Specifications of plausible stock structure hypotheses for western North Pacific common minke whales

Luis A. Pastene, Mutsuo Goto and Naohisa Kanda

Institute of Cetacean Research, Toyomi 4-5, Chuo-ku, Tokyo 104-0055, Japan

ABSTRACT

The *pre-implementation assessment* of western North Pacific common minke whale was completed satisfactorily at the 2010 IWC SC meeting. Therefore at this meeting the IWC SC agreed to start the two-year *Implementation* process for this stock. One of the important works at the start of the *Implementation* is a final review of the plausible hypotheses on stock structure. For this aim detailed specification of hypotheses is necessary. This paper provides technical specifications for a hypothesis considered consistent with the available genetics and non-genetics data. It also provides specifications for three alternative hypotheses considered less plausible.

KEYWORDS: COMMON MINKE WHALES, WESTERN NORTH PACIFIC, STOCK STRUCTURE HYPOTHESES, RMP *IMPLEMENTATION,* PLAUSIBILITY

INTRODUCTION

The RMP *ISTs* for western North Pacific common minke whales were completed in 2003. However those *ISTs* were conducted in absence of the process for *Implementation* (e.g. *pre-implementation assessment* followed by two-year *Implementation*), which was developed and accepted by the IWC SC in a later date. For that reason instead of carrying out a typical *Implementation Review* after five years of completed the *ISTs*, the IWC SC agreed to carry out a *pre-implementation assessment* and the two-year *Implementation* process as specified in the process.

The *pre-implementation assessment* of western North Pacific common minke whale was completed satisfactorily at the 2010 IWC SC meeting. Therefore at this meeting the IWC SC agreed to start the two-year *Implementation* process for this stock.

During the 2010 *pre-implementation assessment* a total of five stock structure hypotheses were agreed by the Working Group on the *Pre-implementation assessment* of Western North Pacific Common Minke Whales. This agreement was made despite considerable controversy on the plausibility of Hypothesis 5. Some members prepared a minority statement arguing that Hypothesis 5 was not supported by the best available scientific evidence and that such hypothesis was very hard to address with additional data. Further discussion on the consistency of Hypothesis 5 with the available data is required when detailed specifications for this hypothesis become available.

One of the important works at the start of the *Implementation* is the final review of the plausible hypotheses on stock structure. To this aim the different hypotheses should be specified to the level of details allowing an evaluation on whether or not such hypotheses are consistent with the data. This paper provides technical specifications for a hypothesis considered consistent with the available genetics and non-genetics data (Hypothesis 1). It also provides specifications for three alternative hypotheses considered less plausible (Hypotheses 2, 3 and 4).

It should be noted that these four hypotheses derived from different analyses of the available genetic and non-genetic data, recommended by the IWC SC through the years.

DESCRIPTION OF PLAUSIBLE STOCK STRUCTURE HYPOTHESES

Hypothesis 1 (Figure 1)

Single J stock distributed in the Yellow Sea, Sea of Japan and in the Pacific side of Japan. Single O stock occurs in sub-areas 7, 8 and 9, which migrate in summer mainly to the Okhotsk Sea. Both J and O stocks overlap temporally in the Pacific coast and the southern part of the Okhotsk Sea.

Rational for single O stock

Sub-structure within the O stock had been proposed and discussed by the IWC SC since 1993. In this year the IWC SC proposed a complicated sub-stock scenario with several sub-stocks composing the O stock and hypothesized a western stock ('W' stock) in offshore areas in the Pacific side of Japan (IWC, 1994)

The issue of stock structure was discussed again by the IWC SC in 1996. During that meeting the IWC SC discussed the new scientific information derived from JARPN and concluded that the sub-stock scenario proposed in 1993 was not plausible (IWC, 1997).

The IWC SC reviewed the results on stock structure during the JARPN Workshop conducted in 2000. The information based on genetics, morphometric, ecological markers, biological parameters was not contradictory with the view of a single O stock scenario in sub-areas 7, 8 and 9 (Pastene *et al.*, 2000). Based on the mtDNA information, the Workshop did not discard the hypothesis of occurrence of W stock in offshore areas in the Pacific side of Japan, at least in some years of the period of JARPN. The Workshop recommended that further research was necessary to examine the hypothesis of the W stock (IWC, 2001).

At the later stage of the *ISTs*, new analyses were presented based on genetics (mtDNA and microsatellites), body proportion and biological parameters, which were again not contradictory with the single O stock scenario. As noted above only the mtDNA analysis suggested the possibility of sporadic occurrence of a different stock in part of sub-area 9 (see Hypothesis 2 below).

