Examination of the effects on whale stocks of future JARPN II catches

TAKASHI HAKAMADA
The Institute of Cetacean Research: 4-5, Toyomi-cho, Chuo-ku, Tokyo104-0055, Japan

ABSTRACT
The effects on whale stocks of the planned JARPN II catches of common minke (*Balaenoptera acutorostrata*), sei (*Balaenoptera borealis*) and Bryde's (*Balaenoptera edeni*) whales for the next 20 years were examined by using HITTER methodology and updated information on stock structure and abundance estimation. Results of the HITTER calculations showed that the minke, sei and Bryde's whales stocks involved would increase during the next 20 years in all cases examined. For comparative purposes in the case of the Bryde's whales the effect was also assessed by the population dynamics model adopted in the Revised Management Procedure (RMP)'s *Implementation Simulation Trials (ISTs)*. Both methods showed similar results. Catches of a maximum of 10 sperm whales are assumed to have no negative impact on the stock given the abundance of this species in the western North Pacific (level of catch corresponds to approximately 0.1% of the abundance). Results of these analyses suggest no negative impact on the whale stocks targeted by JARPN II as had been expected before the start of this research program.

INTRODUCTION
The effects of scientific permit catches on the stocks of common minke, Bryde's and sei whales were examined in the original and revised plans of the Japanese Whale Research under Special Permit in the western North Pacific-Phase II (JARPN II) (Government of Japan, 2002; 2004). Information on historical catches, stock structure and abundance estimation used in these calculations were available from comprehensive assessments conducted by the IWC Scientific Committee (IWC SC) for the western North Pacific common minke (IWC, 1992) and Bryde's (IWC, 1996; 1997), and from past studies conducted on sei whales in this ocean basin (Ohsumi et al., 1971; Masaki, 1976; Ohsumi, 1979).

With progress of the JARPN II new information on stock structure and abundance estimation of common minke, Bryde's and sei whales stocks became available (*e.g*. Kanda *et al*, 2009a; 2009b; 2009c; Goto *et al*., 2009; Hakamada *et al*., 2009). Furthermore the IWC SC started the in-depth assessment of the North Pacific common minke whale with emphasis on the J stock, and new information has emerged for this stock as well.

In this study the effect on the stocks of common minke, sei and Bryde's whales of JARPN II catches is re-assessed using updated information, mainly on stock structure and abundance estimation.

MATERIALS AND METHODS

Western North Pacific common minke whales

Stock structure scenario

The IWC SC adopted four stock structure hypotheses of the common minke whale during the *IST*s completed in 2003. Recent results of genetic and non-genetic studies based on JARPN and JARPN II surveys (Kanda *et al*., 2009a; Goto *et al.*, 2009; Hakamada and Bando, 2009) provided support for the single O stock scenario in sub-areas 7, 8, 9, 11 and 12 (stock structure under Scenario B in IWC (2004)).. Based on these results, it is considered that the single O stock scenario in the Pacific side of Japan (scenario B) has a high plausibility. Therefore scenario B is adopted for the examination of the effect of future JARPN II catches. For sensitivity, the case of stock structure under Scenario A (occurrence in some years of stock W in sub-area 9W) was also considered. The following two stock structure scenarios were considered:

Baseline B: 2-stock scenario ('J' and 'O').
Baseline A: 3-stock scenario ('J' 'O' and 'W') with W found only sporadically in subarea 9W.

The numbers of historical and future catches from O stock

The past commercial and research catches listed in IWC (2004) were used in the calculation. Commercial catches in sub-areas 7, 8, 9, 11 and 12 were assumed to be taken from O stock and those in sub-areas 1, 5, 6 and 10 were assumed to be taken from J stock. Future annual catch by JARPN II are 220 in total, 160 from sub-areas 7 and 30 each from sub-areas 8 and 9, respectively. Mixing rate of J stock in the past and future JARPN II catches were assumed to be same as the proportion of J stock animals by sub-areas estimated by the genetic analysis in Kanda *et al*., (2009d) (Table 1).

Incidental catches off Japan

Incidental catches until 2000 were the same as in option (Jii) in IWC (2004). From 2001 to 2007 the reported incidental catches listed in the Japan Progress Reports on Cetacean Research presented to the IWC SC were used. It should be noted that the new Japanese regulation for incidental catches were applied from the second half of 2001. It was assumed that the future annual incidental catches off Japan correspond to the annual average of those from 2001 to 2007. Mixing rate of J stock and sex ratio in past and future incidental catches were assumed to be those by sub-area and year in the catches after the change of regulation (2001-2007). The mixing rates of J stock were shown in Table 2. More details of the method for estimation of the mixing rate were described in Kanda *et al*, (2009d). The numbers of past and assumed future incidental catches off Japan from 'O' and 'J' stocks are shown in Table 3.

Incidental catches off Korea

The number of the incidental catches until 2001 provided in IWC (2004) was used. For the period 2002-2007, the numbers were as those reported in the Republic of Korea Progress Report on Cetacean Research presented to the IWC SC. For the incidental catches until 2001, average sex ratio of male during 1996-1997 of 25.7% was assumed (IWC, 2004). For incidental catches whose sex was unknown during 2002-2007, sex ratio of male using samples whose sex in known in each year was assumed. For future incidental catches, average sex ratio of male (59.1%) and the number during 2002-2007 were assumed. The numbers of past and assumed future incidental catches off Korea from 'J' stock are shown in Table 4.

Sex ratio

For the past commercial catches, the ratio showed in IWC (2004) was used. For past scientific whaling catches the ratio obtained from the JARPN and JARPNII cruise reports was used. For past incidental catches until 2000, the ratio of (Jii) option in IWC (2004) was used and those from 2001 to 2006, the ratio presented in the Japan Progress Reports on Cetacean Research for the period 2001-2007 was used. For future JARPN II catches the average ratio from the offshore component of JARPN II during 2002-2007 was assumed. For future catches by JARPN II coastal component the average ratio from costal component of JARPN II during 2002-2007 was assumed. For future incidental catches the average ratio for the incidental catches in the period 2001 to 2007 was assumed.

By using past catch statistics by sub-areas, assumed mixing rate of J stock and sex ratio of males described above, the past and future annual sex-disaggregated catches of this stock are shown in Table 5 and 6 for 'O' and 'J 'stocks, respectively.

Biological parameters

In these HITTER computations the parameter values adopted by the RMP/*ISTs* (IWC, 2004), were used:

Age at recruitment (same for both sexes): 4 (50%) and 7.53 (95%)
Age at maturity (same for both sexes): 7 (50%) and 10.53 (95%)
Natural mortality (age-dependent and independent of sex):

$$M(a) = \begin{cases} 0.085 & \text{if } a \leqq 4 \\ 0.0775 + 0.001875\, a & \text{if } 4 < a < 20 \\ 0.115 & \text{if } a \geqq 20 \end{cases}$$

where *a* is age.
MSY level (*MSYL*): 60% (of *K*)

Abundance estimate in 'O' and 'J' stocks

As for 'O' stock, the number of the common minke whales in the JARPN II survey area in July and August is estimated using sighting data during 2006-2007 and the estimate was 2,179 (CV=0.414) assuming g(0)=1 (Hakamada *et al*., 2009). The abundance estimate of common minke whales in the Sea of Okhotsk in 2003 was 24,058 (CV 0.207, 95%C.I. 16,115 – 35,916). In the east of the Kamchatka Peninsula and the Kuril Island, the abundance was estimated as 972 (CV 0.52, 95%C.I. 373 – 2,534) in 2005. All animals are assumed as of the O-stock. See Appendix 1 for details of abundance estimates in Russian waters. The total abundance is 27,207 (CV=0.187) assuming g(0)=1. Assuming g(0)=0.732 with its CV of 0.309 (Okamura *et al*., 2008), the estimates is 37,170 (CV=0.361, lower limit of 90%CI=20,879), and these are applied to 2005. Under stock structure Scenario A, half of the abundance estimate in sub-area 9 was subtracted from the abundance estimate in the JARPN II survey area in July and August under the assumption that half of the abundance in sub-area 9, were W stock animals. Basis for this assumption is that probability of occurrence in W stock in sub-area 9W was assumed to be 50% in stock scenario A. In this scenario, the estimate in JARPN II survey area was 1,304 (CV=0.395) and abundance estimate in O stock was 35,975 (CV=0.363) in total applying *g*(0)=0.732. Its lower limit of 90%CI was 20,159. Summary of the abundance estimate in 'O' stock used in this study was summarised in Table 7.

As for 'J' stock, abundance estimate in the Sea of Okhotsk is 4,378 (CV=0.388) under the assumption for division of J-stock and O-stock by the IWC SC. For more details, see Appendix 1. Abundance estimate in sub-areas 5, 6 and 10 were shown in Table 8 (Miyashita, 2005, 2007; Park *et al*., 2006). Weighted average of these estimates by inverse variance for replicated area and extrapolate abundance estimate to unsurveyed area are shown in Table 9. Abundance estimate for 'J' stock is 16,644 (CV=0.162) in total assuming *g*(0)=1. Applying *g*(0)=0.732, abundance estimate in 'J' stock was 22,737 (CV=0.349) and its lower limit of 90%CI was 13,024 (Table 10).

The following years are chosen for the examination; 2009 (current year), 2015 (after 6 years), 2021 (after 12 years) and 2029 (after 20 years). Results from JARPN and JARPN II feasibility surveys suggested that males are dominant in the research area therefore for catches from the offshore component of the survey, male sex ratio of 79.2% (the smallest value of those in 1996-2001 in sub-areas 7) and for catches from the coastal component a ratio of 74.9%, which were obtained from the samples collected during JARPN and JARPN II feasibility study, are also considered for both scenarios. In the HITTER calculations, *MSYR*(1+), is used same as in the case of the Bering-Chukchi-Beaufort Seas stock of bowhead whales (IWC, 1998).

Western North Pacific sei whales

Stock structure scenario

Examination of the stock structure of the sei whale in the North Pacific based on both micro satellite and mtDNA was carried out by (Kanda *et al*., 2009b). Both samples from JARPN II (143°E -170°E) and past commercial (165°E-139°W) were used. These authors found no significant genetic heterogeneity in the wide area examined. They concluded that all sei whales examined came from a genetically same stock of sei whales inhabiting North Pacific. Although there is no genetic evidence for different stocks in the North Pacific a two stocks scenario was considered for the calculation (divided by the 180° longitudinal line (IWC, 1971)). Effect on the stock was assessed for the stock distributed west of 180°.This is the same scenario as that used in previous analysis (Government of Japan, 2004).

Historical and future catch

It is assumed that 100 sei whales are caught every year. Historical catch is taken from IWC (1996). Sex ratio of historical and future catch is assumed to be 1:1. This assumption is supported by the statistics in BIWS. Catches are allocated to west of 180° and east of 180° according to the ratio estimated from Ohsumi *et al.*, (1971). Historical catch and future catch are shown in Table 11.

Biological parameters

Because the size limit to take this whale species was set in the Schedule by the IWC to be 12.2 m (40 feet) for the pelagic whaling and 10.7 m (35 feet) for the coastal whaling which are less than the body length at the sexual maturity of 12.7 m for the male and of 13.5 m for the female (Ohsumi, 1974), it can be assumed that age-at-recruitment is less than age-at-maturity for the sei whale. Masaki (1976) estimated age-at- sexual maturity as 7.0 years old. Ohsumi (1979) estimated natural mortality coefficient as $0.07yr^{-1}$. Based on these estimates, the following biological parameters are used:

Age of recruitment: 5.0 years old
Age of maturity: 7.0 years old
Natural mortality (independent of age and sex): $0.07yr^{-1}$
MSY level (*MSYL*) 60% (of *K*)

Extrapolated abundance estimate for western North Pacific (west of 180° and north of 30° N)
In order to assess the effect of the catches on the stock, an abundance estimate for Western North Pacific (west of 180° and north of 30° N) was made by extrapolating abundance estimate in JARPN II survey area in early (May and June) and late (July and August) season (Hakamada *et al*., 2009). To extrapolate these estimates to outside the JARPN II survey area (east of 170° E), JSV data in the early and late seasons were used, respectively.

Extrapolated abundance (P_E) for western North Pacific of this species, which was weighted by the Japanese Scouting Vessel (JSV) data (sighting rate of 5°×5°square) collected in May to August during 1972 to 1988 were analyzed by the following formula;

$$P_E = P \times \Sigma / \Sigma^* \qquad (5),$$

where P is the abundance estimates to be extrapolated (Hakamada *et al*, 2009)

$$\Sigma = \sum_{i,j} (n/L)_{i,j} A_{i,j} \quad \text{(sum over all squares in the west of 180° and the north of 30°N)}$$

$$\Sigma^* = \sum_{i,j} (n/L)_{i,j} p_{i,j} A_{i,j} \quad \text{(sum over only squares for which abundance estimate applied)}$$

n : number of sei whales, L: searching distance n.miles,

$(n/L)_{i,j}$: sighting rate of 5°×5°square of latitudinal band i and longitudinal band j.

$A_{i,j}$: Area size of 5°×5°square of latitudinal band i and longitudinal band j

$p_{i,j}$: Proportion of area size of surveyed area during JARPNII survey within 5°×5°square of latitudinal band i and longitudinal band j

We estimate the extrapolation factor (=Σ/Σ^*) from JSV data in August and September because sighting survey was conducted in August and September. CV of extrapolation factor is estimated by Jackknife method (Gray and Schucany, 1972; Miller, 1974) taking year as a sampling unit. Using delta method, CV of the extrapolated abundance was approximated by

$$CV\left(P_E\right) = \sqrt{CV\left(P\right)^2 + CV\left(\frac{\Sigma}{\Sigma^*}\right)^2} \qquad (6).$$

Abundance was also estimated using GAM analyses considering environmental factors (*e.g*. sea surface temperature, sea depth, salinity and so on). More details of this estimate are described in Appendix 2.

As it was done in previous HITTER examinations, the cases of the lower 5%-ile of the estimates were also examined. The following years are chosen for the examination; 2009 (current year), 2015 (after 6 years), 2021 (after 12 years) and 2029 (after 20 years).

Western North Pacific Bryde's whales
Assumptions on parameters are based on those adopted in the RMP/IST for the Bryde's (IWC, 2008).

Stock structure scenario
The IWC SC adopted four stock structure hypotheses during the *ISTs* for this species in the western North Pacific. Stock structure scenarios 1 and 2 were used for the calculation:

Stock structure 1: Only one stock distributes in sub-areas 1 and 2.
Stock structure 2: Two stock structure scenario in sub-areas 1 and 2. One stock distributes in sub-area 1 and the other in sub-area 2.

Historical and future catch
Historical catch by sex for each sub-areas are shown in Table 12 for the stock structure scenario 1 and Table 13 for the stock structure scenario 2, which are referred from JCRM 10 (suppl.) 112-3. Future catch is assumed to be 30 from sub-area 1W (west of 165^{o}E) and 20 from sub-area 1E (east of 165^{o}E). Sex ratio of the future catch is assumed to be 1:1.

Biological parameters
The following biological parameters were used, which were adopted during the *ISTs* (IWC, 2008):

Age at recruitment: 5.0 years old
Age at maturity: 6.0 years old
Natural mortality (independent of age and sex): 0.08yr^{-1}
MSY level (*MSYL*) 60% (of *K*)

Abundance estimate
Abundance estimate of 20,501 (CV=0.337) were used for the calculation (Kitakado *et al*., 2008). This estimate was agreed by IWC SC. This estimate applies to the whole sub-areas 1W, 1E and 2, and 16,170 (CV=0.382) are assumed to be the abundance for sub-area 1. As it was done in previous HITTER examinations, the cases of the lower limit of 90% confidence interval of the estimates were also examined. The following years are chosen for the examination: 2009 (current year), 2015 (after 6 years), 2021 (after 12 years) and 2029(after 20 years).

Population dynamics adopted in RMP/IST for this species
For comparative purposes the effect on the stocks was also studied based on the population dynamics model adopted in *ISTs*. For more details see IWC (2008). For the 8 base trials

(Br01-Br08), the effect of future catches of 30 from sub-area 1W and 20 from sub-area 1E were examined. Cherry Allison (IWC Secretariat) kindly conducted these calculations and provided the results to us. Details of the calculations were given in Appendix 3.

RESULTS AND DISCUSSIONS

Western North Pacific minke whales

O stock

Table 14 shows results of HITTER calculation under the stock scenario B for best estimate and lower limit of 90%CI of abundance estimate for *MSYR* (1+) = 1%, 2%, 3%, 4% and 5%. For sensitivity, HITTER calculation for the stock scenario A was also conducted. The result of this calculation was shown in Table 15. The results show that there is no adverse effect of the future research takes on the 'O' stock for the next 20 years.

