# Some analyses on the possibility of the existence of W-stock minke whale in sub-area 9 using the information on conception dates

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## ABSTRACT

The present study examines the possibility of the existence of W-stock minke whale in sub-area9 making use of conception date data taken from JARPN survey. Three hypotheses were set up on the state of stocks in sub-area 9 : O-stock model, W-stock model and Mixed model. The O-stock model gained support among three on the basis of the AIC. In addition, the examination of the statistical power was simulated. It was concluded that the existence of the W-stock minke whale was negative from the result of the present study.

## INTRODUCTION

For the management of minke whales, *Balaenoptera acutorostrata*, it is very important to know the stock structure in detail. At present one of the most valid method to clarify it is a genetic analysis such as the RFLP analyses of the mitochondrial DNA (mt-DNA) control region. However the other information such as conception dates, heavy metals, parasites, fatness, etc. is also useful to identify the stock structure. In this paper we tried to elucidate the stock structure by focusing on the conception dates.

It is known that minke whales in the Sea of Japan have dissimilar genetic trait from those in the Pacific (Goto and Pastene, 1997). Minke whale that breeds in the Sea of Japan is called J-stock. That in the Pacific off Japan is called O-stock. Kato (1992) found two different foetus cohorts due to different peak of conception as one in winter and the other in autumn derived from different biological stock. This was confirmed by further analyses of Best and Kato (1992) and now it is believed that Okhotsk Sea-West Pacific stock (O-stock) has peak for conception in mid winter (February to March) while in October to November for Sea of Japan stock (J-stock).

With incorporating this nature main interest of the present paper is to explicate the possibility of the existence of W-stock minke whale in the North Pacific. W-stock is a hypothesized stock and the evidence of the existence has not been obtained until now. A sea area of the North Pacific minke whale is divided into some parts (Fig.1). We especially pay attention to sub-area 9 where W-stock might exist if it were. If W-stock exists in sub-area 9, it is possible that the distribution of conception dates obtained from sub-area 9 is different from that of sub-area 7 in which O-stock is.

## MATERIALS AND METHODS

The information on foetus of minke whales was brought from commercial catches and the JARPN survey. We used foetus data in sub-area 7 collected from 1974 to 1999 (1974-1987 : commercial catch, 1996,1998 and 1999 : JARPN) as the representative sample from O-stock. Foetus samples from sub-area 9 were collected in 1994,1995 and 1997 by JARPN. Their catch dates and foetus length in sub-area 7 and 9 are shown in Figure 2.

The conception dates were calculated from the foetus growth formula estimated for southern minke whales (Kato and Miyashita, 1991), which needs the catch dates and foetus body length data. The formula is as follows :

$$t = 0.0655\, y^{2.676} \quad (y < 15) \tag{1}$$

$$t = 1.6220\, y^{0.892} \quad (y \geqq 15) \tag{2}$$

where y is the fetus body length in cm and t is the number of days since conception. We estimated the conception dates by subtracting the estimated t's from catch dates.

It is assumed that the conception dates are normally distributed. The mean conception date and the standard deviance of O-stock were estimated from data of sub-area 7. Firstly, *t*-test is executed at the significance level of 5% to know whether the mean conception date in sub-area 9 is significantly different from that in sub-area 7. Furthermore, thinking over the possibility that O-stock and W-stock are mixing in relation to the probability distribution of conception dates in sub-area 9, the following model is assumed :

$$\alpha f(x_i \mid \mu_W, \sigma_W) + (1-\alpha) f(x_i \mid \mu_O, \sigma_O) \tag{3}$$

where $\alpha$ is the mixing rate, $\mu_W$ and $\sigma_W$ are a mean conception date and the standard deviation of W-stock, $\mu_O$ and $\sigma_O$ are a mean conception date and the standard deviation of O-stock (estimated from data in sub-area 7), $x_i$ is the estimated conception date of $i$ th individual in sub-area 9 and f is the probability density function of the normal distribution. $\alpha$, $\mu_W$ and $\sigma_W$ are parameters.

The log-likelihood function is

$$L = \sum_{i=1}^{n} \log\{\alpha f(x_i \mid \mu_W, \sigma_W) + (1-\alpha) f(x_i \mid \mu_O, \sigma_O)\} \tag{4}$$

where n is the number of samples in sub-area 9. To maximize this log-likelihood function gives us the estimates of $\alpha$, $\mu_W$ and $\sigma_W$.