The only evidence suggesting further division of the O stock (apart from the W stock) comes from the Boundary Rank analysis on mtDNA data, which proposed division of the O stock into Ow and Oe at 147°E. Some authors interpreted these results as the occurrence of two stocks, one coastal and other offshore that mix in a transition area. However the Boundary Rank was considered by the original authors just as an exploratory method and results obtained by such method should be checked with independent data. Geographical sub-divisions suggested by the Boundary Rank analyses were never tested using independent data. Therefore no other lines of evidence were available to support such sub-divisions. Furthermore the proposed existence of a small coastal O stock (Ow) was inconsistent with the pattern of CPUE series of the former commercial minke whaling: given the past level of catches, a small coastal stock would have been depleted already, which could not be revealed by the CPUE series. Furthermore a recent update of the Boundary Rank analyses showed no support for the occurrence of a coastal O stock.

Recent genetic analyses based on a larger set of samples (1994-2007) have been valuable to examine these past hypotheses. Papers were presented to the JARPN II review meeting (IWC, 2010a) and subsequently revised versions of those papers that responded to some of the suggestions of the JARPN II review meeting were presented to the IWC SC meeting in 2009 (IWC, 2010b). One of the most valuable pieces of information was the work on microsatellites to assign individuals to J and O stocks (Kanda *et al.*, 2009a). This information allowed subsequent hypothesis testing analyses to be conducted separately for these two stocks within sub-area 7W, as it had been recommended by the IWC SC several times in the past (e.g. IWC, 2003). Hypothesis testing analyses were conducted for the samples collected in 1994-2007 for both mtDNA (Goto *et al.*, 2009a) and microsatellites (Kanda *et al.*, 2009b). The microsatellite analyses included an analysis of statistical power providing support for the single O stock hypothesis. Results of these analyses therefore were consistent with the single O stock scenario.

The most recent genetic analyses were conducted for both O and J stock individuals separately and both microsatellite and mtDNA analyses found not significant heterogeneity within the O stock, providing further support for the single O stock hypothesis (Kanda *et al.*, 2010a; Park *et al.*, 2010).

Therefore the single O stock scenario is supported by the best available genetic evidence, and it is also not contradicted by the non-genetic analyses presented to the JARPN review meeting (IWC, 2001) and also summarized when the *ISTs* were completed in 2003 (IWC, 2004). See also Pastene *et al.* (2000).

Rational for single J stock

Different genetic analyses have been conducted in the Sea of Japan by combining Japanese and Korean genetic data. Some preliminary results were presented at the 2008 IWC SC meeting. Due to time constraint, data set could not be completed in time for the IWC SC 2009 meeting so the analyses on the J stock structure in this year were based only on Japanese samples (Goto *et al.*, 2009b; Kanda *et al.*, 2009c).

The most recent genetic analyses were conducted for both Japanese and Korean samples following some recommendations from the IWC SC in 2009. The analyses were conducted separately for O and J stock individuals and both microsatellite and mtDNA analyses in general found not significant heterogeneity within the J stock providing support for the single J stock scenario in the Yellow Sea, Sea of Japan and Pacific side of Japan (Kanda *et al.*, 2010a; Park *et al.*, 2010). The microsatellite analysis found some degree of heterogeneity but the differences between samples were very small and this result was contradictory with that found by the mtDNA analysis.

Non-genetic information is very limited for whales in the Sea of Japan so that no meaningful comparisons among groups of whales within the Sea of Japan have been possible.

In summary most of the recent genetic analyses have considered useful suggestions made by the IWC SC and JARPN review workshop. In particular the IWC SC welcomed the power analysis conducted for the hypothesis testing analysis of microsatellite data (IWC, 2010b). That study suggested that the statistical power for testing stock structure using the Japanese samples was quite high. The most recent hypothesis testing analyses based on mtDNA and microsatellites were conducted for 'total' samples as well O stock and J stock samples separately. This was possible by the microsatellite assignment study by Kanda *et al.* (2009a). There are some discussions on the effect of unassigned individuals and on how these samples can affect the conclusion of the stock structure. The unassigned individuals could be whales from some other additional weakly differentiated stocks or simply could be whales that could not be assigned to J and O stocks simply due to the low statistical power of the *STRUCTURE* analysis. The IWC SC provided some useful suggestions to elucidate this problem (IWC, 2010b). Some of those suggestions were responded by Kanda *et al.* (2010a) in their microsatellite analysis, and they concluded that the possibility of a third stock (intermediate stock between O and J stocks) represented by the unassigned samples is low.

Hypothesis 2 (Figure 2)

Same as Hypothesis 1 but W stock sporadically intrudes into sub-area 9 (see rational and specifications in the next section).

