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# Abundance Estimates of Southern Hemisphere Minke Whale in 1991/92 and 1992/93 seasons Using Data from Japanese Whale Research Programme Under Special Permit in Antarctic

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## ABSTRACT

Abundances of southern minke whales in Area IV and V were estimateded using sighting data with sampling activity of the Japanese Research Programme Under Special Permit in Antarctic (JARPA) in 1991/92 and 1992/93, and they were used for correction of analysis of age distribution. In order to investigate the effect of sampling activity and seasonallity on the abundance estimates, sighting manner of the JARPA in 1992/93 was modified as follows: 1) one dedicated sighting vessel (*SV*) was exclusively engaged in sighting in all the research areas along the independent sighting track line from sighting/sampling vessels (*SSV*). 2) a sighting of survey was conducted, with the survey efforts concentrated on the peak migration season of minke whales in the Antarctic, to match the procedure taken by the International Decade Cetacean Research (IDCR) as much as possible. Abundance of minke whaless in Area V were estimated to be 159,640 individuals (*C.V.* 0.383) by the *SV* in 1992/93 compared with and 211,150 individuals (*C.V.* 0.174) IDCR from the closing mode in the IDCR in 1985/86 (Butterworth, 1988). Abundance estimate of the JARPA in 1992/93 season is some 24.4% lower than the 1985/86 IDCR estimate by closing mode, and they are not statistically different from that each other.

## INTRODUCTION

The Japanese Whale Programme Under Special Permit in Antarctic (JARPA) has been conducted to estimate of biological parameters required for the stock management of southern hemisphere minke whale and elucidation of the role of whales in the Antarctic marine ecosystem. These were conducted in Areas IV and V in every other year. Both research areas had been surveyed for two seasons on a full scale (Area IV in 1989/90 and 1991/92, and Area V in 1990/91 and 1992/93). Abundances of southern minke whales in Areas IV and V were estimated using sighting data with sampling activity of whales and they were used for correction of age distribution and segregation (Fujise *et al.*, 1991).

On the other hand, the International Decade Cetacean Research (IDCR) had been surveyed these areas twice, too. Area IV was surveyed in 1984/85 and 1988/89 and Area V was surveyed in 1985/86 and 1991/92. The IDCR survey estimated abundance of minke whales in the peak migration season (Butterworth, 1988; Haw, 1990; Borchers, 1993).

The results of abundance estimation by the JARPA were reported to the Scientific Committee of the IWC every year. Some change of the research programme has been done by the reconsideration based on results of previous cruises. Abundances of the southern minke whales in Areas IV and V were estimated using sighting data in 1989/90 and 1990/91, respectirely. However, these results were significantly smaller than those of the IDCR. The reasons of these differences were considered as follows (Kishino *et al.*, 1991; Nishiwaki *et al.*, 1992),:

(1) Difference of the year could provide yearly fluctuation of abundance.
(2) Difference of the length and season of the surveys could result the differnce of abundance estimates.
(3) Change in weather and sea conditions (sighting rate, migration pattern, the shape of research area) could affect the searching effort on the track-lines.
(4) The off-effort steaming (a part of stratum was not surveyed) could affect the searching effort along the track-lines.
(5) Distance for transfer between the track-lines (due to the need advancing the survey without halting) could affect in the searching effort on the track-lines.
(6) Catching activity could affect whale density along track-lines and dispersion of whales could occure density along the track-lines by the reaction of whales.
(7) Three observers allocated on the barrel could affect the detection probability of pods on the track-lines (the small space of the barrel might force for two of the three observers to lay their searching effort more on one side than another).

In order to investigate the effect of sampling activity, a dedicated sighting vessel (*SV*) was arranged in 1991/92 in the southern strata and in all strata in 1992/93.

A series of survey was conducted once in 1992/93, with the survey efforts concentrated in the peak distribution season of minke whales, to match the procedure with that by the IDCR as much as possible.

Further more to investigate seasonal change in distribution density of minke whales, the special monitoring zone (SMZ, 135°E - 155°E) was set before and after the entire survey in 1992/93.

The *SV* surveyed at least 12 n. miles ahead of the sighting/sampling vessels (*SSVs*) to avoid adverse by resulting from the sampling activities of *SSVs*.

And in order to assess the effects of the chasing activity of the *SSVs*, on the dedicated sighting survey, the "reaction monitoring experiment" was conducted from 1990/91.

## OUTLINE OF CRUISES

### Cruise track

The cruise track lines in each stratum were set with the same principal of the 1989/90 (Fujise *et al.*, 1990).

The northern strata were designed asthe same way as the IDCR cruise. In the southern strata (from the ice pack to the line of 45 n. miles off the pack ice except for the Prydz Bay, and East-South stratum in 1992/93), the track line zigzagged from north to south at intervals of 4 degrees longitude.