J stock

Table 16 shows results of HIITER calculation under the case where 23 whales from the'J' stock are caught during JARPN II surveys. When using the best estimate of abundance, the results show there was no adverse effect on the 'J' stock. When using the lower limit of 90% CI of the abundance, population level is increasing except in the case *MSYR*(1+)=1%. Butterworth and Punt (2003) argued that *MSYR*(1+) in most baleen whale cases lay in the 3-6% range. Therefore we can rely on the results assuming *MSYR*(1+) is more than 3% than that assuming MSYR(1+)=1%.

Extrapolated abundance estimates used in this examination may be underestimated because unsurveyed area in sub-areas 5, 6 and 10 includes coastal regions, where higher density of the common minke whale could be expected. The number of incidental catches from 'J' stock is high and rather stable (Table 3 and 4) though the number of fishing gears has not increased. These observations suggest a stable 'J' stock.

Western North Pacific sei whales

Extrapolated abundance estimate

Correction factors and their CV are as shown in Table 17. The estimates of the extrapolated abundances in west of 180^{o} longitudinal line was 21,612 (CV=0.277, lower bound of 90%CI is 13,812) and that in whole of North Pacific (North of 30^{o}N) was 59,443. Previous analysis has problem in estimating correction factors because there was only two sightings in denominator of the correction factor (Hakamada *et al*., 2004) but such problem was resolved because there are enough data in both denominator and numerator of the correction factor as shown in Table 18.

Genetic analysis supported that there was one stock in the North Pacific (Kanda *et al*., 2009b). Therefore assessment based on a single stock with abundance of 59,443 seems to be more appropriate than assessment based only on the western side. This estimate is supported by the estimate of 59,582 derived by GAM analyses (Appendix 2).

Effect on the stock

Results for HITTER runs for abundance estimates in the west of 180^{o} longitudinal line derived from data in early and late season and their lower limit of 90%CI, are given in Table 19 for *MSYR* (1+) = 1%, 2%, 3%, 4% and 5%. This table shows depletion (the ratio of the population for the year indicated to the pre-exploitation level) for mature female. The population of the mature female increases for 20 years in all cases examined. Therefore, it is suggested that there will be no adverse impact on the stock of 100 annual catches under JARPNII survey. It should be noted that results of genetic analyses support there is no significant genetic difference between west and east of 180^{o} longitudinal line.

Western North Pacific Bryde's whales

Results for HITTER runs for two stock scenarios and for both the best estimate and its lower limit of 90%CI, are given in Table 20 and 21, respectively for *MSYR* (1+) = 1%, 2%, 3%, 4%, 5% and 6%. These tables show depletion (the ratio of the population for the year indicated to the pre-exploitation level) for mature female. The population of the mature female increases for 20 years in all cases examined. Therefore, it is suggested that there will be no adverse impact on the stock of 50 annual catches under JARPNII survey. Appendix 3 conducted the assessment of the effect of the catches on the Bryde's whale stock using the population dynamics model adopted in *ISTs*.. Results from both approaches are very similar.

Western North Pacific sperm whales

HITTER method cannot be applied to this species because the HITTER is a model developed for baleen whales. The abundance estimate for this stock is 102,000 assuming *g*(0)=0.32 (Kato and Miyashita, 1998). Annual catch of 10 animals for this species is very small (less than 0.1% of the abundance estimate). Therefore, it can be assumed that the planned catches will have no negative effect on the stock.

ACKONOWLEDGEMENT

The author would like to express his gratitude to the following persons: Tomio Miyashita (National Institute of Far Seas Fisheries) for kindly providing JSV data, area size of 5x5 grids, and information on the common minke abundance; Naohisa Kanda (Institute of Cetacean Research) for kindly providing information on mixing rate and stock identification for individual whales of common minke whales. The author also would like to thank Hiroshi Hatanaka (Institute of Cetacean Research) for his useful comments to improve this manuscript. My acknowledgement to Greg Donovan and Cherry Allison (International Whaling Commission) for providing calculation on Bryde's whales summarized in Appendix 3. .

REFERENCES

Kato, H. and Miyashita, T. 1998. Current status of the North Pacific sperm whales and its preliminary abundance estimate. Paper SC/50/CAWS2 presented the IWC Scientific Committee (unpublished), 8pp.

Butterworth, D. S. and Punt, A. E. 2003. *MSYR* – should the information which has become available since selections were made for RMP development in 1987 have changed perceptions on the likely range and relative plausibilities of values for this parameter for baleen whales? Paper SC/55/RMP10 presented to the Scientific Committee, May 2003, (unpublished) 15pp.

Government of Japan. 2002. Research Plan for Cetacean Studies in the Western North Pacific under Special Permit (JARPN II) Paper SC/54/O2 presented to the IWC Scientific Committee, May 2002 (unpublished). 115pp

Government of Japan. 2004. Revised research plan for cetacean studies in the western North Pacific under special permit (JARPN II). Paper SC/56/O1 presented to Science Committee, Sorrento, June, 2004. (unpublished). 14pp.

Goto, M., Kanda, N., Kishiro, T., Yoshida, H., Kato, H. and Pastene, L.A. Mitochondrial DNA analysis of stock structure of western North Pacific common minke whales using samples from JARPN and JARPNII. Paper SC/J09/JR29 presented to the JARPN II Review Workshop, Tokyo, January 2009 (unpublished).10pp.

Gray, H. L. and Schucany, W. R. 1972. The generalized Jackkife Statistic. Marcel Dekker. New York. 308pp.

Hakamada, T., Matsuoka, K. and Nishiwaki, S. 2004. Preliminary analysis of abundance estimate for Western north Pacific Sei whales (west of 180^{o}). Paper SC/56/O19 presented to Science Committee, Sorrento, June, 2004. (unpublished). 9pp.

Hakamada, T., Matsuoka, K. and Miyashita, T. 2009. Distribution and the number of western North Pacific common minke, Bryde's, sei and sperm whales distributed in JARPN II Offshore component survey area for estimation of prey consumption by the whales. Paper SC/J09/JR15 presented to the JARPN II Review Workshop, Tokyo, January 2009 (unpublished). 17pp.

International Whaling Commission. 1971. Report of Scientific Committee. *Rep. int. Whal. Commn* 21:24-31.

International Whaling Commission. 1992. Report of Scientific Committee, Annex F. Report of the Sub-Committee on North Pacific Minke Whales. *Rep. int. Whal. Commn* 42:156-177.

International Whaling Commission. 1996. Report of Scientific Committee, Annex G. Report of the Sub-Committee on North Pacific Bryde's Whales. *Rep. int. Whal. Commn* 46:147-159.

International Whaling Commission. 1997. Report of Scientific Committee, Annex G. Report of the Sub-Committee on North Pacific Bryde's Whales. *Rep. int. Whal. Commn* 47:163-168.

International Whaling Commission. 1998. Report of Scientific Committee, Annex I. Report of the Standing Working Group on the development of an Aboriginal Substance Whaling Management Procedure (AWMP). *Rep. int. Whal. Commn* 48:203-236.

International Whaling Commission. 2004. Report of Scientific Committee, Annex D. Report of the Sub-Committee on Revised Management Procedure. *J. Cetacean Res. Manage.* 6 (*Suppl.*): 75-184.

International Whaling Commission. 2008. Report of Scientific Committee, Annex D. Report of the Sub-Committee on Revised Management Procedure. *J. Cetacean Res. Manage.* 10 (*Suppl.*): 90-119.

Kanda, N., Goto, M., Kishiro, T., Yoshida, H., Kato, H. and Pastene, L.A. 2009a. Microsatellite analysis of minke whales in the western North Pacific. Paper SC/J09/JR30 presented to the JARPN II Review Workshop, Tokyo, January 2009 (unpublished). 14pp..

Kanda, N., Goto, M., Yoshida, H. and Pastene, L.A. 2009b. Stock structure of sei whales in the North Pacific as revealed by microsatellites and mitochondrial DNA analyses. Paper SC/J09/JR32 presented to the JARPN II Review Workshop, Tokyo, January 2009 (unpublished). 14pp.

Kanda, N., Goto, M. and Pastene, L.A. 2009c. Stock structure of Bryde's whales in the western North Pacific as revealed by microsatellites and mitochondrial DNA. Paper SC/J09/JR31 presented to the JARPN II Review Workshop, Tokyo, January 2009 (unpublished). 8pp.

Kanda, N., Goto, M., Kishiro, T., Yoshida, H., Kato, H. and Pastene, L.A. 2009d. Individual identification and mixing of the J and O stocks around Japanese waters examined by microsatellite analysis. Paper SC/J09/JR26 presented to the JARPN II Review Workshop, Tokyo, January 2009 (unpublished). 9pp.

Kato, H. and Miyashita, T. 1998. Current status of the North Pacific sperm whales and its preliminary abundance estimate. Paper SC/50/CAWS2 presented the IWC Scientific Committee (unpublished), 8pp.

Kitakado, T., Shimada, H., Okamura, H. and Miyashita, T. 2008 CLA abundance estimates for western North Pacific Bryde's whales and their associated CVs with taking the additional variance into account. Paper SC/60/PFI3 presented to Scientific Committee, May, 2008, Santiago (unpublished) 27pp.

Masaki, Y. 1976. Biological studies on the North Pacific sei whales. *Bull. Far Seas Fish. Res. Lab.* 14:1-104.

Miller, R. G. 1974. The Jackknife – a review. Biometrika, 61: 1-15.

Miyashita, T., Kato, H., Matsuoka, K., Hakamada, T., Nishiwaki, S., and Ohsumi, S. 2002. Abundance and biomass of major cetaceans occurring in the western North Pacific particularly in sub-areas 7, 8 and 9 and biological aspects of cetacean species to be sampled by JARPN II. Paper Appendix 1 of SC/54/O2 presented to Scientific Committee, April 2002, Shimonoseki (unpublished). 21pp.

Miyashita, T. 2005. Abundance estimate of J-stock minke whales using the Japanese sighting data. Document SC/57/NPM3. 6pp.

Miyashita, T and Okamura, H., 2007. Abundance estimate of common minke whales in the northern Sea of Japan including the Russian EEZ using IO sighting data in 2006. Document SC/59/NPM4 presented to Scientific Committee, May 2007, Alaska (unpublished). 10pp.

Ohsumi, S., Shimadzu, Y. and Doi, T. 1971. Report of Scientific Committee, Annex J. The seventh memorandum on the results of Japanese stock assessment of whales in the North Pacific. *Rep. int. Whal. Commn* 21: 76-89.

Ohsumi, S. 1974. *Geirushigen. Shuyoenyougyogyoushigen*. [In Japanese].

Ohsumi, S. 1979. Interspecies relationships among some biological parameters in cetaceans and estimation of the natural mortality coefficient of the Southern Hemisphere minke whales. *Rep. int. Whal. Commn.* 29:397-406.

Okamura, H., Miyashita, T. and Kitakado, T. 2008. Abundance estimation on common minke whales in the Russian waters of sub-area 10 using the IO sighting data in 2006. Paper SC/60/NMP7 presented to IWC Scientific Committee, May 2008 (unpublished). [Available from IWC Secretariat]. 7pp.

Park, K. J., Kim, Z.G., An, Y. R. Choi, S. G., Kim, H. W. and Song, K. J. 2006. Abundance estimation of minke whale, *Balaenoptera acutorostrata*, from sighting surveys conducted Korean waters. Paper 06NOV/WSMK/03 presented to Workshop on the sighting survey collaborations for the common minke whales off the Korean Peninsula, November 2006, Ulsan, Republic of Korea. (unpublished). 20pp.

Table 1. Assumed mixing rates of J stock by sub-areas for research takes, which was the proportions of J stock common minke whales by sub-areas identified by microsatellite analysis using samples collected during JARPN and JARPN II surveys (Kanda *et al*., 2009b).CK7 and CS7 are samples from JARPN II coastal component in Kushiro region and in Sanriku region, respectively.

sub-areas	11	CK7	CS7	7W	7E	8W	8E	9W	9E
prop. of J	0.319	0.167	0.200	0.065	0.000	0.000	0.000	0.008	0.000

Table 2. Assumed mixing rates of J stock common minke whales by sub-areas for incidental catches, which was the proportions of J stock animals by sub-areas identified by microsatellite analysis using incidental catches (Kanda *et al*., 2009b).

sub-areas	2	6	7	10	11
prop. of J	0.859	0.990	0.502	1.000	1.000

Table 3. Historical and future incidental catch off Japan for the O and J stocks of minke whales in the North Pacific from 1900.

O stock

year	male	female
1900-2000	5	7
2001	9	10
2002	12	12
2003	12	14
2004	11	12
2005	10	14
2006	14	17
2007	11	17
2008+	11	14

J stock

year	male	female
1900-2000	38	49
2001	43	46
2002	39	46
2003	42	56
2004	39	53
2005	43	60
2006	52	64
2007	56	71
2008+	45	57

Table 4. Historical and future incidental catches off Korea for J stock common minke whales in the North Pacific from 1989.

year	male	female
1989	3	8
1990	6	17
1991	9	25
1992	11	33
1993	14	41
1994	17	50
1995	20	58
1996	33	96
1997	20	58
1998	9	36
1999	17	39
2000	20	57
2001	38	110
2002	48	41
2003	60	32
2004	40	29
2005	59	50
2006	53	27
2007	47	33
2008+	51	35

Table 5. Historical catch from 1900 to 2007 and assumed future catch from the O stock minke whales in the North Pacific used in this study, including incidental catch.

O stock			O stock (continued)		
year	male	female	year	male	female
1900-1929	5	7	1971	146	128
1930	12	13	1972	133	216
1931	12	13	1973	270	251
1932	12	13	1974	186	196
1933	12	14	1975	190	156
1934	19	17	1976	156	195
1935	19	17	1977	166	92
1936	19	17	1978	250	162
1937	37	32	1979	267	137
1938	43	37	1980	205	171
1939	43	37	1981	221	149
1940	50	41	1982	172	149
1941	37	32	1983	143	148
1942	43	37	1984	203	176
1943	62	51	1985	197	134
1944	50	41	1986	182	141
1945	43	37	1987	187	129
1946	51	57	1988	5	7
1947	59	68	1989	5	7
1948	86	94	1990	5	7
1949	80	69	1991	5	7
1950	131	84	1992	5	7
1951	118	127	1993	5	7
1952	120	186	1994	23	10
1953	120	126	1995	95	16
1954	116	169	1996	60	17
1955	171	215	1997	92	20
1956	243	225	1998	93	18
1957	167	202	1999	45	14
1958	230	298	2000	39	12
1959	129	165	2001	99	17
1960	117	150	2002	120	41
1961	150	195	2003	120	45
1962	107	144	2004	139	32
1963	101	131	2005	150	70
1964	134	167	2006	146	59
1965	132	192	2007	137	73
1966	166	206			
1967	116	166			
1968	82	144	Future catch		
1969	82	146	(including incidental catch)		
1970	160	164	2008+	143	53

Table 6. Historical catch from 1900 to 2007 and assumed future catch from the J stock minke whales in the North Pacific used in this study, including incidental catch.

J stock		
year	male	female
1900-1929	38	49
1930	38	49
1931	38	49
1932	38	49
1933	38	49
1934	38	49
1935	38	49
1936	38	49
1937	38	49
1938	38	49
1939	38	49
1940	91	91
1941	134	135
1942	164	163
1943	134	135
1944	127	128
1945	48	49
1946	38	49
1947	38	49
1948	97	87
1949	63	83
1950	69	60
1951	107	90
1952	190	93
1953	166	101
1954	104	81
1955	80	79
1956	103	93
1957	219	206
1958	174	209
1959	195	240
1960	173	244
1961	116	181
1962	139	205
1963	212	260
1964	268	295
1965	184	199
1966	208	281
1967	232	305
1968	230	298
1969	270	335
1970	433	488

J stock (continued)		
year	male	female
1971	437	502
1972	448	510
1973	512	568
1974	352	409
1975	375	415
1976	320	382
1977	579	643
1978	578	602
1979	521	607
1980	514	513
1981	437	426
1982	406	437
1983	285	289
1984	236	244
1985	106	111
1986	90	66
1987	38	49
1988	38	49
1989	41	57
1990	44	65
1991	47	74
1992	50	82
1993	52	90
1994	55	98
1995	59	107
1996	79	148
1997	58	107
1998	49	85
1999	58	88
2000	59	106
2001	84	156
2002	95	91
2003	107	94
2004	89	84
2005	116	120
2006	117	100
2007	117	115

Future catch
(including incidental catch)

2008+	109	102

Table 7. Summary for abundance estimates for 'O' stock minke whales used in this study for stock structure scenarios B and A.

	stock scenario			
	B		A	
	P	CV	P	CV
JARPN II area	2,179	0.414	1,304	0.395
Sea of Okhotsk	24,058	0.207	24,058	0.207
East of Kuril Is. - Kamchatka pen.	972	0.520	972	0.520
total	27,209	0.187	26,334	0.191
g(0)=0.732	37,170	0.361	35,975	0.363

Table 8. Summary for abundance estimates of common minke whales in sub-areas 5, 6 and 10.

