Examination of the effect of skip on the abundance estimate for Antarctic minke whales in JARPA

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Abstract
To investigate if the abundance estimate is under-estimated due to skip, the correlation between encounter rate (the number of whales detected per 1 n.mile) of Antarctic minke whales (*Balaenoptera bonaerensis*) and three kinds of skipping (that were caused by night streaming to the start point of next day, that is due to catch up with the schedule of survey and that were caused by closing and chase), are examined. As for the first kind of skip, positive correlations with density were observed and the extent of the effect can be examined. As for the second one, posititve correlations with density were not observed and no effect of such skip on abundance is expected. As for the third kind, dependence on the density was observed for all years examined. This dependency would bias abundance estimates, however, this bias can be corrected as discussed in Haw (1991).

KEY WORDS: ABUNDANCE ESTIMATE, ANTARCTIC MINKE WHALES

INTRODUCTION

At JARPA review meeting in 1997, possible bias of abundance estimate due to under-surveying in higher density area was pointed out (IWC, 1998). In order to examine this possible biases, Hakamada *et al*. (2005) examined if abundance estimate is different between Sampling and Sighting Vessel (SSV) and Sighting Vessel (SV) and between closing mode and passing mode using Haw's method (Haw, 1991) and showed there are significant differences in abundance estimate between them. The difference between SSV and SV is partly due to skipping caused by interruption of sighting survey to confirm whale species and school size of detected whales and, if they were Antarctic minke whales, to sample them and it is partly due to skipping sighting survey caused by night streaming to the start point of next day. The effect of former skip on abundance estimate can be corrected by same method in Haw (1991). But it is necessary to reconsider how to deal with the effect of the latter skip. In order to examine relation between each type of skip and abundance estimate, we investigate questions following.

(1) Does skipping distance after the end of the survey of the day (skip type (A) defined later) correlate to encounter rate of the day from 1989/90 to 1992/93 when pre-determined distance per day was set up?
(2) From 1993/94, pre-determined distance was not set up but the skip to catch up with the schedule (skip type (B) defined later) occurred for some reasons. Are these skips correlated to encounter rate of the day?
(3) Does skipping distance that occurs after detection (skip type (C) defined later) increase as encounter rate increases?

MATERIALS AND METHODS

Skip of sighting surveys during JARPA surveys

Process of sighting surveys in a day
Fig. 1 illustrates movement of a SSV in a day. SSV started from point A in the morning. It had planned to proceed to point C in the day. A school was detected and sighting survey was interrupted at point D1. SSV closed to the detected school to confirm species and school size. If the detected school was identified as Antarctic minke whales, SSV chased targeted minke whale to sample it. After SSV sampled it, SSV transport it to Research Base Vessel, returned to point E1 on the trackline and resumed sighting survey. As a result, trackline between D1 and E1 was skipped. The same situation occurred between D2 and E2 and between D3 and E3. However, sometimes the trackline wasn't skipped as in the case of trackline between D2 and E2. In this case, D2 and E2 are the same position. When the time to end the daily survey came, SSV arrived at the point B. If SSV didn't reach point C, SSV moved without surveying from B to C by the beginning of the survey next day. Conversely, if SSV reached to C or proceed over the point C, SSV stayed there until the next morning. As far as the pre-determined distance per day is concerned, it was applied until 1992/93.

The skips occurred during JARPA are classified into three types as follows.

(A) Skip occurring after end of daily survey (proceeding along the trackline in the night without sighting surveys), in order to fulfill the pre-determined distance per day.
(B) Skip due to catch up with the schedule within a stratum.
(C) Skip accompanied a detection of whales due to closing to a detected school and chasing a targeted minke whale.
(D) Skip due to bad weather conditions.

Skip type (A)
The pre-determined distance per day is a task on daily movement on the research track line. It was applied to JARPA from the 1989/90 to the 1992/93 seasons. The SSVs had to steam during the night to the start point of next day, when they did not achieved pre-determined distance during the daytime. This type of skip was caused by shortage of searching distance in a day due to bad weather conditions and/or sampling activity in the high-density area of the minke whales. The concern was that such skip might cause biased population estimate because SSV tended to skip over high-density areas of whales after sampling activity of a day (IWC, 1998). However, pre-determined distance per day was abolished from the 1993/94 season because total distance of planned trackline in one survey was reduced. The survey in the Areas IV and V was conducted once in the peak migration season of the minke whales from the 1992/93 season whereas SSV surveyed whole of Area IV/V twice in a year before then. Type (A) skip is represented as segment BC which is illustrated as blue dotted line in Fig. 1.