### Sighting manner

The principal sighting manner was similar to that of previous JARPA (Kato *et al.*, 1989,1990; Fujise *et al.*, 1990; Kasamatsu *et al.*, 1993; Fujise *et al.*, 1993a, 1993b).

Three track lines of a main and two sub-courses were set. The sub-courses were set parallel by to the main course 9 n. miles away from either sides.

In order to steaming whole research area during the cruises, the minimum proceeding distances were set in each stratum. These distances were as 150 n. miles in all strata in 1991/92, and 140 n. miles in each stratum, excluding 100 n. miles in the West-North stratum, in the 1992/93.

As an improvement of the sighting manner in 1991/92, the *SV* was allocated to the main course in the southern strata, and was allocated in the same way in all strata in 1992/93 (Fujise *et al.*, 1993a,1993b).

For investigation seasonal change in distribution of minke whales, the SMZ (135°E - 155°E) was set before and after the entire survey in 1992/93.

### Research period

The JARPA surveys were carried out from early December to middle March, usually.

The 1991/92 survey was conducted in Area two times IV to investigate seasonal change in distribution of minke whales in the Antarctic as same as previous years. However the 1992/93 survey was conducted once in the peak season of minke whales in the entire research area to match the procedure IDCR cruises.

The survey periods in each stratum of each year were shown in previous cruise reports (Fujise *et al.*, 1993a,1993b).

### The size of stratum

The size of each stratum was calculated using the data of the three research vessels and the NAVY/NOAA Joint Ice Center (JIC) information (Table 1-a,1-b).

## MATERIALS AND METHODS

### Number of sightings

All sighting data were smeared by the method 2 of Buckland and Anganuzzi (1988), using the result of the distance and angle estimation experiment which was carried out in each cruise. The sightings of minke whale schools within 2.0 n. miles from the track line (after smearing) were used for the estimation of the population abundance.

**Effective Search Width**

The half Effective Search Widths (*ESW*) of whale schools were obtained in each stratum and periods. The hazard rate model (Hayes and Buckland, 1983) was fit to the perpendicular distance of sightings.

$$g(y|a,b) = 1 - \exp(-(\frac{y}{a})^{1-b})$$

$$\hat{w} = 1/f(0), \quad (f(y) = g(y)/w)$$

Because it was expected that the larger schools are easier to be detected than the smaller schools. The sighting data were stratified into two school size groups, singleton and schools with 2 or more individuals.

The *ESW* from the sighting data of *SSVs* were pooled to get the reasonable sample sizes and the *ESW* from the *SV* were calculated. The variances of the estimates were evaluated by bootstrap procedure (Efron, 1979) of resampling the legs with replacement (100 times). The tendency of larger *ESW* are observedfor the schools with 2 or more than those for the singleton.

**Estimation of Population Abundance**

The *ESW* of each groups of each stratum was estimated (Kasamatsu *et al.*, 1990), and the population abundance of whales in each stratum was estimated from the following formula:

$$\hat{N}_i = \hat{D}_i \cdot A = \frac{n_i s_i}{2 w_i L} \cdot A \ , \quad \hat{N} = \sum_{i=1}^{n} \hat{N}_i \quad (i = 1, 2)$$

($n_i$ : number of sightings, $s_i$ : school size, $A$ : research area, $L$ : searching distance, $\hat{w}_i$ : effective search width, $\hat{D}$ : estimation of density, $\hat{N}, \hat{N}_i$ : etimation of population abundance)

The variances of the estimates were evaluated by bootstrap procedure of resampling the legs with replacement (100 times).

## RESULTS

**Searching Distance**

Table 1-a shows the searching distance ($L$) in 1991/92, and those of the *SSVs* were 2,168.8 n. miles in the first period and 2,949.2 n. miles in the second period. The *SV* was carried survey in the southern strata (including the Prydz Bay stratum), and the total searching distance by the *SV* were 1,811.9 n. miles in the first period and 2,064.8 n. miles in the second period. The average searching distance by the *SSVs* in the southern strata were 550.9 n. miles in the first period and 690.5 n. miles in the second period. When the searching distance by the *SV* was compared with that of the *SSV* in southern strata, the searching distance by the *SV* were larger than that by the *SSV*. The difference of the searching distance between the *SV* and *SSVs* were observed in the West-South and the Prydz Bay strata where the large number of

sightings for minke whales was observed.

