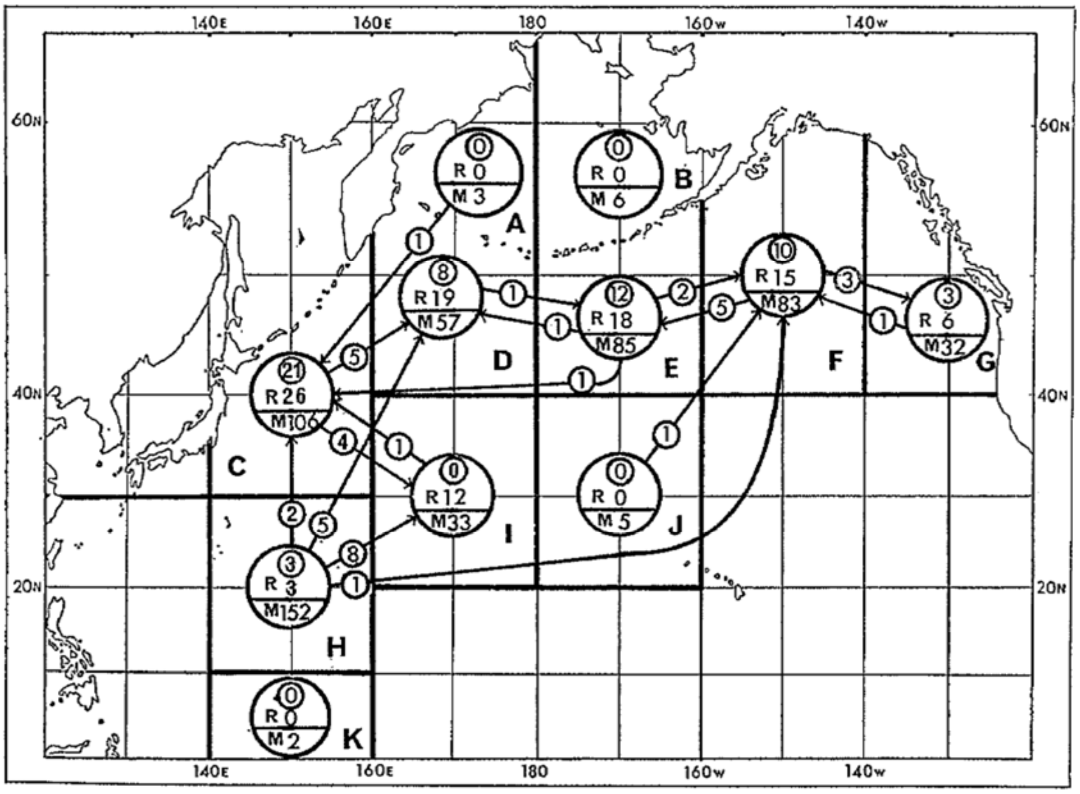

Fig.1. Movements of tagged-recovered sei whales in the North Pacific by areas (from Masaki, 1976).
M = total number of whales tagged; R = total number of whales recaptured; Number in the small circle = number of whales recaptured at the same area; Number in the small circle with arrow = number of whales tagged and recaptured at different areas.

