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# Abundance Estimate of the Southern Hemisphere Minke Whales in Area V from the Sightings in the Japanese Research in 1990/91

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## ABSTRACT

The Japanese research in 1990/91 was conducted combining the systematic sighting and sampling surveys in the whole research area of Area V for the first time. Abundance was estimated by sightings data in this cruise. The research area was divided into four strata in the survey. In order to detect the temporal change of migration pattern in the feeding season, the survey was carried out twice. It was covered from December 21 to January 31 in the First period and February 2 to March 20 in the Second period. Abundance estimates were significantly different between the research periods, that is larger in the Second period than in the First period. In addition, in comparison of each stratum, it was larger in the West Sector than in the East Sector in the First period and larger in the South strata than in the North strata in the Second period. The results were assumed to be caused by the temporal change of migration pattern in the feeding season. Abundance estimates were given as $41,636 \pm 12,685$ individuals in the First period and $75,201 \pm 14,839$ individuals in the Second period.

# INTRODUCTION

In 1987/88 and 1988/89, Japan conducted two feasibility studies of the Southern Hemisphere Minke Whale (Kato *et al.*, 1989 ; 1990). Following the completion of the feasibility study, the regular research program commenced in Area IV in 1989/90 (Fujise *et al.*, 1990).

The Japanese research in 1989/90 was scheduled to obtain the abundance and the biological information of this stock in the whole feeding season (Government of Japan, 1989). Continuously the Japanese research in 1990/91 in already Area V was also carried out combining of the systematic sighting and sampling surveys. The details were described in the cruise report (Kasamatsu *et al.*, 1991).

Abundance estimate in this survey was attempted from the sighting data with the random sampling in the whole research area of Area V for the first time. In the survey, sightings were made independently by three research vessels rotating daily along the track-lines. The three estimates of the population abundance were obtained from the sightings on the track-lines.

These results were also used for correction of the analysis of age distribution and segregation in the 1990/91 Japanese research take (Fujise *et al.*, 1992).

# MATERIAL AND METHODS

## *Research summary*

The research area in this cruise was limited from the pack-ice fringe to south of 60° S latitude, and from 130° E to 166° W longitude (include a part of the Ross Sea).

This survey was divided into four strata (the East-Middle, West-Middle, East-South and West-South). Each stratum was surveyed twice to detect the temporal change of the characteristics in the feeding season. The research periods for four strata are listed in Table 1.

Positions and sizes of stratum were different between the First and Second periods for the temporal change in pack-ice fringe (Table 2 and Fig. 1-a and 1-b). The northern boundaries and the South strata set to 45 n. miles line from the ice-edge rather than 60 n. miles in the IDCR cruise. The northern boundary in the East-South stratum (Ross Sea) in the Second period were set to 69° S latitude. Advance distance in the research area was arranged each stratum for few research days. Accordingly the starting points were set beforehands, so that the vessels ran 100 n. miles every day in the South strata, 160 n. miles in the Middle strata and 140 n. miles in the East-South stratum (Ross Sea) in the Second period. The research area and the cruise-tracks are listed in Figs. 1-a and 1-b. Searching distances in each stratum are shown in Table 3.

Sightings were made independently from three sampling vessels Kyomaru No.1 (K01), Toshimaru No.18 (T18) and Toshimaru No.25 (T25). These vessels ran along three parallel track-lines, rotating daily their relative positions.

## *Number of sightings*

All sighting data were smeared by use of the method 2 of Buckland and Anganuzzi (1988), using the result of the angle and distance experiment carried out during the survey. The sightings within 2.0 n. miles from the track-lines (after smearing) were used for the estimation of the population abundance.

*Effective search width*

The half effective search width for whale schools was obtained in each stratum and research period. The hazard rate model (Hayes and Buckland, 1983) was fitted to the perpendicular distances of sightings.

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

Because it was expected that the larger schools were easier to be found than smaller schools, the sightings data were stratified into two groups, solitary whales and two or more whales in a school. In the estimation of the effective search width, the sightings data of the three track-lines were pooled to get the reasonable sample sizes. The variances of the estimates were evaluated by resampling the legs with replacement (Efron, 1979).