Table 1-b shows the searching distances (*L*) in 1992/93. The total searching distances in the entire survey area were 3,670.6 n. miles by the *SV*, 2,175.7 n. miles by the average of the *SSVs*. On the other hand, the searching distance by the *SSV* in the SMZ was 883.4 n. miles in the first period, 919.2 n. miles in the second period, 706.7 n. miles in the third period. Similarly the searching distance by the *SV* in the SMZ was 1,321.2 n. miles in the first period, 1,383.3 n. miles in the second period, 969.2 n. miles in the third period. The difference of searching distance in 1992/93 was observed between the *SV* and *SSVs*.

Mean School Size

The Mean School Size (*MSS*) of the *SV* in 1991/92 was larger than that of the *SSV* in the southern strata. Difference of the *MSS*, as 3.8 individuals by the *SV* and 2.7 individuals by the *SSV*, was observed especially in the Prydz Bay stratum (Table 1-a).

In the entire survey area in 1992/93, difference of the *MSS* was observed that the *MSS* of the *SV* was larger than that of the *SSV*. Significant difference, as 7.5 individuals of the *SV* and 1.4 individuals of the *SSV* was observed in the East-North stratum. Seasonal change in the *MSS* in the SMZ were not confirmed both in the SV and the SSV through the all periods (Table 1-b).

**The Number of Sightings and Sighting Rate**

Table 1-a shows the sighting rate (*n/L*) in 1991/92. The *n/L* of the *n/L* of *SV* in each stratum (excluding the West-South stratum) were higher than that by the *SSV*. Particularly, the difference of the *n/L* between the *SV* (0.352) and the *SSV* (0.188) was observed in the Prydz Bay stratum.

The *n/L* in 1992/93 were similar to that in 1991/92 as shown in Table 1-b. The searching distance of the *SV* was longer than that of the *SSV*, because the *SSVs* did not steam on the track line in the high density area, it was indicated that the *n/L* decreased in the northern and southern strata from the first to the third period.

Effective Search Width

The difference of this value was not confirmed between the *SSV* and the *SV* (Table 1-a, 1-b).

Estimation of Density

Table 1-a shows the estimated density (*D*) in 1991/92. The density in the second period was higher than that in the first period. The *D* in the East-Middle stratum in the first period was lower than that in the West-Middle stratum in the first period, and the *D* in the East-Middle stratum in the second period was not estimated because of zero number of sightings.

Table 1-b shows the *D* in the SMZ in 1992/93. Difference of *D* were not indicated between the first and second periods, but they were significantly different between the second and third periods. The *D* in the third period was smaller than that in the first and the second periods.

Comparing with the *D* between the *SV* and the *SSV* in 1991/92 and 1992/93, the *D* of the *SV* was larger than that of the *SSVs* in and 1992/93, the *D* of the *SV* was larger than that of the *SSVs* in all were seen strata, especially in the stratum where large sightings of the minke whales.

**Estimation of population abundance**
Tables 1-a and 1-b show the results of estimation of population abundance (*P*) in 1991/92 and 1992/93.
In order to estimate of the biological parameters of the southern hemisphere minke whale, these results which were obtained in 1991/92 and 1992/93 seasons were used for correction of the age distribution.

## DISCUSSION

**Comparison of results with the *SV* and the *SSV***
By the comparison of results of the JARPA in 1991/92 and 1992/93 seasons, the reasons of the difference between the *SV* and the *SSV* were as follows:

The searching distance of the *SV* was more than those of the *SSV*. Difference of searching distance decreased in the sub-area of low density and limitation of sampling. The reasons of these differences are clearly related to sampling activity.

The difference of density indexes between the *SV* and the *SSV* was also clear in high density areas. It is indicated that density of the *SSV* is underestimated in high density area. Therefore, the lengh of searching distance in high density area is extremely related to sighting density.

Difference of *MSS* and *ESW* were not confirmed between the *SV* and the *SSV*.

The *D* of the *SSVs* in a research area changed to remarkably by the degree of density.

**Yearly and seasonal changes of the *D***
Table 2 shows the *D* of the *SSV* in Area IV in 1989/90 and 1991/92 and in Area V in 1990/91 and 1992/93. In Area IV, yearly changes were remarkably different in the Prydz Bay and the Eastern sector, and they were no clear in the Western sector. The *D* in the first period was lower than that the second period.

In 1992/93, an entire survey was conducted once in the peak migration season of minke whales in the Antarctic. Therefore comparing with results of the entire survey in 1992/93 and those in the second period in 1990/91, they were different in a part of the northern strata, and not clear in the southern strata. And seasonal changes of the *D* in the SMZ in 1992/93 were confirmed to decrease from the first period to the third period gradually. On the basis of those results, the change in whale density in the research area were seen seasonally and yearly.

