Progress in the development of stock structure hypotheses for western North Pacific common minke whales

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ABSTRACT

This paper examines recent progress in the development of stock structure hypotheses for western North Pacific common minke whale (O and J stocks), and conduct a preliminary evaluation of these hypotheses in the context of the available scientific information, mainly genetics, presented and discussed at the IWC SC in recent years. The aim is to make a proposal of stock structure scenarios that is consistent with the data. A total of four hypotheses are considered consistent with the available scientific data.

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

INTRODUCTION

Based on the original works of Omura and Sakiura (1956) and Ohsumi (1977) the IWC SC recognized in 1993 two stocks of common minke whales, the Okhotsk Sea/Western Pacific ('O' stock) and the Yellow Sea/East China Sea/Sea of Japan ('J' stock). Subsequently the IWC SC has been engaged in investigating additional structure within these two stocks. Information on stock structure is important for the *Implementation Simulation Trials* (*ISTs*), which are conducted to evaluate the conservation performance before the calculation of a catch quota for commercial whaling under the RMP.

The RMP *ISTs* for western North Pacific common minke whales were completed in 2003. However these *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. This decision makes sense given the substantial amount of scientific information, notably genetics, accumulated after 2003.

Different stock structure scenarios have been listed by the IWC SC in recent meetings, which are based on different levels of supporting evidences. The objective of this study is to summarize and conduct a preliminary evaluation of these hypotheses in the context of the scientific information, mainly genetics, presented and discussed at the IWC SC in recent years.

HYPOTHESES ON STOCK STRUCTURE

O stock

Several meetings were conducted by the IWC SC in the context of the RMP's *ISTs*, which were completed in 2003 (IWC, 2004). Final hypotheses on stock structure were based mainly on genetic analyses conducted using the past commercial samples and new samples collected in sub-areas 7, 8 and 9 by JARPN (1994-1999) and JARPN II between 2000 and 2001 (e.g. Goto *et al*., 2002; Kanda *et al*., 2002; Taylor and Martien, 2002).

The following four hypotheses on stock structure were used in the RMP' *ISTs* (Figure 1). Unfortunately the IWC SC was unable to develop a scientific method to assign plausibility to these hypotheses. The IWC SC arbitrarily assigned high plausibility to all these hypotheses (IWC, 2004).

Hypothesis A: three-stock scenario in the Pacific side of Japan ('J', 'O', 'W') with the 'W' stock found only in part of sub-area 9 and only sporadically (Figure 1-AB);

Hypothesis B: two stock scenario in the Pacific side of Japan ('J' and 'O') with no W stock as a limiting case of Baseline A (Figure AB);

Hypothesis C: four-stock scenarios overall in the Pacific side of Japan, with 'O_W', 'O_E' and 'W' to the east of Japan. Boundaries are fixed at 147°E and 157°E and there is no mixing between the stocks (Figure 1-C);

Hypothesis D: three-stock scenario in the Pacific side of Japan ('J', 'O', 'W'), with 'O' and 'W' mixing over 147°E and 162°E, O being dominant to the west and W to the east (Figure 1-D).

J-Stock

The IWC SC has been conducting an *in-depth assessment* of western North Pacific common minke whale with emphasis on the J stock. The IWC SC listed a total of four primary hypotheses on stock structure of the J stock (Figure 2).

Hypothesis 1: Single J stock in the Yellow Sea, Sea of Japan and Pacific coast of Japan.

Hypothesis 2: Two J stocks, one distributed around the Korean Peninsula and the other in the west and east coasts of Japan.

Hypothesis 3: Two J stocks, one distributes in the Yellow Sea and the other in the Sea of Japan and Pacific coast of Japan.

Hypothesis 4: Two J stocks migrate through the Sea of Japan at different times of the year.

These four hypotheses were agreed by the IWC SC in 2007. In subsequent meetings some members proposed other hypotheses involving three J stocks (Hypotheses 5, 6 and 7 in Figure 2).