Pre-determined distance was set in 1989/90 and 1990/91as shown in Table 1. Pre-determined distance is less in south strata than in north strata because it was expected that whale density is higher in south strata than in north strata.

Skip type (B)
After 1993/94, pre-determined distances were not set. Even if a survey vessel covered a shorter distance than expected, it would not skip the sighting survey in the night. However, in the case that it became difficult to finish the survey in a stratum within the planned schedule, planned trackline would be skipped during night to catch up with the schedule. Compared with skip type (A), daily distance of this skip tends to be less (Table 2).

Skip type (C)
This type of skip occurs accompanied with the detection of the minke whales. In the case of SV, it is caused by only closing to confirm species and school size of the detected school. In the case of SSVs, it is caused by closing, chasing and sampling of a targeted minke whale. Type (C) skip is the union of the segment D1E1 and D3E3. It should be noted that type (C) skip is same kind of skip examined in Haw (1991), which occurred in the IDCR/SOWER surveys. Skipped distance due to this skip for each stratum is shown in Table 2.

Skip type (D)
Clearly, skip due to bad weather is independent of the density of the minke whales. Therefore, skip type (D) would not affect the abundance estimate and is not examined in this study. This type of skip would occur during surveys other than JARPA.

Methods
We examined the relation between the density of the minke whales and skip of type (A), (B) and (C). Unfortunately, skipping distance data is not available for all years and all tracklines, so we used the data of main course (center of three parallel SSVs) in 1989/90, 1991/92, 1993/94 and 2001/02 in Area IV and 1990/91, 1992/93, 1994/95 and 2000/01 in Area V, which were sampled from sighting effort records and track charts.

To solve questions (1) and (2) listed in the introduction section above, first, we made plots of the number of detected whales per one n.mile of the day as a *x*-axis and distance of type (A)/(B) skip as y-axis for six years by strata. Second, we examined if the slope of the fitted regression line is significantly different from 0.

To solve question (3) above, first, we made plots of the number of detected whales per one n.mile of the day as a *x*-axis and normalised distance of type (C) skip to distance covered during the survey (i.e. (D1E1+D2E2+D3E3)/AB in Fig. 1) as y-axis for six years by strata. Second, we examined if the slope of the fitted regression line is significantly different from 0.

RESULTS

Fig. 2 shows the plot of the number of detected whales per one n.mile of the day as the *x*-axis and distance of skip type (A) for the first four years as y-axis by strata and Fig. 3 shows the plot of the number of detected whales per one n.mile of the day as a *x*-axis and distance of skip type and (B) for 1993/94, 1994/95, 2000/01 and 2001/02 seasons as y-axis by strata. Table 3 shows the probability that the slope of regression lines is not significantly different from 0. From Fig.3 and Table 3, the distances of skip type (B) are independent of density. Different from these four years, the distances of skip type (A) depend on the density from 1989/90 to 1992/93 except some strata. Comparison between Fig 2 and Fig 3 shows that the skipping distances in the first four years is more than those after 1993/94. After 1993/94, most of the daily skipping distance is less than 40 n.miles, whereas daily skipping distances of more than 60 n.miles were observed in the north strata in 1989/90 and in all strata in 1990/91.

Fig. 4 shows the plots of the number of detected whales per one n.mile of the day as the *x*-axis and the ratio of distance of type (C) skip to distance covered during the daily survey as the *y*-axis for six years by strata. Table 4 shows the probability that the slope of regression lines is not significantly different from 0. Positive correlation between the ratio and density was observed for all six years. The slope of the regression line is significantly different from 0 for most of the strata.

Therefore, answer to question (1) is yes, (2) is no and (3) is yes.