We have three hypothesized models to be considered about the status of stock in sub-area 9 :

MODEL I $\quad H^1_0 : \alpha = 0$

MODEL II $\quad H^2_0 : \alpha = 1$

MODEL III $\quad H^3_0 : \alpha = \text{MLE}$ (The condition that $\sigma_W = \sigma_O$ is imposed).

where MLE is a maximum likelihood estimate. The condition of standard deviation in MODEL III is imposed because of small sample size (If we do not impose this condition, MODEL III will converge to the mixed stock of the O-stock and an unrealistic stock with $\sigma_W = 0$). MODEL I means only the O-stock exists in sub-area 9, MODEL II means only the W-stock in sub-area 9 and MODEL III means the mixed stock of O-stock and W-stock in sub-area 9.

The AIC (Akaike Information Criteria, Akaike 1973) enables us to select the best model among above three models. The AIC is as follows :

$$\text{AIC} = -2 \times \text{log-likelihood} + 2 \times (\text{the number of estimated parameters}). \tag{5}$$

MODEL I has no parameter and both MODEL II and III have two parameters.

## RESULTS AND DISCUSSION

Data of Figure 2 were converted to conception dates using the foetus growth formula estimated for southern minke whales. Their histograms were shown in Figure 3. The number of 365 (1 year) was added to three points in the circle of Figure 2 after the conversion to conception dates because we thought that they belonged to earlier breeding cycle than other data.

Table 1 shows the result of *t*-test for samples of sub-area 7 and sub-area 9. Statistical significant difference was not detected there (Significance Level = 0.05).

Table 2 shows the result of parameter estimations and the AIC evaluation. The result of MODEL III describes that the stock in sub-area 9 is the mixed one of O-stock and W-stock with the mixing rate of 93 to 7. This means almost individuals should belong to O-stock if the mixed stock exists in sub-area 9. The model that was selected as the best model in Table 1 by AIC was MODEL I (O-stock Model).

The likelihood ratio test between MODEL I and MODEL II showed no statistically significant difference like the result of *t*-test (a lower table of Table 2).

This analysis has a fault that the sample size is small (n=13). Therefore we executed a simple simulation to take the statistical power into account. In simulation, it was assumed that the least difference of mean conception dates between different stocks was one month on the assumption that only the single stock other than O-stock exists in sub-area 9 (MODEL II). The stock whose mean conception date is one month later than that estimated from sub-area 7 and whose standard deviation is the same as that of sub-area 7 was created. Although the different breeding stocks may have biologically much distant difference in conception timing because J-stock and O-stock seemed to have the peaks of seasonally different conception dates (Kato,1992), we assumed the difference of one month between mean conception dates, which would be conservative. Drawing some samples from this stock, t-test was executed at the significance level of 5% to know whether mean conception dates between both stocks are different. We repeated this operation 1000 times and counted the number of the possession of statistical difference. The sample sizes drawn were 5, 10, 15, 20, 25 and 30. The result is shown in Table 3. The satisfactory power was gained for considerable small sample size.

From the result mentioned above, we knew the fact that the difference between samples of sub-area 7 and sub-area 9 was not detected in spite of enough power and the model selection by AIC gave strong support to O-stock model. In view of these results, it was concluded that the evidence of the existence of the W-stock minke whale was scarce.

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Table 1. The result of $t$-test for samples of sub-area 7 and sub-area 9.

| Degree of Freedom | t-value | P-value |
|---|---|---|
| 111 | 0.851 | 0.802 |

Table2. Parameter estimates and AIC in each model.

The result of model selection using AIC

| | $\alpha$ | $\mu_0$ (fixed) | $\sigma_0$ (fixed) | $\mu_W$ | $\sigma_W$ | log-likelihood | AIC |
|---|---|---|---|---|---|---|---|
| MODEL I | 0 | 2-Mar | 43.6 | – | – | −66.22 | 132.44 |
| MODEL II | 1 | – | – | 13-Mar | 39.0 | −65.57 | 135.15 |
| MODEL III | 0.0705 | 2-Mar | 43.6 | 10-Jun | 43.6* | −65.72 | 135.45 |

The $\sigma_W$ in MODEL II was estimated using the unbiased estimator

–: not used

*: The condition that was equal to that of O-stock was imposed.

The result of likelihood ratio test between MODEL I and II

| Likelihood ratio | P value |
|---|---|
| 1.297 | 0.523 |

Table 3. The calculation of statistical power using resampling.