Sub-area	Season	Survey by	EEZ	Area (nm ^2)	% covered	Reseaech distance (nm)	No. primary sightings	g(0)=1			
								N	CV	95%LCI	95%UCI
10	2002	Japan	Japan*	28,823	21.4	501.6	12	1,089	0.544	401	2,954
	2003			27,822	20.7	582.8	7	303	0.610	100	913
	2006		Russia**	77,662	57.7	1,422.0	46	3,042	0.220	1,726	5,358
6	2002		Japan*	98,736	54.8	2,314.3	26	1,365	0.503	538	3,460
	2003			90,932	50.5	1,830.9	21	1,081	0.298	609	1,916
	2002	Korea***	Koera	7,074	3.9	1,169.3	30	521	0.426	231	1,176
	2003			8,063	4.5	1,081.6	16	758	0.680	208	2,762
	2005			6,703	3.7	1,144.5	28	1,349	0.524	500	3,640
	2006			14,968	8.3	1,069.8	20	1,645	0.531	593	4,561
5	2002			30,552	25.4	813.2	10	1,965	1.564	189	20,402
	2004			36,084	30.0	1,787.2	18	1,287	0.645	385	4,303

*: Miyashita (2005, SC/57/NMP3), **: Miyashita (2007), ***: Park et al. (2006)

Table 9. Summary for extrapolated abundance estimate of common minke whales in sub-areas 5, 6 and 10.

Sub-area	Abundance in surveyed area[1]	CV	95%LCI	95%UCI	%covered[2]	Extrapolated abundance	CV	95%LCI	95%UCI
Case: g(0)=1									
10	3,415	0.203	2,304	5,060	78.7	4,336	0.203	4,609	10,120
6	1,800	0.194	1,236	2,622	57.8	3,117	0.194	2,472	5,244
5	1,333	0.601	449	3,960	27.7	4,812	0.601	898	7,919
Total	6,548	0.170	4,701	9,120		12,266	0.170	9,402	18,240

1: Average weighted by inverse variance for replicated area. 2: Mean %coverage

Table 10. Summary for abundance estimate for 'J' stock minke whale used in this study.

	abundance	CV
Sub-areas 5, 6 and 10	12,266	0.170
Sea of Okhotsk	4,378	0.388
total	16,644	0.162
g(0)=0.732	22,737	0.349

Table 11. Historical and future catches of sei whale used in this study. Historical catch from 1946 to 2007 and assumed future catch from the west of 180° of sei whales in the North Pacific.

	Catches from the west of 180°			
	coastal		pelagic	
year	male	female	male	female
1946	272	272	8	8
1947	191	191	42	42
1948	280	280	30	30
1949	409	410	39	39
1950	175	175	75	75
1951	235	235	84	84
1952	427	427	124	124
1953	335	336	35	35
1954	386	386	43	43
1955	308	308	14	14
1956	476	477	18	18
1957	293	293	57	57
1958	579	580	99	99
1959	735	736	36	36
1960	465	465	74	74
1961	417	417	16	16
1962	571	571	160	160
1963	435	436	415	415
1964	454	454	605	605
1965	233	233	595	595
1966	155	156	1,067	1,067
1967	276	277	1,554	1,554
1968	403	403	1,400	1,400
1969	233	233	1,331	1,331
1970	242	242	1,142	1,142
1971	138	138	773	773
1972	107	107	600	600
1973	21	22	515	515
1974	24	24	350	350
1975	15	15	136	136
2002	15	24	0	0
2003	23	27	0	0
2004	47	53	0	0
2005	51	49	0	0
2006	48	52	0	0
2007	54	46	0	0
2008+	50	50	0	0

Table 12. Historical and future catches of the Bryde's whale in the North Pacific used in the scenario 1. Historical catch from 1946 to 2007 and assumed future catch from sub-areas 1 and 2.

	sub-areas 1 and 2			
	coastal		pelagic	
year	male	female	male	female
1906	6	7	0	0
1907	17	18	0	0
1908	39	42	0	0
1909	23	24	0	0
1910	24	26	0	0
1911	75	81	0	0
1912	38	43	0	0
1913	58	66	0	0
1914	24	32	0	0
1915	72	97	0	0
1916	45	60	0	0
1917	88	93	0	0
1918	69	79	0	0
1919	77	84	0	0
1920	41	51	0	0
1921	40	49	0	0
1922	37	44	0	0
1923	32	43	0	0
1924	48	63	0	0
1925	55	64	0	0
1926	60	73	0	0
1927	53	65	0	0
1928	36	44	0	0
1929	29	34	0	0
1930	27	35	0	0
1931	64	71	0	0
1932	51	53	0	0
1933	37	47	0	0
1934	45	48	0	0
1935	46	46	0	0
1936	40	48	0	0
1937	59	64	0	0
1938	77	83	0	0
1939	87	105	0	0
1940	49	61	0	0
1941	64	80	0	0
1942	9	12	0	0
1943	17	12	0	0
1944	37	37	0	0
1945	5	7	0	0
1946	52	74	0	0
1947	48	58	0	0
1948	58	77	0	0
1949	101	97	0	0
1950	132	156	0	0
1951	166	141	0	0
1952	303	188	0	0
1953	25	36	0	0
1954	31	44	0	0
1955	34	60	0	0
1956	12	12	0	0
1957	12	27	0	0

	sub-areas 1 and 2 (continued)			
	coastal		pelagic	
year	male	female	male	female
1958	113	141	0	0
1959	153	110	0	0
1960	188	216	0	0
1961	83	84	0	0
1962	209	295	0	0
1963	100	110	0	0
1964	25	43	0	0
1965	1	7	0	0
1966	19	36	0	0
1967	17	28	0	0
1968	70	101	0	0
1969	34	55	0	0
1970	36	37	27	39
1971	102	133	280	404
1972	38	46	26	50
1973	190	402	40	67
1974	287	422	267	347
1975	358	343	356	375
1976	390	461	395	213
1977	416	371	80	79
1978	274	216	175	131
1979	670	570	23	18
1980	401	354	0	0
1981	249	236	0	0
1982	275	207	0	0
1983	403	142	0	0
1984	353	175	0	0
1985	249	108	0	0
1986	217	100	0	0
1987	256	61	0	0
1988	0	0	0	0
1989	0	0	0	0
1990	0	0	0	0
1991	0	0	0	0
1992	0	0	0	0
1993	0	0	0	0
1994	0	0	0	0
1995	0	0	0	0
1996	0	0	0	0
1997	0	0	0	0
1998	0	1	0	0
1999	0	0	0	0
2000	20	23	0	0
2001	17	33	0	0
2002	25	25	0	0
2003	19	31	0	0
2004	18	26	1	6
2005	21	29	0	0
2006	17	19	4	10
2007	23	25	0	2
2008+	15	15	10	10

Table 13. Historical and future catches of the Bryde's whale in the North Pacific used in scenario 2. Historical catch from 1946 to 2007 and assumed future catch from sub-area 1.

	sub-area 1					sub-area 1 (continued)			
	coastal		pelagic			coastal		pelagic	
year	male	female	male	female	year	male	female	male	female
1906	6	7	0	0	1958	113	141	0	0
1907	17	18	0	0	1959	153	110	0	0
1908	39	42	0	0	1960	188	216	0	0
1909	23	24	0	0	1961	83	84	0	0
1910	24	26	0	0	1962	209	295	0	0
1911	75	81	0	0	1963	100	110	0	0
1912	38	43	0	0	1964	25	43	0	0
1913	58	66	0	0	1965	1	7	0	0
1914	24	32	0	0	1966	19	36	0	0
1915	72	97	0	0	1967	17	28	0	0
1916	45	60	0	0	1968	70	101	0	0
1917	88	93	0	0	1969	34	55	0	0
1918	69	79	0	0	1970	36	37	16	24
1919	77	84	0	0	1971	102	133	179	264
1920	41	51	0	0	1972	38	46	22	41
1921	40	49	0	0	1973	190	402	20	31
1922	37	44	0	0	1974	287	422	120	186
1923	32	43	0	0	1975	358	343	129	167
1924	48	63	0	0	1976	390	461	370	207
1925	55	64	0	0	1977	416	371	78	72
1926	60	73	0	0	1978	274	216	167	126
1927	53	65	0	0	1979	670	570	23	16
1928	36	44	0	0	1980	401	354	0	0
1929	29	34	0	0	1981	249	236	0	0
1930	27	35	0	0	1982	275	207	0	0
1931	64	71	0	0	1983	403	142	0	0
1932	51	53	0	0	1984	353	175	0	0
1933	37	47	0	0	1985	249	108	0	0
1934	45	48	0	0	1986	217	100	0	0
1935	46	46	0	0	1987	256	61	0	0
1936	40	48	0	0	1988	0	0	0	0
1937	59	64	0	0	1989	0	0	0	0
1938	77	83	0	0	1990	0	0	0	0
1939	87	105	0	0	1991	0	0	0	0
1940	49	61	0	0	1992	0	0	0	0
1941	64	80	0	0	1993	0	0	0	0
1942	9	12	0	0	1994	0	0	0	0
1943	17	12	0	0	1995	0	0	0	0
1944	37	37	0	0	1996	0	0	0	0
1945	5	7	0	0	1997	0	0	0	0
1946	52	74	0	0	1998	0	1	0	0
1947	48	58	0	0	1999	0	0	0	0
1948	58	77	0	0	2000	20	23	0	0
1949	101	97	0	0	2001	17	33	0	0
1950	132	156	0	0	2002	25	25	0	0
1951	166	141	0	0	2003	19	31	0	0
1952	303	188	0	0	2004	18	26	1	6
1953	25	36	0	0	2005	21	29	0	0
1954	31	44	0	0	2006	17	19	4	10
1955	34	60	0	0	2007	23	25	0	2
1956	12	12	0	0	2008+	15	15	10	10
1957	12	27	0	0					

Table 14. The case where 197 minke whales out of 220 are caught from 'O' stock during 2009-2029 under the stock scenario B (reference case), taking the incidental catch into account. Depletion is given for the mature female component.

a) Hit 2005 total (1+) population of 37,170 (best estimate)

Statistic	MSYR (1+) (%)				
	1	2	3	4	5
K (1+)	44,015	40,176	38,649	38,032	37,757
Depletion - 2009	82.9%	90.8%	94.6%	96.3%	97.2%
Depletion - 2015	83.3%	91.3%	94.7%	96.0%	96.7%
Depletion - 2021	83.7%	91.8%	94.9%	96.1%	96.7%
Depletion - 2029	84.3%	92.4%	95.1%	96.2%	96.9%
RY - 2009	222	225	201	186	180
MSY (+1)	264	482	696	913	1,133

b) Hit 2005 total (1+) population of 20,879 (lower limit of 90%CI)

Statistic	MSYR (1+) (%)				
	1	2	3	4	5
K (1+)	28,865	24,743	22,760	21,901	21,530
Depletion - 2009	70.1%	81.4%	88.8%	92.8%	94.6%
Depletion - 2015	70.5%	82.7%	89.5%	92.6%	94.0%
Depletion - 2021	70.8%	83.9%	90.2%	92.9%	94.1%
Depletion - 2029	71.3%	85.2%	90.9%	93.2%	94.4%
RY - 2009	210	238	217	195	185
MSY (+1)	173	297	410	526	646

Table 15. The case where 197 minke whales out of 220 are caught from 'O' stock during 2009-2029 under the stock scenario A (sensitivity test), taking the incidental catch into account. Depletion is given for the mature female component.

a) Hit 2005 total (1+) population of 35,975 (best estimate)

Statistic	MSYR (1+) (%)				
	1	2	3	4	5
K (1+)	42,873	39,014	37,468	36,842	36,564
Depletion - 2009	82.3%	90.4%	94.4%	96.2%	97.1%
Depletion - 2015	82.8%	91.0%	94.5%	95.9%	96.6%
Depletion - 2021	83.2%	91.5%	94.7%	96.0%	96.6%
Depletion - 2029	83.7%	92.1%	95.0%	96.1%	96.8%
RY - 2009	221	226	202	187	181
MSY (+1)	257	468	674	884	1,097

b) Hit 2005 total (1+) population of 20,159 (lower limit of 90%CI)

Statistic	MSYR (1+) (%)				
	1	2	3	4	5
K (1+)	28,227	24,100	22,081	21,198	20,816
Depletion - 2009	69.2%	80.6%	88.3%	92.4%	94.4%
Depletion - 2015	69.5%	81.9%	89.1%	92.3%	93.7%
Depletion - 2021	69.8%	83.2%	89.8%	92.6%	93.9%
Depletion - 2029	70.3%	84.6%	90.6%	93.0%	94.2%
RY - 2009	209	239	219	196	185
MSY (+1)	169	289	397	509	624

Table 16. The case where 23 minke whales out of 220 are caught from 2009 to 2029 from 'J' stock minke whale, taking the incidental catch into account. Depletion is given for the mature female component.

a) Hit 2004 total (1+) population of 22,737 (best estimate)

Statistic	MSYR (1+) (%)				
	1	2	3	4	5
K (1+)	41,335	34,271	29,878	27,105	25,434
Depletion - 2009	50.3%	60.1%	68.7%	75.8%	81.1%
Depletion - 2015	50.7%	63.0%	72.9%	79.9%	84.2%
Depletion - 2021	51.0%	65.7%	76.4%	82.8%	86.2%
Depletion - 2029	51.4%	69.1%	80.1%	85.3%	87.7%
RY - 2009	206	317	350	328	286
MSY (+1)	248	411	538	651	763

b) Hit 2004 total (1+) population of 13,024 (lower limit of 90%CI)

Statistic	MSYR (1+) (%)				
	1	2	3	4	5
K (1+)	33,789	27,764	23,783	20,949	18,846
Depletion - 2009	33.2%	39.8%	45.8%	51.6%	57.0%
Depletion - 2015	32.2%	41.4%	50.2%	58.3%	65.3%
Depletion - 2021	31.2%	43.1%	54.8%	64.7%	72.1%
Depletion - 2029	29.7%	45.7%	60.8%	71.9%	78.2%
RY - 2009	145	249	329	376	390
MSY (+1)	203	333	428	503	565

Table 17. Abundance estimate of sei whales in JARPN II survey area and extrapolated into west of 180 degrees when using the data in May – June and those in July and August..

period	JARPNIIarea	factor	CV	extrapolated	CV
May-June	7,646	2.83	0.05	21,612	0.28
July-Aug	5,370	3.04	0.12	16,341	0.32

Table 18. The number of sightings of sei whales and searching distance (n.minles) by JSV during 1972-1988.

period	area	effort	sightings
May-Jun	JARPNII area	65219	209
	outside	83805	322
Jul-Aug	JARPNII area	39121	83
	outside	34713	130

Table 19. The effect on the sei whale stock of 100 annual catches by JARPN II in two cases of using data in early and late seasons. Depletion is given for the mature female component.

data in early season (May-June)

a) Hit 2007 total (1+) population of 21,612 (best estimate)

Statistic	MSYR (1+) (%)				
	1	2	3	4	5
K (1+)	52,229	44,227	38,915	35,048	32,009
Depletion - 2009	38.3%	42.8%	46.5%	49.7%	53.0%
Depletion - 2015	40.1%	47.8%	54.8%	61.1%	67.1%
Depletion - 2021	41.9%	53.0%	63.1%	71.9%	79.0%
Depletion - 2029	44.4%	60.1%	73.4%	82.9%	88.8%
RY - 2009	225	398	537	641	710
MSY (+1)	313	531	700	841	960

b) Hit 2007 total (1+) population of 13,812 (lower limit of 90%CI)

Statistic	MSYR (1+) (%)				
	1	2	3	4	5
K (1+)	47,413	41,246	36,962	33,670	31,206
Depletion - 2009	26.5%	28.6%	30.0%	30.9%	31.5%
Depletion - 2015	27.5%	32.0%	36.2%	40.2%	43.8%
Depletion - 2021	28.5%	35.8%	43.3%	50.8%	57.8%
Depletion - 2029	29.9%	41.5%	54.0%	65.8%	75.3%
RY - 2009	161	293	415	525	624
MSY (+1)	284	495	665	808	936

data in late season (July-August)

a) Hit 2007 total (1+) population of 16,341 (best estimate)