DISCUSSION

Effect of skip type (A)

As for distance of skip type (A), positive correlation to density was observed for some of the strata. Due to this type of skip, abundance would be under-estimated under the assumption that density in skipped trackline due to this skip is same as that in surveyed trackline of the day. But this assumption may be violated because skipped distance is so long that not all the skipped distance is likely to be a higher density area. In such case, correction of abundance estimate under this assumption may result in overestimating the abundance. Tanaka (1999) estimated the length of higher density areas to be 10-20 n.miles and assumed this in his simulation study, based on the geographical distribution of detected minke whales in southern strata observed during 1992/93 JARPA surveys. He also showed that abundance estimate derived from Burt and Borchers (1997) is overestimated by simulation study (Tanaka, 1999).

Effect of skip type (B)

As for distance of skip type (B), positive correlation to density was not observed. Therefore, it is suggested that there is no effect of this type of skip on abundance and that it is not necessary to correct abundance with respect to this type of skip.

Effect of skip type (C)

As for distance of skip type (C), positive correlation to density was observed in all years examined for most of the strata, as had been expected. This type of skip also occurred in IDCR/SOWER surveys and biased abundance estimates (Haw, 1991). The bias caused by this kind of skip can be corrected by the method in Haw (1991) assuming that abundance estimate obtained from survey data in passing mode is unbiased.

Comparison of application of the method of Haw (1991) in Hakamada *et al*. (2005)

In Hakamada *et al*. (2005), two correction factors *R*1 and *R*2 were estimated. *R*1 was the correction factor of SSV standardized to SV closing assuming the factor is constant for all years. This factor can be the combined effect of skip type (A) and skip (C) due to chasing and sampling. *R*2 was the correction factor of SV closing standardized to SV passing. *R*2 can therefore be considered as the effect of skip type (C) due to closing. If the effect of the skip type (A) is substantial, the assumption that *R*1 is constant would be violated and bias the abundance trend. As discussed in the next paragraph, there are some possibilities that the effect of the skip type (A) is not significant. But it is necessary to examine abundance trend assuming that *R*1 is different between up to 1992/93 and from 1993/94 onward.

Correction of abundance estimate due to skip type (A)

To consider whether and how much the abundance estimate is biased due to skips type (A), there are three methods. First is spatial modeling (Hedley *et al*., 1999). Second is applying Haw's method separately to two data sets (up to 1992/93 and after 1993/94). From the former data set, combined effect of skip type (A) and (C) would be obtained and the effect of skip type (C) from the latter data set. But Haw's correction factor obtained from data up to 1992/93 is possibly unreliable due to small sample size. Third is the method of Burt and Borchers (1997). This method corrected encounter rate of the day assuming that that density in skipped trackline due to skip type (A) is same as that in surveyed trackline of the day. By applying this method to sighting data by SSVs for the first four years, biases due to skip type (A) could be eliminated and then Haw's method is applied. But this method could overestimate abundance. One possible solution of this overestimation, is assuming the density on skipped trackline is the average of density in the day and that of next day. In conclusion, though both candidate methods may need further investigations, we can examine maximum impact of the skip type (A) on abundance estimate and investigate whether the impact is significant.

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Table 1. Pre-determined distance from 1989/90 to 1992/93.

1989/90	distance	1990/91	distance
North-West (NW)	170 n.miles	North-West (NW)	160 n.miles
North-East (NE)	170 n.miles	North-East (NE)	160 n.miles
South-West (SW)	100 n.miles	South-West (SW)	100 n.miles
South-East (SE)	100 n.miles	South-East (SE)	140 n.miles
Prydz Bay (PB)	120 n.miles		
1991/92	distance	1992/93	distance
North-West (NW)	150 n.miles	North-West (NW)	140 n.miles
North-East (NE)	150 n.miles	North-East (NE)	140 n.miles
South-West (SW)	Not applied(*)	South-West (SW)	100 n.miles
South-East (SE)	Not applied(*)	South-East (SE)	140 n.miles
Prydz Bay (PB)	Not applied(*)		

*: Same distance as SV proceeded in the day.