EXAMINATION OF THE STOCK STRUCTURE HYPOTHESES

No quantitative method has been agreed in the IWC SC for evaluating plausibility of different hypotheses. During the 2002 IWC SC meeting Japanese scientists presented the results of an AIC (Akaike's Information Criterion)-based evaluation of the plausibility of baseline stock scenarios for North Pacific common minke whales. These were based exclusively on mtDNA data. However there was no agreement at the SC on the validity of using AIC for evaluating plausibility.

Recognizing that plausibility of stock structure hypotheses will be addressed by the IWC SC in a later stage here a qualitative analysis is conducted by listing up the scientific evidences (genetics and non-genetics) pro and again different hypotheses.

O-Stock

Hypotheses A, B, C and D

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) (see Figure 3 for the definition of sub-areas for management by the IWC SC).

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 final results of JARPN during a Workshop conducted in 2000. The information based on genetics, morphometric, ecological markers, biological parameters supported the single O stock scenario in sub-areas 7, 8 and 9. 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).

These analyses and agreements by the IWC SC were the basis for the formulation of Hypotheses A and B. At the later stage of the *ISTs* new analyses were presented based on genetics (mtDNA and microsatellites),

body proportion and biological parameters, which were consistent with the single O stock scenario (Hypothesis B). As noted above the mtDNA analysis suggested the possibility of sporadic occurrence of a different stock (W stock) in part of sub-area 9, which was the basis to formulate Hypothesis A.

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 (Hypothesis C). Some authors interpreted these results with the occurrence of two stocks, one coastal and other offshore that mix in a transition area (Hypothesis D). However the result of the Boundary Rank analysis was not supported by other lines of evidence. 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, which could not be revealed by the CPUE series.

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, 2009a) 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, 2009b). 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. Hypothesis testing analyses were conducted for the samples collected in 1994-2007, grouping the samples as suggested by Hypotheses A, C and D for both mtDNA (Goto *et al*., 2009a) and microsatellites (Kanda *et al*., 2009b). Results of these analyses were inconsistent with stock scenarios C and D.

The microsatellite analysis however 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 (Hypothesis A).

Hypotheses A and B, which are supported by the best available genetic evidence, is consistent with other non-genetic analyses presented to the JARPN review meeting (IWC, 2001) and final *ISTs* meetings (IWC, 2004).

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). More recently Kanda *et al*. (2010) completed a microsatellite analyses on O and J stock structure in response to some suggestions by the IWC SC in 2009. Based on the information from these studies a preliminary evaluation of the stock structure of J stock listed by the IWC SC in 2009 is made below.

Hypothesis 1

Results of recent genetic analyses are consistent with this hypothesis. J stocks animals from both sides of Japan showed no significant differences in both mtDNA and microsatellites (Goto *et al*., 2009b; Kanda *et al*., 2009c). Apart from the weak differences found by the microsatellite analysis between Japan and Korean J stock animals, no other evidence is available to support strong differentiation between animals from these two localities.

Hypothesis 2

Results of recent genetic analyses are not consistent with this hypothesis. Although J stocks animals from both side of Japan showed no significant differences in both mtDNA and microsatellites (Goto *et al*., 2009b; Kanda *et al*., 2009c) (as suggested by this hypothesis), the weak microsatellite differentiation found between Japan and Korean J stock animals were attributed to whales in sub-area 5 (Yellow Sea) (Kanda *et al*., 2010).

Hypothesis 3

Results of recent genetic analyses (microsatellites) are consistent with this hypothesis. J stocks animals from both side of Japan showed no significant differences in both mtDNA and microsatellites (Goto *et al*., 2009b; Kanda *et al*., 2009c). Some levels of seasonal genetic differentiation were found 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*., 2010).

Hypothesis 4
Results of recent genetic analyses are not consistent with this hypothesis. J stocks animals from both side of Japan showed no significant differences in both mtDNA and microsatellites. Furthermore no seasonal genetic differences were found in the Sea of Japan coast of Japan (Goto *et al*., 2009b; Kanda *et al*., 2009c).