Rational

The microsatellite analysis found significant differences between western and eastern sectors of sub-area 9 (Kanda *et al.*, 2009b) while the mtDNA analysis found significant differences between those sectors using *Fst* for a particular year (1995) (Goto *et al.*, 2009a). These results were consistent with the sporadic intrusion of an offshore stock into sub-area 9 (W). There is no evidence from non-genetic markers supporting the occurrence of a W stock therefore we assigned less weight to this hypothesis in relation to Hypothesis 1.

Hypothesis 3 (Figure 3)

Same as Hypothesis 1 but a different stock (Y stock) resides in the Yellow Sea and overlaps with the J stock in the south part of sub-area 6.

Rational

Microsatellite analyses suggested some levels of seasonal genetic differentiation in the Korean samples but not in the Japanese sample. Yearly heterogeneity and the very weak heterogeneity between the Japanese and Korean samples from sub-area 6 could be due to a different stock in the Yellow Sea (Y stock) moving north at some extent along the Korean coast (Kanda *et al.*, 2010a). Mature animals have been observed in the Yellow Sea in summer. Results of the mtDNA analysis did not show this pattern of heterogeneity therefore we assigned less weight to this hypothesis in relation to Hypothesis 1.

Hypothesis 4 (Figure 4)

Same as Hypothesis 1 but with W stock sporadically intrudes into sub-area 9 and a different stock (Y stock) residing in the Yellow Sea, which overlap with the J stock in the southern part of sub-area 6. For the reasons given above, we assigned less weight to this hypothesis in relation to Hypothesis 1.

SPATIAL AND TEMPORAL PATTERN OF OCCURRENCE BY STOCK AND STOCK COMPONENTS

Hypothesis 1

Pattern of migration and temporal occurrence by stock and stock component

Under this hypothesis the migration pattern of adult and juvenile J stock is as suggested by Hatanaka *et al.* (2010) and Goto *et al.* (2010). Migration of adult and juvenile O stock is as suggested by Hatanaka and Miyashita (1997). The temporal and spatial overlap between J and O stocks along the Japanese coast is as proposed by Kanda *et al.* (2009a).

Pattern of migration of J stock

The migratory pattern of J stock as suggested by Hatanaka *et al.* (2010) has the following characteristics:

a) Northward (feeding) migration begin in January-February
b) Pregnant females migrate into the southern part of Okhotsk Sea in April following the retreat of sea ice
c) The main feeding season is April-June
d) Southward (breeding) migration start in July
e) Segregation by sex and maturity occurs

- Pregnant females migrate to northernmost distribution area
- In general, adult animals migrate and distribute in offshore waters in the Sea of Japan
- The migration of juveniles is different from adult animals. They stay close to the coast of Japan and Korea almost year around.

Goto *et al.* (2010) showed that this hypothesis was consistent with several kinds of data.

Pattern of migration of O stock

The migratory pattern of O stock as suggested by Hatanaka and Miyashita (1997) has the following characteristics:

a) Immature animals migrate into the coastal area of southern sub-area 7 in April and then disperse to northern sub-area 7 and the southern Okhotsk Sea
b) Mature males appear widely from coastal waters to offshore waters in May
c) Mature females enter the Okhotsk Sea in April ad May and then move further to the middle and northern Okhotsk Sea

Spatial and temporal overlap of J and O stocks in sub-area 7

In sub-area 7 J stock animals occur mainly within 10n miles from coast (Kanda *et al.*, 2010b). Kanda *et al.* (2009a) showed the relative occurrence of J and O stocks in sub-area 7 by months. The general pattern is that J stocks animals are more frequent in autumn/winter and O stock animals in spring/summer (see Table 6 in Kanda *et al.*, 2009a). We consider that this information is the most valuable to represent the pattern of overlap of J and O stocks in sub-area 7.

Figure 1 attempt to summarize the occurrence of the two stocks by sub-area, months and stock component based on the studies summarized above.

Hypothesis 2 (W)

Specifications for O and J stocks are the same as in Hypothesis 1. Under Hypothesis 2 the sporadic occurrence of W stock in sub-area 9 is considered. W stock occur in sub-area 9 each year with 17% probability (occurrence of a W stock in sub-area 9W has been found in one of six years of surveys in sub-area 9W, see Table 5 of Goto *et al.*, 2009b). The microsatellite analysis showed a near-to-significant *p*

value in the comparison among years in sub-area 9E (Kanda *et al.*, 2009b), However no clear trend was obtained in the pairwise comparison among years in that sub-area.