Table 2. Skipping distance of (a) type (A) for 1989/90 and 1990/91 and type (B) for 1993/94, 1994/95, 2000/01 and 2001/02 due to higher density area, (b) type (C) skip in each stratum

	1989/90		1993/94		2001/02	
stratum	(a)	(b)	(a)	(b)	(a)	(b)
NW	397.6	134.5	0.0	248.5	0.0	246.7
NE	314.3	64.9	158.4	152.6	0.0	264.2
SW	167.4	132.5	61.8	253.8	0.0	260.6
SE	225.6	126.2	76.6	142.9	0.0	280.1
PB	15.6	41.7	0.0	63.2	0.0	165.6

	1990/91		1994/95		2000/01	
stratum	(a)	(b)	(a)	(b)	(a)	(b)
NW	284.3	135.9	126.6	148.4	69.2	178.8
NE	369.0	124.1	4.8	156.6	368.8	230.0
SW	295.3	164.0	64.4	207.7	0.0	189.5
SE	286.0	240.8	0.0	234.2	152.9	250.1

Table 3. Significance of the slope of the regression lines in Figs. 2 and 3. Underlines indicate that probability is less than significant level of 0.05.

Area IV

	1989/90	1991/92	1993/94	2001/02
North-West (NW)	<u>0.006</u>	0.147	0.065	0.853
North-East (NE)	<u>0.029</u>	0.095	0.906	0.769
South-West (SW)	0.308	0.084	0.926	0.213
South-East (SE)	0.999	<u>0.031</u>	0.933	0.641
Prydz Bay (PB)	0.927	0.606	0.707	0.645

Area V

	1990/91	1992/93	1994/95	2000/01
North-West (NW)	<u>0.001</u>	<u>0.001</u>	0.895	0.234
North-East (NE)	<u>0.007</u>	0.442	0.586	0.888
South-West (SW)	<u>0.004</u>	<u>p<0.001</u>	0.601	0.540
South-East (SE)	<u>0.024</u>	0.407	0.690	0.206

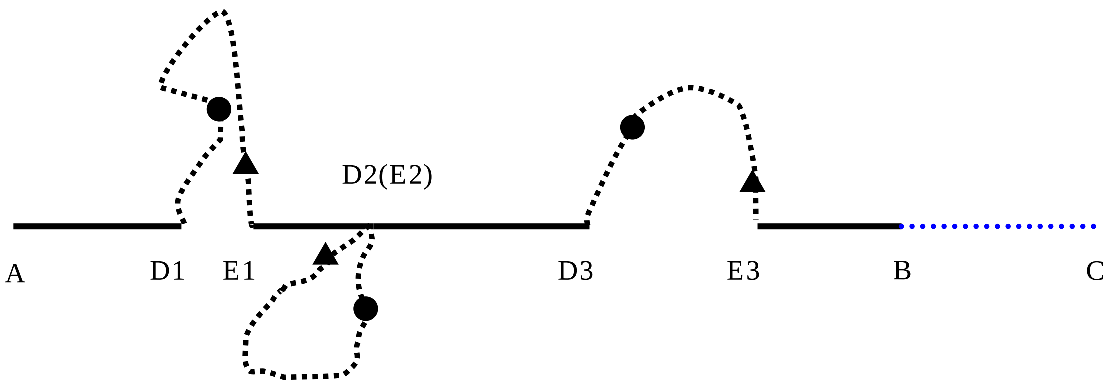
Table 4 Significance of the slope of the regression lines in Fig. 4. Underlines indicate that probability is less than significant level of 0.05.

Area IV

	1989/90	1991/92	1993/94	2001/02
North-West (NW)	0.078	0.253	0.027	0.615
North-East (NE)	0.317	0.008	0.001	0.042
South-West (SW)	0.046	0.003	0.288	0.033
South-East (SE)	0.001	0.017	0.076	0.010
Prydz Bay (PB)	0.139	0.015	0.045	0.039

Area V

	1990/91	1992/93	1994/95	2000/01
North-West (NW)	0.030	p<0.001	0.029	0.005
North-East (NE)	0.080	0.829	0.071	p<0.001
South-West (SW)	0.073	p<0.001	p<0.001	p0.001
South-East (SE)	0.117	0.030	p<0.001	p<0.001



A: Starting position of the day,
B: Ending position of the day
C: Starting position of the next day
D1,D2,D3: Sighting position of the 1st, 2nd and 3rd detection of the day, respectively.
E1,E2, E3: Position of restarting sighting survey after the 1st, 2nd and 3rd detection of the day, respectively.
In this case, point D2 and E2 are the same position.
Bold line indicates track line where sighting survey was actually conducted.
Dotted line indicates survey vessel proceeded without sighting surveys
Filled circle indicates point where both species and size of detected school were confirmed.
Filled triangle indicates point where a targeted minke whale was taken.

