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Review of the studies on stock identity in the minke whale *Balaenoptera acutorostrata* from the North Pacific

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ABSTRACT

We presented a review of the studies on stock identity in the North Pacific till May 1999. In the western side of the North Pacific these studies started as early as 1956. The main approaches used to investigate intra-specific structure are genetics, morphology/morphometry and analysis of conception dates. Catch distribution, ecological markers and pollutant burden has been also used. Genetic studies in the decade of the 80's were based exclusively on allozymes. In the decade of the 90's approaches based on both mitochondrial and nuclear DNA were used. Samples until 1994 were available basically from past commercial coastal whaling operations in both Japan and Korea and then the analyses were restricted to coastal areas of these two countries. From 1994 samples were available from the JARPN surveys in offshore areas in the western North Pacific. Results of different studies strongly support the view that two genetic stocks occurs in the western North Pacific: one in the Yellow Sea, East China Sea and Sea of Japan (J-stock) and the other in the Pacific side of Japan and the Okhotsk Sea (O-stock) with a spatial/temporal mixing of stocks in the southern part of the Okhotsk Sea in April and August. No evidence for additional stock structure in the western North Pacific (from the Japanese coast to 170°E) has been found. We also summarized the different hypotheses on stock structure of the North Pacific minke whale discussed at the IWC Scientific Committee.

CONTENTS

1. INTRODUCTION

This document reviews the available information on stock identity in the North Pacific, with especial emphasis in the western side, where most of the studies have been concentrated. This review is prepared as a background information for the discussions to be carried out during the Japanese Whale Research Program under Special Permit in the North Pacific (JARPN) review meeting.

Different authors have used different terminology for referring the geographical localities in the western North Pacific and Sea of Japan. In addition a SC Working Group on North Pacific Minke Whale Management Trials in Preparation for Implementation of RMP created in 1993 a complicated sub-stock scenario with 13 sub-areas in the western North Pacific (Fig. 1) (IWC, 1994). Authors in recent analyses have referred these sub-areas. The equivalent of terminologies used in the past with those used in recent studies is as follow:

Yellow Sea = sub-area 5
Southern Sea of Japan = sub-area 6
West Kyushu = sub-area 6 south
Wakasa Bay = sub-area 6 north
Sea of Japan coast of Hokkaido = sub-area 10
Okhotsk coast of Hokkaido = sub-area 11
North Okhotsk Sea = sub-area 12
Pacific coast of Hokkaido = sub-area 7 north
Sanriku coast = sub-area 7 south
Western North Pacific offshore 8 = sub-area 8
Western North Pacific offshore 9 = sub-area 9

2. BACKGROUND

The western North Pacific minke whale is one of the best studied species from the point of view of intra-specific structure. Studies on stock identity started as early as 1956. As a background for the review of the studies on stock identity in the North Pacific minke whale, we briefly described here three related matters: abundance, catch history and seasonal movement.

2.1 Abundance

Abundance estimations for the 'O' stock were given during the comprehensive assessment of the minke whale (IWC, 1992). The estimates were based on a survey conducted during August and September 1989 and 1990. The southern and eastern limits of the survey were 39°N and 170°E. Abundance in the Okhotsk Sea (sub-area 11 from the near-shore areas up to 12n. miles of the Russian coast) was estimated at 19,209 animals with 95% confidence interval (10,069, 36,645) and that in the northwest Pacific was estimated at 5,841 whales (2,835, 12,032). The combined total for the 'O' stock was 25,049 (13,689, 45,835). Abundance estimate of the 'J' stock were presented during the meeting of the Working Group on North Pacific Minke Whale Trials (IWC, 1997). Estimates for sub-areas 6 and 10 were based on a sighting survey conducted in July –September 1992. The surveys covered 56.8% and 30.0% of sub-areas 6 and 10, respectively. Abundance in sub-areas 6 and 10 was estimated at 893 ad 707 animals, respectively. Both estimates were considered minimal.

2.2 Catch history

Catches by the sub-areas shown in Figure 1 and year, were summarized in the Report of the Working Group on North Pacific Minke Whale Trials (IWC, 1997). Information on catches were summarized for the period 1930-1987. The main exploited sub-areas were sub-areas 5, 6, 7 and 11. The total catches in these sub-areas for the period mentioned above were 10,714, 7,889, 8,347 and 4,692 whales, respectively.

2.3 Seasonal movements

Regarding to seasonal movements, Omura and Sakiura (1956) suggested the occurrence of two stocks on either side of Japan. Regarding whales in the Sea of Japan, they suggested that whales move to the north in the spring in the order of west Kyushu (sub-area 6 south), Wakasa Bay (sub-area 6 north), Sea of Japan coast of Hokkaido (sub-area 10) entering into the Okhotsk coast of Hokkaido (sub-area 11) and staying there in summer. Ohsumi (1983) based on analyses on length distribution suggested, however, that animals in Okhotsk coast of Hokkaido (sub-area 11) are closer to Pacific side animals. Subsequent studies reviewed below showed that a temporal/spatial mixing of two stocks occur in that geographical area.

Hatanaka and Miyashita (1997) conducted the newest examination of movement of minke whales in the western North Pacific. They used length composition data from the Japanese small-type whaling (JSTY) for the period 1977-1987 in the sub-areas 7 and 11 of Fig. 1, length composition data from test whaling between 1973-75 in sub-areas 8 and 12, length composition data from the JARPN in 1994 and 1995 in sub-area 9 and catch data for each whale taken in commercial operations around Japan between 1977 and 1987. In addition information on gender and sexual maturity were used.

They summarized the pattern of seasonal movements of the O stock as follow: i) young (immature) males migrate into the coastal area of sub-area 7 south in April and then disperse to sub-area 7 north and the southern Okhotsk Sea from June. They remain in these coastal areas until the end of the feeding season and then leave for an unknown wintering ground. They are rare in the northern and middle Okhotsk Sea and offshore waters, ii) young (immature) females follow a similar pattern to their male counterparts, but larger immature are also relatively abundant in sub-area 11 in May and June. It is suggested that females tend to migrate further north to the southern Okhotsk Sea as they become larger and they also tend to enter the feeding ground in the Okhotsk Sea, as do the mature females, iii) mature males are found throughout coastal and offshore waters from May to September. Little information is available on their migratory timings or routes and iv) mature females are found in the Okhotsk Sea in May, after which they move further north to the middle and northern Okhotsk Sea. Some feed in sub-area 7 north but they are rare in sub-area 7 south and offshore waters of the western North Pacific. It thus appears that the main feeding ground for mature females is the Okhotsk Sea (Hatanaka and Miyashita, 1997). Fig. 2 is a schematic representation of the pattern of migration after these authors.

3. RESULTS OBTAINED ON STOCK IDENTITY BY METHODS USED

3.1 Genetics

Several genetic markers have been used to investigate stock identity in the North Pacific minke whale. The studies conducted in the decade of the 80's used allozyme. In the decade of the 90's, apart the allozyme, other techniques based on DNA have been used. Two of those techniques were based on mitochondrial DNA (mtDNA): restriction fragment length polymorphism (RFLP) and sequencing analyses of the mtDNA control region. Two other techniques were based on nuclear DNA (nDNA): microsatellite and random amplification of genomic DNA (RAPD) analyses.

Table 1 shows a summary of the main genetic studies conducted to investigate stock identity in the North Pacific minke whales. For a better understanding, the geographic localities indicated in the table make reference to the sub-areas shown in Fig. 1.

3.1.1 *Allozymes*

Wada (1984)

This study used tissue samples collected by the Korean Coastal Whaling (KCW) and by the JSTW. Sampling involved five localities: Yellow Sea or sub-area 5 (n=3), southern part of the Sea of Japan or sub-area 6 (n=42), Okhotsk coast of Hokkaido or sub-area 11 (n=68), Pacific coast of Hokkaido or sub-area 7 north (n=40) and Sanriku coast or sub-area 7 south (n=128).

Samples in the Yellow Sea and southern part of the Sea of Japan were taken in a period from 6 September to 22 October 1982. Although the exact sampling date for the Japanese coastal water samples are not specified in the report, we assume that they were taken in the period of the whaling operation from April to September in 1981 and 1982.