**Compaison of abundance estimates between JARPA and IDCR**
Kishino *et al.* (1991) and Nishiwaki *et al.* (1992) noted that abundance estimate by the JARPA were significantly smaller than those of the IDCR. Similar tendency is observed in the present surveys. The reasons of these differences can be analyzed by several factors with which surveys were conducted. Differences of

estimates between the JARPA and the IDCR were considered particularly to be related to the sampling activity and seasonality. Comparing results of survey (Area IV in 1989/90 and 1991/92 with those in Area V in 1990/91 and 1992/93), it was confirmed that the yearly fluctuation in migration of minke whales occured. In of the SMZ, differences of the length and timing of the survey period were confirmed to be affected to the seasonal change of abundance. Searching distance of the *SV* was significantly more than those of the *SSV*. Remarkable differences of the abundance were observed in high density area. As searching distance in the high density was affected by sampling activity, the density of minke whales by the *SV* was also significantly higher than those from the *SSV*.

In 1992/93, an entire survey conducted once in the cruise, in the peak migration season of minke whales to match the procedure of the IDCR. Abundance estimates in Area V were 159,640 individuals (*C.V.* 0.383) by the *SV* of the JARPA and 211,150 individuals (*C.V.* 0.174) by the closing mode of the IDCR in 1985/86 (Butterworth, 1988). Abundance estimate of the JARPA in 1991/92 is 24.4% lower thanthat in the 1985/86 IDCR. However, they are not significantly different from each other, comparing the values of *C.V.*

Difference between the JARPA and the IDCR is produced by the effective search width. Kishino *et al.* (1991) noted that the searching widths were apparently widened by additional observer on the barrel. Although this manner was introduced to try to achieve the $g(0)$ to be 1, the small space on the barrel might force the two of the three observers to lie their searching effort more direction of one side. Additionally, Fig. 2 shows that observers in other platforms lay their searching effort to one side. It is also point out rate of sightings in other platforms of the JARPA (50%) is higher than that of the IDCR (30% to 40%). The number of sightings in other platforms was considered to effect largely the *ESW*. However, the tendency of such a searching behavior of observers in other platforms will not be solved, because the top mast are obstacle for the observes to search forward.

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Table 1-a. Comparison of the result of analysis between SSVs and SV in the 1991/92 survey.