*Abundance estimate*

The density, $Di$, and the number of schools of size $N_i$, were estimated by

$$\hat{D}_i = \frac{n_i}{2\hat{w}_i L},$$

$$\hat{N}_i = \frac{n_i A}{2\hat{w}_i L},$$

Here, $n_i$, $A$, $w_i$ and $L$ are the number of sightings, the size of the research area, the estimated half effective search width and the searching distance, respectively. The total number of animals in each stratum obtained by summing up the estimated numbers of whales in all school sizes (Kasamatsu *et al.*, 1990), as the numbers of animals in each school size was estimated by

$$\hat{N} = \sum_i i\hat{N}_i,$$

*Comparison with other methods*

Alternative approach is to multiply the estimated number of schools by the estimated mean school size (IWC, 1988).

To take account of unequal covering probabilities of locations, the procedure developed by Cooke (1984, 1987) and extended by Taga (1991) were also applied. This procedure sums up the inverse of the coverage probabilities of sightings to obtain the number of individuals as

$$\hat{N} = \sum_{i=1}^{n} \frac{1}{2\hat{w}\hat{p}(x_i)}.$$

Here, $x_i$ is the location of the $i$ -th sighting, and $p(x)$ is probability that the area within the distance of 0.5 n. miles from the track-lines covers the location $x$. $P(x_i)$ was estimated by drawing sets of track-lines other than the actual one, based on the survey design in the planning meeting. The detailed procedure was explained by Taga (1991).

# RESULTS

## *The number of sightings and sighting rate*

As shown in Table 4, the number of sightings was larger in the West Sector than that in the East Sector and that in the Middle strata than that in the South strata in the First period. In the Second period, it was larger in the East Sector than that in the West Sector and that in the South strata than that in the Middle strata.

The sightings rate ($n/L$) was indicated similar result in the number of sightings as shown in Table 5.

## *Abundance estimate*

The density of whales in the each stratum was estimated from the number of the sightings (Table 5) and the estimated search width (Table 6). As shown in Table 7, the estimated density of whales was higher in the West Sector than in the East Sector, significant difference between the South and Middle strata was detected in the First period. In the Second period, it was higher in the South strata than that in the Middle stratum and not significantly different between the West and East Sectors.

Abundance was estimated by multiplying the estimated whale densities and size of each stratum (Tables 2 and 7). As shown in Table 8, abundance estimates were significantly different between two research periods, and it was larger in the Second period than that in the First period. In addition, it was larger in the West Sector than that in the East Sector in the First period, and it was larger in the South strata than that in the Middle sstrata in the Second period. The results were caused clearly by the temporal change of migration pattern in the feeding season. The estimated population abundance was $41,636 \pm 12,685$ individuals in the First period and $75,201 \pm 14,839$ individuals in the Second period.

The three methods gave fairly similar abundance estimates as shown in Table 9.

# DISCUSSION

Kishino *et al.*, (1991) noted that abundance estimate obtained by the Japanese research take was significantly smaller than those from the data of the IDCR. Similar tendency is observed from the present survey. The reasons of these differences can be analysed into several factors with which research was conducted. These are as follows;

1. Difference of the year could affect yearly fluctuation of abundance.
2. Difference of the length and timing of the survey period could affect seasonal change of abundance.
3. Weather and sea conditions (changes in sighting rate and migration pattern by year, changes in the shape of survey map and space of research area due to different meteorological conditions) 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 within a stratum (due to the need advancing the program without halting) could affect in the searching effort on the track-lines.
6. Catching activity could affect whale density along track-lines and dispersion and gathering of whale density along the track-lines by the whale reaction.

7. Three observers allocated on the barrel could change the detection probability of pods on the track-lines (the small space on the barrel might have forced the two of the three observers to lay their searching effort more on one side).

We have started a new working group to investigate how above factors can affect the abundance estimates, and we intend to get the conclusions in the near future.

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**Table 1.** The survey period of the Japanese Research of the Antarctic Area V in 1990/91.

| Stratum | The First period | The Second period |
|---|---|---|
| East-South | 12/22-12/31 | 2/ 1- 2/15 |
| West-South | 1/11- 1/20 | 2/27- 3/ 9 |
| East-Middle | 1/ 1- 1/ 9 | 2/16- 2/25 |
| West-Middle | 1/21- 1/31 | 3/10- 3/20 |

**Table 2.** The size of stratum (n. miles$^2$) in the present survey.

| Stratum | The First period | The Second period |
|---|---|---|
| East-South | 33,091.0 | 208,511.0 |
| West-South | 62,354.5 | 69,915.2 |
| East-Middle | 181,121.3 | 347,440.2 |
| West-Middle | 232,898.0 | 256,089.8 |