A total of 15 allozyme loci were used to examine the samples. Of them 5 were polymorphic (*Adh-1, 6-Pgd, Icd-1, Icd-2* and *Adh-2*).

The observed phenotypic distribution fitted the expected proportion predicted from the Hardy-Weinberg equilibrium for both Korean and Japanese coastal minke whales.

For the homogeneity test (based on G-test), the two localities in Korea were pooled as did the three localities in Japan. The Japanese coastal sample involved an additional 34 samples from a previous study (Wada, 1983). Two loci, *Adh-1* and *6-Pgd* were useful to discriminate minke whales from coastal Korea and coastal Japan. The G-test showed significant differences in the allele frequencies of these loci between coastal Korea and coastal Japan minke whales.

Wada and Numachi (1991)

This study is a worldwide allozyme analysis in the minke and other baleen whale species. Regarding the North Pacific, the study used tissue samples (liver, muscle and heart) collected by the KCW and JSTW. Sampling involved five localities: Yellow Sea or sub-area 5, southern part of the Sea of Japan or sub-area 6, Okhotsk coast of Hokkaido or sub-area 11, Pacific coast of Hokkaido or sub-area 7 north and Sanriku coast or sub-area 7 south. The total sample size for the Korean coastal sample (sub-area 5+6) was 46 and that for Japanese coastal sample (sub-areas 7, 11) was

416.

Samples in the Yellow Sea and southern part of the Sea of Japan were taken in a period from 6 September to 22 October 1982. Although the exact sampling date for the Japanese coastal waters samples are not specified in the report, we assume that they were taken in the period of the whaling operation from April to September between 1980 and 1983.

A total of 45 allozyme loci were used to examine the total samples, which also involved a sample set from the Antarctic. Of them eleven were polymorphic (*Adh-1, Idh-1, Gpi, Mdh-1, Mdh-2, Mpi, PepB, PepC, PepD, 6-Pgd and Pgm-1*) in the northern minke whales.

The observed phenotypic distribution fitted the expected proportion predicted from the Hardy-Weinberg equilibrium for both Korean and Japanese coastal minke whales.

The G-test was used to compare statistically Korean and Japanese coastal samples. Significant differences between these two samples were found in the allele frequencies of the following loci: *Adh-1, Gpi, Mdh-1, PepB, PepD, 6-Pgd and Pgm-1* as well for the eleven polymorphic loci combined.

Wada (1991)

This study used tissue samples (liver) collected by the JSWT. Sampling involved four localities: Okhotsk coast of Hokkaido or sub-area 11 (n=310), Pacific coast of Hokkaido or sub-area 7 north (n=285), Sanriku coast or sub-area 7 south (n=391) and the Sea of Japan coast of Hokkaido or sub-area 10 (n=18). Sampling in the two former localities was carried out in April-September for the years 1980-87. In Sanriku samples were from April-July and in Sea of Japan coast of Hokkaido from June and August-September period for the same years. For comparison samples from Yellow Sea or sub-area 5 and southern part of the Sea of Japan or sub-area 6 (examined in a previous study), were used.

Three previously known polymorphic allozyme loci were used: *Adh-1*, *Gpi* and *6Pgd*. Monthly and regional differences in the Japanese sample were examined using data of *Adh-1* and the G-test.

The regional differences of allele frequencies were tested first using the total sample. The significant P value obtained suggested heterogeneity in the total sample. Furthermore genotypic departure from the Hardy-Weinberg expectations was also significant in the total sample and in the Okhotsk coast of Hokkaido sample.

A statistical test for monthly variation showed no significant differences in the Pacific coast of Hokkaido or in the Sanriku coast. However a significant monthly differences was found in the sample from the Okhotsk coast of Hokkaido with the April sample being significant different from the other months. In addition, in the April sample a significant genotypic departure from the Hardy-Weinberg equilibrium was found. It was also found that the frequency of *Adh-1d* was high early in April but become lower late in April. The author concluded that the sample in April consist of at least two genetically different populations.

Allele frequencies for sub-area 10 were similar to sub-area 11 (excluding April). In addition the average body lengths for 16 males and 11 females in sub-area 10 were the same as those of sub-areas 11 and 7 north in June. Based on this information, the author suggested that minke whales off the Okhotsk coast of Hokkaido and/or Pacific coast of Hokkaido migrate in summer into the northern part of the Sea of Japan coast of Hokkaido. Other factors such as gender and reproductive status of the animals were used to interpret the results.

Wada (1995), Wada (1996)

These were the first allozyme studies that used samples obtained by the JARPN surveys in an offshore area of the western North Pacific (sub-area 9, Fig. 1). A total of 121 minke whales taken in that sub-area by JARPN surveys in 1994 and 1995 were examined and compared with coastal Japanese and Korean samples used in a previous study (Wada, 1991).

Three allozyme loci were used: *Adh-1*, *Gpi*, and *6Pgd*. No significant inter-annual differences were found in sub-area 9. No significant deviation in the observed genotype frequencies from the Hardy-Weinberg expectations was found in the pooled sample from sub-area 9.

Using the G-test, no significant differences in allele frequencies were found between the offshore sub-area 9 and samples from coastal Japan. Significant differences were found, however, between sub-area 9 and the Korean samples.

Wada (1997)

In this study the author used three allozyme loci (*Adh-1, Gpi,* and *6Pgd)* to examine minke whales sampled by the JARPN in 1996 in sub-areas 7, 8 and 11 (Fig. 1) and compared these samples with those of his previous studies (Wada, 1991; 1995;1996). No significant allozyme heterogeneity was found in the 1996 sample. As expected, G-test demonstrated significant differences with the Korean sample of the previous study but no significant differences with the Japanese samples of the previous study were found.

3.1.2 RFLP analysis of whole mtDNA
Wada *et al.* (1991)

This study was a worldwide mtDNA analysis of minke whales. The sample from the Northern Hemisphere involved one from the southern part of the Sea of Japan or sub-area 6 (n=32) and one from the Sanriku coast or sub-area 7 (n=30). The liver samples were collected by the KCW in Korea (September-October 1982) and JSTW in Japan (1986-87).

A total of 14 kind of six-base restriction enzymes were used (*AccI, AvaI, BamHI, BglI, EcoRI, EcoRV, HaeII, HincII, HindIII, HpaI, ScaI, SphI, StuI and XbaI)* and three haplotypes were discriminated in the Northern Hemisphere minke whales. The Sea of Japan and the Sanriku localities shared the same main haplotype (in frequencies of 100% and 83.3%, respectively). The other two haplotypes were represented only in the Sanriku locality. A G-test showed no significant differences between these two localities.

3.1.3 RFLP analysis of mtDNA control region
Goto and Pastene (1997a)

This genetic study used tissue samples (liver, muscle) from both past coastal whaling operations (KCW and JSTW) and from the JARPN. The samples from the JARPN were from an offshore area in the western North Pacific or sub-area 9 taken in two years, 1994 and 1995. The geographic localities examined were: Yellow Sea and southern part of the Sea of Japan or sub-areas 5+6 (n=30), Okhotsk coast of Hokkaido or sub-area 11 (n=173), Pacific coast of Hokkaido or sub-area 7 north (n=51), Sanriku coast or sub-area 7 south (n=102) and an offshore area in the western North Pacific or sub-area 9 (n=121).

Samples from sub-areas 5 and 6 were the same as those used in the allozyme analysis. They were taken in September-October 1982. Samples from sub-area 11 were taken in the period April-September 1983-1987; those from sub-area 7 north in June-September 1983-1987; those from sub-area 7 south in April-August 1983-1987 and those from sub-area 9 in June-September 1994-1995.

Polymorphism in the PCR-amplified mtDNA control region was investigated using eight kind of four-base restriction enzymes. Five of them revealed polymorphic patterns among the total sample (*Afa*I, *Dde*I, *Hae*III, *Hinf*I and *Sau96*I). A total of six polymorphic sites defined eight unique haplotypes among 477 minke whales. The study found a marked segregation of haplotypes between sub-areas 5 and 6 around Korea and the other sub-areas around Japan.