Hypotheses 5
Results of recent genetic analyses are not consistent with this hypothesis. Weak microsatellite differentiation between Korean and Japan J stock was attributed to animals in sub-area 5 (Kanda *et al*., 2010).

Hypotheses 6 and 7
Results of recent genetic analyses are not consistent with this hypothesis. J stocks animals from both sides of Japan showed no significant differences in both mtDNA and microsatellites (Goto *et al*., 2009b; Kanda *et al*., 2009c).

SUMMARY OF PLAUSIBLE HYPOTHESES

The best available scientific evidence, though not perfect, is consistent with four hypotheses, which are actually a combination of hypotheses A and B for the O stock and hypotheses 1 and 3 for the J stock:

1) Single J stock distributed in the Yellow Sea, Sea of Japan and Pacific side of Japan (pattern of interaction between J and O stocks along the Japanese coast as proposed by Kanda *et al*., 2009a). Migration pattern of adult and juvenile J stock is as suggested by Goto *et al*. (2010). Single O stock in sub-areas 7, 8 and 9. Migration of O stock is as suggested by Hatanaka and Miyashita (1997).
2) Same as in 1) but W stock sporadically intrudes into sub-area 9.
3) J stock distributed in the Sea of Japan and Pacific side of Japan (pattern of interaction between J and O stocks along the Japanese coast as proposed by Kanda *et al*., 2009a). A different stock (Y stock) resides in the Yellow Sea and interacts with the J stock in the south part of sub-area 6. Migration pattern of adult and juvenile J stock is as suggested by Goto *et al*. (2010). Single O stock in sub-areas 7, 8 and 9. Migration of O stock is as suggested by Hatanaka and Miyashita (1997).
4) Same as in 3) but with W stock sporadically intrudes into sub-area 9.

The Japanese data base for common minke whale mtDNA is being corrected for some inconsistencies detected recently. The evaluation of hypotheses in this paper will be updated once the results of new mtDNA analyses become available.

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, 2009b). 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, 2009b). Some of those suggestions were responded by Kanda *et al*. (2010) 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.

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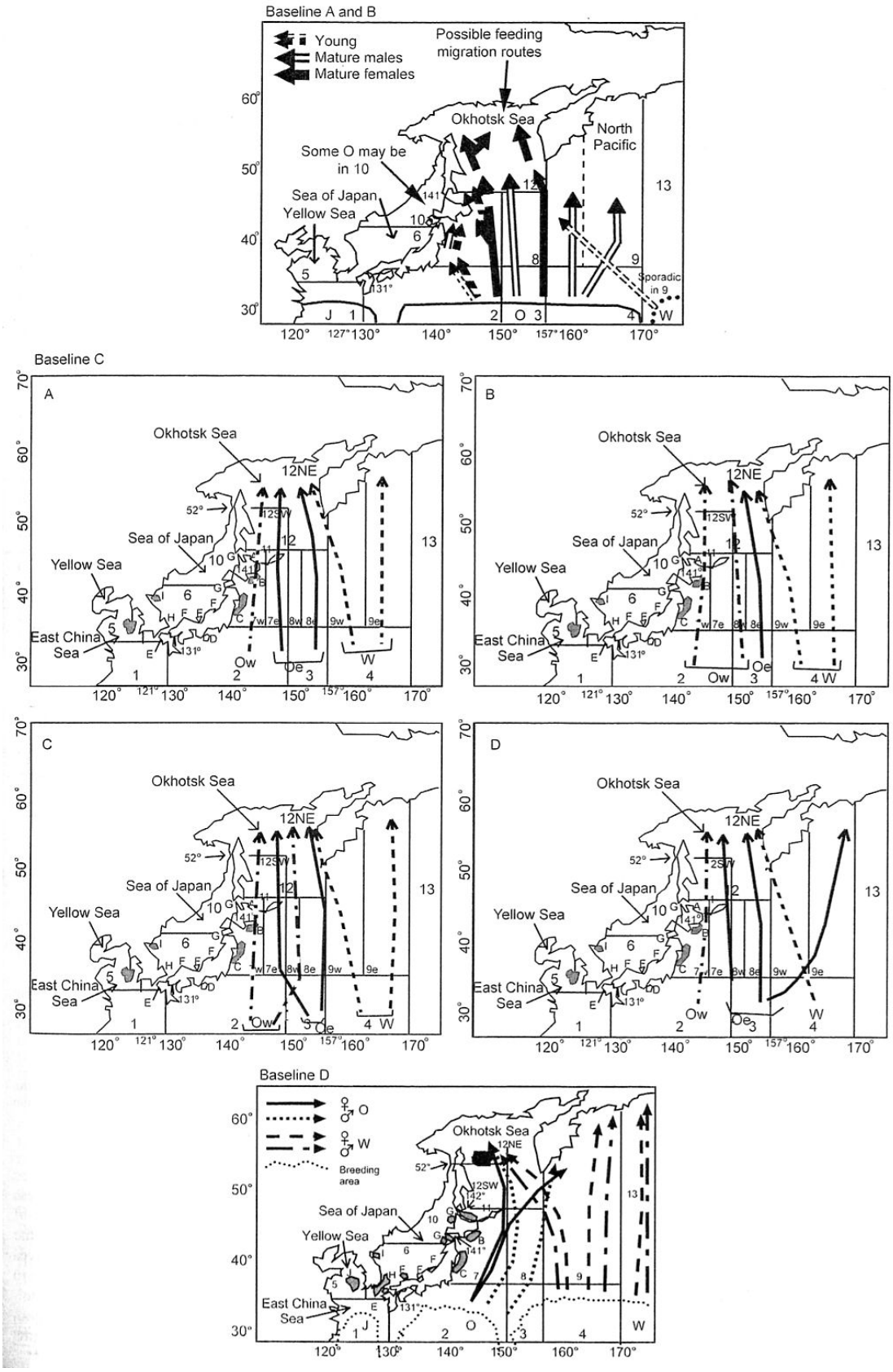