**Table 3.** The searching distance (n. miles) in the present survey. The figures in parentheses were obtained by extrapolation of the searching distance to the whole legs.

| Stratum | The First period | | The Second period | |
|---|---|---|---|---|
| East-South | 523.6 | ( 723.1) | 541.4 | (1621.2) |
| West-South | 454.6 | (1359.0) | 822.3 | (1660.6) |
| East-Middle | 572.2 | (1178.7) | 353.2 | ( 978.0) |
| West-Middle | 774.2 | (1679.7) | 574.7 | (1647.9) |

**Table 4.** The number of sightings within 2.0 n. miles (after smearing) from three track-lines were combined. $n_1$, $n_{s,\geq 2}$, $n_{w,\geq 2}$, $n_s$, $n_w$ represent the sightings of solitary whales, schools of size over 1, individuals that belong to schools of size over 1, schools of all size , individuals that belong to schools of all size, respectively.

| Season | East-South | West-South | East-Middle | West-Middle |
|---|---|---|---|---|
| The First period | | | | |
| $n_1$ | 4.7 | 13.3 | 7.0 | 29.7 |
| $n_{s\geq 2}$ | 2.0 | 19.7 | 3.0 | 18.0 |
| $n_{w\geq 2}$ | 4.0 | 66.7 | 6.0 | 71.0 |
| $n_s$ | 6.7 | 30.0 | 10.0 | 47.0 |
| $n_w$ | 8.7 | 80.0 | 13.0 | 100.7 |
| The Second period | | | | |
| $n_1$ | 38.7 | 9.0 | 10.0 | 3.7 |
| $n_{s\geq 2}$ | 31.3 | 16.7 | 8.7 | 5.3 |
| $n_{w\geq 2}$ | 115.0 | 66.0 | 26.3 | 14.3 |
| $n_s$ | 70.0 | 25.7 | 18.7 | 9.0 |
| $n_w$ | 153.7 | 75.0 | 36.3 | 18.0 |

**Table 5.** Ratio of the number and school in the sighting per 1 n. miles of in on the searching this the ratios of sighting rate $(n/L)$. The figures in the parentheses are the standard errors.

| Season | East-South | | West-South | | East-Middle | | West-Middle | |
|---|---|---|---|---|---|---|---|---|
| The First period | | | | | | | | |
| $n_{s=1}/L$ | 0.0092 | (0.0052) | 0.0248 | (0.0033) | 0.0122 | (0.0023) | 0.0385 | (0.0094) |
| $n_{s\geq 2}/L$ | 0.0038 | (0.0018) | 0.0354 | (0.0060) | 0.0052 | (0.0023) | 0.0226 | (0.0094) |
| $n_{w\geq 2}/L$ | 0.0077 | (0.0036) | 0.1223 | (0.0239) | 0.0105 | (0.0047) | 0.0878 | (0.0543) |
| $n_s/L$ | 0.0130 | (0.0069) | 0.0602 | (0.0082) | 0.0174 | (0.0036) | 0.0611 | (0.0166) |
| $n_w/L$ | 0.0169 | (0.0086) | 0.1472 | (0.0250) | 0.0227 | (0.0056) | 0.1263 | (0.0593) |
| The Second period | | | | | | | | |
| $n_{s=1}/L$ | 0.0726 | (0.0197) | 0.0264 | (0.0081) | 0.0128 | (0.0028) | 0.0062 | (0.0011) |
| $n_{s\geq 2}/L$ | 0.0643 | (0.0182) | 0.0473 | (0.0166) | 0.0112 | (0.0046) | 0.0094 | (0.0055) |
| $n_{w\geq 2}/L$ | 0.1621 | (0.0522) | 0.2155 | (0.0730) | 0.0345 | (0.0136) | 0.0254 | (0.0144) |
| $n_s/L$ | 0.1369 | (0.0273) | 0.0738 | (0.0228) | 0.0240 | (0.0065) | 0.0156 | (0.0056) |
| $n_w/L$ | 0.2347 | (0.0538) | 0.2420 | (0.0796) | 0.0472 | (0.0145) | 0.0316 | (0.0143) |

**Table 6.** The estimated effective half search width for single ($w_1$), schools of size over 1 ($w_{\geq 2}$) and all schools ($w_s$). Taking account of the sample size for the fitting the hazard rate model. The figures in parentheses are the standard errors.