Quantification of the geographical mtDNA sub-division was carried out using an analysis of variation modified for use with pairwise data (Analysis of Molecular Variance, AMOVA). These authors found no significant differences between sexes in the sub-areas, thus, they pooled female and males for the comparison among sub-areas. No significant monthly differences were found in sub-area 7 south nor in sub-area 9. However a significant monthly difference was found in sub-area 11 due to the April samples. Because the April sample (predominantly females) in sub-area 11 presented a relatively high frequency of the main haplotypes of the Korean samples (sub-areas 5 and 6), the authors concluded that whales of at least two stocks are present in April in sub-area 11. No significant differences were found between coastal (sub-area 7) and offshore (sub-area 9) minke whales. It should be noted that apart of sub-area 9, no statistical test for yearly variation was conducted in sub-areas 11 and 7.

Goto and Pastene (1997b)

This mtDNA study was an extension of the RFLP study of Goto and Pastene (1997a). It examined the same localities and samples of Goto and Pastene (1997a) but added into the analysis samples obtained by the JARPN in 1996 in sub-areas 7, 8 and 11. This study added 31 samples from sub-area 7 (obtained between July and September) and 32 (including two biopsies) from sub-area 11 (obtained in August). In addition samples from sub-area 8 (n=16, obtained in July-August), were used.

Biochemical and statistical procedures were the same as in the previous study. Results were the same with two additions: i) minke whales from sub-area 8 were similar to those from sub-areas 11 (excluding April), 7 and 9 and ii) a relatively high proportion of the main haplotypes of the Korean sample was found in the male sample of sub-area 11 taken in August.

Goto and Pastene (1998)

This study was an extension of the two previous RFLP analyses (Goto and Pastene, 1997a;1997b). It included minke whale samples taken by the JARPN in 1997 in sub-areas 7 (n= 2 obtained in June), 8 (n=31 obtained in July) and 9 (n=67 obtained in May-June).

Biochemical and statistical procedure were the same as in the previous two studies. Despite the fact of increasing the sample size in the sub-areas and the temporal covering of the sampling, no significant genetic heterogeneity was detected in minke whales from the Okhotsk coast of Hokkaido (except the April sample) and Pacific side of Japan.

3.1.4 Sequencing of the mtDNA control region
Goto and Pastene (1998)

This study involved tissue samples (liver, muscle) from former KCW in Korea and tissue samples (liver, muscle) of minke whales sampled by the JARPN surveys in 1995 and 1996.

Localities examined were: Yellow Sea and southern part of the Sea of Japan or sub-areas 5 and 6 (n=28 obtained in September-October 1982); Pacific coast of Hokkaido or sub-area 7 north (n=30 obtained in August-September 1996) and an offshore area in the western North Pacific or sub-area 9 (n=95 obtained in June-August 1995).

A segment of 487bp of the PCR-amplified mtDNA control region was sequenced. A total of 25 polymorphic sites defined 41 unique sequences (haplotypes). There was a strong segregation of haplotypes between sub-areas 5-6 and sub-areas 7-9.

Nucleon and nucleotide diversity for sub-area 6 (0.5529 and 0.0046, respectively) were lower than in sub-areas 7 (0.9701 and 0.0088, respectively) and 9 (0.9438 and 0.0076, respectively).

Quantification of the geographical mtDNA sub-division was carried out using AMOVA. Results of this analysis confirmed the striking differences between minke whales from coastal Korean and Pacific side of Japan. No significant differences were found between coastal (sub-area 7) and offshore (sub-area 9) minke whales.

Goto and Pastene (1999)

This sequencing study increased the geographical coverage and sample size regarding the previous sequencing study. Apart the samples from sub-areas 5-6, all samples were from the JARPN surveys as follow: Pacific coast of Hokkaido and Sanriku or sub-area 7 (n=89 obtained in May-September 1996-1998), offshore area in the western North Pacific or sub-area 8 (n=91 obtained in May-August 1996-1998) and offshore area in the western North Pacific or sub-area 9 (n=188 obtained in May-September 1994-1995, 1997). In addition 6 samples from the eastern North Pacific (four from California and two from Alaska) were added into the analysis.

Biochemical and statistical procedures were the same as in the previous sequencing analysis. Nucleon and nucleotide diversity for sub-area 8 was 0.9602 and 0.0083, respectively. For the sample of the eastern North Pacific was 1.0000 and 0.0049, respectively (n=6).

The homogeneity test based on Hst and Kst* showed neither significant yearly variation nor significant monthly variation within sub-areas. Apart of the samples from sub-areas 5-6, no other significant source of temporal or geographic heterogeneity was found. Each of the samples from the eastern North Pacific presented a different haplotypes. However all these haplotypes were represented in the western North Pacific sample.

3.1.5 Nuclear DNA (microsatellites)
Abe *et al.* (1997)

As in the previous genetic studies samples used were from two sources: former coastal whaling operations (KCW and JSTW) and from the JARPN. Localities examined were Yellow Sea and southern part of the Sea of Japan or sub-areas 5+6 (n=26, obtained in September-October 1982), Pacific coast of Hokkaido and Sanriku or sub-area 7 (n=104, obtained in April-August 1983-87, 1996) and an offshore area in the western North Pacific or sub-area 9 (n=98, obtained in June-August 1994-95).

A total of 4 microsatellite loci were used: GT023, GATA028, GATA098, and GATA417. Basically four kinds of statistical analyses were carried out: heterozygosity, probability of identity, Hardy-Weinberg equilibrium and homogeneity test using G-based statistics.

The expected heterozygosity in minke whales from sub-areas 5 and 6 was lower than in the other sub-areas ranging from 0.37 and 0.75 in the former sub-areas and 0.59 and 0.88 in the latter areas. Probability of identity in sub-areas 5 and 6 ranged from 0.084 to 0.409 while in sub-areas 7 and 9 ranged from 0.024 to 0.212. A significant deviation and a close-to-significant deviation from the Hardy-Weinberg equilibrium were observed in sub-areas 7 and 9, respectively.

The G-test based homogeneity test showed significant differences between sub-areas 5+6 and sub-areas 7 and 9. No significant differences were observed between sub-areas 7 and 9.

Abe *et al.* (1998)

This study was a extension of the previous microsatellite study. The sample sizes were increased in sub-areas 7 and 9 as well the number of loci (from four to six). In sub-area 7 a total of 184-206 samples were analyzed (taken in April-September 1983-87, 1996) while in sub-area 9 the sample size was 177-188 (taken in May-September 1994-95, 1997). In addition to the four loci used in the previous study, two new loci were added in this study, EV1Pm and EV37Mn.

By increasing the sample size, there was not significant deviation from the Hardy-Weinberg equilibrium in sub-area 9 but in sub-area 7 the significant deviation remained. Results of the homogeneity test were the same as in the previous study.

3.1.6 Nuclear DNA (RAPD)
Martinez and Pastene (1998)

This RAPD study involved samples from the North Atlantic and North Pacific. Regarding the North Pacific, samples were from the JARPN survey in 1996: sub-areas 7 (n=21 taken in July-September), 8 (n=16 taken in July-August) and 11 (n=20 taken in August).

Nine primers generated 20 RAPD-markers. The matrix of absence/presence of the markers was applied to principal component analysis (PCA) and to analysis of AMOVA. Minke whales from sub-areas 7, 8 and 11 did not form separated clusters and no significant differences among sub-areas were found using AMOVA.

3.2 Morphology and morphometry

Table 2 shows a summary of the main morphological and morphometric studies conducted to investigate stock identity in the North Pacific minke whales. For a better understanding, the geographic localities indicated in the table make reference to the sub-areas shown in Fig. 1. In this section we explain in further details each of these studies regarding the sampling, analyses and main results.

Omura and Sakiura (1956)

Among several biological items, these authors examined the length distributions in the catches from six Japanese whaling grounds for the period 1948-1954: west coast of Kyushu or sub-area 6 south (n=316 taken in January-September), Wakasa Bay or sub-area 6 north (n=339 taken in February-July), Sea of Japan coast of Hokkaido or sub-area 10 (n=105 taken in March-October), Okhotsk coast of Hokkaido or sub-area 11 (n=632 taken in April-October), Pacific coast of Hokkaido or sub-area 7 north (n=124 taken in June-October) and Sanriku coast or sub-area 7 south (n=741 taken in January-July). They concluded that whales from the south whaling grounds are smaller than those from the north. This is a similar result to that obtained by Matsuura (1936).