Fig. 1. Illustration of skip type (A) and (C).
Type (C) skip is the union of the segment D1E1 and D3E3. Type (A) skip is the segment BC. It had been planned sighting survey on the segment AC. If there had been no detection on the day, survey vessel could be proceed to point C. Bold black line represent actually surveyed, vessel go along dotted curves to close a detected school and chase a targeted whale. Blue dotted line indicates trackline skipped in the night.

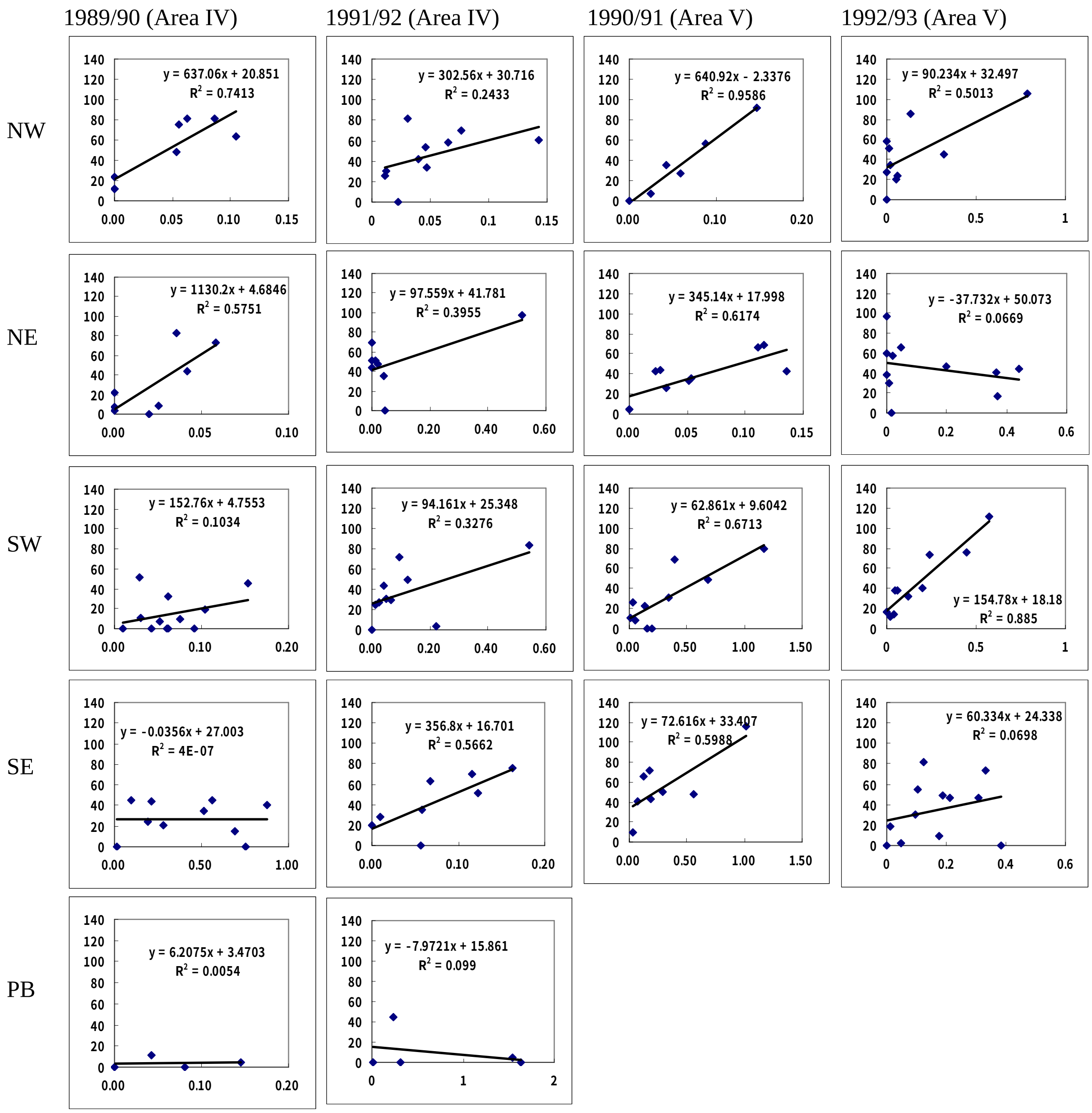


Fig. 2. Correlations between density and distance of skip type (A) from 1989/90 to 1992/93 seasons.