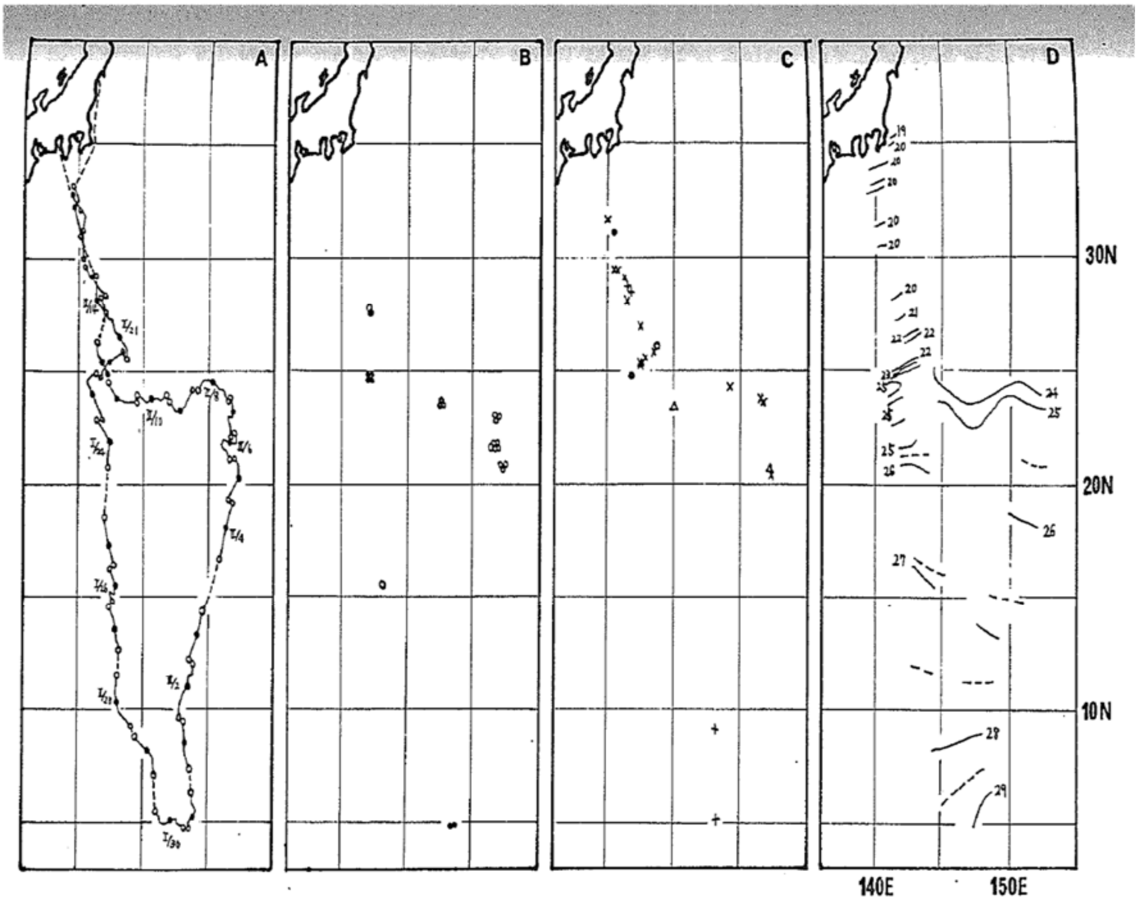

Fig.2. Winter whale sighting survey in 1972 (from Ohsumi and Masaki, 1973).

A. Solid line: working distance, broken line: cruise only, open circle: start or end of working, closed circle: noon position.
B. Position of baleen whale school found. ○: sei, ●: Bryde's, x: humpback, +: minke, △: fin.
C. Position of toothed whales school found. ○:Ziphidae, ●: sperm, x: Delphinidae, +: Kogia, riangle, △: Globicephalidae.
D. Surface water temperature (celsius).