Ohsumi (1983)

This author also examined length distribution in the catches. He used samples from the JSTW operation in 1981 in four localities: Okhotsk coast of Hokkaido or sub-area 11 (n=92 taken in April-September), Pacific coast of Hokkaido or sub-area 7 north (n=49 taken in July-September), Sanriku coast or sub-area 7 south (n=218 taken in April-July) and Sea of Japan coast of Hokkaido or sub-area 10 (n=15 taken in July-August).

He found that the size distribution pattern of minke whales in different whaling ground differs, but he associated these differences to variation in segregation and migration routes by region. For example smaller, younger animals are found in lower latitudinal waters (Sanriku coast) whereas most of the animals in the north (Okhostk coast of Hokkaido) are larger and older. This explain in part the results by Matsuura (1936) and Omura and Sakiura (1956) who suggested that whales in the southern whaling grounds, e.g. Sanriku coast, are smaller than in the north.

However, he suggested that differences in sizes between Sea of Japan coast of Hokkaido animals and those from the other localities could be due to stock differences. His argument was that the modal lengths of the larger part of the size distributions of males and females in the Sea of Japan appear different to those of the other localities and that the maximum body length in the Sea of Japan is shorter than in the other localities. He concluded that whales from the Sea of Japan are from a different stock.

Kato *et al.* (1992)

These authors conducted a discriminant analysis on body proportion measurements as well an analysis of the coloration of flippers and largest baleen plate.

Localities examined were from both Sea of Japan and Pacific sides of Japan as follow: Sanriku coast or sub-area 7 south between 38-39°N, north Okhotsk Sea or sub-area 12 north between 56-58°N, and south Okhotsk Sea between 44-49°N or sub-areas 12 south and 11, Japan Sea or sub-areas 6 and 10 between 38-40°N, 43-45°N and eastern Hokkaido or sub-areas 7, 8 between 42-44°N.

Most of the data collected from Sanriku were from the JSTW in 1987. The rest of the data were collected from a factory-catcher boat between 1973 and 1975. Some of the body proportion data in southern Okhotsk Sea (21 individuals) and in Sanriku (two individuals) were from a previous study (Omura and Sakiura, 1956).

The number of animals with body proportion measurements for Sanriku (sub-area 7 south), north Okhotsk Sea (sub-area 12 north), southern Okhotsk Sea (sub-areas 12 south and 11) and Sea of Japan (sub-areas 6 and 10) was 34, 20, 30 and 17, respectively. No body proportion data was available for eastern Hokkaido (sub- areas 7 and 8). The discriminant analysis was restricted to three variables: total length, tip of snout to center of blowhole and notch of tail flukes to anus. The analysis was carried out for males only with sample size of 9, 12, 9 and 14 for these localities, respectively.

The number of samples examined for baleen plate and flipper coloration was 34,34; 11,43; 41,96; 47,73 and 61,63 for Sanriku, eastern Hokkaido, north Okhotsk Sea, south Okhotsk Sea and Sea of Japan, respectively.

Discriminant analysis on external body proportions suggested that 66.7% of the samples from the Okhotsk Sea belong to the 'Pacific' group and the rest to the 'Sea of Japan' group. However, the authors suggested that the reliability of this result is uncertain due to three factors: low percentages of correct classification, small sample size and insufficient number of measurement variables.

The analysis of baleen plate coloration was inconclusive, however, the authors concluded that the flipper coloration is a more useful character for stock separation. They found that an unusual pattern with an obscure white band was relatively frequent in the Sea of Japan (28.6% of samples) and was also observed in early summer in the southern Okhostk Sea (2.8%).

Kato (1992)

Among several biological analyses, this author examined length distribution in the catches from four whaling grounds of the JSTW for the period April-September, 1977-1987. The localities examined were: Sanriku or sub-area 7 south (n=1,424), Pacific coast of Hokkaido or sub-area 7 north (n=1,265), Okhostk coast of Hokkaido or sub-area 11 (n=921) and Sea of Japan coast of Hokkaido or sub-area 10 (n=81).

Results of his analysis confirmed previous reports that the mean length of animals from Sanriku (sub-area 7 south) is smaller than for the other grounds. A same pattern was observed for the minimum length. The author found no differences in either the mean or minimum lengths among the remaining whaling grounds, including that from the Sea of Japan.

Fujise and Kato (1995)

These authors carried out a discriminant analysis of body proportion measurements using samples from an offshore locality in the western North Pacific or sub-area 9 (n=21) and compared these samples with those examined in a previous study by Kato *et al.* (1992). Samples from sub-area 9 were from the JARPN survey taken between July and September 1994.

A total of 39 measurements of body proportion were made but the discriminant analysis was restricted to only 20 of them. They found that whales from the offshore locality (sub-area 9) were similar in these morphometric characteristics to those from coastal Japan (sub-area 7). However, the authors considered these results as preliminary due to the small sample size in the offshore locality.

Fujise and Kato (1996)

These authors presented an extension of the previous morphometric study by examining additional samples from offshore sub-area 9 available from JARPN surveys in 1994 and 1995. They compared these samples with those examined by Kato *et al.* (1992). The sample size from sub-area 9 was 121. These whales were sampled between June and September.

The discriminant analysis of body proportion was based on 18 measurement points. Even by analyzing a larger sample size the authors did not find any substantial differences in body proportion between offshore (sub-area 9) and inshore (sub-area 7) minke whales.

In addition they compared flipper coloration pattern following the criteria used by Kato *et al.* (1992). They found that most of the whales from sub-area 9 presented a similar pattern of coloration than whales from the pacific coast of Japan.

3.3 Other approaches

3.3.1 Analysis of tagging data
To our knowledge no tagging experiments have been conducted in the North Pacific minke whales.

3.3.2 Pollutant burden
Fujise (1995) examined levels of accumulation of heavy metals (Cd and Hg) and organochlorines (PCB's and DDT's) in minke whales from two localities, Sanriku coast or sub-area 7 south and an offshore locality in the western North Pacific or sub-area 9.

Samples from sub-area 7 south were from the JSTW operation in 1987. Samples from sub-area 9 were from the 1994 JARPN survey in that sub-area. The heavy metal analysis was conducted separately for males and females. For male

23 liver tissues and 20 kidney tissues were examined from sub-area 7; 10 liver and kidney tissues were examined from sub-area 9. For female 15 liver tissues and 12 kidney tissues were examined from sub-area 7 while from sub-area 9 two liver and two kidney tissues were examined.

Regarding organochlorine only male samples were examined, 10 blubber tissues from each sub-areas 7 and 9.

Level of concentration of Cd, Hg and PCB were higher in the offshore sub-area. No significant differences were observed in level of accumulation of DDE. The authors explained such differences on the basis of the age and body size-related accumulation characteristics of these pollutants. Larger whales occur in sub-area 9 while smaller whales distribute in sub-area 7.

Fujise (1996) conducted an analysis of heavy metals (Cd and Hg) using minke whale samples from the same sub-areas examined in the previous study. The number of samples available from sub-area 7 was 38 (23 males and 15 females) while that from sub-area 9 was 121 (109 males and 12 females). Three internal tissues were used in the analysis: muscle, liver and kidney.

As in the previous study the author found higher level of concentrations in the offshore sub-area 9, which was explained again by the body length-related accumulation nature of these pollutants. Larger individuals distribute in the offshore sub-area.

3.3.3 Ecological markers (parasites)

Kuramochi *et al.* (1996) examined the occurrence of nematode *Anisakis simplex* in four cetacean species (minke whales, Dall's porpoise, Pacific white-sided dolphin and northern right whale dolphin). Minke whales examined were 21 samples obtained during the 1994 JARPN survey in offshore sub-area 9. This study showed that the mean intensity of infection of this parasite and the abundance of adults were clearly higher in minke whales than in small cetaceans. No comparative analysis among regional areas was made on the infection rate of this nematode.

Araki *et al.* (1997) conducted a more stock identity-oriented analysis of parasite fauna occurrence in the minke whale. They examined 100 whales sampled by the JARPN survey in sub-area 9 in 1995. They found a total of eight ecto and endoparasites and their prevalence in different tissues were given. Furthermore two species of epizoits were reported. The incidence of these parasites in whales from sub-area 9 was compared with the incidence in coastal whales given in the literature.