$\mu W = \mu O + 30$, $\sigma W = \sigma O$

| n | 5 | 10 | 15 | 20 | 25 | 30 |
|---|---|---|---|---|---|---|
| Simulated Power | 0.316 | 0.533 | 0.714 | 0.801 | 0.881 | 0.935 |

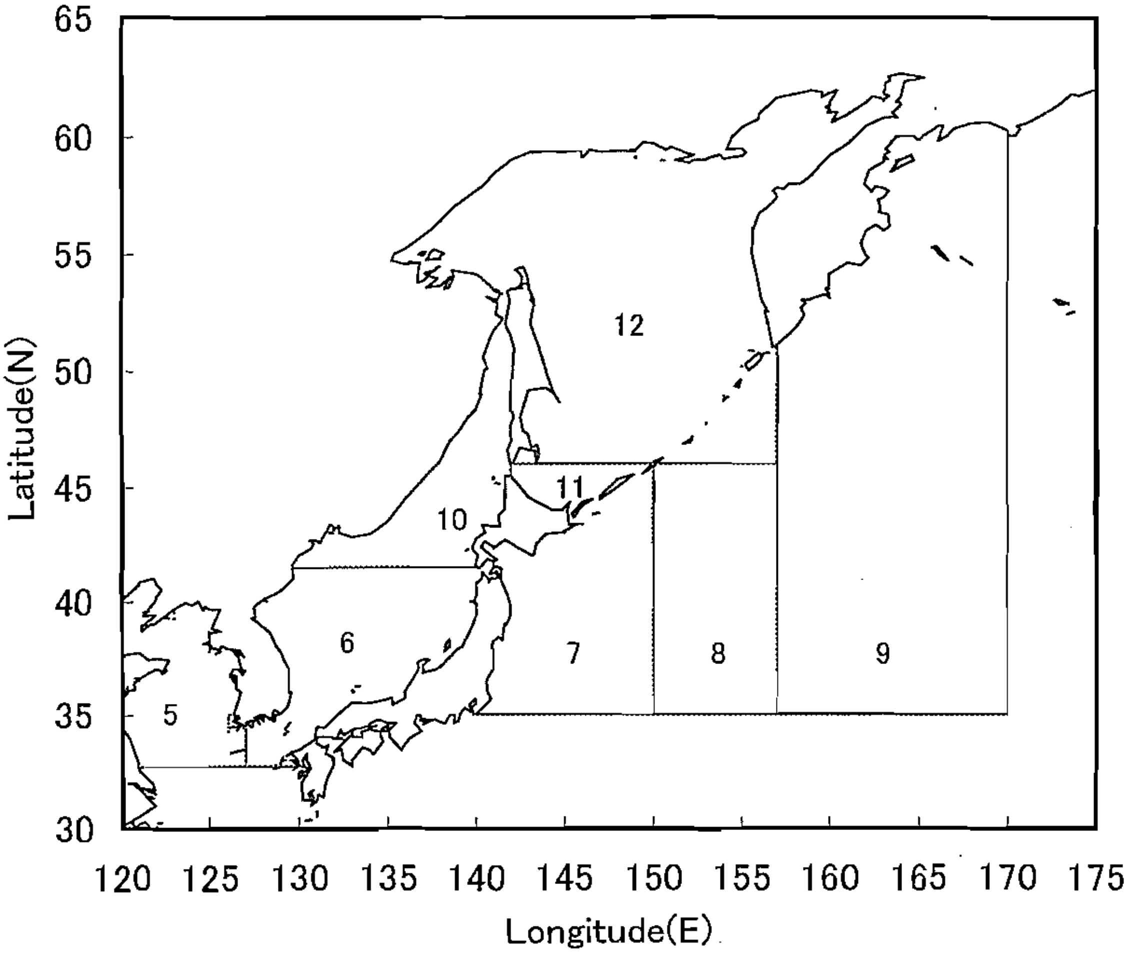
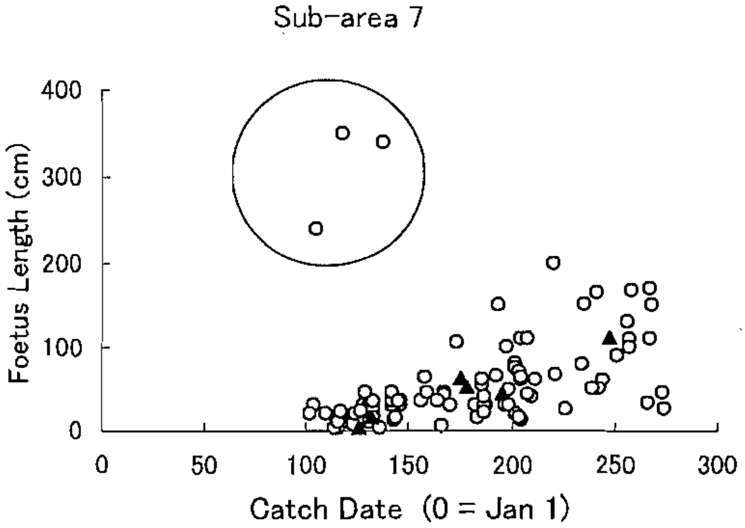



Fig 1. The sub-areas used for the North Pacific minke whales.