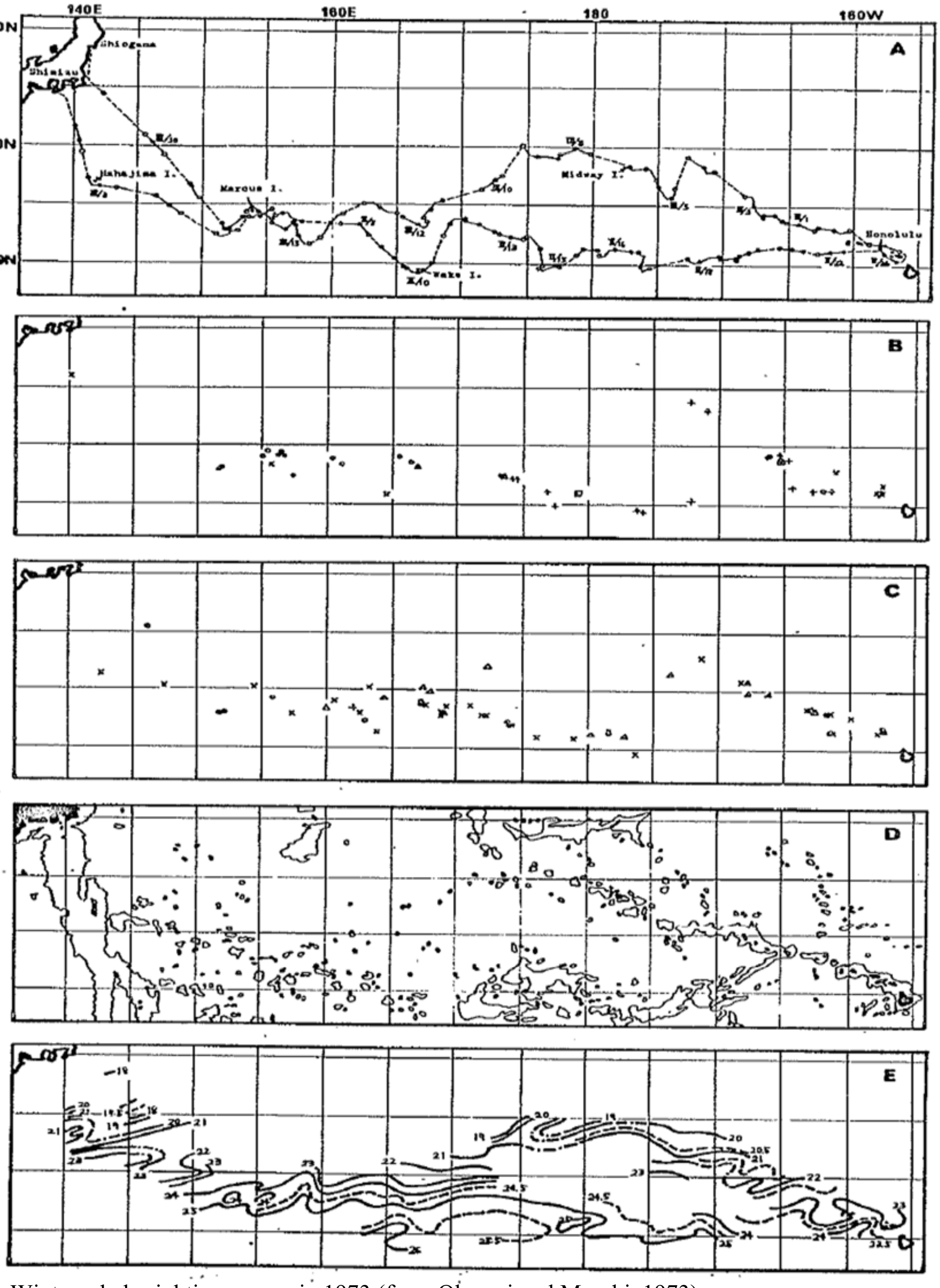

Fig.3. Winter whale sighting survey in 1973 (from Ohsumi and Masaki, 1973).

A. Wake. Solid line: working distance, broken line: cruise only, open circle: start or end of working, closed circle: noon position.
B. Position of baleen whale school found. ○: sei, ●: Bryde's, x: humpback, +: minke, △: fin.
C. Position of toothed whales school found. ○:Ziphidae, ●: sperm, x: Delphinidae, +: Kogia, riangle, △: Globicephalidae.
D. Topography of sea bottom. Thin line: 2,000 fathom, and 1,000 fathom.
E. Surface water temperature (celsius).

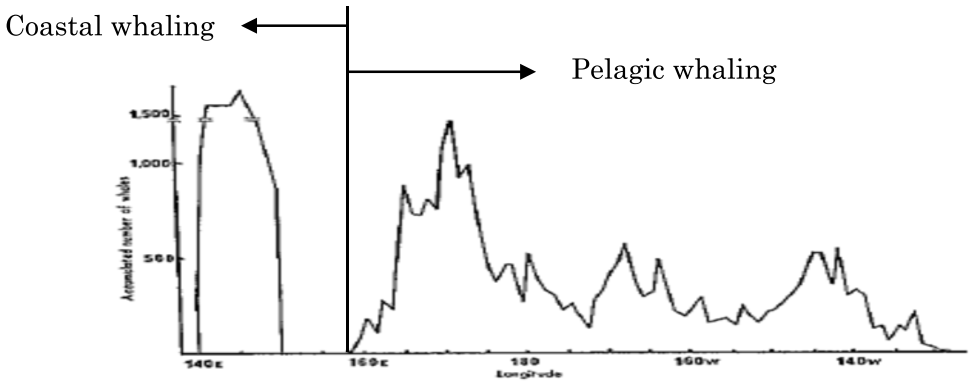

Fig.4. Accumulated number of sei whales caught by Japan by one degree longitude from 1952 to 1972 in the North Pacific (from Masaki, 1976). It should be noted that the operations of commercial whaling were divided into the pelagic and coastal at 159°E by the law issued by Japanese government to protect coastal whaling. No commercial catch was recorded from 150°E to 159°E because 150°E was the farthest distance at which the coastal whaling catcher boats were able to bring back the whales taken without putrefaction of whale's internal organs. Therefore the gap of commercial catches was entirely caused by the artificial reason and didn't indicate existence of biologically separated stocks.