Regarding two parasites, *Bolbosoma nipponicum* and *Anisakis simplex* they suggested that both of these species heavily infect minke whales in both coastal and offshore waters of the western North Pacific. A similar situation was suggested for two cestode *Diphyllobothrium macroovatum* and *Diplogonoporus balaenopterae*. They finally concluded that information on the other parasite species is fragmentary and that more research was need especially for coastal minke whales.

3.3.4 Conception dates

Conception date can be estimated by analysis of body sizes of fetus and date of sampling if information on conception period and body length at birth is available. Omura and Sakiura (1956) were the first authors to use this approach to study minke whales from the eastern side of Japan and from the Sea of Japan side. Materials examined were 111 fetus sampled during operations of the JSTW between 1948 and 1954. They plotted the fetus length against their dates. Most of the fetuses were confined to the period March-July. Furthermore they found two groups of fetuses one smaller (A) and the other bigger (B), being group A the predominant. Considering that the birth takes place at 280cm of body length, the growth curve for the smaller group (A) indicated that birth would take place in December and then conception should occur at the end of February or beginning of March in this group considering a conception period of about 10 months.

The growth curve for the bigger group (B) drew parallel to the curve of the smaller group with an interval of six months. Following the same criteria, conception and parturition would take place at about August-September and June-July, respectively. They found representatives of both groups on Sea of Japan and Pacific sides of Japan indicating that the two groups were not completely separated geographically in this area.

Kato (1992) and Best and Kato (1992) showed a similar phenomenon in the southern Okhotsk Sea, where two apparent peaks of conception were seen, one in January-March (equivalent to Group A of the previous study) and one in October-November (equivalent to group B of the previous study). The former group was predominant. They interpreted these results as a mixing of two stocks with different conception periods in the southern Okhotsk Sea in summer. Their analysis, however, did not take into account seasonality.

Fujise *et al.* (1996) used this approach to examine seven fetuses sampled in offshore sub-area 9 in 1994 and 1995. They concluded that they belong to the Group A of the study indicated above.

3.3.5 Photo-identification

To our knowledge the only photo-id studies on North Pacific minke whales is that of Dorsey *et al.* (1990). They reported three features useful for identifying individuals in this species: dorsal fin, small oval scars and lateral body pigmentation. These characters were constant over the time or changed slowly enough to allow re-identification spanning up to 11 years. The study was concentrated in three localities of the eastern North Pacific: Monterey Bay in central California, San Juan Islands in northern Washington and Johnstone Strait area of northern Vancouver Island, British Columbia. A total of 55 individuals were recognized on 444 occasions in these localities and 31 individuals were seen in two or more years. No individual was seen in more than one locality and many individuals were seen year after year in the same locality suggesting some degree of site specificity.

3.3.6 Survey distributions

According to our knowledge there is no study using sighting distribution pattern to investigate stock identity.

3.3.7 Catch distributions

Omura and Sakiura (1956) examined the occurrence and migration of minke whales on the basis of the distribution (temporal and geographical) of catches in six whaling grounds in Japan: west Kyushu (sub-area 6 south, Wakasa Bay (sub-area 6 north) Sea of Japan coast of Hokkaido (sub-area 10) in the Sea of Japan; Okhotsk coast of Hokkaido (sub-area 11) in the Okhotsk Sea; Sanriku coast (sub-area 7 south) and Pacific coast of Hokkaido (sub-area 7 north) in the Pacific side of Japan. Catch reports from 1948 and 1954 were examined. In addition they used information on length distribution and sex ratio in the catches. They concluded that there are two stocks in the waters around Japan, one distributed in the Sea of Japan and the other in the Pacific side of Japan. The Sea of Japan stock migrate to the north in the spring in the order of sub-area 6 south, sub-area 6 north and sub-area 10, entering into Okhotsk coast of Hokkaido (sub-area 11) and staying there in summer. The Pacific stock comes to Sanriku coast (sub-area 7 south) early in spring staying there in that season and moving into the Pacific coast of Hokkaido (sub-area 7 north) later.

Ohsumi (1983) examined the trend in CPUE in three Japanese whaling grounds for the period 1977-1981. The whaling grounds examined were the Okhotsk coast of Hokkaido (sub-area 11), the Pacific side of Hokkaido (sub-area 7 north) and the Sanriku coast (sub-area 7 south). All but sub-area 7 north showed a constant trend in CPUE. Furthermore by a combination analysis of location of whaling grounds, period of whaling and length distribution of the catches he supported the previous view of two separated stocks to the east and west of Japan. In contrast with the opinion of Omura and Sakiura (1956) he suggested that whales in the Okhotsk coast of Hokkaido were closer to whales of the Pacific side of Japan.

4. HISTORICAL CONCLUSIONS ON STOCK IDENTITY OF THE SPECIES IN THE WESTERN NORTH PACIFIC

Results of different studies strongly support the view that two genetic stocks occurs in the western North Pacific: one in the Yellow Sea, East China Sea and Sea of Japan (J-stock) and the other in the Pacific side of Japan and the Okhotsk Sea (O-stock) with a spatial/temporal mixing of stocks in the southern part of the Okhotsk Sea in April and August. No evidence for additional stock structure in the western North Pacific (from the Japanese coast to 170°E) has been found.

As mentioned earlier Omura and Sakiura (1956) on the basis of an examination of length distributions in the catches and the timing of occurrence of whales off the coast of Japan, were the first to conclude that there were two stocks off Japan, one to the east and one to the west off Honshu.

Based on the evidence presented by Omura and Sakiura (1956) and Ohsumi (1977) the IWC Scientific Committee noted in 1976 the possibility of two stocks off Japan, to the east and west of Japan (IWC, 1977). In 1977 the Committee recognized two exploited stocks in the North Pacific: the Okhotsk Sea/West Pacific stock and the Sea of

Japan stock (IWC, 1978). Based on Ohsumi (1983), who reviewed the non-genetic evidence for the boundaries such as location of whaling grounds, differences in length distributions, temporal/spatial differences in migration, the Committee in 1982 recognized the occurrence of two stocks: the Yellow Sea/East China Sea/Sea of Japan stock and the Okhotsk Sea/West Pacific stock. A division at 180° was established separating the Okhotsk Sea/West Pacific stock from a 'Remainder' stock (IWC, 1983) (Fig. 3).

The next time the SC examined in detail the issue of stock identity was during the comprehensive assessment (CA) of the species in 1991 (IWC, 1992). During the CA new evidence derived from genetics and morphometric studies mainly, confirmed the previous view of two stocks in the western North Pacific and a possible mixing of stocks in the Okhotsk coast of Hokkaido (sub-area 11) in part of the year.

The issue of stock identity in the North Pacific minke whale was discussed again at the 1993 Committee meeting. In that meeting a Working Group on North Pacific Minke Whale Trials in Preparation for Implementation of RMP recognized the two stocks defined by the Committee in 1982, the Okhotsk Sea/Western Pacific and the Yellow Sea/East China Sea/ Sea of Japan stocks, which the Group called the 'O' and 'J' stocks, respectively. In that opportunity the Group created a complicated sub-stock scenario with several sub-stocks composing the 'J' and 'O' stocks and hypothesizing a western stock ('W' stocks) in offshore areas of the western North Pacific (Fig. 1) (IWC, 1994).

It should be noted that until the 1993 meeting all the analyses on stock identity were based on samples and data derived from coastal whaling operations in Japan and Korea and then these analyses were restricted to the coastal areas of these countries. In 1994 and 1995 the JARPN survey covered an offshore area in the western North Pacific (sub-area 9) and then the geographical coverage of different analyses on stock identity was extended to compare coastal and offshore minke whales.

The issue of stock identity was discussed again by the Committee in 1996. During that meeting a Working Group on North Pacific Minke Whale Trials discussed the new information on stock identity derived mainly from the analysis of sample and data of the JARPN surveys. The Group concluded that there was not scientific background supporting the sub-stock scenario, however, no consensus was reached in the Group on whether additional stock structure occur in offshore areas of the western North Pacific (e.g. 'W' stock) (IWC, 1997).