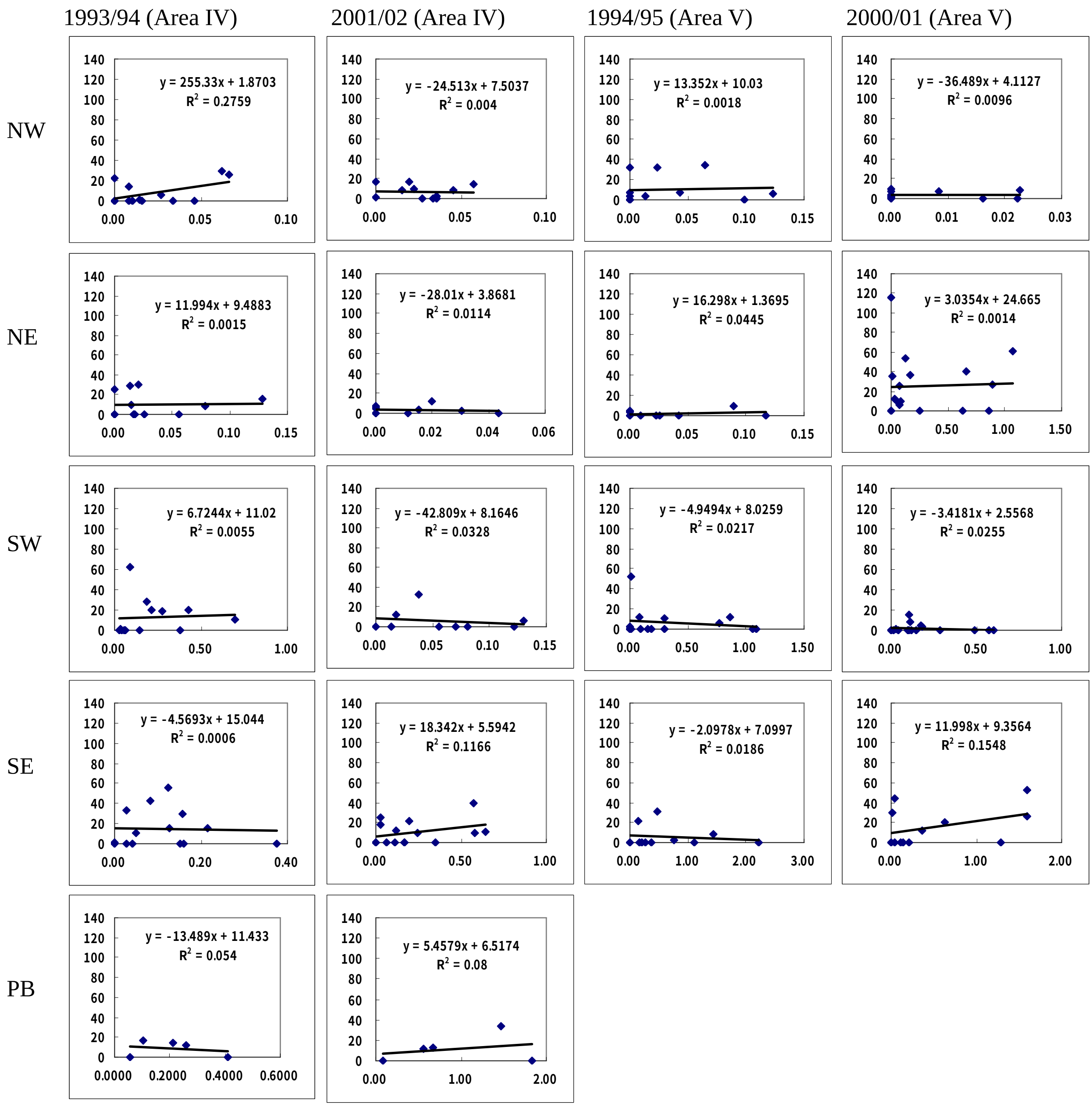


Fig. 3. Correlations between density and distance of skip type (B) for 1993/94,1994/95, 2000/01 and 2001/02 seasons.