Statistic	MSYR (1+) (%)				
	1	2	3	4	5
K (1+)	48,937	42,159	37,611	34,011	31,421
Depletion - 2009	30.6%	33.4%	35.3%	37.0%	38.2%
Depletion - 2015	31.9%	37.5%	42.5%	47.4%	51.7%
Depletion - 2021	33.2%	41.9%	50.3%	58.6%	65.8%
Depletion - 2029	35.0%	48.3%	61.4%	72.9%	81.2%
RY - 2009	184	332	465	581	680
MSY (+1)	294	506	677	816	943

b) Hit 2007 total (1+) population of 9,740 (lower limit of 90%CI)

Statistic	MSYR (1+) (%)				
	1	2	3	4	5
K (1+)	45,023	39,861	35,964	32,972	30,884
Depletion - 2009	19.4%	20.5%	21.1%	21.5%	21.4%
Depletion - 2015	19.8%	22.7%	25.5%	28.2%	30.5%
Depletion - 2021	20.2%	25.2%	30.8%	36.7%	42.4%
Depletion - 2029	20.7%	29.1%	39.3%	50.5%	61.0%
RY - 2009	123	222	316	405	488
MSY (+1)	270	478	647	791	927

Table 20. The effect on the Bryde's whale stock of 30 annual catches from sub-area 1W and 20 from sub-area 1E by JARPN II under the stock scenario 1. Depletion is given for the mature female component.

a) Hit 2000 total (1+) population of 20,501 (best estimate)

Statistic	*MSYR* (1+) (%)					
	1	2	3	4	5	6
K (1+)	32,656	27,657	24,658	22,809	21,712	21,105
Depletion - 2009	63.5%	76.0%	85.2%	91.3%	95.0%	96.9%
Depletion - 2015	66.0%	80.3%	89.3%	94.1%	96.4%	97.4%
Depletion - 2021	68.3%	83.9%	92.0%	95.5%	96.9%	97.4%
Depletion - 2029	71.3%	87.6%	94.2%	96.3%	97.0%	97.3%
RY - 2009	160	215	194	143	99	70
MSY (+1)	196	332	444	547	651	760

b) Hit 2000 total (1+) population of 11,961 (lower limit of 90%CI)

Statistic	*MSYR* (1+) (%)					
	1	2	3	4	5	6
K (1+)	25,650	21,304	18,528	16,596	15,188	14,141
Depletion - 2009	47.1%	58.1%	67.8%	76.1%	82.8%	88.0%
Depletion - 2015	49.1%	63.4%	75.3%	84.0%	89.6%	93.0%
Depletion - 2021	51.2%	68.5%	81.4%	89.1%	93.1%	94.9%
Depletion - 2029	54.1%	74.7%	87.3%	92.8%	94.9%	95.7%
RY - 2009	126	205	240	233	198	155
MSY (+1)	154	256	334	398	456	509

Table 21 The effect on the Bryde's whale stock of 30 annual catches from sub-area 1W and 20 from sub-area 1E by JARPN II under the stock scenario 2. Depletion is given for the mature female component.

a) Hit 2000 total (1+) population of 16,170 (best estimate)

Statistic	*MSYR* (1+) (%)					
	1	2	3	4	5	6
K (1+)	27,967	23,373	20,565	18,758	17,609	16,921
Depletion - 2009	58.4%	71.1%	81.0%	88.2%	92.9%	95.6%
Depletion - 2015	60.8%	75.8%	86.0%	92.0%	95.1%	96.5%
Depletion - 2021	63.1%	79.8%	89.6%	94.1%	95.9%	96.7%
Depletion - 2029	66.0%	84.3%	92.5%	95.3%	96.3%	96.6%
RY - 2009	142	202	196	155	110	78
MSY (+1)	168	280	370	450	528	609

b) Hit 2000 total (1+) population of 8,806 (lower limit of 90%CI)

Statistic	*MSYR* (1+) (%)					
	1	2	3	4	5	6
K (1+)	22,138	18,267	15,815	14,116	12,870	11,923
Depletion - 2009	39.9%	49.9%	58.9%	66.9%	73.7%	79.4%
Depletion - 2015	41.5%	54.8%	66.9%	76.6%	83.6%	88.4%
Depletion - 2021	43.1%	59.9%	74.1%	83.9%	89.5%	92.5%
Depletion - 2029	45.4%	66.5%	81.8%	89.7%	93.1%	94.4%
RY - 2009	103	176	223	240	230	204
MSY (+1)	133	219	285	339	386	429

Appendix 1.

Abundance of common minke whales in the Russian EEZ in the Sea of Okhotsk and east of Kuril Islands - Kamchatka peninsula, estimated from 2003 and 2005 sighting surveys

Tomio Miyashita

National Research Institute of Far Seas Fisheries

2-12-4 Fukuura, Kanazawa-ku, Yokohama-shi, Kanagawa 236-8648, Japan

Contact e-mail: miyachan@fra.affrc.go.jp

Survey outline

a. 2003 survey (Miyashita, 2004)

Period: 22 July – 19 September

Area : Sea of Okhotsk. Block (Fig. 1), Pre-determined track line (Fig. 2 and 3)

Research vessel: *Shonan-maru* (SM1) and *Shonan-maru No.2* (SM2)

Scientists onboard:

SM1: T.Saito, T. Hayashi and E.Chvestov (TINRO-centre)

SM2: T.Miyashita, D.Tokuta and A.Vlamidirov (VNIRO)

Research method: IO passing mode

Research distance: 903nmi (SM1), 1,805 nmi (SM2)

Track line traversed with sighting effort: (Fig. 4).

Common minke whale sighting results: (Tables 1 and 2).

SM1: 12 schools with 12 animals as primary sightings

SM2: 69 schools with 78 animals as primary sightings

Sighting positions of common minke whale: (Fig. 4)

b. 2005 survey (Miyashita, 2006)

Period: 29 July – 20 September

Area : East of Kamchatka Peninsula (SM1) and east of Kuril Islands (SM2).

Block (Fig. 5), Pre-determined track line (Fig. 6 and 7)

Research vessel: *Shonan-maru* (SM1) and *Shonan-maru No.2* (SM2)

Scientists onboard:

SM1: T.Miyashita, H.Hiruta and S.Kornev (Kam TINRO)

SM2: T.Saito, S.Noji and P.Gusakov (VNIRO)

Research method: IO passing mode

Research distance: 1,441nmi (SM1), 929nmi (SM2)

Track line traversed with sighting effort: (Fig. 8).

Common minke whale sighting results: (Tables 3 and 4).

SM1: 5 schools with 5 animals as primary sightings

SM2: 6 schools with 6 animals as primary sightings

Sighting positions of common minke whale: (Fig. 8)

Abundance estimate

Method: Traditional line transect method using the program DISTANCE 4.1 (Thomas *et al.*, 2003).

Detection curve fitting: The information of the distance and angle for the first sighing from the top barrel and the IO platform was used for the fitting of detection curve. Because of small sample size but the common vessel type though these cruises, all primary sighting are accumulated and the detection curve was fitted (Fig. 9).

Abundance: (Table 5).

In the Sea of Okhotsk, abundance of common minke whales was estimated as 28,436 (CV 0.185, 95%C.I. 19,866 – 40,703). Following the option of assumption for division of J-stock and O-stock by SC, the abundance of O-stock was estimated as 24,058 (CV 0.207, 95%C.I. 16,115 – 35,916).

East of the Kamchatka Peninsula and the Kuril Island, the abundance was estimated as 972 (CV 0.52, 95%C.I. 373 – 2,534). All animals can be assumed as O-stock.

References.

Miyashita, T. 2004. Report of the common minke whale sighting surveys in the sea of Okhotsk in 2003. Document SC/56/MP1. 10pp.

Miyashita, T. 2006. Cruise report of the sighting survey in the waters east of the Kuril Islands and the Kamchatka Peninsula in 2005. SC/58?NPM5. 9pp.

Thomas, L., Laake, J.L., Strindberg, S., Marques, F.F.C., Buckland, S.T., Borchers, D.L., Anderson, D.R., Burnham, K.P., Hedley, S.L., Pollard, J.H. and Bishop, J.R.B. 2003. Distance 4.1. Release 2. Research Unit for Wildlife Population Assessment, University of St. Andrews, UK. http://www.ruwpa.stand.ac.uk/distance/

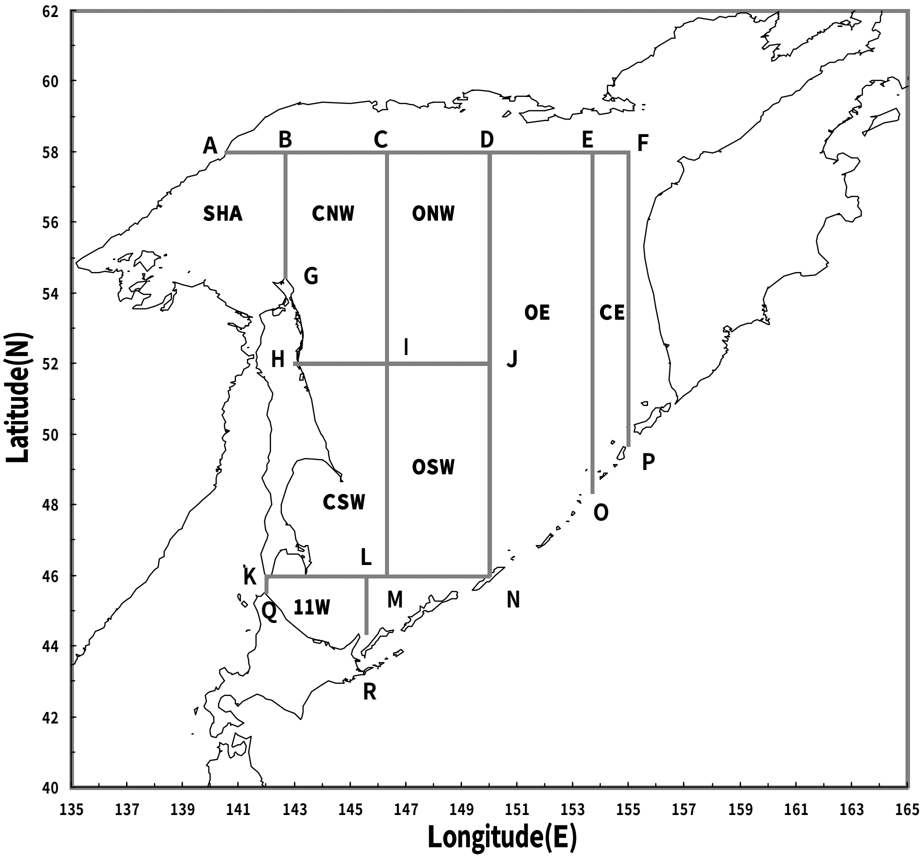

Fig. 1. Definition of block for 2003 sighting survey.

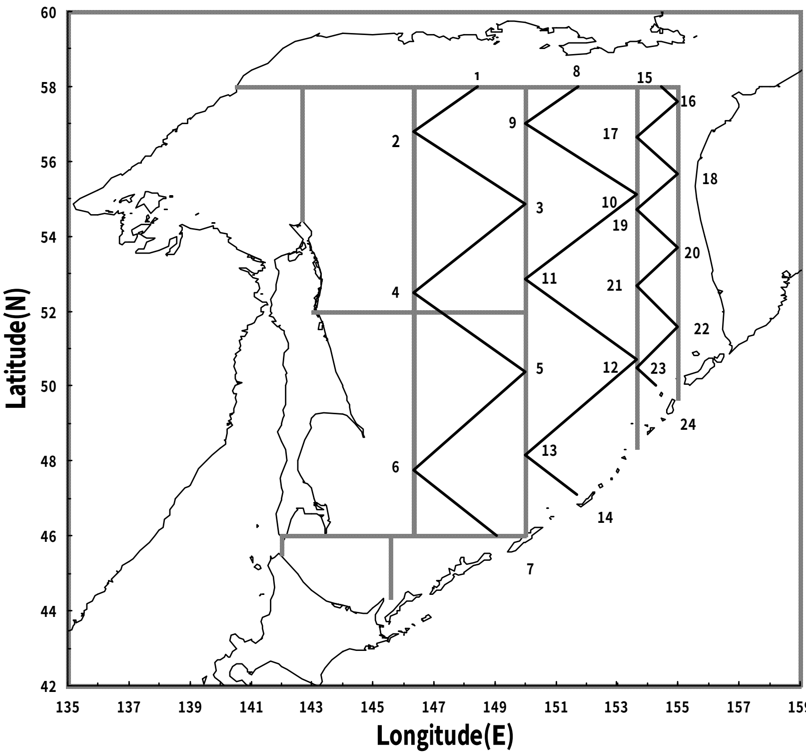

Fig. 2. Pre-determined track line for *Shonan-maru* in 2003.

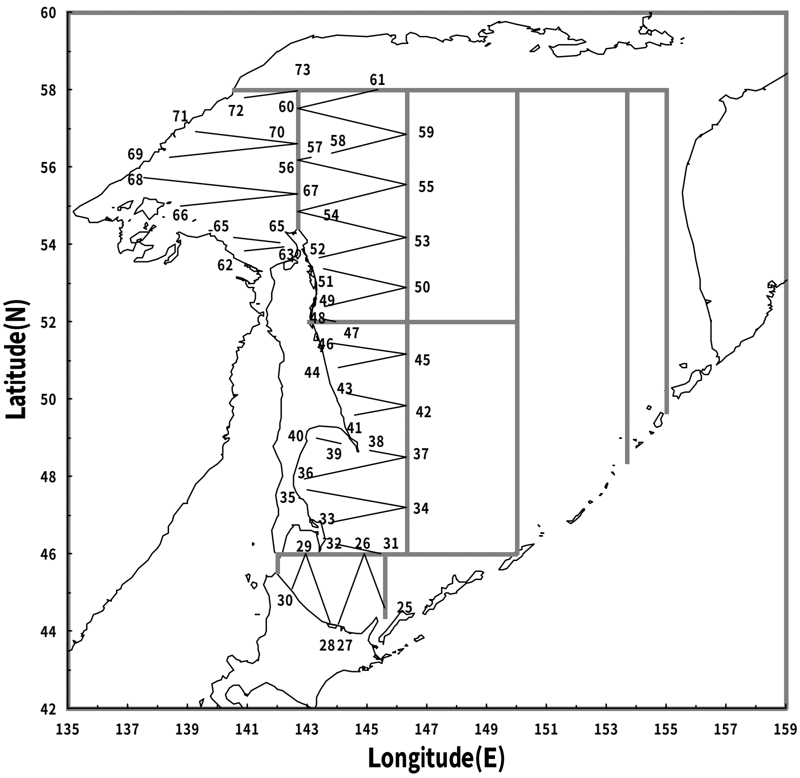

Fig. 3. Pre-determined track line for *Shonan-maru No.2* in 2003.

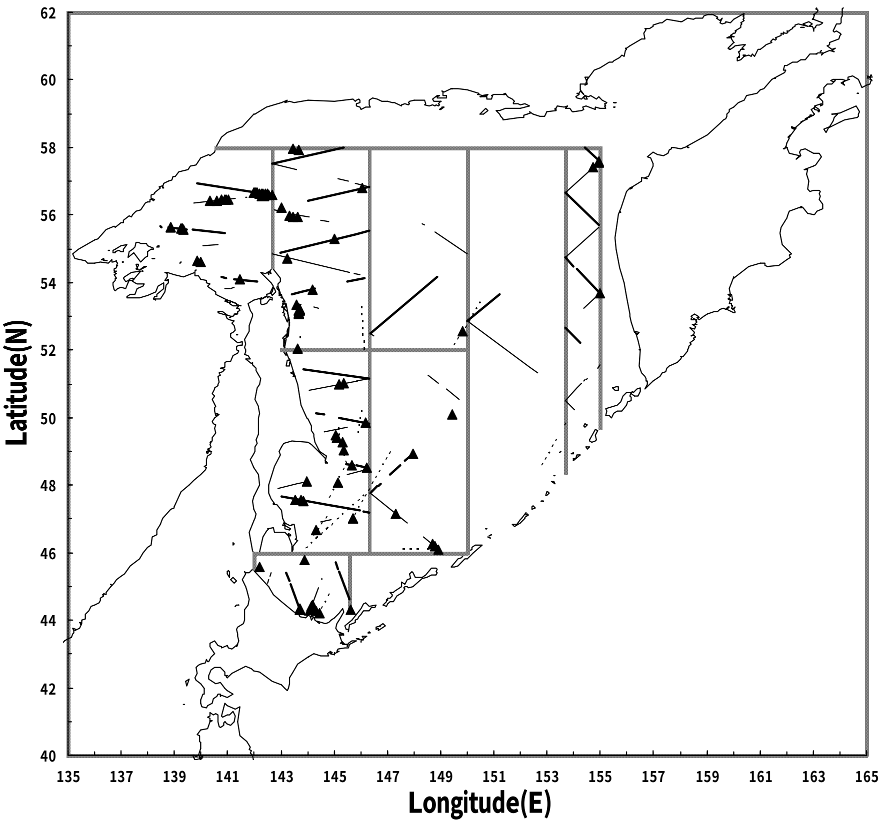

Fig. 4. Track line traversed with sighting effort and sighting position of common minke whale school (black triangle) in 2003.