Figure 1: Hypotheses on stock structure of North Pacific common minke whale used in the *Implementation Simulation Trials* of the RMP (IWC, 2004). See text for details.

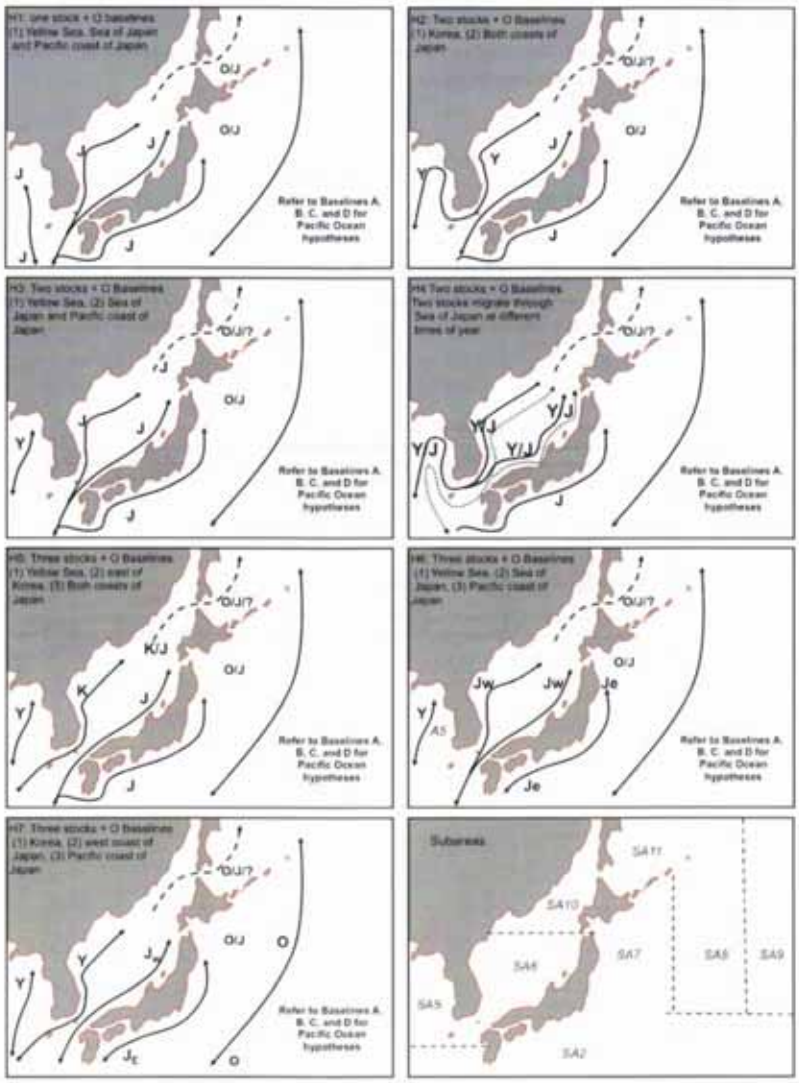

Figure 2: Hypotheses on stock structure of J stock listed