Hypothesis 3 (Y)
Specifications for O and J stocks are the same as in Hypothesis 1. Under Hypothesis 3 the occurrence of a Y stock in the Yellow Sea is considered. There is no sufficient information to specify the occurrence of Y stock in the Yellow Sea. We assume that it is mainly a resident stock with all sexual classes occurring through the year. A component of that stock would carry out short seasonal migration in winter-late spring to the south part of the Sea of Japan.

REFERENCES

Goto, M., Kanda, N., Kishiro, T., Yoshida, H., Kato, H. and Pastene, L.A. 2009a. Further mitochondrial DNA analysis on stock structure in the western North Pacific common minke whales. Paper SC/61/JR7 presented to the IWC Scientific Committee, May 2009, Madeira, Portugal (unpublished), 10pp.

Goto, M., Kanda, N. and Pastene, L.A. 2009b. Update of the mitochondrial DNA analysis on sub-stock structure of the J stock common minke whales from the Japanese waters. Paper SC/61/NPM4 presented to the IWC Scientific Committee, May 2009, Madeira, Portugal (unpublished), 8pp.

Goto, M., Miyashita, T., Kanda, N., Pastene, L.A. and Hatanaka, H. 2010. A hypothesis on the migration pattern of J-stock common minke whales. Paper SC/62/NPM1 presented to the IWC Scientific Committee, June 2010, Agadir, Morocco (unpublished), 14pp.

Hatanaka, H. and Miyashita, T. 1997. On the feeding migration of Okhotsk Sea-West Pacific stock of minke whales, estimates based on length composition data. *Rep. int. Whal. Commn* 47:557-564.

Hatanaka, H., Miyashita, T. and Goto, M. 2010. A hypothesis on the migration of J-stock minke whales. *J . Cetacean Res. Manage.* 11 (Suppl. 2):213-214.

International Whaling Commission. 1994. Report of the Working Group on North Pacific minke whale management trials. *Rep. int. Whal. Commn* 44:120-144.

International Whaling Commission. 1997. Report of the Working Group on North Pacific minke whale trials. *Rep. int. Whal. Commn* 47:203-226.

International Whaling Commission. 2001. Report of the workshop to review the Japanese Whale Research Programme under Special Permit for North Pacific minke whales (JARPN). *J. Cetacean Res. Manage* 3(Suppl.):375-413.

International Whaling Commission. 2003. Report of the Workshop on North Pacific common minke whale (*Balaenoptera acutorostrata*) *Implementation Simulation Trials. J. Cetacean Res. Manage. (Suppl.)* 5:455-488

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

International Whaling Commission. 2010a. The Report of the Expert Workshop to review the ongoing JARPN II Programme. *J Cetacean Res Manage.* 11 (Suppl. 2):405-449.

International Whaling Commission. 2010b. Report of the Working Group on the In-Depth Assessment of western North Pacific common minke whales, with a focus on J stock. *J Cetacean Res Manage.* 11 (Suppl. 2):198-217.

Kanda, N., Goto, M., Kishiro, T., Yoshida, H., Kato, H., and Pastene, L.A. 2009a. Individual identification and mixing of the J and O stocks around Japanese waters examined by microsatellite analysis. Paper SC/61/JR5 presented to the IWC Scientific Committee, May 2009, Madeira, Portugal (unpublished), 14pp.

Kanda, N., Goto, M., Kishiro, T., Yoshida, H., Kato, H., and Pastene, L.A. 2009b. Further microsatellite analysis of minke whales in the western North Pacific. Paper SC/61/JR8 presented to the IWC Scientific Committee, May 2009, Madeira, Portugal (unpublished), 14pp.

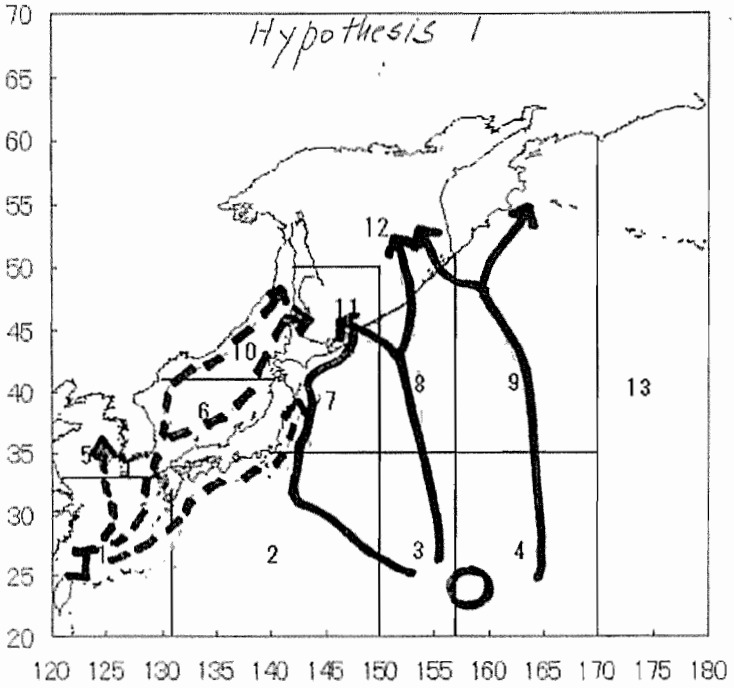
Kanda, N., Goto, M. and Pastene, L.A. 2009c. Update of the microsatellite analysis on sub-stock structure of the J stock common minke whales from the Japanese waters. Paper SC/61/NPM8 presented to the IWC Scientific Committee, May 2009, Madeira, Portugal (unpublished), 9pp.