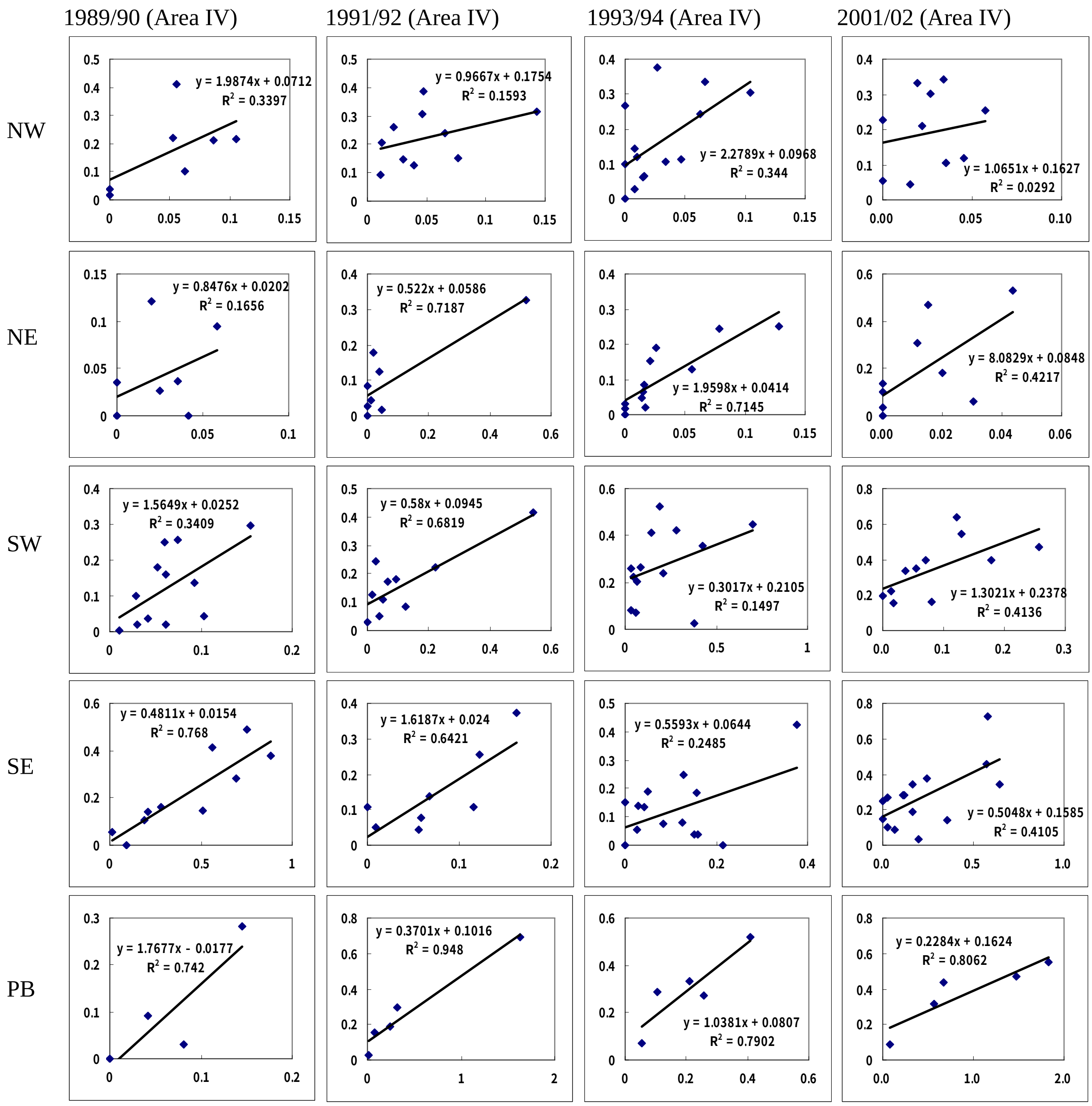


Fig.4. Correlations between density and skipping distance due to closing and chasing (i.e. skip type (C)).