during the in-depth assessment of western North Pacific common minke whales with emphasis on the J stock (IWC, 2009b). See text for details.

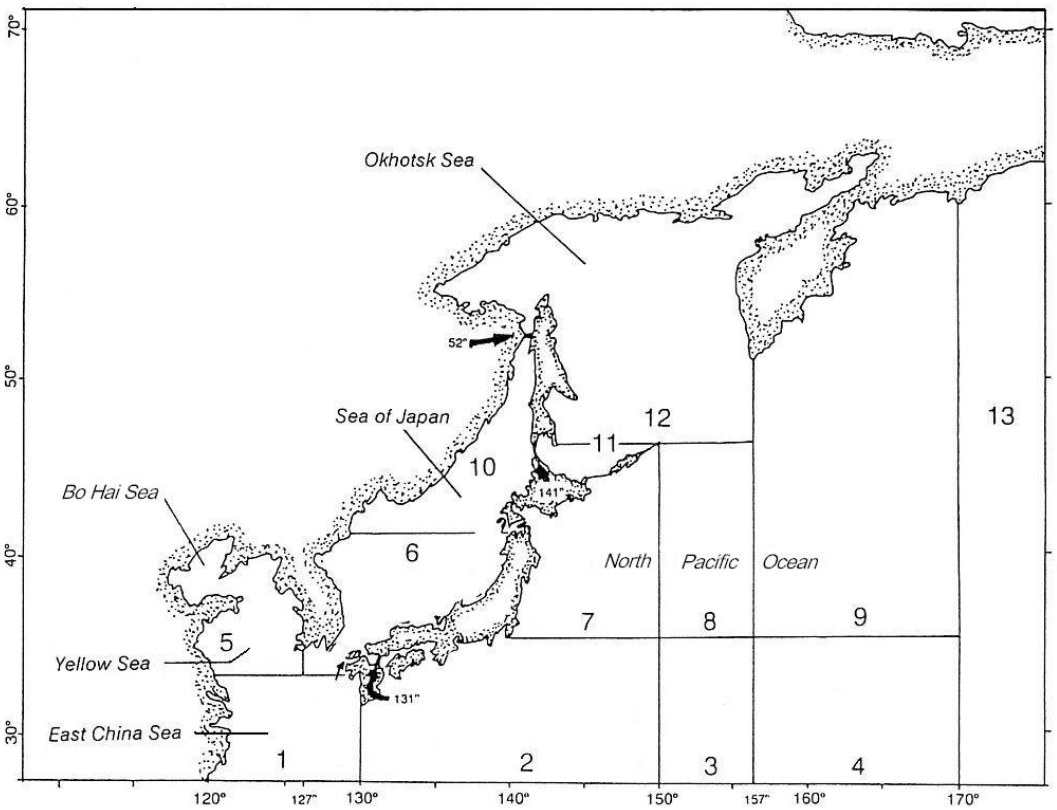

Figure 3: Sub-areas used by the IW SC for management purposes of the common minke whale.