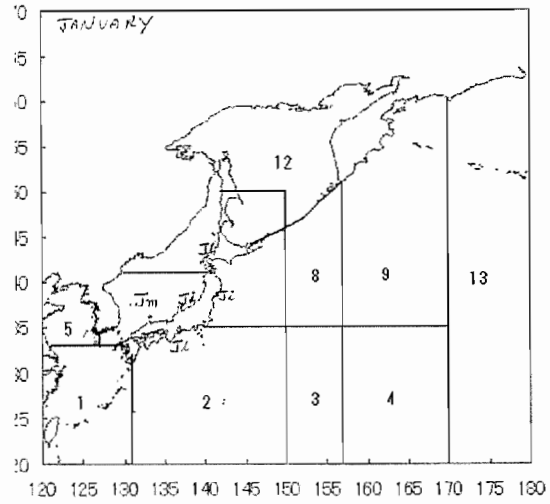
Kanda, N., Park, J.Y., Goto, M., An, Y.R., Choi, S.G., Moon, D.Y., Kishiro, T., Yoshida, H., Kato, H. and Pastene, L.A. 2010a. Genetic analysis of western North Pacific minke whales from Korea and Japan based on microsatellite DNA. Paper SC/62/NPM11 presented to this meeting.

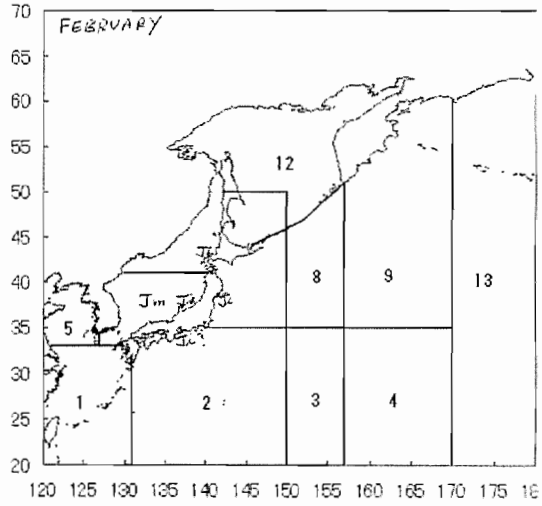
Kanda, N., Hatanaka, H. and Goto, M. 2010b. Limiting whaling operations on O stock common minke whales to waters 10 nautical miles or more from the Japanese Pacific coast minimizes catch of J stock whales. Report of the Working Group on the *pre-implementation assessment* of western North Pacific common minke whales. Appendix 8.