Regarding mixing, DNA data have been used recently to estimated the mixing rate of J and O stocks in the Okhotsk coast of Hokkaido (sub-area 11). Butterworth *et al.* (1996) used mtDNA RFLP haplotype frequency data of Goto and Pastene (1997a) to estimate the mixing proportion of 'J' stock in sub-area 11 in April. They estimated that proportion in 0.42 with associated 95% confidence interval (0.27, 0.57). Subsequently Pastene *et al.* (1998) using mtDNA RFLP haplotype data estimated the proportion of J stock female animals in the April sample in sub-area 11 in 0.4075 (SE=0.0806) and that of male animals in August in 0.3147 (SE=0.1160).

5. ACKNOWLEDGEMENTS

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Legends for Figures

Fig. 1: Sub-areas adopted by the Working Group on North Pacific Minke Whale Management Trials in Preparation for Implementation of RMP in 1993 (After IWC, 1994). *[IWC44:122]*

Fig. 2: Possible feeding migration routes of Okhotsk Sea-West Pacific Stock of minke whale (after Hatanaka and Miyashita, 1997). *[IWC47:562]*

Fig. 3: Stock boundaries for the North Pacific minke whale adopted by the IWC in 1982 (IWC, 1983). *[After RIWC 33:98]*

Table1: Summary of the main genetic analyses conducted on the North Pacific minke whale to investigate intra-specific structure.
Key: sa=sub areas shown in Fig.1; KCW=Korean Coastal Whaling; JSTW=Japanese Small Type Whaling; JARPN=Japanese Whale Research Program under Special Permit in the North Pacific; SWFSC=Southwest Fisheries Science Center; RE=restriction enzymes; SE=length of sequence segment; it=internal tissue; b=biopsy; st=stranding
H-W=Hardy-Weinberg

Gen.marker / Authors	Geographic Locality	Period of Sampling	n	Sample Source	Number of Loci/RE/SE	Statistical Analysis	Main Results
Allozyme							
Wada (1984)	Yellow Sea (sa 5)	Sept.-Oct. 1982	3	KCW(it)	15 loci	H-W test	sa 5,6 ≠ sa 11,7
	Southern Sea of Japan (sa 6)	Sept.-Oct. 1982	42	JSTW(it)	(5 polymorphic)	Homogeneity test	
	Okhotsk coast of Hokkaido (sa 11)	Apr.-Sept. 1981-82	68	JSTW(it)		(G-test)	
	Pacific coast of Hokkaido (sa 7N)	Apr.-Sept. 1981-82	40	JSTW(it)			
	Sanriku coast (sa 7S)	Apr.-Sept. 1981-82	128	JSTW(it)			
Wada and Numachi (1991)	Yellow Sea (sa 5)	Sept.-Oct. 1982	46	KCW(it)	45 loci	H-W test	sa 5,6 ≠ sa 11,7
	Southern Sea of Japan (sa 6)	Sept.-Oct. 1982		KCW(it)	(11 polymorphic)	Homogeneity test	
	Okhotsk coast of Hokkaido (sa 11)	Apr.-Sept. 1980-83		JSTW(it)		(G-test)	
	Pacific coast of Hokkaido (sa 7N)	Apr.-Sept. 1980-83	416	JSTW(it)			
	Sanriku coast (sa 7S)	Apr.-Sept. 1980-83		JSTW(it)			
Wada (1991)	Yellow Sea (sa 5)	Sept.-Oct. 1982	45	KCW(it)	3 polymorphic	H-W test	Departure from
	Southern Sea of Japan (sa 6)	Sept.-Oct. 1982		KCW(it)	loci	Homogeneity test	H-W equilibrium
	Okhotsk coast of Hokkaido (sa 11)	Apr.-Sept. 1980-87	310	JSTW(it)		(G-test)	in April in sa 11
	Pacific coast of Hokkaido (sa 7N)	Apr.-Sept. 1980-87	285	JSTW(it)			
	Sanriku coast (sa 7S)	Apr.-Jul. 1980-87	391	JSTW(it)			
	Sea of Japan coast of Hokkaido (sa 10)	Jun.,Aug.-Sept. 1980-87	18	JSTW(it)			
Wada (1995,1996)	Yellow Sea (sa 5)	Sept.-Oct. 1982	45	KCW(it)	3 polymorphic	H-W test	sa 11 = sa 7 = sa 9
	Southern Sea of Japan (sa 6)	Sept.-Oct. 1982		KCW(it)	loci	Homogeneity test	sa 9 ≠ sa 5,6
	Okhotsk coast of Hokkaido (sa 11)	Apr.-Sept. 1980-87	310	JSTW(it)		(G-test)	
	Pacific coast of Hokkaido (sa 7N)	Apr.-Sept. 1980-87	285	JSTW(it)			
	Sanriku coast (sa 7S)	Apr.-Jul. 1980-87	391	JSTW(it)			
	Western North Pacific Offshore 9 (sa 9)	Jun.-Sept. 1994-95	121	JARPN (it)			
RFLP Whole mtDNA							
Wada *et al*. (1991)	Southern Sea of Japan (sa 6)	Sept.-Oct. 1982	32	KCW(it)	14 restriction	Homogeneity test	sa 6 = sa 7
	Sanriku coast (sa 7S)	Apr.-Sept. 1986-87	30	JSTW(it)	enzymes	(G-test)	
					(2 polymorphic)		

Table1: cont.

Gen.marker / Authors	Geographic Locality	Period of Sampling	n	Sample Source	Number of Loci/RE/SE	Statistical Analysis	Main Results
RFLP mtDNA Control Region							
Goto and Pastene (1997a)	Southern Sea of Japan + Yellow Sea (sa 5 + sa 6)	Sept.-Oct. 1982	30	KCW(it)	8 restriction	Homogeneity test	sa 7 = sa 11 = sa 9
	Okhotsk coast of Hokkaido (sa 11)	Apr.-Sept. 1983-87	173	JSTW(it)	enzymes	(AMOVA / PHI-st)	sa 5,6 ≠ sa 7,11,9
	Pacific coast of Hokkaido (sa 7N)	Jun.-Sept. 1983-87	51	JSTW(it)	(5 polymorphic)		Significant monthly
	Sanriku coast (sa 7S)	Apr.-Aug. 1983-87	102	JSTW(it)			differences in sa 11
	Western North Pacific Offshore 9 (sa 9)	Jun.-Sept. 1994-95	121	JARPN (it)			due to April
Goto and Pastene (1997b)	Southern Sea of Japan + Yellow Sea (sa 5 + sa 6)	Sept.-Oct. 1982	30	KCW(it)	8 restriction	Homogeneity test	sa 8 = sa 7 = sa 9
	Okhotsk coast of Hokkaido (sa 11)	Apr.-Sept. 1983-87,1996	205	JSTW(it),JARPN(it,b)	enzymes	(AMOVA / PHI-st)	= sa 11(excluding April)
	Pacific coast of Hokkaido+Sanriku (sa 7)	Apr. Sept. 1983-87,1996	184	JSTW(it),JARPN(it,b)	(5 polymorphic)		≠ sa 5,6
	Western North Pacific Offshore 8 (sa 8)	Jul.-Aug. 1996	16	JARPN(it)			
	Western North Pacific Offshore 9 (sa 9)	Jun.-Sept. 1994-95	121	JARPN(it)			
Goto and Pastene (1998)	Southern Sea of Japan + Yellow Sea (sa 5 + sa 6)	Sept.-Oct. 1982	30	KCW(it)	8 restriction	Homogeneity test	sa 8 = sa 11
	Okhotsk coast of Hokkaido (sa 11)	Apr.-Sept. 1983-87,1996	205	JSTW(it),JARPN(it,b)	enzymes	(AMOVA / PHI-st)	(excluding April)
	Pacific coast of Hokkaido+Sanriku (sa 7)	Apr.-Sept. 1983-87,1996,1997	186	JSTW(it),JARPN(it)	(5 polymorphic)		= sa 7 = sa 9
	Western North Pacific Offshore 8 (sa 8)	Jul.-Aug. 1996,1997	47	JARPN(it)			sa 8 ≠ sa 5,6
	Western North Pacific Offshore 9 (sa 9)	May-Sept. 1994-95,1997	188	JARPN(it)			
Sequencing mtDNA Control Region							
Goto and Pastene (1998)	Southern Sea of Japan + Yellow Sea (sa 5 + sa 6)	Sept.-Oct. 1982	28	KCW(it)	487 bp-segment	Nucleon diversity	sa 6 ≠ sa 7,9
	Pacific coast of Hokkaido (sa 7N)	Aug.-Sept. 1996	30	JARPN(it)	(25 polymorphic sites)	Nucleotide diversity	sa 7 = sa 9
	Western North Pacific Offshore 9 (sa 9)	Jun.-Aug. 1995	95	JARPN(it)		Homogeneity test	
						(AMOVA / PHI-st)	
Goto and Pastene (1999)	Southern Sea of Japan + Yellow Sea (sa 5 + sa 6)	Sept.-Oct. 1982	28	KCW(it)	487 bp-segment	Nucleon diversity	sa 6 ≠ sa 7,8,9
	Pacific coast of Hokkaido (sa 7)	May-Sept. 1996-98	89	JARPN(it)	(32 polymorphic sites)	Nucleotide diversity	sa 7 = sa 8 = sa 9
	Western North Pacific Offshore 8 (sa 8)	May- Aug. 1996-98	91	JARPN(it)		Homogeneity test	
	Western North Pacific Offshore 9 (sa 9)	May- Sept. 1996-98	188	JARPN(it)		(Hst,Kst*)	
	Eastern North Pacific:	-	6	SWFSC(b,st)			

Table1: cont.