Table 1. Number of sightings of common minke whales by *Shonan-maru* in 2003.

Block	CE					OE					ONW					OSW					Transit		Total		
Mode*	IO-pass		IO-close		NF	IO-pass		IO-close		NF	IO-pass		IO-close		NF	IO-pass		IO-close		NF	Passing				
Distance (nmi)	226.7		222.5			134.9		3.6			9.8		126.2			115.5		64.5			NA		903.7		
Primary/Secondary	Pri.	Sec.	Pri.	Sec.	Sec.	Pri.	Sec.	Pri.	Sec.	Sec.	Pri.	Sec.	Pri.	Sec.	Sec.	Pri.	Sec.	Pri.	Sec.	Sec.	Pri.	Sec.	Pri.	Sec.	Total
Schools	4															4					4	6	12	6	18
Animals	4															4					4	7	12	7	19

* IO-pass: IO passing mode, IO-close: IO but closing after abeam pasing, NF: Non effort, Passing: normal passing.

Table 2. Number of sightings of common minke whales by *Shonan-maru 2* in 2003.

Block	SHA					CNW					CSW					11W					Transit		Total		
Mode*	IO-pass		IO-close		NF	IO-pass		IO-close		NF	IO-pass		IO-close		NF	IO-pass		IO-close		NF	Passing				
Distance (nmi)	114.0		190.2			235.5		339.5			229.1		307.2			62.8		119.7			206.3		1804.3		
Primary/Secondary	Pri.	Sec.	Pri.	Sec.	Sec.	Pri.	Sec.	Pri.	Sec.	Sec.	Pri.	Sec.	Pri.	Sec.	Sec.	Pri.	Sec.	Pri.	Sec.	Sec.	Pri.	Sec.	Pri.	Sec.	Total
Schools	13		16	1	2	1		3		6	3		5		1	16		3			9	6	69	16	85
Animals	17		16	1	2	1		3		7	3		5		1	19		3			11	7	78	18	96

*same as in Table 1.

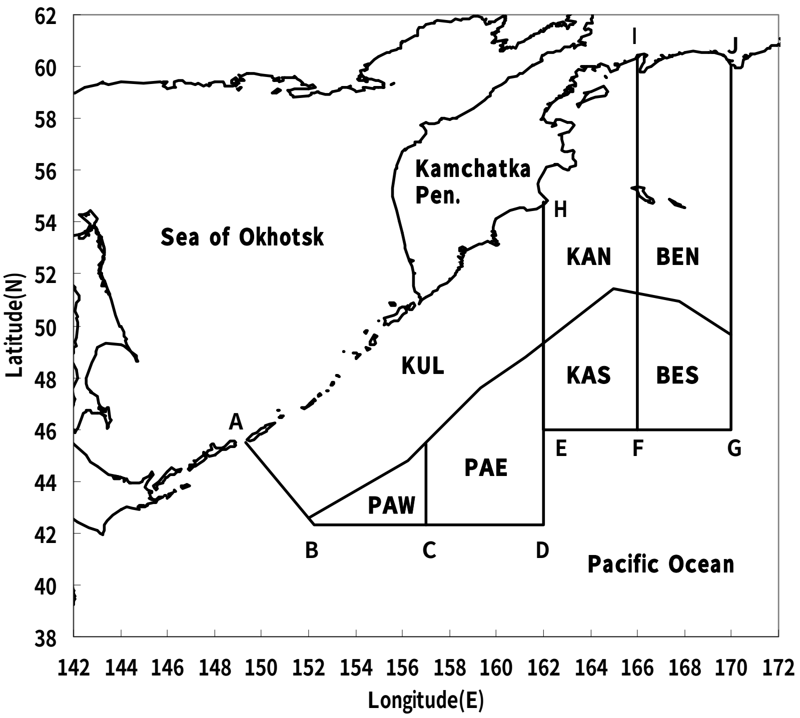

Fig. 5. Definition of block for 2005 sighting survey.

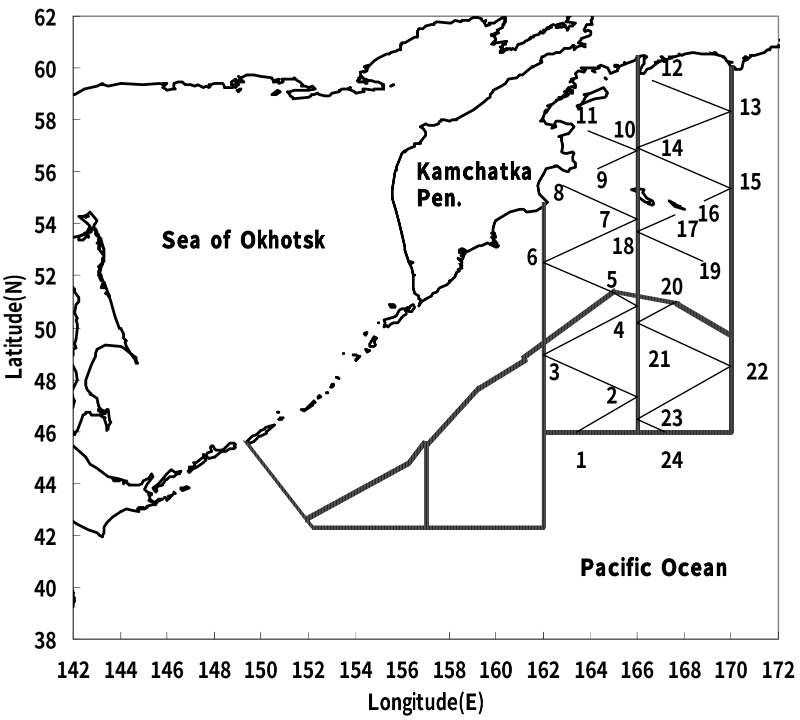

Fig. 6. Pre-determined track line for *Shonan-maru* in 2005.

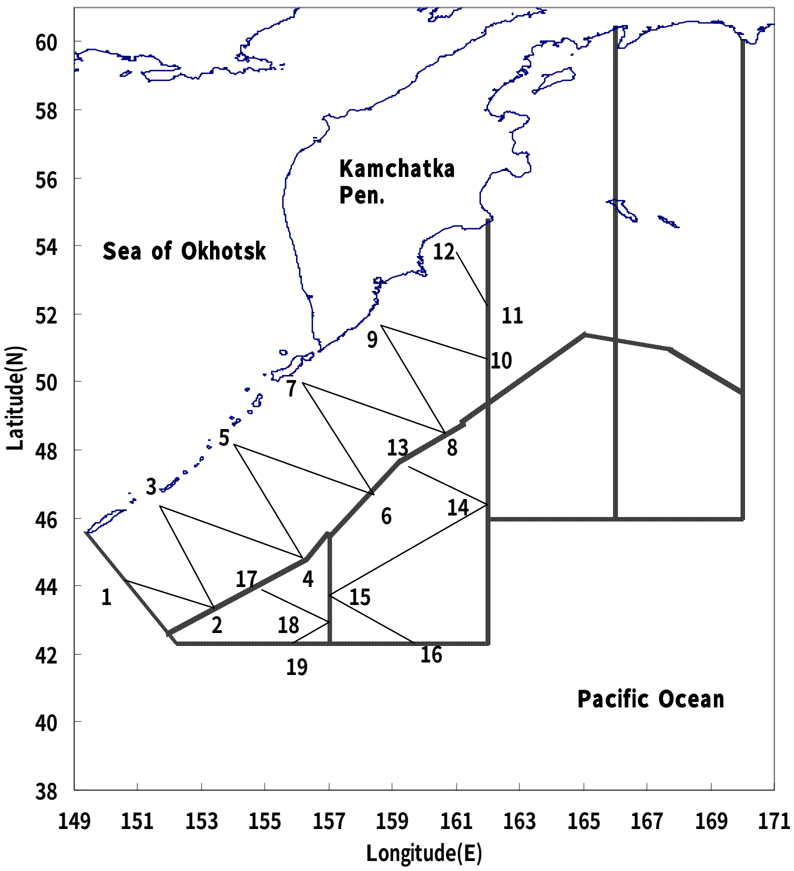

Fig. 7. Pre-determined track line for *Shonan-maru No.2* in 2005.

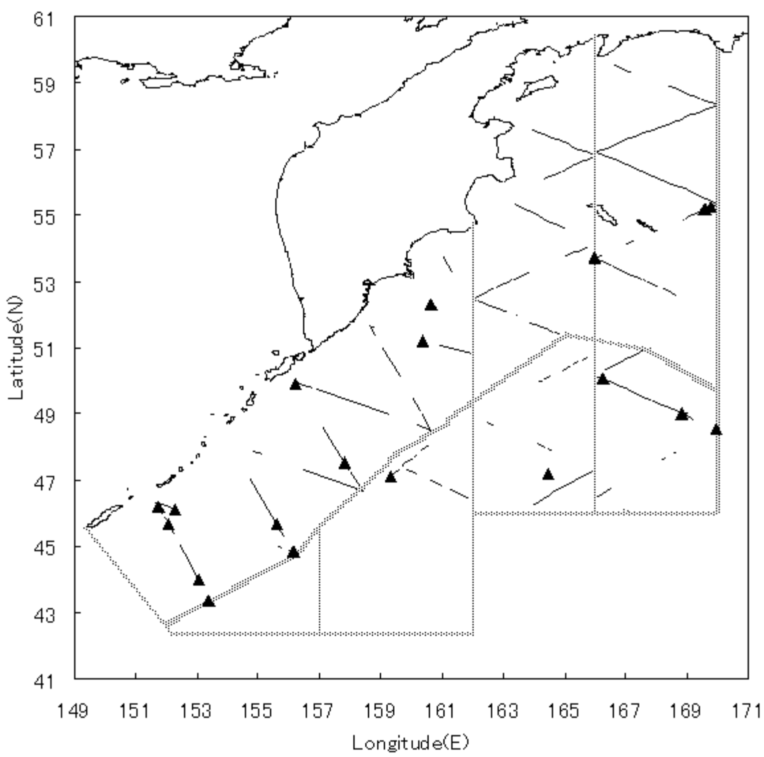

Fig. 8. Track line traversed with sighting effort and sighting positions of common minke whale (black triangle) in 2005.

Table 3. Number of sightings of common minke whales by *Shonan-maru* in 2005.

Block	BEN		BES		KAN		KAS		Transit		Total	
Mode*	IO-pass	NF	IO-pass	NF	IO-pass	NF	O-pass	NF	Passing			
Distance (nmi)	578.1		259.5		418.4		184.9				1441.2	
Primary/secondary	Pri.	Sec.	Pri.	Sec.	Pri.	Sec.	Pri.	Sec.	Pri.	Sec.	Pri.	Sec.
Schools	2	5	2	1	0	0	0	1	1	1	5	8
Animals	2	5	2	1	0	0	0	1	1	1	5	8

*same as in Table 1.

Table 4. Number of sightings of common minke whales by *Shonan-maru No.2* in 2005.

Block	KUL		PAE		PAW		Transit		Total	
Mode*	IO-pass	NF	IO-pass	NF	IO-pass	NF	Passing			
Distance (nmi)	868.2		60.7		0				928.9	
Primary/secondary	Pri.	Sec.	Pri.	Sec.	Pri.	Sec.	Pri.	Sec.	Pri.	Sec.
Schools	6	7	0	0	0	0	2	0	8	7
Animals	6	7	0	0	0	0	2	0	8	7

*same as in Table 1.

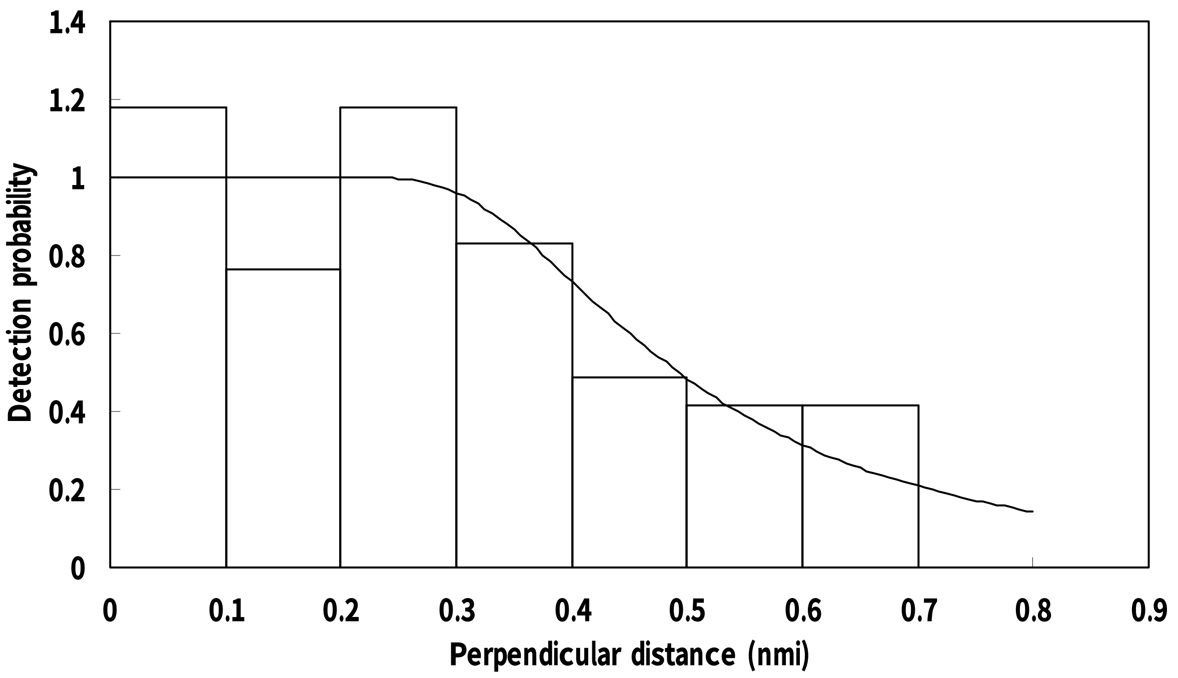

Fig. 8. Detection curve fitted to the sighting data of *Shonan-maru* and *Shonan-maru No.2* in 2003 and 2005.

Table 5. Abundance estimate of common minke whales in the Russian EEZ assuming g(0)=1.

Block	N	CV%	95% C.I.			J/O
Sea of Okhotsk (2003)						
11W	1,496	92.6	320	-	6,994	J
CSW	2,882	34.1	1,506	-	5,516	J
Subtotal	4,378	38.8	2,102	-	9,120	J
CE	935	49.6	373	-	2,342	O
CNW	772	36	390	-	1,529	O
ONW	1,335	36.7	666	-	2,678	O
OSW	4,035	88.9	904	-	18,002	O
SHA	16,981	19.8	11,571	-	24,920	O
Subtotal	24,058	20.7	16,115	-	35,916	O
Total	28,436	18.5	19,866	-	40,703	

East of Kuril Islands - Kamchatka pen. (2005)						
KUL	728	47	303	-	1,747	O
BEN	244	152.3	29	-	2,088	O
Total	972	52	373	-	2,534	

Not to be cited without permission from the authors

Appendix 2

Preliminary results of estimation of sei whale (*Balaenoptera borealis*) distributuion and abudnace in the whole North Pacific basin

HIROTO MURASE[1], TAKASHI HAKAMADA[1], HIROSHI KIWADA[1], DENZO INAGAKE[2], MAKOTO OKAZAKI[2], NAOKI TOJO[3] AND KOJI MATSUOKA[1]

[1]*The Institute of Cetacean Research, 4-5 Toyomi-cho, Chuo-ku, Tokyo, 104-0055, Japan*
[2]*National Research Institute of Fisheries Science, 2-12-4 Fukuura, Kanazawa, Yokohama, Kanagawa 236-8648, Japan*
[3]*Graduate School of Environmental Science, Hokkaido University, 3-1-1 Minato-cho, Hakodata, Hokkaido 041-8611, Japan*

ABSTRACAT

Distribution pattern and abundance of sei whales in the whole North Pacific basin were estimated by using a GAM based spatial model. A hierarchical model with two spatial strata was used in this study: (1) presence and absence of school and (2) school density given its presence. Model fitting was conducted using sighting data set collected by JARPN II in July from 2000 and 2007. Fitted model were then used to estimate the abundance and to draw the distribution map in the whole North Pacific basin. Nine environmental factors, sea surface temperature, sea surface chlorophyll concentration and water temperature and salinity at 50, 100 and 200 m, were used as covariates in the hierarchical model. Sea surface covariates were derived from satellites while subsurface data were obtained by CTD and XCTD casts and the Argo profiling floats. The abundance in JARPN II survey area and the whole North Pacific basin was 9,500 and 59,600 individuals, respectively. Latter estimate can be considered as current population size of the North Pacific stock of sei whale. Abundance estimate of sei whales in the North Pacific had not been conducted since 1977. Tillman (1977) reported that the abundance in 1974 as 8,600 individuals. The results of this study indicated that the population size of the North Pacific stock of sei whale could be recovered to initial population level as estimated by Ohsumi *et al.* (1971) after ban of commercial harvesting. The estimated map suggested that vast majority of the population could be distributed in the offshore region of the Gulf of Alaska where no sighting effort was allocated in recent years. Sighting survey in the region is required to verify the results of this analysis.