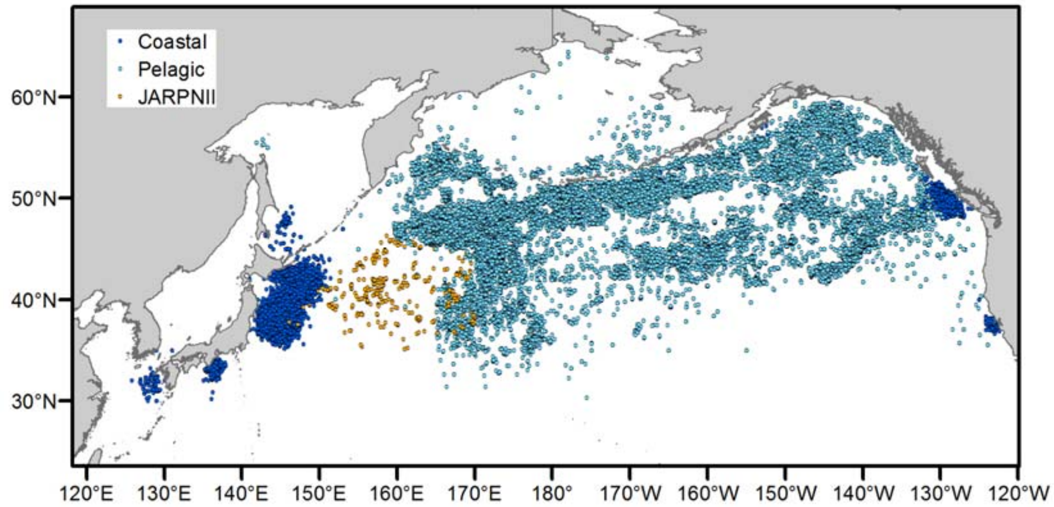

Fig. 5. Catch positions of sei whales by coastal and pelagic expeditions, and JARPNII (2002-2006) in summer (June - August) recorded in the IWC catch database version 4 released in 2008. Some of catch positions especially in the south of 40°N would be Bryde's whales because sei and Bryde's whales were not separated in the Japanese catch statistics at least before 1955 (Omura, 1959). Northern limit of distribution of Bryde's whales was around 40N (Kato and Perrin, 2009). Takes by JARPNII shown in this figure fulfilled the artificial gap shown in Fig, 4.