| Stratum | | The First period | | The Second period | |
|---|---|---|---|---|---|
| East-South | $w_1$ | 0.322 | (0.223) | 0.533 | (0.111) |
| | $w_{\geq 2}$ | 0.375 | (0.236) | 0.955 | (0.161) |
| | $w_s$ | 0.531 | (0.153) | 0.694 | (0.055) |
| West-South | $w_1$ | 0.425 | (0.167) | 0.613 | (0.124) |
| | $w_{\geq 2}$ | 0.981 | (0.141) | 0.667 | (0.105) |
| | $w_s$ | 0.673 | (0.131) | 0.629 | (0.052) |
| East-Middle | $w_1$ | 0.376 | (0.083) | 0.266 | (0.143) |
| | $w_{\geq 2}$ | 0.569 | (0.264) | 0.451 | (0.256) |
| | $w_s$ | 0.463 | (0.128) | 0.324 | (0.077) |
| West-Middle | $w_1$ | 0.395 | (0.127) | 0.643 | (0.259) |
| | $w_{\geq 2}$ | 0.532 | (0.143) | 0.909 | (0.328) |
| | $w_s$ | 0.458 | (0.102) | 0.920 | (0.216) |

**Table 7.** The estimated density of whales (10 n. miles$^2$) from the Japanese Research of the Antarctic Area V in 1990/91. The figures in parentheses are the standard errors.

| Stratum | The First period | | The Second period | |
|---|---|---|---|---|
| East-South | 0.173 | (0.106) | 1.392 | (0.485) |
| West-South | 0.740 | (0.229) | 1.385 | (0.570) |
| East-Middle | 0.255 | (0.233) | 0.670 | (0.220) |
| West-Middle | 0.935 | (0.510) | 0.169 | (0.257) |

**Table 8.** The estimated population abundance in the Japanese Research of the Antarctic Area V in 1990/91. The figures in parentheses are the standard errors.

| Stratum | Track-line A | | Track-line B | | Track-line C | | Average | |
|---|---|---|---|---|---|---|---|---|
| The First period | | | | | | | | |
| East-South | 530 | ( 264) | 674 | ( 297) | 1,232 | ( 747) | 812 | ( 350) |
| West-South | 6,047 | ( 2,137) | 7,753 | ( 2,376) | 3,411 | ( 1,454) | 5,737 | ( 1,427) |
| East-Middle | 5,335 | ( 5,455) | 2,670 | ( 2,867) | 5,816 | ( 5,619) | 4,607 | ( 4,214) |
| West-Middle | 23,250 | ( 7,663) | 50,490 | (27,800) | 17,700 | ( 4,781) | 30,480 | (11,882) |
| Total | 35,162 | ( 9,650) | 61,587 | (28,054) | 28,159 | ( 7,558) | 41,636 | (12,685) |
| The Second period | | | | | | | | |
| East-South | 19,720 | ( 6,012) | 40,580 | (14,980) | 53,670 | (12,070) | 37,990 | (10,121) |
| West-South | 11,170 | ( 6,268) | 9,883 | ( 4,476) | 12,540 | ( 4,626) | 11,198 | ( 3,987) |
| East-Middle | 31,590 | ( 6,608) | 17,430 | ( 7,355) | 14,600 | (10,740) | 21,207 | ( 7,654) |
| West-Middle | 5,083 | ( 7,270) | 4,913 | ( 5,392) | 4,421 | ( 8,024) | 4,806 | ( 6,568) |
| Total | 67,563 | (13,114) | 72,806 | (18,103) | 85,231 | (18,623) | 75,201 | (14,839) |

**Table 9.** The comparison of the estimated population abundance, ($\hat{P}$) with the estimates, ($\hat{P}'$) and ($\hat{P}''$) obtained by two alternative procedures. One ($\hat{P}'$) is to estimate the population abundance by multiplying the estimated number of schools by the corrected mean school size. The other ($\hat{P}''$), which was considered by Cooke (1984, 1987) and further modified by Taga (1991), calculates the coverage probability of the location of each sighting. The numbers in parentheses are the standard errors. The standard errors of the estimates by Cooke's procedure were obtained from the variances among the three track-lines.