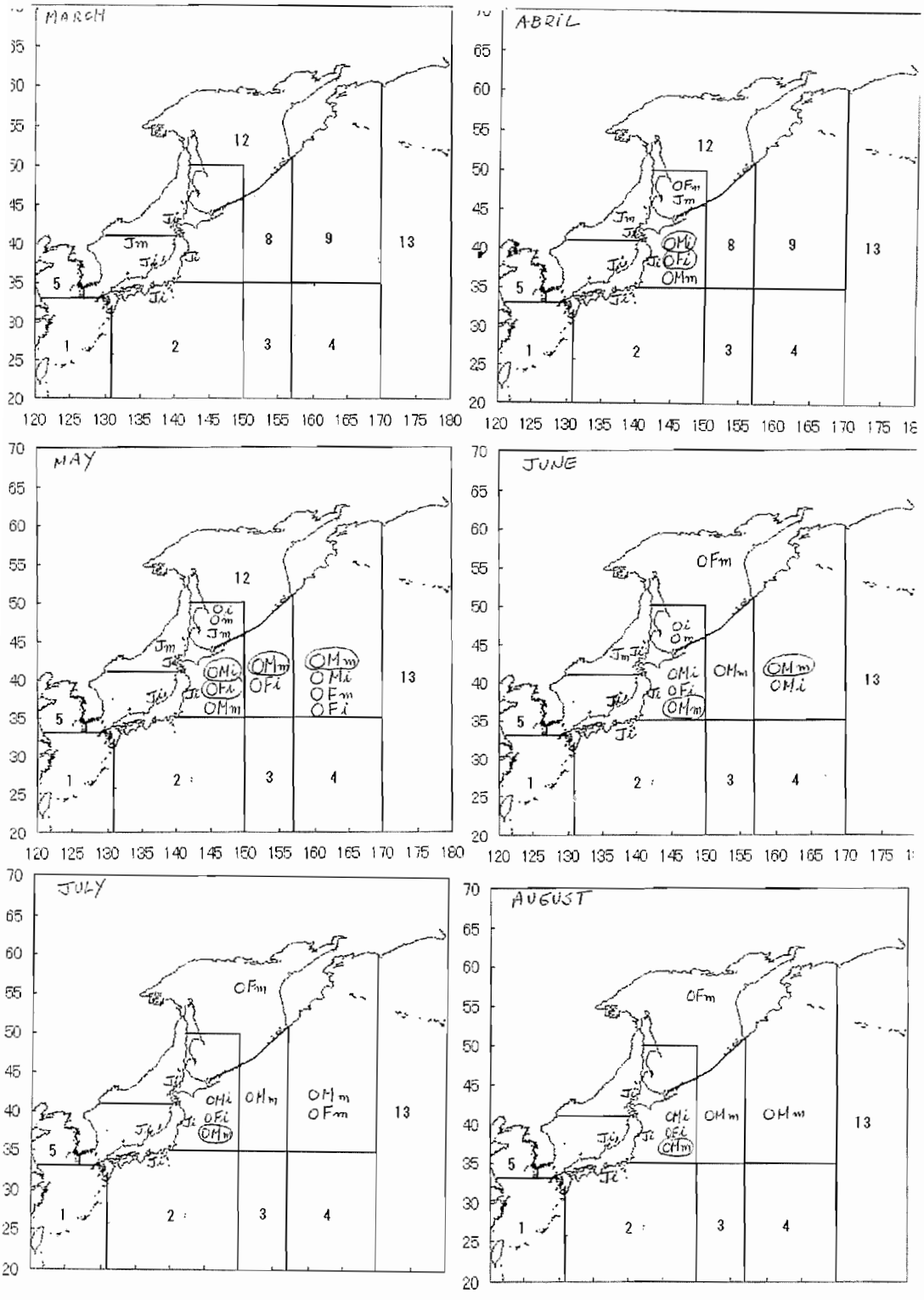
Park, J.-Y., Goto, M., Kanda, N., Kishiro, T., Yoshida, H., Kato, H. and Pastene, L.A. 2010. Mitochondrial DNA analyses of J and O stocks common minke whales in the western North Pacific SC/62/NPM21.

Pastene, L.A., Goto, M. and Fujise, Y. 2000. Review of the studies on stock identity in the minke whale *Balaenoptera acutorostrata* from the North Pacific. SC/F2K/J1


Hypothesis 1
70
65
60
55
50
45
40
35
30
25
20
120 125 130 135 140 145 150 155 160 165 170 175 180
1
2
3
4
5
6
7
8
9
10
11
12
13