'N' is the number of sightings (sch., ind.), N/L is the number of sightings per one n. mile, 'D' is the estimated density of whales (ind./10n. miles$^2$), 'ESW' is effective half strip width for whales (n. miles), 'MSS' is the mean school size (ind.), 'P' is the estimated population abundance (ind.), the figures are the C.V..

| Research mode | Period /Stratum | AREA | DIST. | N Sch | N Ind | MSS | N/L* (n1/L) | (n2/L) | ESW* (W1) | (W2) | MSS | D | P* (P1) | (P2) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SSVs | First period | | | | | | | | | | | | | |
| | East-Middle | 217,764 | 721.2 | 26 | 33 | 1.3 | 0.009 (0.533) | 0.003 (0.430) | 0.914 (0.410) | 0.861 (0.427) | 1.3 | 0.084 (2.590) | 1,062 (4.420) | 776 (0.578) |
| | West-Middle | 258,237 | 1,036.1 | 32 | 59 | 1.8 | 0.009 (0.222) | 0.006 (0.647) | 0.782 (0.459) | 0.651 (0.140) | 1.9 | 0.162 (1.205) | 1,273 (3.302) | 2,915 (0.717) |
| | East-South | 34,871 | 667.9 | 40 | 73 | 1.8 | 0.013 (0.285) | 0.014 (0.254) | 0.430 (0.235) | 0.828 (0.222) | 1.6 | 0.389 (0.521) | 545 (0.432) | 813 (0.744) |
| | West-South | 38,978 | 433.8 | 23 | 40 | 1.7 | 0.028 (0.364) | 0.023 (0.777) | 1.058 (0.253) | 0.893 (0.280) | 1.8 | 0.479 (0.515) | 509 (0.518) | 1,358 (0.556) |
| | Second period | | | | | | | | | | | | | |
| | East-Middle | 223,666 | 768.5 | 0 | 0 | - | - - | - - | - - | - - | - | - - | - - | - - |
| | West-Middle | 219,773 | 827.4 | 77 | 129 | 1.7 | 0.016 (0.355) | 0.012 (0.346) | 0.452 (0.333) | 0.518 (0.208) | 1.7 | 0.493 (0.262) | 3,994 (0.252) | 6,839 (0.332) |
| | East-South | 34,745 | 621.5 | 47 | 182 | 3.9 | 0.011 (0.324) | 0.023 (0.432) | 0.385 (1.101) | 1.244 (0.216) | 2.2 | 0.583 (0.532) | 566 (0.630) | 1,458 (0.618) |
| | West-South | 34,259 | 567.6 | 61 | 137 | 2.2 | 0.018 (0.138) | 0.032 (0.341) | 0.570 (0.396) | 0.944 (0.251) | 2.0 | 0.673 (0.713) | 557 (0.472) | 1,747 (0.964) |
| | Prydz Bay | 27,733 | 191.9 | 77 | 264 | 3.4 | 0.070 (1.024) | 0.117 (0.672) | 1.006 (0.209) | 0.622 (0.123) | 2.7 | 3.468 (0.514) | 983 (0.896) | 8,634 (0.471) |
| SV | First period | | | | | | | | | | | | | |
| | East-South | 34,871 | 904.1 | 30 | 76 | 2.5 | 0.009 (0.422) | 0.019 (0.215) | 0.125 (3.406) | 0.993 (0.244) | 1.6 | 0.704 (0.497) | 1,230 (0.846) | 1,224 (0.499) |
| | West-South | 38,978 | 907.8 | 27 | 46 | 1.7 | 0.017 (0.283) | 0.010 (0.338) | 0.595 (0.407) | 0.647 (0.136) | 1.8 | 0.377 (0.355) | 541 (0.512) | 929 (0.432) |
| | Second period | | | | | | | | | | | | | |
| | East-South | 34,745 | 837.2 | 36 | 176 | 4.9 | 0.012 (0.389) | 0.027 (0.404) | 0.858 (0.348) | 1.450 (0.138) | 4.5 | 0.733 (0.647) | 242 (0.245) | 2,304 (0.718) |
| | West-South | 34,259 | 1,009.0 | 52 | 171 | 3.3 | 0.012 (0.248) | 0.033 (0.355) | 0.291 (0.481) | 0.464 (0.540) | 3.1 | 1.718 (0.586) | 699 (0.393) | 5,188 (0.679) |
| | Prydz Bay | 27,733 | 218.6 | 84 | 665 | 7.9 | 0.146 (0.902) | 0.206 (0.996) | 0.757 (0.098) | 1.151 (0.122) | 3.8 | 6.826 (0.815) | 2,683 (0.646) | 16,247 (0.842) |