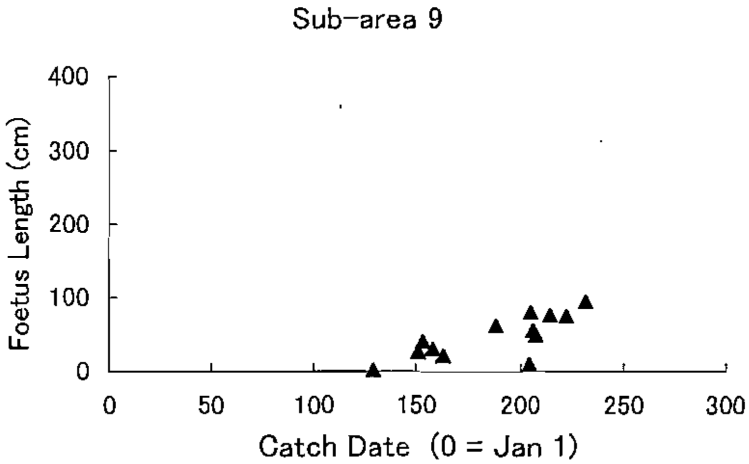
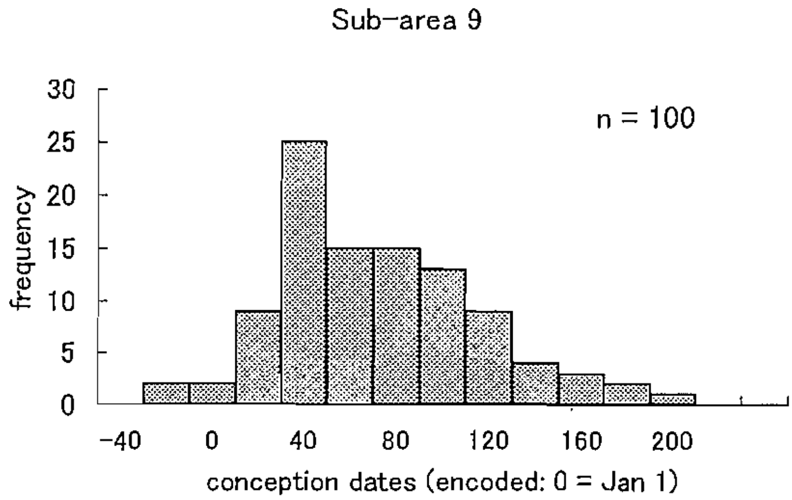




Fig.2 the relation between foetus lengths and cumulative days in each sub-area.
(○: commercial catch, ▲: JARPN data)



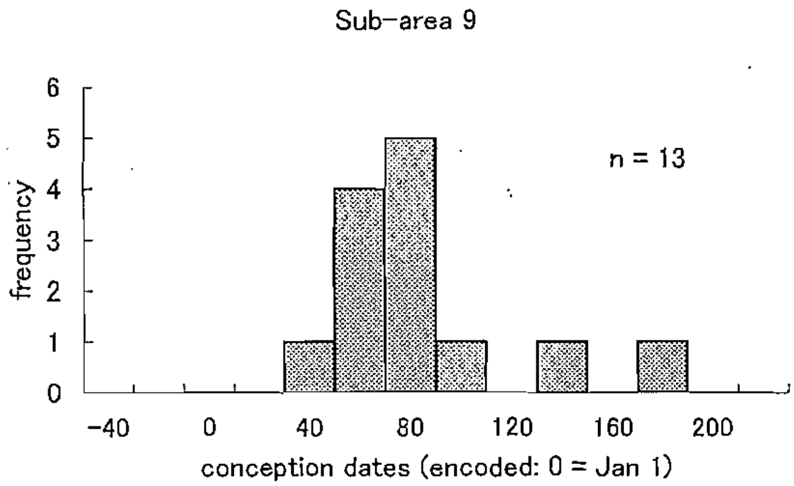




Fig 3. The histogram of estimated conception dates in sub-area 7 and sub-area 9.