JANUARY
120 125 130 135 140 145 150 155 160 165 170 175 180
1
2
3
4
5
8
9
12
13


FEBRUARY
70
65
60
55
50
45
40
35
30
25
20
120 125 130 135 140 145 150 155 160 165 170 175
1
2
3
4
5
8
9
12
13


MARCH
ABRIL
MAY
JUNE
JULY
AUGUST

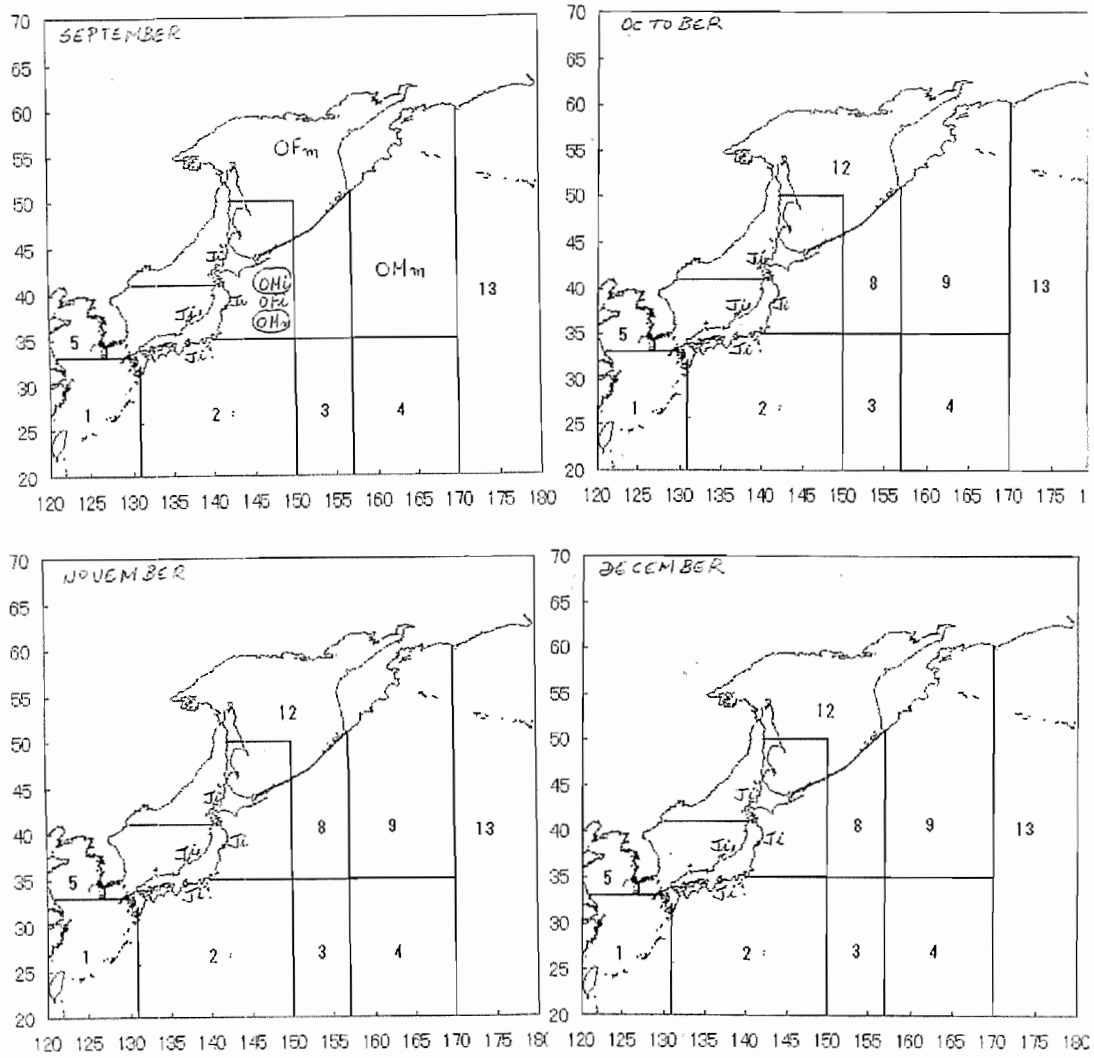


Figure 1. Schematic representation of Hypothesis 1. O= O stock; J= J stock. The figure is a first attempt to show the occurrence of animals by stock, sub-areas and stock component: OMi= O stock male immature; OMm= O stock male mature; OFi= O stock female immature; OFm= O stock female mature; JMi= J stock male immature; JMm= J stock male mature; JFi= J stock female immature; JFm= J stock female mature; Ji= J stock immature both sexes; Jm= J stock mature both sexes; Oi= O stock immature both sexes; Om= O stock mature both sexes. Main source of the information was Zenitani *et al.* (2002) (for O stock in the Pacific side of Japan), Hatanaka and Miyashita (1997), Goto *et al.* (2010), Kanda *et al.* (2009a). Symbols in circle indicate the predominant sexual class of the O stock according to Zenitani *et al* (2002). By-caught immature J stock animals occur almost year round in the Japanese coast within 3 n. miles.