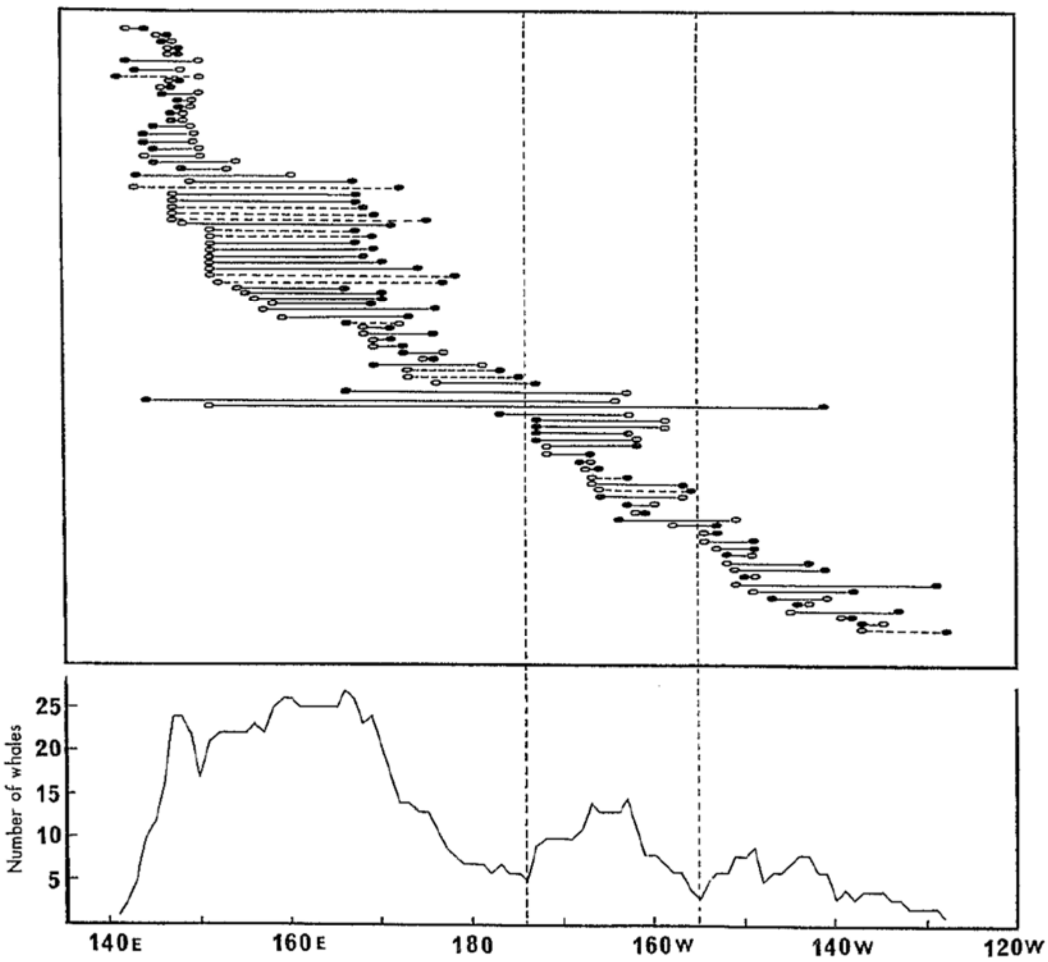

Fig.6. East-west movement of sei whales based on the mark-recapture experiments in the North Pacific and the number of the whales crossing every one longitudinal degree areas derived from the upper figure (from Masaki, 1976).
Dashed line = tagged and recaptured in the same year; Solid line = tagged and recaptured at the different years; Open circle = tagged position; Closed circle = recaptured position.

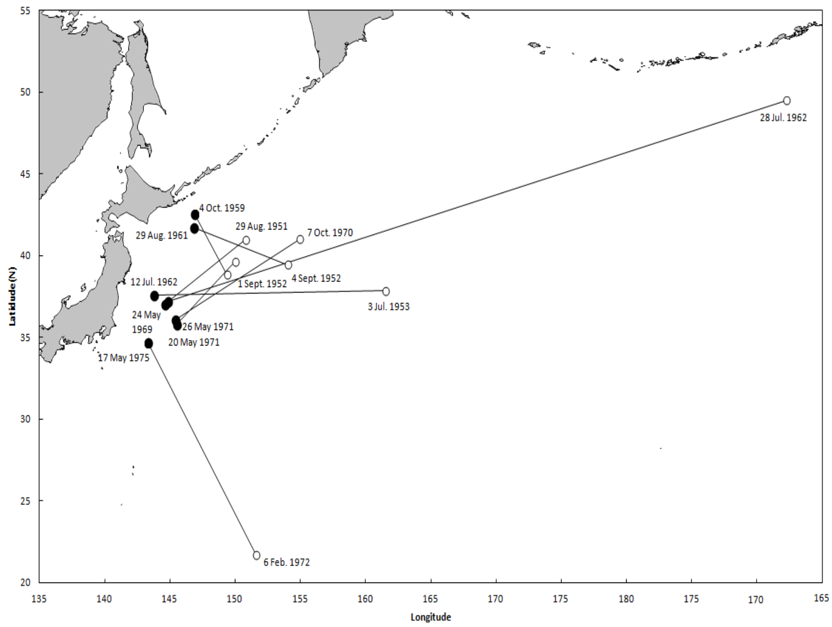

Fig.7. Movements of sei whales recaptured in the coastal area of Japan in 1959 to 1975.
Open circle = tagged position; Closed circle = recaptured position.

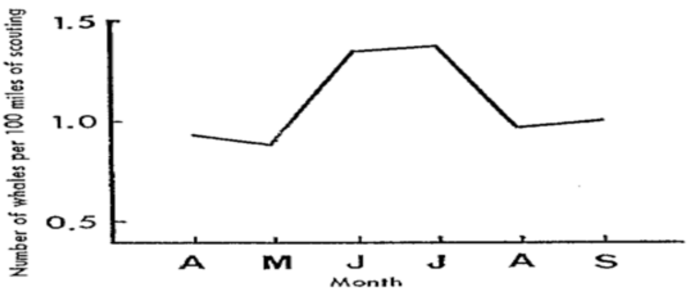

Fig.8. Abundance index by month for sei whales in the whole North Pacific north of 40N (from Masaki, 1976).