* : the sightings data were poststratified into two school size groups(singleton and schools with 2 or more individuals)

Table 1-b. Comparison of the result of analysis between SSVs and SV in the 1992/93 survey.
'N' is the number of sightings (sch., ind.), N/L is the number of sightings per one n. mile, 'D' is the estimated density of whales (ind./10n. miles$^2$), 'ESW' is effective half strip width for whales (n. miles), 'MSS' is the mean school size (ind.), 'P' is the estimated population abundance (ind.), the figures are the C.V..

| Research mode | Period /Stratum | AREA | DIST. | N Sch | N Ind | MSS | N/L* (n1/L) | (n2/L) | ESW* (W1) | (W2) | MSS | D | P* (P1) | (P2) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SSVs | The entire research area | | | | | | | | | | | | | |
| | East-North | 290,526 | 472.2 | 37 | 56 | 1.5 | 0.026 (0.142) | 0.013 (0.388) | 0.586 (0.222) | 0.966 (0.158) | 1.4 | 0.397 (0.142) | 6,564 (0.168) | 4,962 (0.376) |
| | West-North | 332,682 | 688.5 | 38 | 57 | 1.5 | 0.017 (0.235) | 0.011 (0.640) | 0.353 (0.277) | 0.641 (0.148) | 1.3 | 0.428 (0.470) | 7,824 (0.426) | 6,416 (0.536) |
| | East-South | 180,745 | 563.5 | 114 | 260 | 2.3 | 0.045 (0.419) | 0.056 (0.237) | 0.952 (0.179) | 0.901 (0.379) | 2.3 | 1.267 (0.236) | 4,296 (0.502) | 18,604 (0.286) |
| | West-South | 43,572 | 451.5 | 78 | 299 | 3.8 | 0.022 (0.276) | 0.060 (0.413) | 0.718 (0.200) | 1.202 (0.138) | 3.4 | 1.447 (0.450) | 710 (0.454) | 5,595 (0.481) |
| | The SMZ survey | | | | | | | | | | | | | |
| | First-North | 189,441 | 488.5 | 33 | 52 | 1.6 | 0.011 (0.169) | 0.012 (0.564) | 0.475 (0.225) | 0.587 (0.169) | 2.1 | 0.480 (0.374) | 2,234 (0.143) | 6,865 (0.501) |
| | First-South | 29,394 | 394.9 | 62 | 240 | 3.9 | 0.014 (0.464) | 0.065 (0.467) | 0.860 (0.260) | 0.910 (0.279) | 3.8 | 1.679 (0.791) | 244 (1.091) | 4,690 (0.808) |
| | Second-North | 210,905 | 546.2 | 20 | 26 | 1.3 | 0.014 (0.222) | 0.005 (0.580) | 0.448 (0.282) | 0.375 (0.263) | 1.3 | 0.287 (0.080) | 3,229 (0.151) | 2,832 (0.053) |
| | Second-South | 34,211 | 373.0 | 57 | 181 | 3.2 | 0.023 (0.327) | 0.049 (0.530) | 0.765 (0.188) | 1.167 (0.144) | 2.9 | 1.101 (0.604) | 538 (0.446) | 3,227 (0.667) |
| | Third-North | 210,905 | 230.3 | 4 | 4 | 1.0 | - - | - - | - - | - - | - | - - | - - | - - |
| | Third-South | 25,733 | 476.4 | 51 | 147 | 2.9 | 0.021 0.338 | 0.036 (0.458) | 1.076 (0.211) | 1.043 (0.283) | 2.9 | 0.781 (0.473) | 249 (0.530) | 1,762 (0.493) |
| SV | The entire research area | | | | | | | | | | | | | |
| | East-North | 290,526 | 717.3 | 16 | 135 | 8.4 | 0.007 (0.539) | 0.015 (0.580) | 0.361 (0.153) | 0.530 (0.049) | 7.5 | 1.808 (0.704) | 2,808 (0.358) | 49,722 (0.731) |
| | West-North | 332,682 | 923.2 | 46 | 72 | 1.6 | 0.030 (0.321) | 0.019 (0.342) | 0.654 (0.170) | 0.622 (0.230) | 1.6 | 0.615 (0.565) | 7,712 (0.716) | 12,738 (0.495) |
| | East-South | 180,745 | 1,024.8 | 167 | 681 | 4.1 | 0.082 (0.397) | 0.081 (0.368) | 0.438 (0.164) | 0.751 (0.164) | 2.8 | 4.164 (0.579) | 16,910 (0.419) | 58,360 (0.681) |
| | West-South | 43,572 | 1,005.3 | 107 | 450 | 4.2 | 0.032 (0.243) | 0.075 (0.311) | 0.299 (0.686) | 0.999 (0.148) | 2.9 | 2.614 (0.465) | 2,319 (0.463) | 9,071 (0.503) |
| | The SMZ survey | | | | | | | | | | | | | |
| | First-North | 189,441 | 682.3 | 27 | 56 | 2.1 | 0.016 (0.206) | 0.023 (0.703) | 0.586 (0.400) | 0.743 (0.189) | 2.0 | 0.582 (0.603) | 2,607 (1.228) | 8,413 (0.696) |
| | First-South | 29,394 | 638.9 | 69 | 270 | 3.9 | 0.039 (0.648) | 0.069 (0.516) | 0.526 (0.161) | 1.338 (0.164) | 2.9 | 1.805 (0.580) | 1,094 (0.748) | 4,213 (0.564) |
| | Second-North | 210,905 | 635.8 | 24 | 37 | 1.5 | 0.022 (0.367) | 0.016 (0.551) | 0.622 (0.051) | 0.784 (0.164) | 1.5 | 0.407 (0.220) | 3,728 (0.191) | 4,859 (0.262) |
| | Second-South | 34,211 | 747.5 | 72 | 208 | 2.9 | 0.031 (0.344) | 0.066 (0.463) | 0.425 (0.911) | 1.118 (0.109) | 2.2 | 1.469 (0.623) | 1,240 (1.036) | 3,787 (0.558) |
| | Third-North | 210,905 | 255.4 | 0 | 0 | - | - - | - - | - - | - - | - | - - | - - | - - |
| | Third-South | 25,733 | 713.8 | 35 | 80 | 2.3 | 0.025 (0.417) | 0.024 (0.377) | 0.345 (0.291) | 0.886 (0.138) | 1.7 | 0.856 (0.366) | 941 (0.549) | 1,261 (0.279) |

* : the sightings data were poststratified into two school size groups(singleton and schools with 2 or more individuals)

Table 2. Comparison of the density (ind./10n.miles$^2$) of SSVs in each year in the Area IV and Area V.