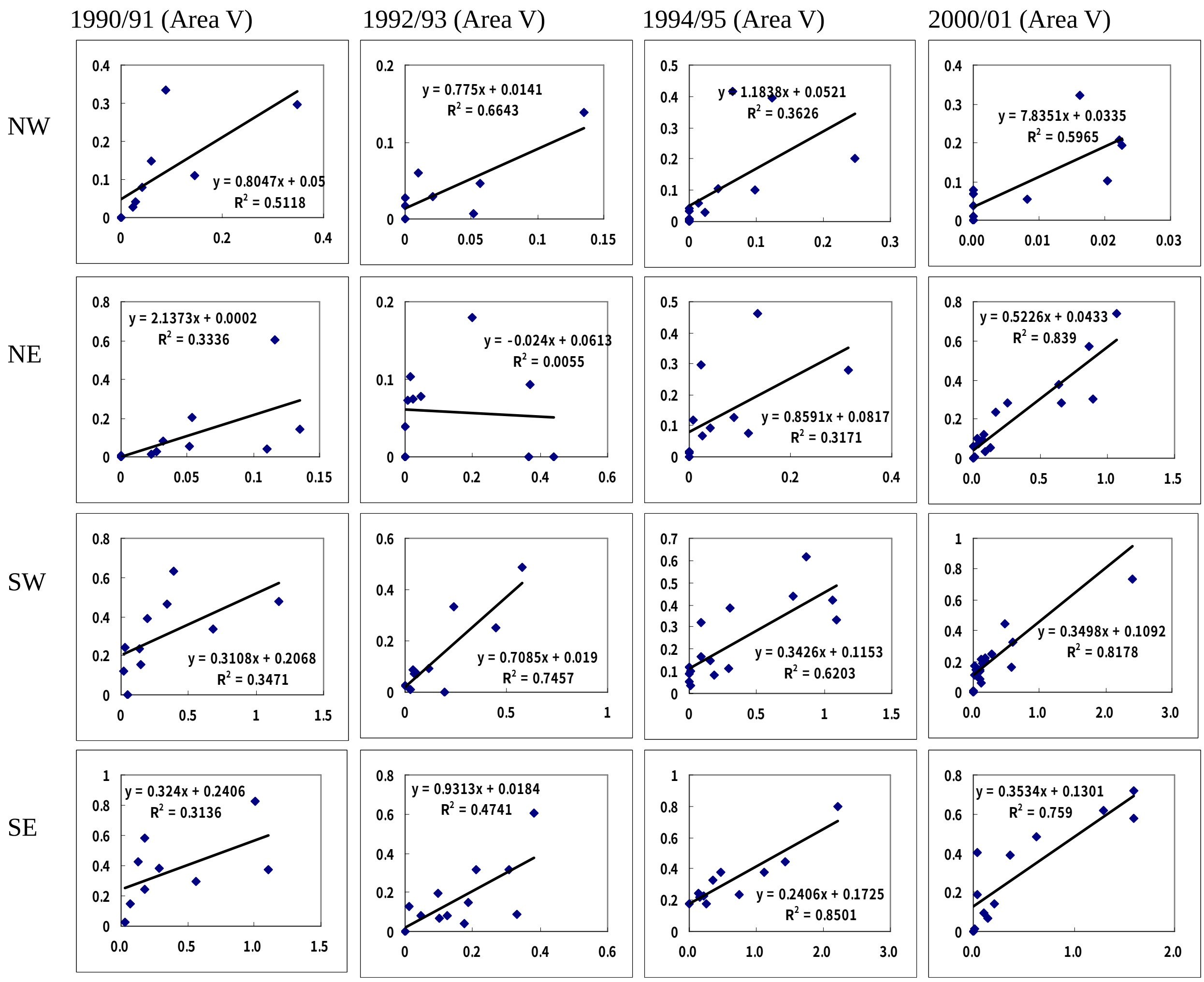


Fig. 4 (continued).