| Stratum | $\hat{P}$ | | $\hat{P}'$ | | $\hat{P}''$ | |
|---|---|---|---|---|---|---|
| The First period | | | | | | |
| East-South | 812 | ( 350) | 558 | ( 241) | 447 | ( 102) |
| West-South | 5,737 | ( 1,427) | 3,683 | ( 916) | 4,735 | ( 398) |
| East-Middle | 4,607 | ( 4,214) | 4,343 | (3,973) | 3,285 | ( 467) |
| West-Middle | 30,480 | (11,882) | 19,842 | (7,735) | 29,780 | (5,009) |
| Total | 41,636 | (12,685) | 28,425 | (8,660) | 38,247 | (5,039) |
| The Second period | | | | | | |
| East-South | 37,990 | (10,121) | 30,038 | ( 8,002) | 30,135 | (3,669) |
| West-South | 11,198 | ( 3,987) | 8,293 | ( 2,953) | 8,267 | (1,225) |
| East-Middle | 21,207 | ( 7,654) | 19,725 | ( 7,119) | 19,336 | (3,810) |
| West-Middle | 4,806 | ( 6,568) | 4,024 | ( 5,499) | 6,133 | (1,199) |
| Total | 75,201 | (14,839) | 62,080 | (12,250) | 63,871 | (5,424) |

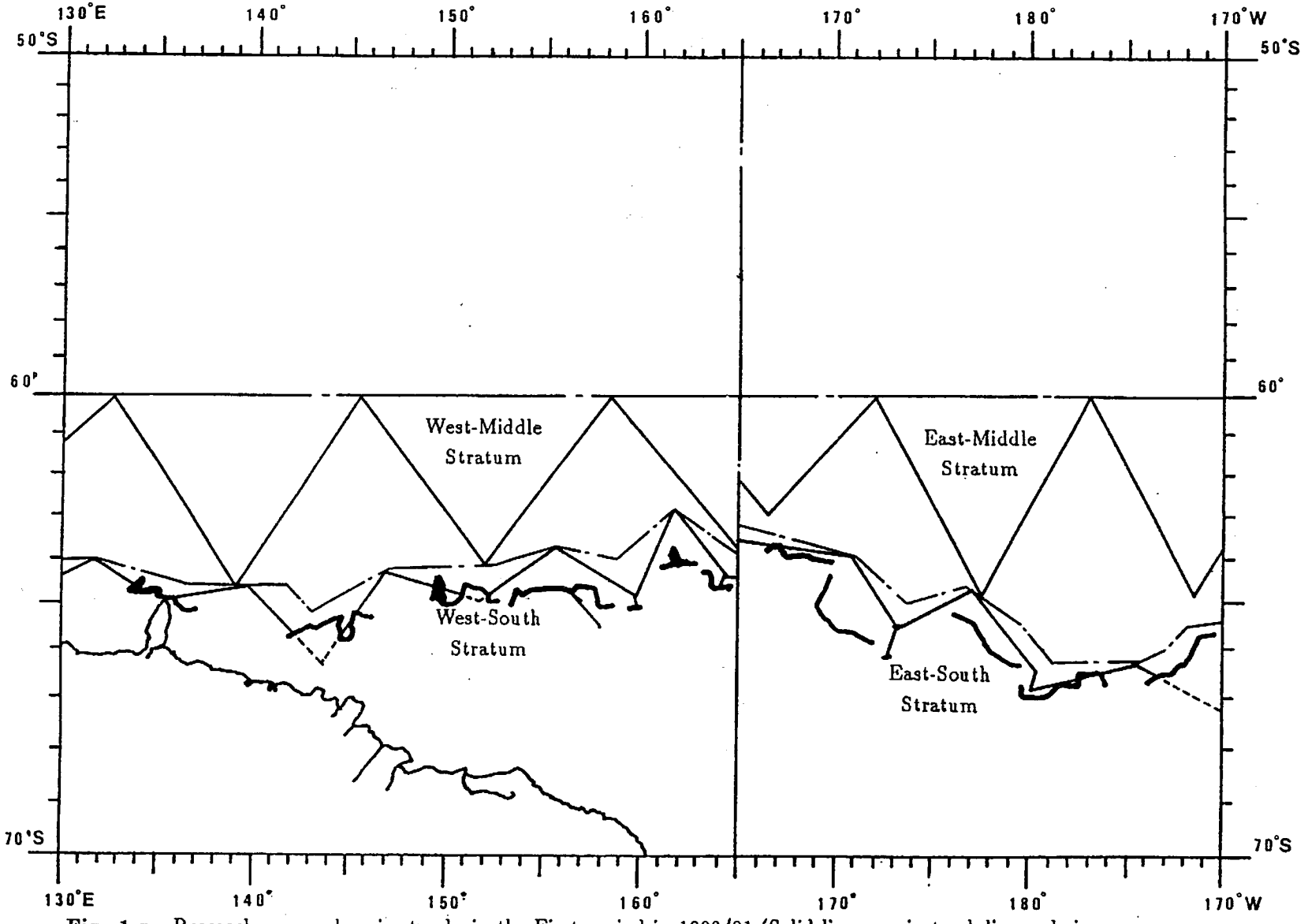


Fig. 1-a. Research area and cruise-tracks in the First period in 1990/91 (Solid line : main track-line ; chain line : boundary between subareas).