Area IV

| Stratum | 1991/92 | 1989/90 |
|---|---|---|
| First Period | | |
| East-Middle | 0.084 (2.590) | 0.517 (0.190) |
| West-Middle | 0.162 (1.205) | 0.313 (0.168) |
| East-South | 0.389 (0.521) | 2.204 (0.789) |
| West-South | 0.479 (0.515) | 0.324 (0.130) |
| Second Period | | |
| East-Middle | 0.000 - | 0.577 (0.123) |
| West-Middle | 0.493 (0.262) | 0.293 (0.104) |
| East-South | 0.583 (0.532) | 2.416 (0.597) |
| West-South | 0.673 (0.713) | 0.589 (0.178)* |
| Prydz-Bay | 3.468 (0.514) | - - |

* including the data in Prydz Bay

Area V

| Stratum | 1992/93 | | 1990/91 |
|---|---|---|---|
| | | First Period | |
| | | East-North | 0.255 (0.233) |
| The entire research area | | West-North | 0.935 (0.510) |
| East-North | 0.397 (0.142) | East-South | 0.173 (0.106) |
| West-North | 0.428 (0.470) | West-South | 0.740 (0.229) |
| East-South | 1.267 (0.236) | | |
| West-South | 1.447 (0.450) | Second Period | |
| | | East-North | 0.670 (0.220) |
| | | West-North | 0.169 (0.257) |
| | | East-South | 1.392 (0.485) |
| | | West-South | 1.385 (0.570) |

| Stratum | 1992/93 |
|---|---|
| The SMZ survey | |
| First-North | 0.480 (0.374) |
| First-South | 1.679 (0.791) |
| Second-North | 0.287 (0.080) |
| Second-South | 1.101 (0.604) |
| Third-North | - - |
| Third-South | 0.781 (0.473) |

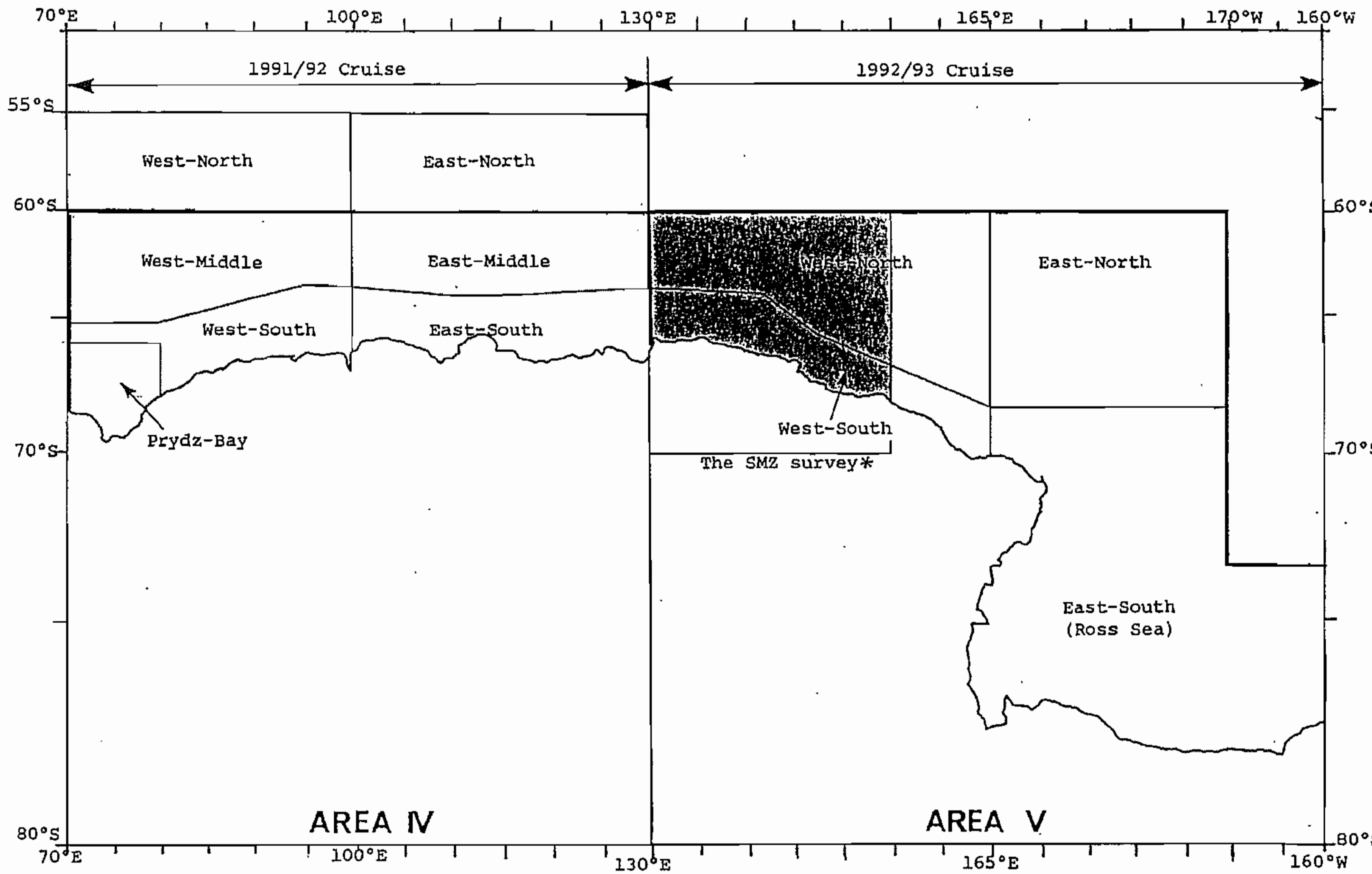


Fig. 1. Geographical location and the stratification of the research area in the JARPA in 1991/92 and 1992/93.