INTRODUCTION

Sei whales (*Balaenoptera borealis*) are medium size baleen whales (body length about 15 m) and distributed in temperate and boreal waters worldwide (Horwood, 1987). The initial population level was estimated as 58,000 – 82,000 individuals in the North Pacific (Ohsumi *et al.*, 1971). It was heavily exploited by commercial harvesting and the population was depleted to 8,600 individuals in 1974 (Tilman, 1977). The commercial harvesting was banned in 1976. Because population assessment of sei whales in the whole North Pacific has not been conducted since 1977, its current status is unknown. The second phase of the Japanese Whale Research Program under Special Permit in the North Pacific (JARPN II) has been conducted since 2000. Systematic sighting surveys have been conducted under JARPN II. They are only basin scale sighting survey in the North Pacific in recent years. In this study, distribution pattern and abundance of sei whales in the whole North Pacific basin was estimated by using a GAM based model to assess the current status. Traditionally, relationship between distribution pattern of sei whales and environmental conditions was studied qualitatively (Nasu, 1966; Uda, 1954; Uda and Nasu, 1956; Uda and dairokuno, 1957). Recently, local distribution pattern of sei whales in the coastal waters of British Columbia was studied based on historical commercial catch data using Generalized Linear Model (GLM) (Gregr and Trites, 2000). However, no quantitative study on relationship between distribution pattern of sei whales and environmental conditions has been conducted at basin scale after ban of commercial harvesting. Recent remote sensing technologies such as satellites and autonomous profiling floats allow us to estimate distribution pattern and abundance using environmental data as covariates. Environmental data recorded by these remote sensing devises were in this analysis.

MAERIALS AND METHODS

The survey area of JARPN II was in the western North Pacific. Southern, northern, eastern and western boundaries of the survey area were 35°N, boundary of economic exclusive zone (EEZ) claimed by a foreign country, 170°E and eastern coast line of Japan, respectively. Sighting data were recorded by a total of 34 sighting vessels from 2000 to 2007. Two types of sighting vessels were operated: dedicated sighting vessels (SVs) and sighting and sampling vessels (SSVs). The survey was conduced in daytime. Survey was stopped when visibility was less than 2 n.miles and/or Beaufaut scale greater than 4. Tracklines of SVs were set systematically in the entire area so that sighting effort was allocated evenly in the survey area. General trackline designs of SSVs were similar to SVs but they also conducted small scale multidisciplinary ecological surveys. Because GAM based spatial modelling is not assume particular survey design in contrast to conventional DISTANCE sampling methods (Hedley *et al.*, 1999), data collected by SVs and SSVs were used in the analysis. Data collected in July from 2000 and 2007 were pooled in the analysis. Sighting distance and angle and number of individuals in each school was recorded for each sighting to estimate effective search width (*esw*) and mean school size (*E(s)*). The *esw* and *E(s)* using pooled data from 2000 to 2007 were estimated by using a software, DISTANCE (Thomas *et al.*, 2006). Year and vessel was used as covariates to estimate the *esw* and *E(s)*.

Interactions between school density of sei whales and the environmental factors were investigated at a scale of 30x30 km grid size. Following nine environmental factors were used as covariates in the spatial modelling: sea surface temperature (SST), sea surface chlorophyll concentration (CHLO), sea surface height anomaly (SSHa) and subsurface temperature and salinity at 50, 100, 200 m water depth. Means of each environmental covariates from 2000 to 2007 were used in the spatial model. Satellite derived data were used for SST, CHL and SSHa. Level 3 monthly mean SST data in July (4x4 km grid) obtained by Moderate Resolution Imaging Spectroradiometer aboard the Terra satellite (Terra MODIS) were used. Level 3 monthly mean CHLO data (4x4 km grid) in July obtained by the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) aboard GeoEye's OrbView-2 were used. Level 3 SST and CHL produced were processed by Feldman and McClain (2008). Weekly gridded Sea level anomalies (1/3°x1/3° on a Mercator grid) data were used. The data were produced by Ssalto/Duacs and distributed by Aviso, with support from Cnes. Subsurface water temperature and salinity data were obtained by CTD, XCTD and the Argo profiling floats. CTD (SBE-19, Seabird, USA) and XCTD (Tsurumi Seiki Co., Japan) data were obtained at 158 and 10 stations in JARPN II survey area from 2000 to 2007. Data of the Argo profiling floats prepared by Oka *et al.* (2007) were also used. Data of the Argo profiling floats were obtained at 3,913 locations in the north of 30°N from 2001 and 2007. All environmental data were imported to a GIS software, ArcView 9.2 (ESRI, USA) to produce mean data at a scale of 30x30 km grid size from 2000 to 2007.

A hierarchical spatial structure with two strata (first stratum: presence and absence of school, second stratum: school density given its presence) was used in this study. In this study, two strata GAM models were used for estimation of and for creating distribution maps of sei whales. A spatial smoother using GAM having a binomial error distribution with the logistic link function was assumed for the first stratum modelling. GAM with a Gamma error distribution with the log link function was used for second stratum modelling. All environmental covariates were considered for the initial models for both the strata. Smoothness parameters were estimated with the generalized cross-validation (GCV). Effective covariates were selected based on Wood (2001). Terms were deleted from the models if the following three criteria of Wood (2001) were met: (1) the estimated degree of freedom for the term close to 1, (2) plotted confidence band for the term includes zero everywhere and (3) the GCV score drops when the term is dropped. For this GAM based modelling, “mgcv” package (version 1.3-29) for R program (R Development Core Team, 2008) was employed. Firstly, model fitting was conducted by using data recorded within JARPN II survey area from 2000 to 2007. Secondary, selected models based on data in the surveyed area was used to extrapolate abundance to unsurveyed area. As the characteristics of the hierarchical model, the school density surface was estimated as the products of outcomes from the two strata. The school density was multiplied by *E(s)* and area of grid (30x30 km) to estimate number of individuals.

RESULTS AND DISCUSSION

A total of 896 individuals in 490 schools were sighted during a total of 56,562 km of sighting effort from 2000 to 2007 in JARPN II. The *esw* and *E(s)* were estimated as 3.387 km (CV=0.06) and 1.829 (CV=0.03), respectively. Maps of nine environmental covariates were shown in Fig. 1. Summary of selected GAM models was shown in Table 1. Shapes of the functional forms for selected covariates of first and second strata GAMs were shown in Figs. 2 and 3, respectively. Surveyed tracklines and sighting positions from 2000 to 2007 as well as estimated distribution pattern of sei whales in JARPN II survey area are shown in Fig. 4. Abundance of sei whales in JARPN II survey area was estimated as 9,472 individuals. Estimated distribution pattern of sei whales in the whole North Pacific basin was shown in Fig. 5. Abundance of sei whales in the whole North Pacific basin was estimated as 59,582 individuals.

A stock structure analysis by using both microsatellites and mitochondrial DNA suggested that sei whales in open water of the North Pacific were belonging to single stock (Kanda *et al.*, 2009). Abundance estimate of sei whales in the whole North Pacific basin in this study can be considered as current population size of the North Pacific stock of sei whale. Initial population level of sei whales in the North Pacific was estimated between 58,000 and 82,000 individuals (Ohsumi *et al.*, 1971). Abundance estimate of sei whales in this study was lower end of initial population level. Sei whales were heavily exploited by commercial harvesting and the population was depleted to 8,600 individuals in 1974 (Tilman, 1977). The results of this study suggested that the population size of the North Pacific stock of sei whale could be recovered to initial population level after ban of commercial harvesting. Because estimated distribution map of sei whales in the whole North Pacific basin was very similar to the commercial catch position maps as shown in Masaki (1977) and Mizroch and Rice (2006), the estimation of this study probably captured the current potential distribution range of sei whales well. Commercial harvesting data indicated that abundance of sei whales was high off coastal British Columbia in July (Gregr *et al.*, 2000). The report by Gregr *et al.* (2000) also coincided with the results of this study. The estimated map suggested that vast majority of the population could be distributed in the offshore region of the Gulf of Alaska where no sighting effort is allocated in recent years. Sighting survey in the region is required to verify the results of this analysis.

ACKNOWLEDGMENTS

Authors expressed thanks to all the crews and researchers who engaged in the offshore component of JARPNII. Data of the Argo profiling floats were provided by the Institute of

Observational Research for Global Change of Japan Agency for Marine-Earth Science and Technology.

REFERENCES

Feldman, G. C., McClain, C. R. 2008. Ocean Color Web, Terra MODIS (Under evaluation Jan. 16, 2007) and SeaWiFS (Reprocessing 5.2). NASA Goddard Space Flight Center. Eds. Kuring, N., Bailey, S. W. http://oceancolor.gsfc.nasa.gov/

Gregr, E. J., Nichol, L., Ford, J. K. B., Ellis, G. and Trites, A. W. 2000. Migration and population structure of northeastern Pacific whales off coastal British Columbia: An analysis of commercial whaling records from 1908-1967. *Mar. Mamm. Sci.* 16: 699-727.

Gregr, E. J. and Trites, A. W. 2001. Predictions of critical habitat for five whale species in the waters of coastal British Columbia. *Can. J. Fish. Aquat. Sci.* 58: 1265-1285.

Hedley, S. L., Buckland, S. T. and Borchers, D. L. 1999. Spatial modelling from line transect data. J. Cetacean Rea and Manage. 1:255-264.

Horwood, J. 1987. The sei whales: population biology, ecology and management. London: Croom Helm.

Kanda, N., Goto, M., Yoshida, H. and Pastene, L. 2009. Stock structure of sei whales in the North Pacific as revealed by microsatellites and mitochondrial DBA analyses. Paper SC/J09/JR32 presented to the JARPN II Review Workshop, Tokyo, January 2009 (unpublished). 14pp.

Masaki, Y. 1977. The separation of stock units of sei whales in the North Pacific. *Rep. Int. Whal. Commn.* (special issue 1): 71-79.

Mizroch, S. A. and Rice, D. W. 2006. Have North Pacific killer whales switched prey species in response to depletion of the great whale populations? *Mar. Ecol. Progr. Ser.* 310: 235-246.

Nasu, K. 1966. Fishery oceanography study on the baleen whaling grounds. *Sci. Rep. Whales Res. Inst.* Tokyo. 20: 157-209.

Ohsumi, S., Simadzu and Doi., T. 1971. The seventh memorandum on the results of Japanese stock assessments of whales in the North Pacific. *Rep. Int. Whal. Commn.* 21:76-89.

Oka, E., L. D. Talley, and T. Suga, 2007: Temporal variability of winter mixed layer in the mid- to high-latitude North Pacific. *J. Oceanogr.* 63: 293-307.

R Development Core Team 2008. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org.

Tilman, M. F. 1977. Estimates of population size for the North Pacific sei whale. *Rep. Int. Whal. Commn.* (special issue 1): 98-106.

Thomas, L., Laake, J.L., Strindberg, S., Marques, F.F.C., Buckland, S.T., Borchers, D.L., Anderson, D.R., Burnham, K.P., Hedley, S.L., Pollard, J.H., Bishop, J.R.B. and Marques, T.A. 2006. Distance 5.0. Release 2. Research Unit for Wildlife Population Assessment, University of St. Andrews, UK. http://www.ruwpa.st-and.ac.uk/distance/

Uda, M. 1954. Studies of the relation between the whaling grounds and the hydrographical conditions (I). *Sci. Rep. Whales. Res. Inst.* Tokyo. 9: 179-187.

Uda, M. and Dairokuno, A. 1957. Studies of the relation between the whaling grounds and the hydrographic conditions. *Sci. Rep. Whales Res. Inst.* Tokyo. 12: 209-224.

Uda, M. and Nasu, K. 1956. Studies of the whaling grounds in the northern sea-region of the Pacific Ocean in relation to the meteorological and oceanographic conditions (Part I). *Sci. Rep. Whales Res. Inst.* Tokyo. 11-163-179.

Wood, S.N. 2001. mgcv: GAMs and Generalized Ridge Regression for R. R News, 1: 20-25.

Table 1. Summary of selected GAM based spatial models. Terms in the parentheses were their abbreviations used in expression of models.

	1st stratum		2nd stratum	
Family	Binomial		Gamma	
Link function	Logit		log	
Deviance explained (%)	30.7%		41.2%	
	df	p-value	df	p-value
Covariates				
SST (*sst*)	8.83	<0.001	-	-
SSHa (*ssha*)	2.16	<0.01	-	-
chlorophyll concentration (*chlo*)	8.71	<0.001	6.82	<0.001
Temperature at 50m (*temp50*)	8.05	<0.001	-	-
Temperature at 100m (*temp100*)	8.18	<0.001	-	-
Temperature at 200m (*temp200*)	7.67	<0.001	8.21	<0.001
Salinity at 50m (sal50)	7.72	<0.01	-	-
Salinity at 100m (*sal100*)	6.98	<0.01	-	-
Salinity at 200m (sal200)	4.99	<0.01	-	-

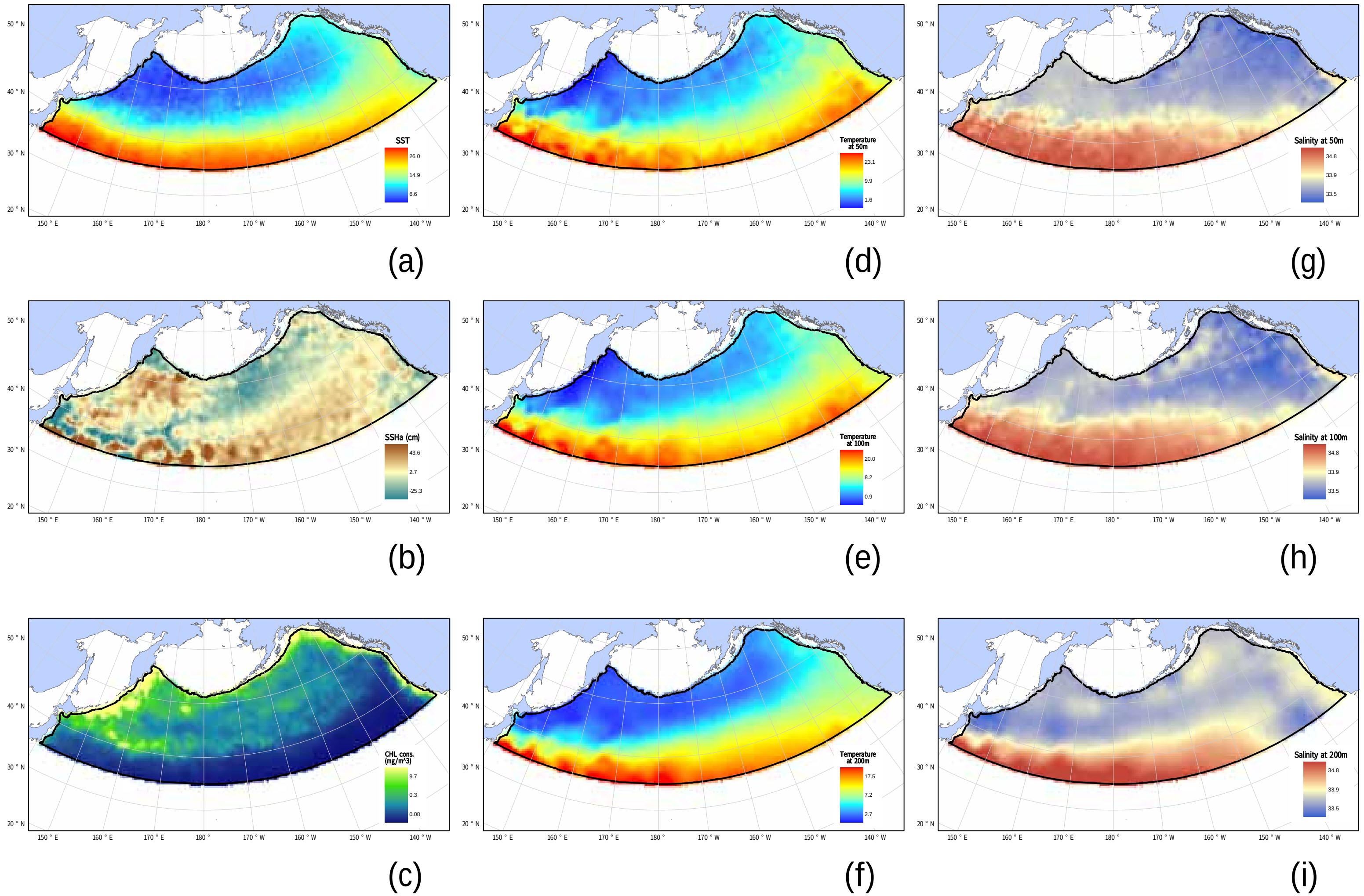

Fig. 1. Maps of environmental covariates used in the GAM based spatial model. Satellite derived SST (a), SSHa (b) and sea surface chlorophyll concentration (c). Subsurface temperature at 50 (d), 100 (e) and 200 m (f). Subsurface salinity at 50 (g), 100 (h) and 200 m (i).