Gen.marker / Authors	Geographic Locality	Period of Sampling	n	Sample Source	Number of Loci/RE/SE	Statistical Analysis	Main Results
NUCLEAR DNA (Microsatellite)							
Abe *et al*. (1997)	Southern Sea of Japan + Yellow Sea (sa 5 + sa 6) Pacific coast of Hokkaido+Sanriku (sa 7) Western North Pacific Offshore 9 (sa 9)	Sept.-Oct. 1982 Apr.-Aug. 1983-87,1996 Jun.-Aug. 1994-95	26 104 98	KCW(it) JSTW(it),JARPN(it) JARPN(it)	4 loci (all polymorphic)	Heterozygosity Probability identity H-W test (chi-square) Homogeneity test (G-based test) Weir's θ	Departure from H-W equilibrium in sa 7 sa 6 ≠ sa 7,9 sa 7 = sa 9
Abe *et al*. (1998)	Southern Sea of Japan + Yellow Sea (sa 5 + sa 6) Pacific coast of Hokkaido+Sanriku (sa 7) Western North Pacific Offshore 9 (sa 9)	Sept.-Oct. 1982 Apr.-Sept. 1983-87,1996 May-Sept. 1994-95,1997	26-28 184-206 177-188	KCW(it) JSTW(it),JARPN(it) JARPN(it)	6 loci (all polymorphic)	H-W test (chi-square) Homogeneity test (G-based test)	Departure from H-W equilibrium in sa 7 sa 6 ≠ sa 7,9 sa 7 = sa 9
NUCLEAR DNA RAPD							
Martinez and Pastene (1998)	Pacific coast of Hokkaido+Sanriku (sa 7) Western North Pacific Offshore 8 (sa 8) Okhotsk coast of Hokkaido (sa 11)	Jul.-Sept. 1996 Jul.-Aug. 1996 August 1996	21 16 20	JARPN(it) JARPN(it) JARPN(it)	9 primers (20 RAPD markers)	Principal component analysis Homogeneity test (AMOVA)	sa 7 = sa 8 = sa 11

Note: A symbol '=' in column 'main results' means that no significant statistical differences were found between sub-areas.
A symbol "≠" means that significant statistically differences were found between sub-areas.

Table 2: Summary of the main morphological and morphrometric analyses conducted on the North Pacific minke whale to investigate intra-specific structure.
Key: sa=sub-areas shown in Fig.1; JSTW=Japanese Small Type Whaling; JFC=Japanese Factory Catcher; JARPN=Japanese Whale Research Program under Special Permit in the North Pacific.

Author	Geographic Locality	Period of Sampling	n	Sample Source	Character Examined	Main Results
Omura and Sakiura (1956)	West Kyushu (sa 6S)	Jan.-Sept. 1948-54	316	JSTW	Length distribution in catches	Whales in south whaling grounds smaller than in the north.
	Wakasa Bay (sa 6N)	Feb.-Jul. 1948-54	339	JSTW		
	Sea of Japan coast of Hokkaido (sa 10)	Mar.-Oct. 1948-54	105	JSTW		
	Okhotsk coast of Hokkaido (sa 11)	Apr.-Oct. 1948-54	632	JSTW		
	Pacific coast of Hokkaido (sa 7N)	Jun.-Oct. 1948-54	124	JSTW		
	Sanriku coast (sa 7S)	Jan.-Jul. 1948-54	741	JSTW		
Ohsumi (1983)	Okhotsk coast of Hokkaido (sa 11)	Apr.-Sept. 1981	92	JSTW	Length distribution in catches	Whales in sa 10 smaller than in sa 7,11
	Pacific coast of Hokkaido (sa 7N)	Jul.-Sept. 1981	49	JSTW		
	Sanriku coast (sa 7S)	Apr.-Jul. 1981	218	JSTW		
	Sea of Japan coast of Hokkaido (sa 10)	Jul.-Aug. 1981	15	JSTW		
Kato *et al*. (1992)	Sanriku coast (sa 7S) *	1987	9,34,34**	JSTW	Body proportion	Flipper coloration pattern different between Sea of Japan and Pacific side of Japan minkes
	North Okhotsk Sea (sa 12N)	1973-75	12,41,96	JFC		
	South Okhotsk Sea (sa 12S,11) *	1973-75	9,47,73	JFC	Coloration of flipper/ largest baleen plate	
	Sea of Japan (sa 6,10)	1973-75	14,61,63	JFC		
	Eastern Hokkaido (sa 7,8)	1973-75	-,11,43	JFC		
Kato (1992)	Sanriku coast (sa 7S)	Apr.-Sept. 1977-87	1,424	JSTW	Length distribution in catches	Whale from Sanriku smaller than in the other two localities
	Pacific coast of Hokkaido (sa 7N)	Apr.-Sept. 1977-87	1,265	JSTW		
	Okhotsk coast of Hokkaido (sa 11)	Apr.-Sept. 1977-87	921	JSTW		
Fujise and Kato (1995)	Western North Pacific Offshore 9 (sa 9)	Jul.-Sept. 1994	21	JARPN	Body proportion	sa 7 = sa 9
	Other localities same as in Kato *et al*. (1992)	-	-			
Fujise and Kato (1996)	Western North Pacific Offshore 9 (sa 9)	Jun-Aug.1994-95	121	JARPN	Body proportion Coloration of flipper	sa 7 = sa 9
	Other localities same as in Kato *et al*. (1992)	-	-			

* Some samples are from Omura and Sakiura (1956)
** Refers to sample size for analysis of body proportion, coloration of baleen plate and coloration of flipper, respectively
Note: A symbol '=' in column 'main results' means that no significant statistical differences were found between sub-areas.