* : Special monitoring zone to investigate the seasonal changes of the distribution andsegregation of minke whales.

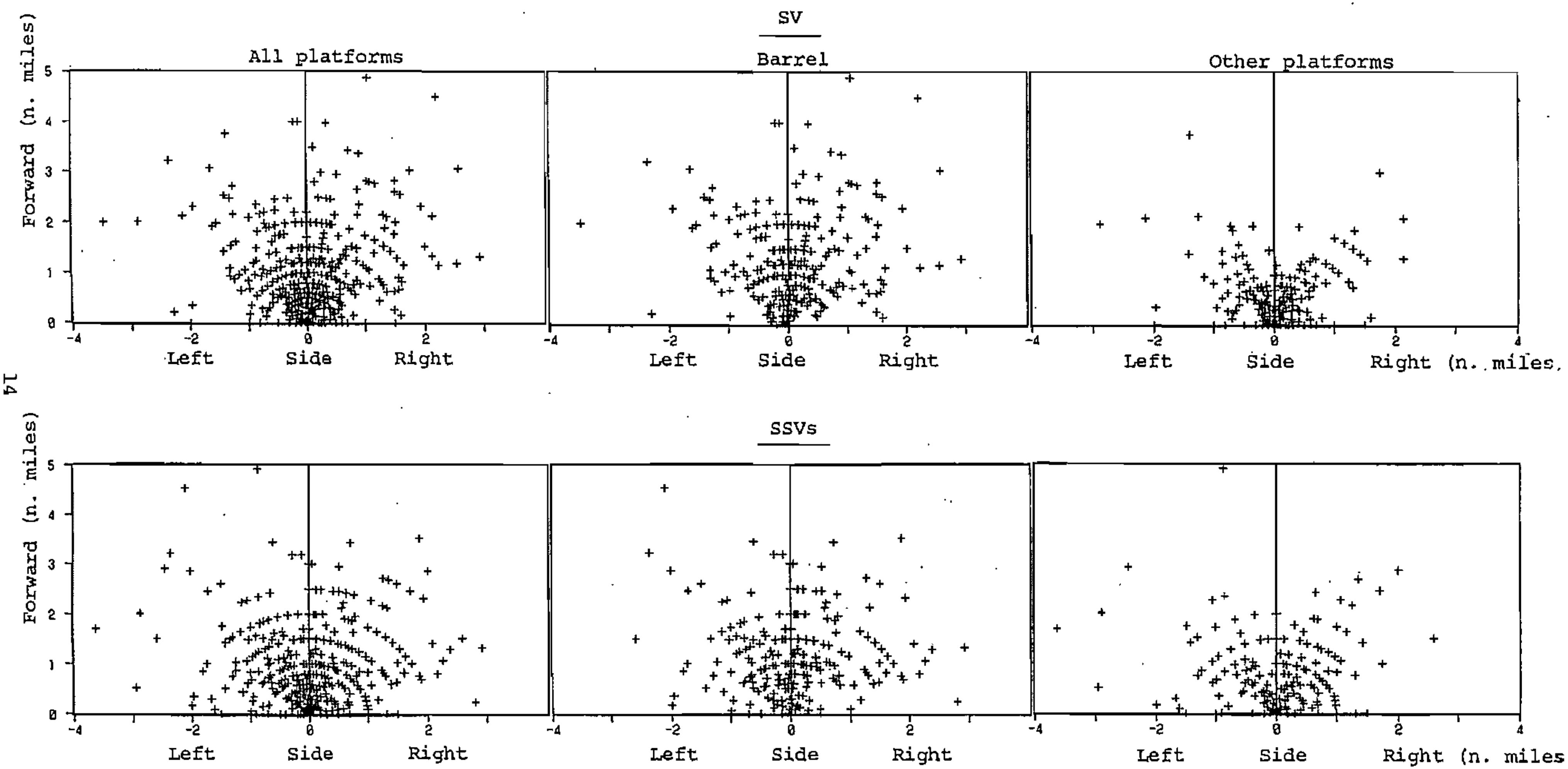


Fig. 2. Plots of primary sightings of minke whales by research vessels (SV and SSVs) in the 1992/93 cruise.