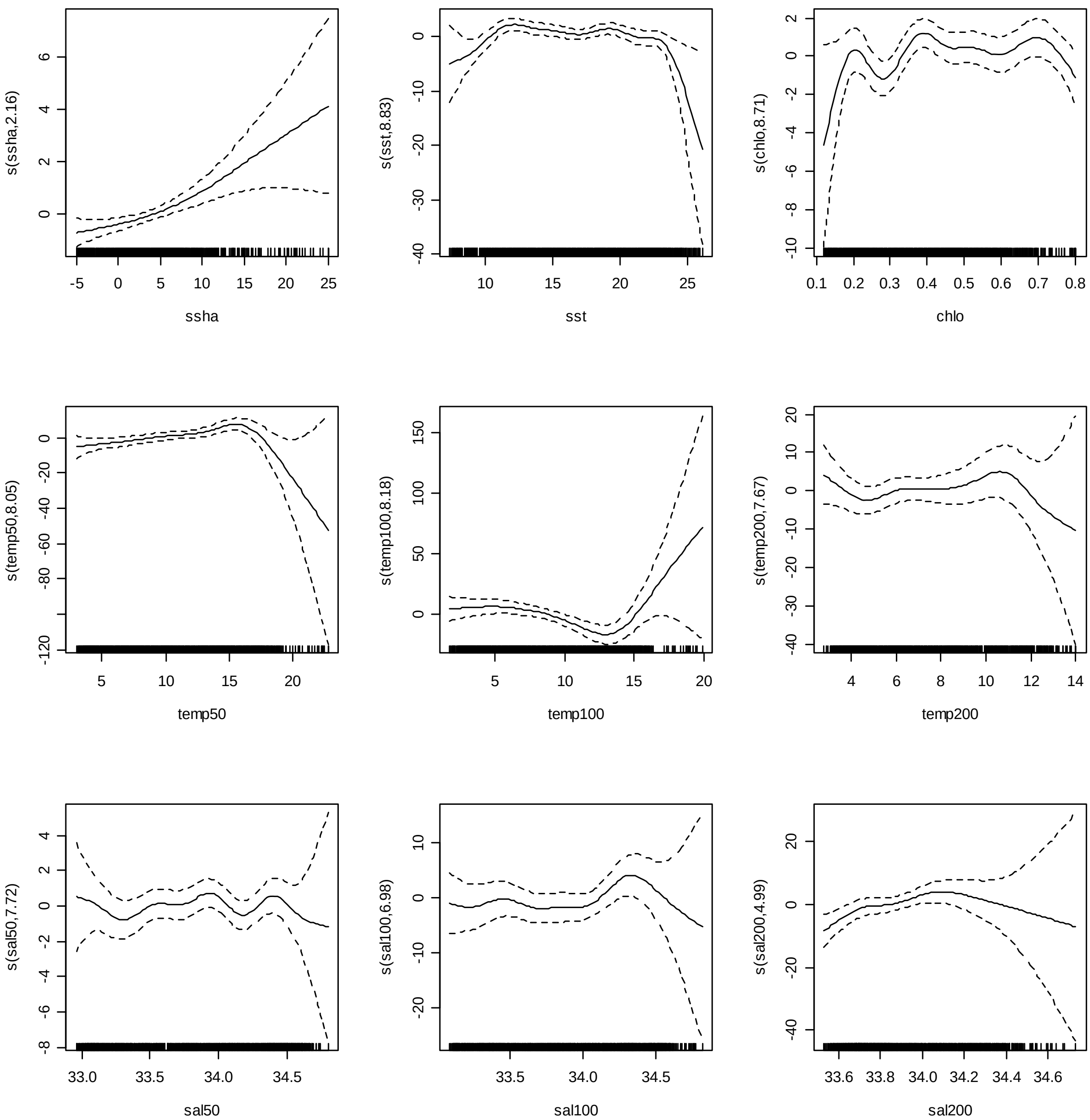

Fig. 2. Estimated functional forms for selected covariates to model the presence/absence of sei whales.

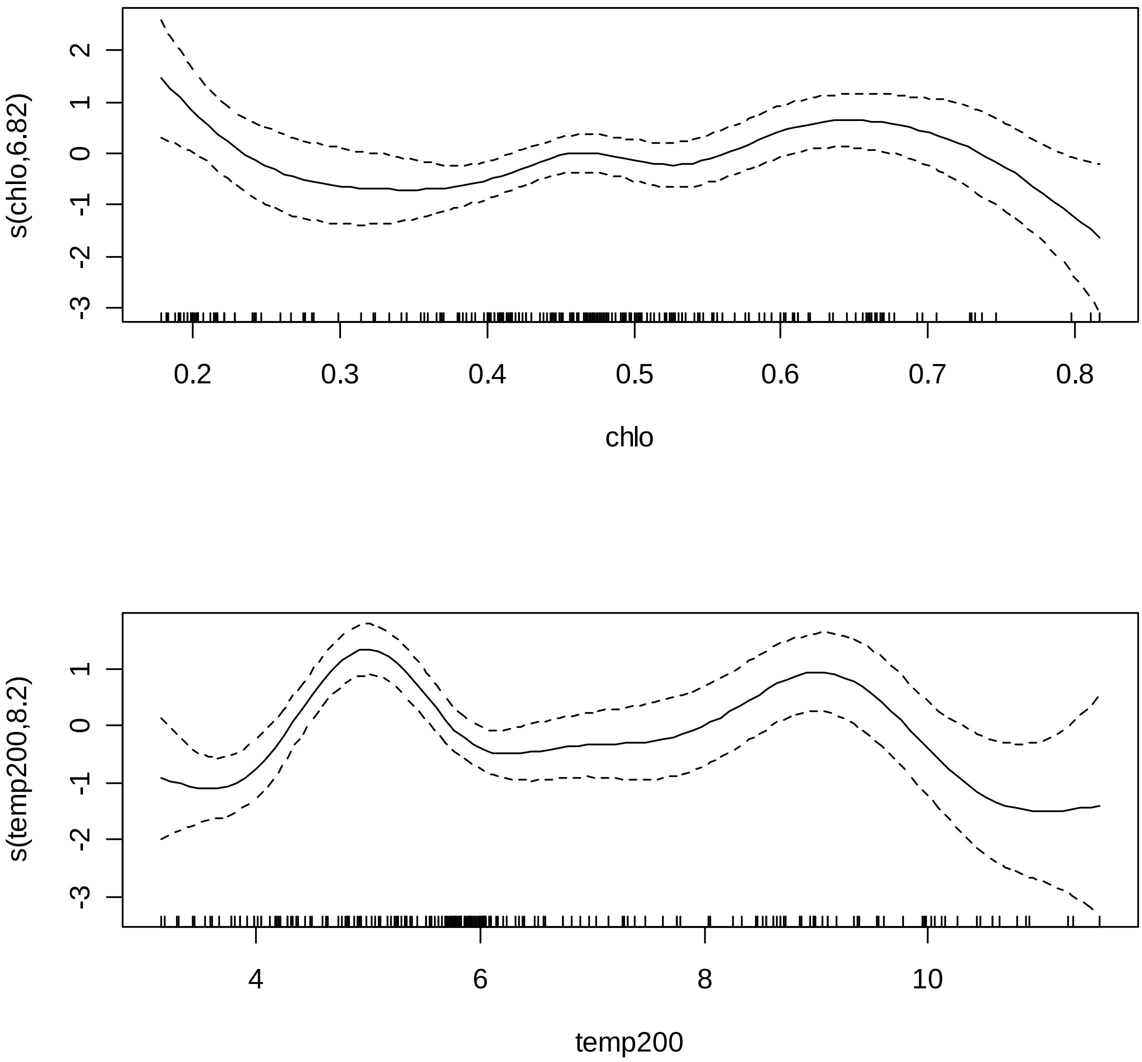

Fig. 3. Estimated functional forms for selected covariates to model the school density of sei whales.

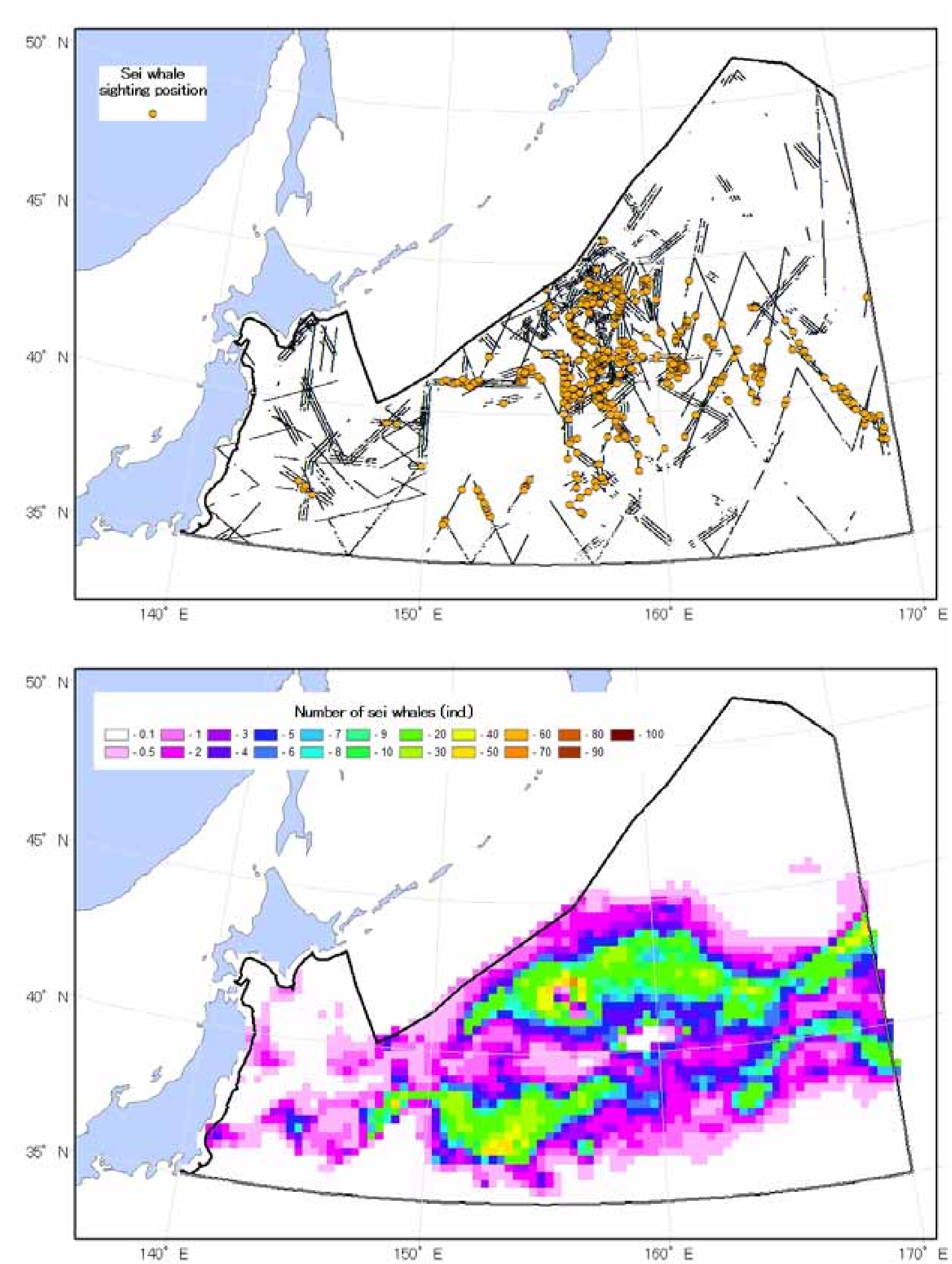

Fig. 4. Surveyed tracklines and sighting positions of sei whales from 2000 to 2007 in JARPN II (top).and estimated distribution pattern of sei whales in JARPN II survey area by GAM based spatial model (bottom). Area surrounded by black line is the survey area.

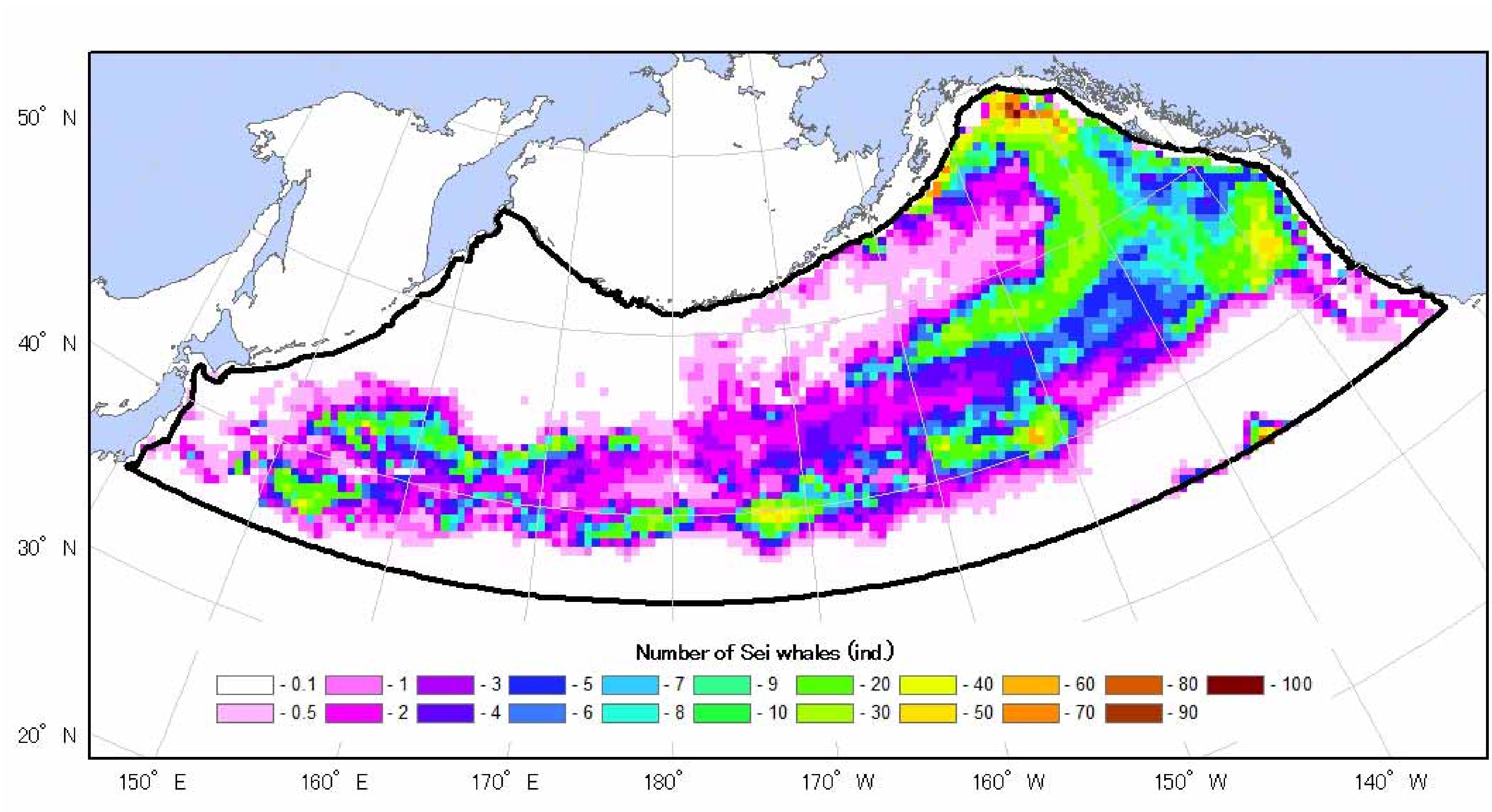

Fig. 5. Estimated distribution pattern of sei whales in the whole North Pacific basin by GAM based spatial model. Area surrounded by black line is the area used for estimation.