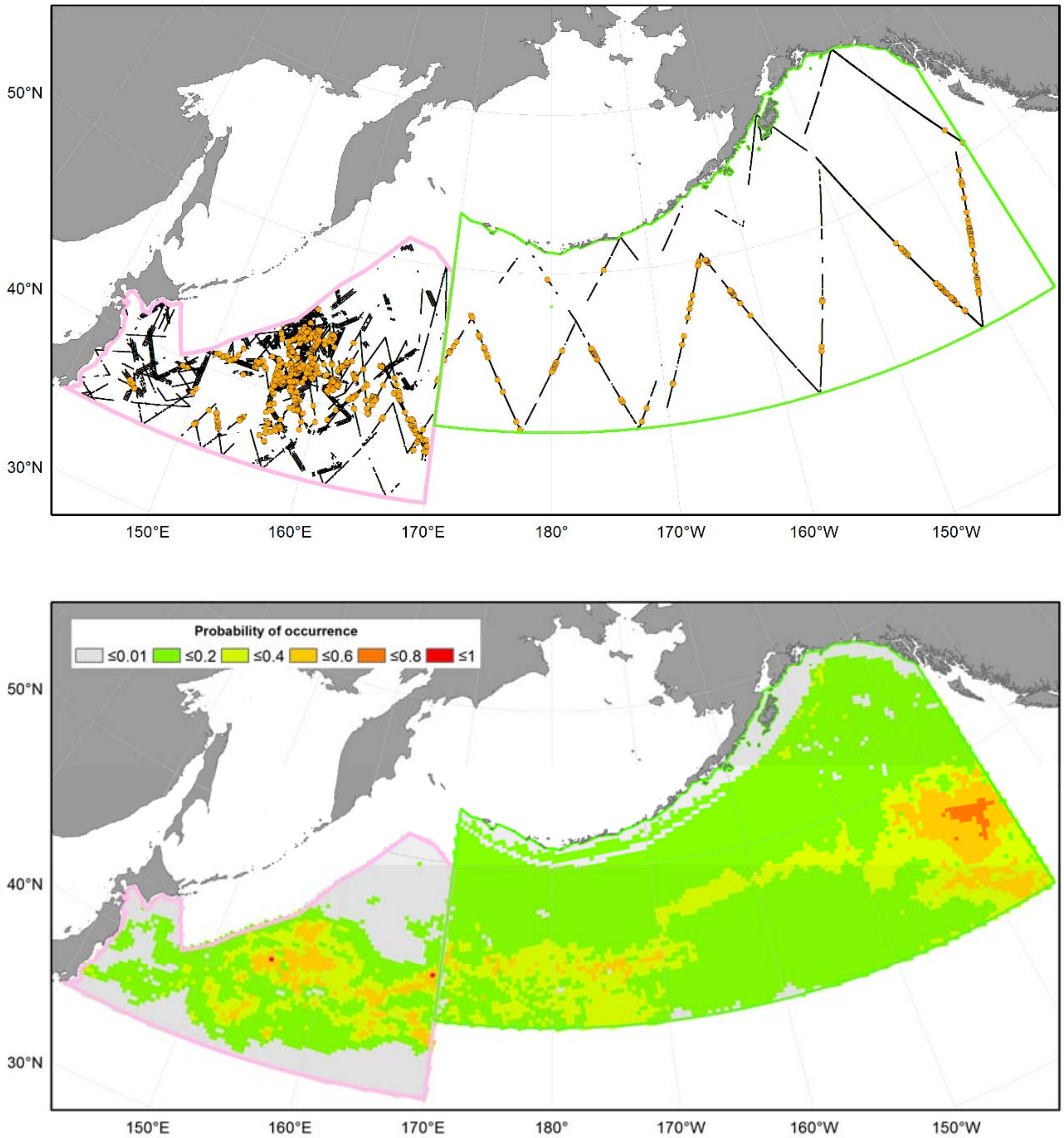

Fig. 9. Sighting effort (black lines) and positions (orange circles) (top) and probability of occurrence of sei whales (bottom) estimated by using data obtained in JARPNII (2000-2007; Murase *et al*., 2009) and POWER (2010-2012; Murase *et al*., 2013). Pink and green lines represent JARPNII and POWER survey areas, respectively.