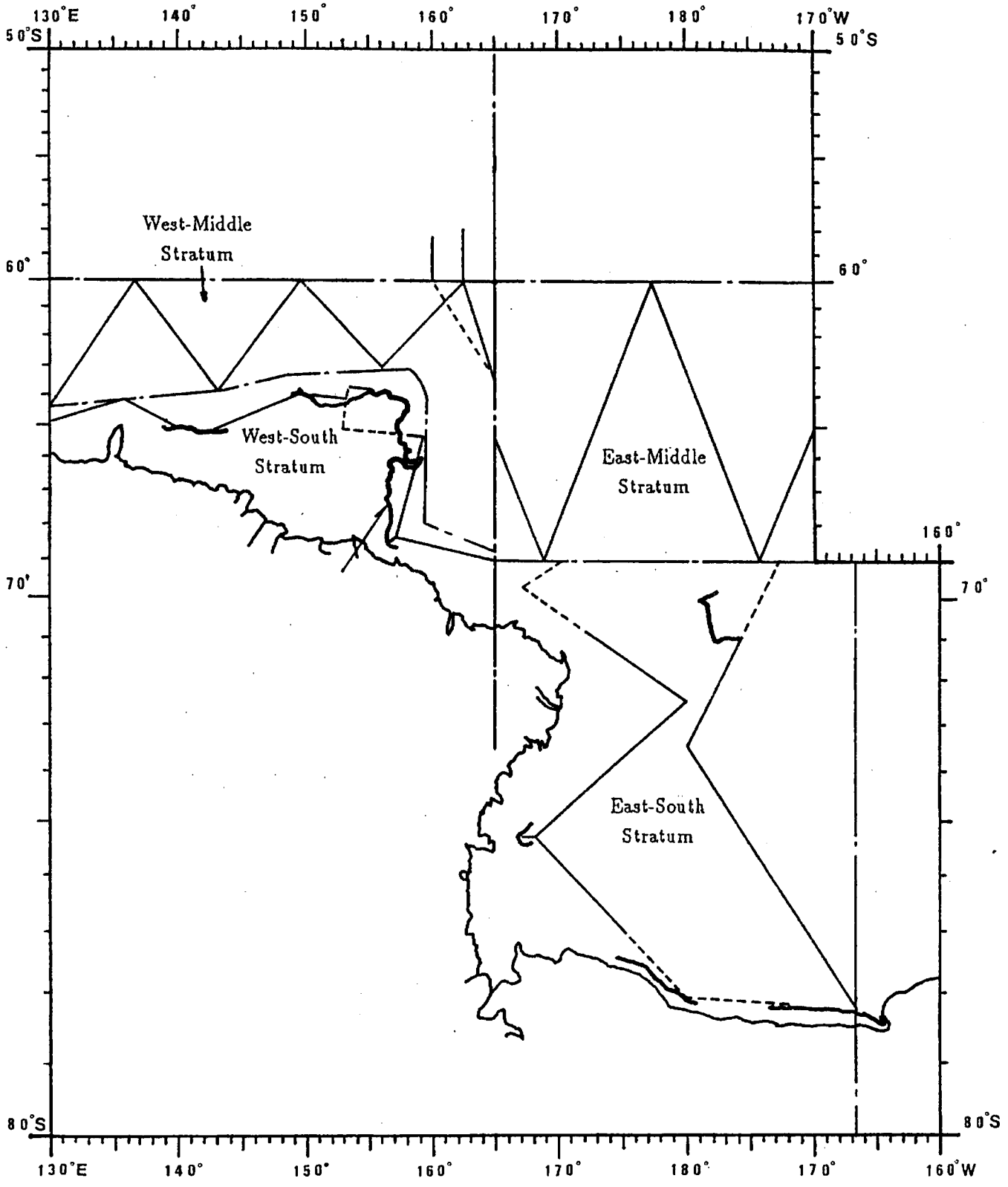


Fig. 1-b. Research area and cruise-tracks in the Second period in 1990/91 (Solid line : main track-line ; chain line : boundary between subareas).