Appendix 3

The effect of the research catches on the Bryde's whale using population dynamics model adopted in RMP/*IST* for the Bryde's whale.

MATERIALS AND METHOD

In order to examine the effect of the annual catch of 30 from 1W and 20 from 1E during JARPN II on the Bryde's whale stock, the population dynamics model adopted in RMP/IST for this species was applied under the same assumptions as the RMP/IST for this species (IWC, 2008).

Br01-Br08 are trials of the IST examined in this study. They are listed in Table 1.

Table 1. Trials examined in this study.

trial	MSYR	stock hypotheses
Br01	1%	1
Br02	4%	1
Br03	1%	2
Br04	4%	2
Br05	1%	3
Br06	4%	3
Br07	1%	4
Br08	4%	4

Note: These trials have a suffix "A" (e.g. Br01A) is has the same parameters as Br01 except *MSYR*, *MSYL* and density dependence are defined on the 1+ population.

There are four general hypotheses regarding stock structure (Fig. 1):

1. There is only one stock of Bryde's whales in sub-areas 1 and 2.
2. There are two stocks of Bryde's whales in sub-areas 1 and 2. One stock is found in sub-area 1 and the other is found in sub-area 2.
3. There are two stocks of Bryde's whales in sub-areas 1 and 2. One stock is found in sub-areas 1 and 2, and the other is found in sub-area 2 only.
4. There are two stocks of Bryde's whales in sub-areas 1 and 2. One stock is found in sub-area 1 and the other is found in sub-area 2. Stock 1 consists of two sub-stocks that mix in sub-areas 1W and 1E.

RESULTS AND DISCUSSIONS

Table 2 summarise depletion in 2009, 2015, 2021 and 2029. For comparison, those without future catches were also shown (variant C0). These results show that Bryde's whale population will be increasing for 20 years under the trials examined and that there is no substantial difference in depletion between the case of 50 annual catches and the case of no annual catches. These calculations show no adverse effect on the Bryde's whale stock.

HITTER calculations were also conducted under the same assumptions Br01A-Br04A. Table 3 shows comparison of depletion between this model and The HITTER for these trials. There is no substantial difference between two models under the same assumption. This result is same as had expected because population dynamics in both models is very similar.

Table 2. Repletion in 2009, 2015, 2021 and 2029 for each trial examined.

Trial	Var	Median Catch				STK	Depletion in 2009			Depletion in 2015			Depletion in 2021			Depletion in 2029		
		Tot	1W	1E	2		5%	Med	95%	5%	Med	95%	5%	Med	95%	5%	Med	95%
Br01	C0	0	0	0	0	1	0.53	0.63	0.71	0.55	0.65	0.73	0.57	0.67	0.75	0.60	0.70	0.78
Br01	C9	50	30	20	0	1	0.52	0.62	0.70	0.53	0.64	0.72	0.54	0.65	0.73	0.56	0.67	0.75
Br01A	C0	0	0	0	0	1	0.59	0.69	0.77	0.62	0.73	0.80	0.66	0.76	0.83	0.71	0.80	0.86
Br01A	C9	50	30	20	0	1	0.58	0.69	0.76	0.61	0.71	0.79	0.63	0.74	0.81	0.66	0.77	0.84
Br02	C0	0	0	0	0	1	0.82	0.91	0.96	0.89	0.96	0.98	0.95	0.99	1.00	0.99	1.00	1.00
Br02	C9	50	30	20	0	1	0.81	0.90	0.95	0.87	0.94	0.97	0.92	0.96	0.98	0.95	0.97	0.98
Br02A	C0	0	0	0	0	1	0.99	1.01	1.01	0.99	1.00	1.02	1.00	1.00	1.00	0.99	1.00	1.00
Br02A	C9	50	30	20	0	1	0.99	1.00	1.00	0.97	0.98	0.99	0.97	0.98	0.98	0.97	0.98	0.99
Br03	C0	0	0	0	0	1	0.49	0.59	0.70	0.51	0.62	0.72	0.53	0.64	0.74	0.56	0.67	0.77
						2	0.64	0.80	0.89	0.66	0.82	0.90	0.68	0.83	0.91	0.71	0.86	0.93
Br03	C9	50	30	20	0	1	0.48	0.59	0.70	0.49	0.60	0.71	0.50	0.61	0.72	0.52	0.63	0.74
						2	0.64	0.80	0.89	0.66	0.82	0.90	0.68	0.83	0.91	0.71	0.86	0.93
Br03A	C0	0	0	0	0	1	0.55	0.66	0.76	0.59	0.69	0.80	0.63	0.73	0.82	0.67	0.77	0.86
						2	0.69	0.84	0.92	0.72	0.87	0.94	0.75	0.89	0.95	0.80	0.91	0.96
Br03A	C9	50	30	20	0	1	0.55	0.65	0.76	0.57	0.67	0.78	0.59	0.70	0.80	0.62	0.73	0.83
						2	0.69	0.84	0.92	0.72	0.87	0.94	0.75	0.89	0.95	0.80	0.91	0.96
Br04	C0	0	0	0	0	1	0.79	0.89	0.95	0.87	0.94	0.98	0.93	0.98	1.00	0.98	1.00	1.00
						2	0.87	0.98	1.00	0.93	1.00	1.00	0.97	1.00	1.00	0.99	1.00	1.00
Br04	C9	50	30	20	0	1	0.78	0.88	0.95	0.84	0.92	0.97	0.89	0.95	0.98	0.94	0.97	0.98
						2	0.87	0.98	1.00	0.93	1.00	1.00	0.97	1.00	1.00	0.99	1.00	1.00
Br04A	C0	0	0	0	0	1	0.99	1.01	1.01	0.99	1.00	1.02	1.00	1.00	1.01	0.99	1.00	1.00
						2	0.99	0.99	1.03	0.99	0.99	1.01	0.99	1.00	1.00	1.00	1.00	1.00
Br04A	C9	50	30	20	0	1	0.98	1.00	1.00	0.97	0.98	0.99	0.97	0.97	0.98	0.97	0.98	0.99
						2	0.99	0.99	1.03	0.99	0.99	1.01	0.99	1.00	1.00	1.00	1.00	1.00
Br05	C0	0	0	0	0	1	0.50	0.61	0.70	0.52	0.63	0.72	0.55	0.65	0.75	0.58	0.68	0.77
						2	0.55	0.81	0.92	0.57	0.82	0.93	0.60	0.84	0.93	0.63	0.86	0.94
Br05	C9	50	30	20	0	1	0.50	0.60	0.70	0.51	0.61	0.71	0.52	0.63	0.73	0.53	0.65	0.74
						2	0.55	0.81	0.92	0.57	0.82	0.93	0.60	0.84	0.93	0.63	0.86	0.94
Br05A	C0	0	0	0	0	1	0.56	0.67	0.76	0.60	0.71	0.79	0.64	0.74	0.82	0.68	0.78	0.86
						2	0.58	0.85	0.94	0.62	0.88	0.95	0.65	0.90	0.96	0.70	0.92	0.97
Br05A	C9	50	30	20	0	1	0.56	0.67	0.76	0.58	0.69	0.78	0.60	0.72	0.80	0.64	0.75	0.83
						2	0.58	0.85	0.94	0.62	0.88	0.95	0.65	0.90	0.96	0.70	0.92	0.97

Table 2 (Continued).

Trial	Var	Median Catch				STK	Depletion in 2009			Depletion in 2015			Depletion in 2021			Depletion in 2029		
		Tot	1W	1E	2		5%	Med	95%	5%	Med	95%	5%	Med	95%	5%	Med	95%
Br06	C0	0	0	0	0	1	0.80	0.90	0.96	0.88	0.95	0.98	0.94	0.98	1.00	0.98	1.00	1.00
						2	0.84	0.98	1.00	0.91	1.00	1.00	0.96	1.00	1.00	0.99	1.00	1.00
Br06	C9	50	30	20	0	1	0.79	0.89	0.95	0.85	0.93	0.97	0.90	0.95	0.98	0.94	0.97	0.98
						2	0.84	0.98	1.00	0.91	1.00	1.00	0.96	1.00	1.00	0.99	1.00	1.00
Br06A	C0	0	0	0	0	1	0.99	1.01	1.01	0.99	1.00	1.02	1.00	1.00	1.00	0.99	1.00	1.00
						2	0.99	1.00	1.03	0.99	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00
Br06A	C9	50	30	20	0	1	0.98	1.00	1.00	0.97	0.98	0.99	0.97	0.98	0.98	0.97	0.98	0.99
						2	0.99	1.00	1.03	0.99	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00
Br07	C0	0	0	0	0	1W	0.46	0.58	0.69	0.48	0.61	0.71	0.50	0.63	0.73	0.53	0.66	0.76
						1E	0.48	0.87	0.91	0.50	0.89	0.92	0.52	0.90	0.93	0.55	0.91	0.94
						2	0.64	0.80	0.89	0.66	0.82	0.90	0.69	0.84	0.91	0.72	0.86	0.93
Br07	C9	50	30	20	0	1W	0.45	0.58	0.69	0.46	0.59	0.70	0.48	0.60	0.71	0.49	0.62	0.73
						1E	0.47	0.86	0.91	0.49	0.86	0.91	0.49	0.86	0.91	0.51	0.86	0.91
						2	0.64	0.80	0.89	0.66	0.82	0.90	0.69	0.84	0.91	0.72	0.86	0.93
Br07A	C0	0	0	0	0	1W	0.53	0.66	0.76	0.57	0.69	0.79	0.60	0.73	0.82	0.65	0.77	0.86
						1E	0.24	0.82	0.94	0.25	0.84	0.95	0.27	0.87	0.96	0.30	0.89	0.97
						2	0.70	0.84	0.92	0.73	0.87	0.94	0.76	0.89	0.95	0.80	0.91	0.96
Br07A	C9	50	30	20	0	1W	0.52	0.65	0.75	0.55	0.67	0.78	0.57	0.70	0.80	0.60	0.73	0.83
						1E	0.23	0.81	0.93	0.25	0.83	0.93	0.26	0.84	0.93	0.29	0.86	0.94
						2	0.70	0.84	0.92	0.73	0.87	0.94	0.76	0.89	0.95	0.80	0.91	0.96
Br08	C0	0	0	0	0	1W	0.71	0.87	0.95	0.80	0.93	0.98	0.88	0.97	0.99	0.95	1.00	1.00
						1E	0.84	0.99	1.00	0.91	1.00	1.00	0.96	1.00	1.00	0.99	1.00	1.00
						2	0.87	0.98	1.00	0.93	1.00	1.00	0.97	1.00	1.00	1.00	1.00	1.00
Br08	C9	50	30	20	0	1W	0.70	0.86	0.94	0.77	0.91	0.96	0.84	0.94	0.97	0.90	0.96	0.98
						1E	0.83	0.98	0.99	0.88	0.97	0.98	0.92	0.97	0.98	0.95	0.97	0.98
						2	0.87	0.98	1.00	0.93	1.00	1.00	0.97	1.00	1.00	1.00	1.00	1.00
Br08A	C0	0	0	0	0	1W	0.99	1.01	1.01	0.99	1.00	1.02	1.00	1.00	1.00	0.99	1.00	1.00
						1E	0.06	0.19	1.00	0.09	0.27	1.00	0.12	0.37	1.02	0.19	0.55	1.03
						2	0.99	1.00	1.03	0.99	0.99	1.01	0.99	1.00	1.00	1.00	1.00	1.00
Br08A	C9	50	30	20	0	1W	0.98	0.99	1.00	0.97	0.98	0.99	0.97	0.97	0.98	0.97	0.98	0.99
						1E	0.06	0.19	0.99	0.08	0.26	0.97	0.12	0.35	0.99	0.18	0.52	1.00
						2	0.99	1.00	1.03	0.99	0.99	1.01	0.99	1.00	1.00	1.00	1.00	1.00

Table 3. Comparison in depletion between this study and the HITTER model.

a) *MSYR*(1+)=1% and stock hypothesis 1 (Br01A)

year	Hitter	Allison		
		5%	Med	95%
2009	0.64	0.58	0.69	0.76
2015	0.67	0.61	0.71	0.79
2021	0.69	0.63	0.74	0.81
2029	0.72	0.66	0.77	0.84

b) *MSYR*(1+)=4% and stock hypothesis 1 (Br02A)

year	Hitter	Allison		
		5%	Med	95%
2009	0.92	0.99	1.00	1.00
2015	0.94	0.97	0.98	0.99
2021	0.96	0.97	0.98	0.98
2029	0.96	0.97	0.98	0.99

c) *MSYR*(1+)=1% and stock hypothesis 2 (Br03A)

year	Hitter	Allison		
		5%	Med	95%
2009	0.62	0.55	0.65	0.76
2015	0.65	0.57	0.67	0.78
2021	0.67	0.59	0.70	0.80
2029	0.70	0.62	0.73	0.83

d) *MSYR*(1+)=4% and stock hypothesis 2 (Br04A)

year	Hitter	Allison		
		5%	Med	95%
2009	0.91	0.98	1.00	1.00
2015	0.94	0.97	0.98	0.99
2021	0.95	0.97	0.97	0.98
2029	0.96	0.97	0.98	0.99

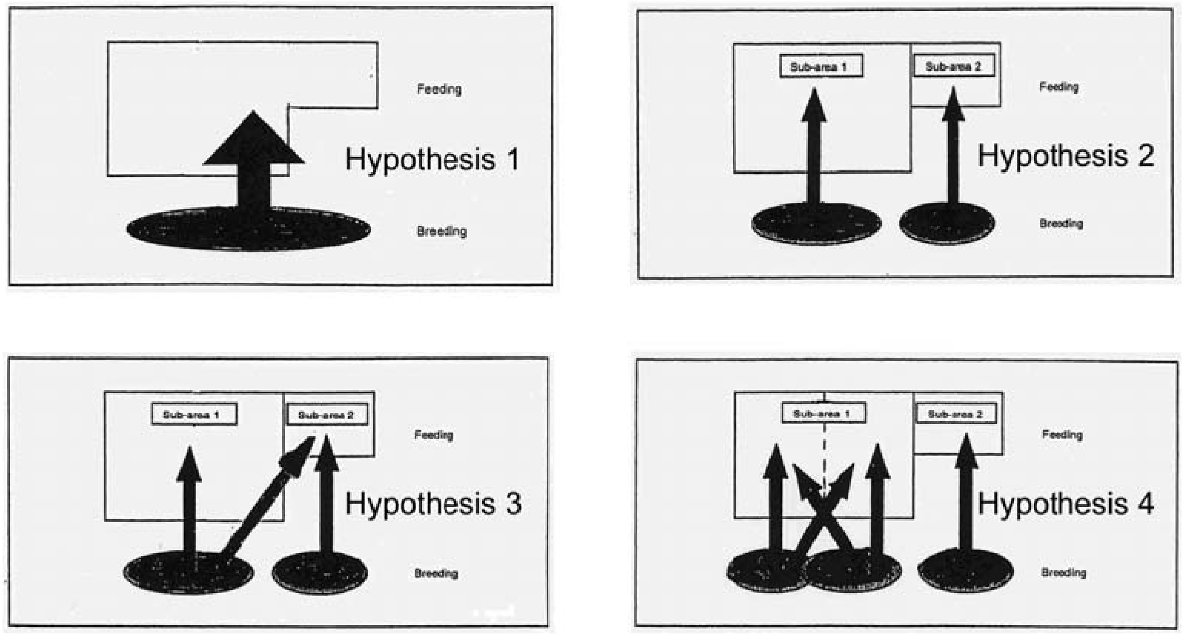

Fig.1. Stock structure hypotheses selected by the Workshop on the pre-implementation assessment of the western North Pacific Bryde's whales (IWC, 2008).