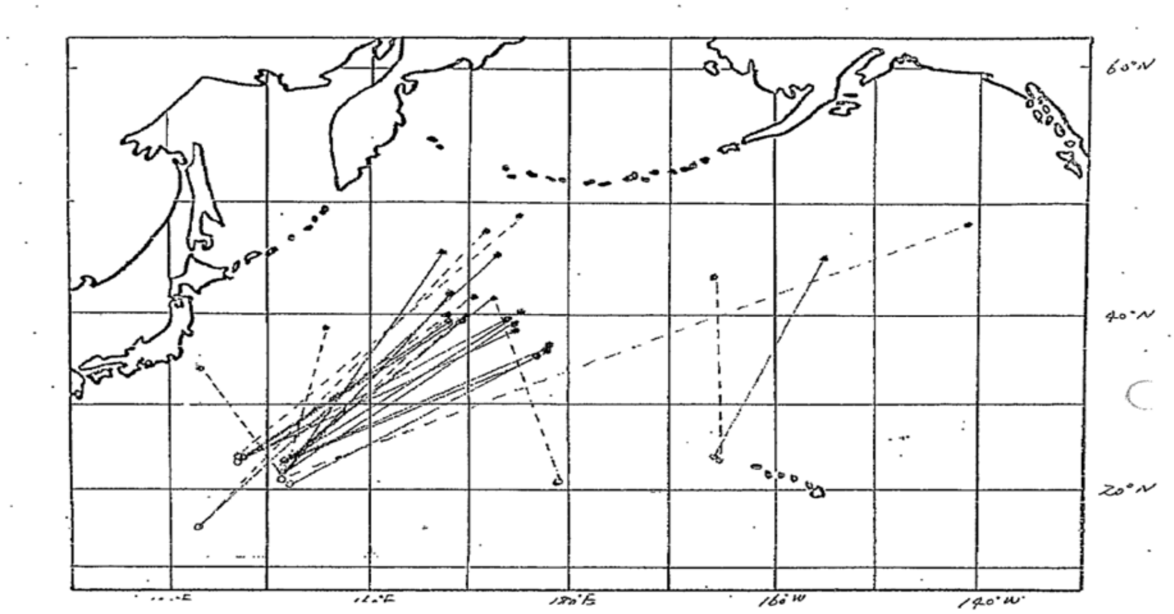

Fig.10. Positions of sei whales tagged in winter and recaptured in summer in the North Pacific.
Solid line = tagged and recaptured in the same year; Dashed line = tagged and recaptured at the different years; Open circle = tagged position; Closed circle = recaptured position.

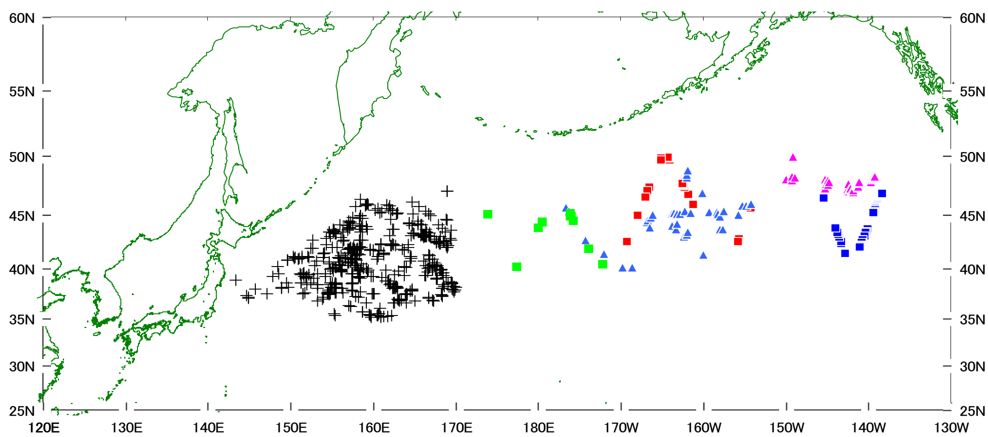

Fig.11. Sampling locations of genetic samples of sei whales in the North Pacific.
■: 2010POWER, ■: 2011POWER, ■: 2012POWER, ▲: Commercial whaling (CWh-central), ▲: Commercial whaling (CWh-eastern), +: JARPNII (Western).