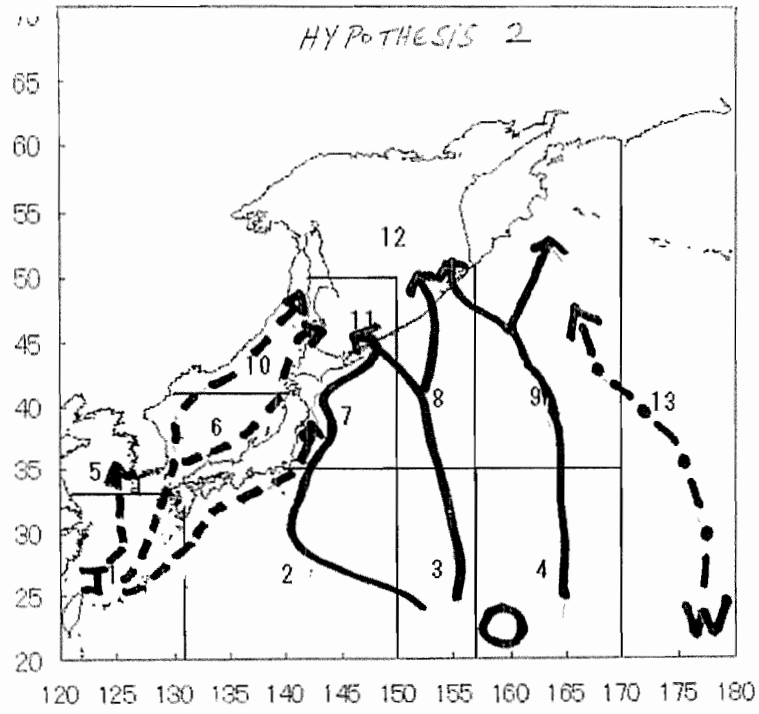


Figure 2. Schematic representation of Hypothesis 2. O= O stock; J= J stock; W= W stock.

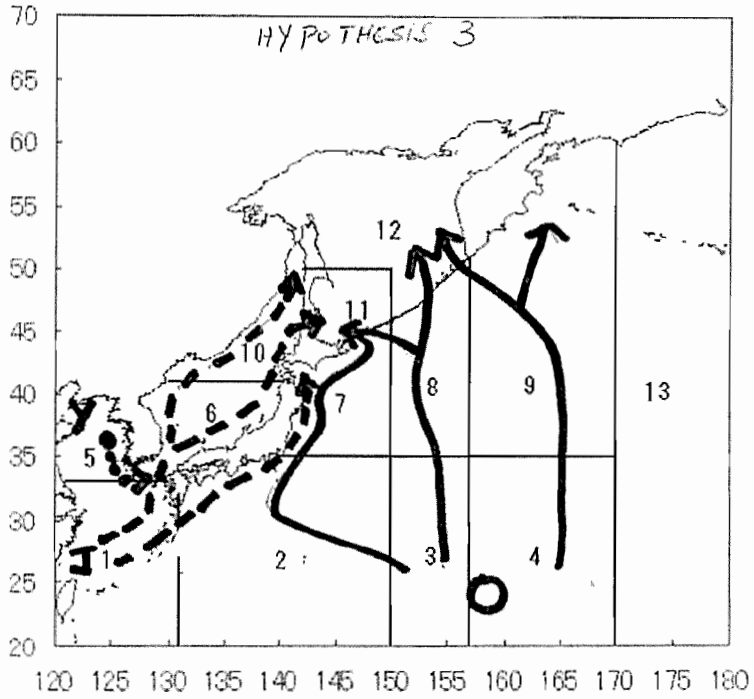


Figure 3. Schematic representation of Hypothesis 2. O= O stock; J= J stock; Y= Y stock.

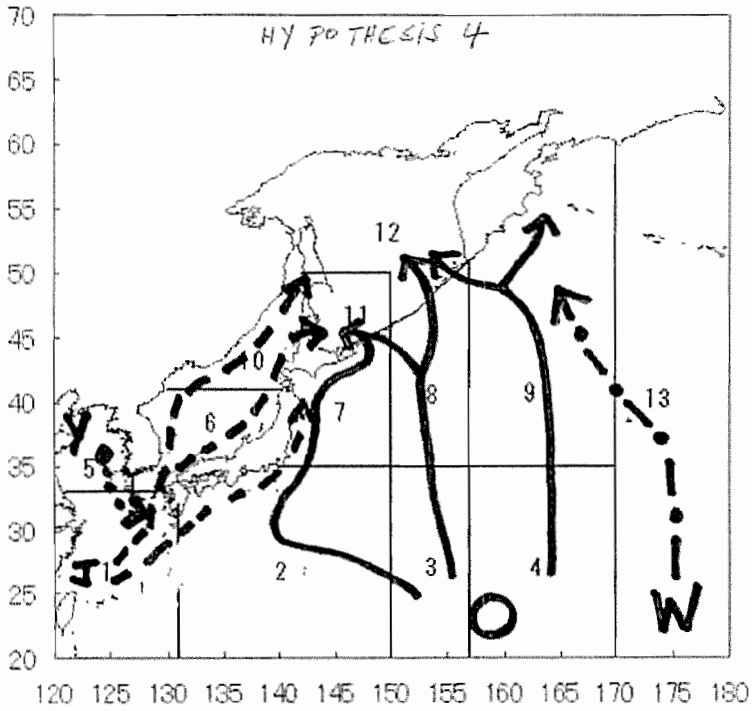


Figure 4. Schematic representation of Hypothesis 4.