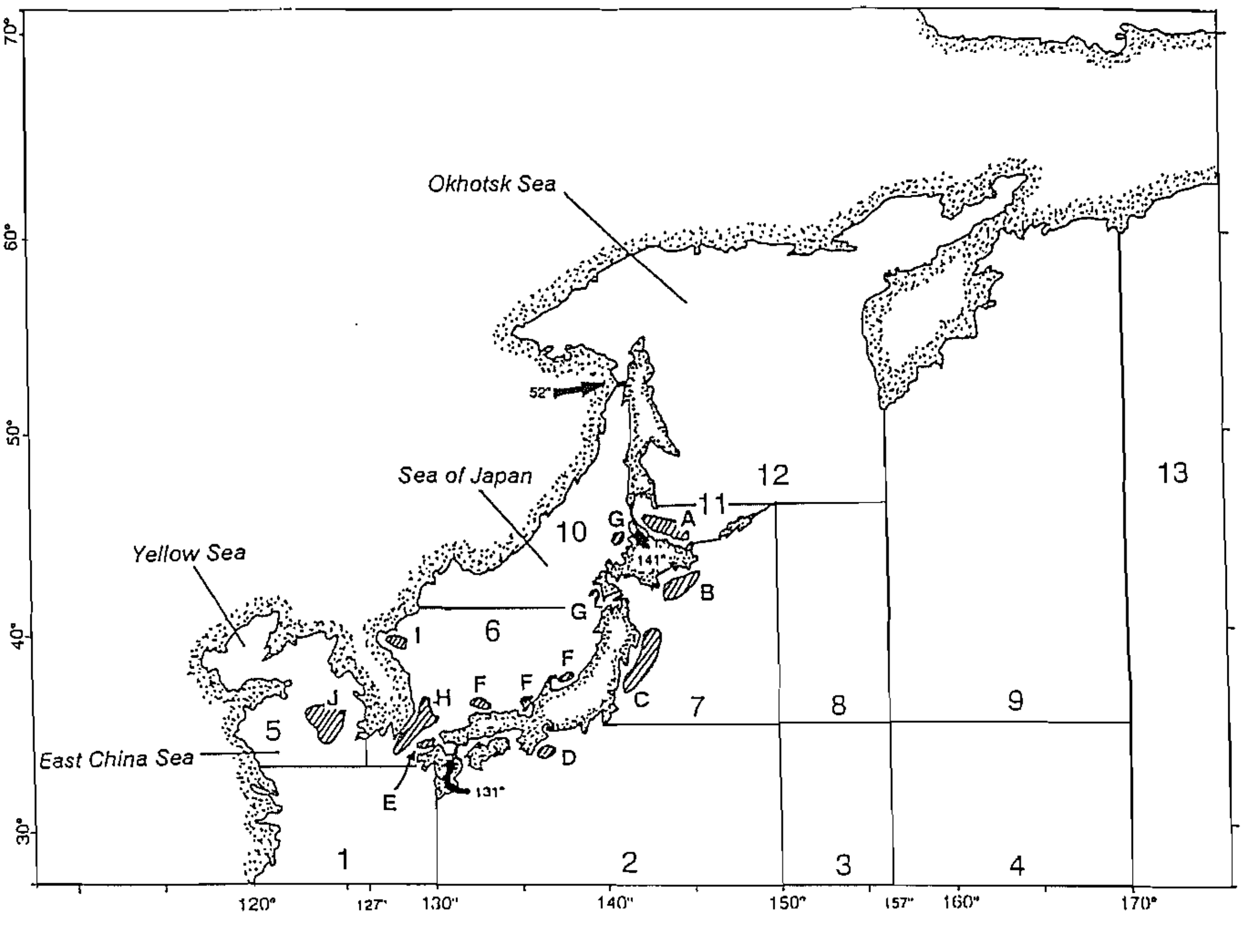

Fig. 1: Sub-areas adopted by the Working Group on North Pacific Minke Whale Management Trials in Preparation for Implementation of RMP in 1993 (After IWC, 1994).

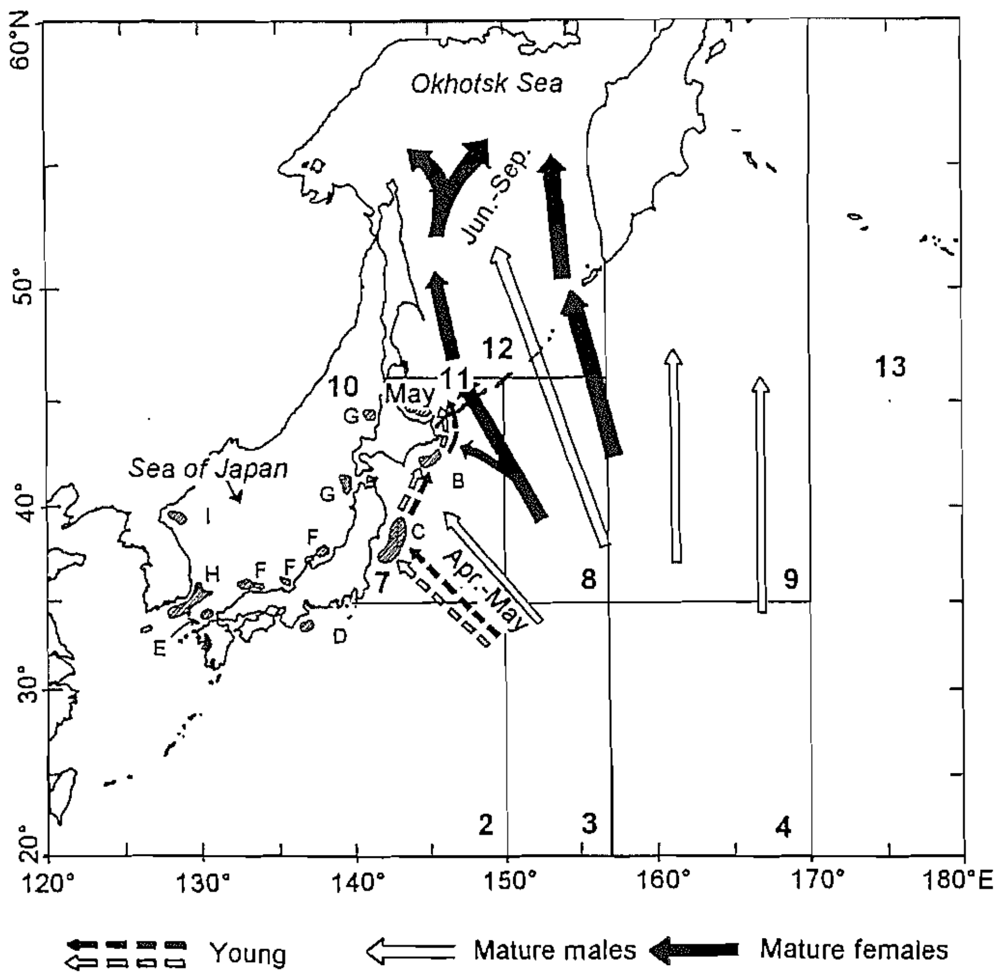

Fig. 2: Possible feeding migration routes of Okhotsk Sea-West Pacific Stock of minke whale (after Hatanaka and Miyashita, 1997).

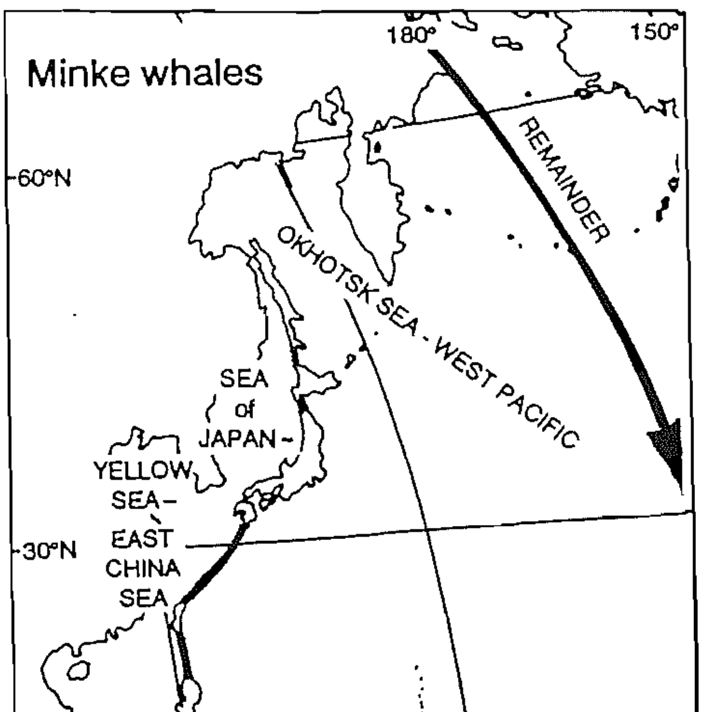

Fig. 3: Stock boundaries for the North Pacific minke whale adopted by the IWC in 1982 (IWC, 1983).

Addendum to Document SC/F2K/J1 (Review of the studies on stock identity in the minke whale *Balaenoptera acutorostrata* from the North Pacific by Pastene *et al.*)

Sections 4 of Document SC/F2K/J1 deal with the historical conclusions on stock identity of the minke whale in the western North Pacific. In this section we summarized the discussions on the different hypotheses on stock structure of this species in the North Pacific, discussed at the IWC Scientific Committee.

We have considered useful emphasize on the most recent discussion of the SC on this matter. The most recent evaluation of the SC in respect of evidence on the O-W and sub-stock hypotheses is reflected in sections 7.3, 7.3.1 and 7.3.2 of the Report of the Working Group on North Pacific Minke Whale Trials (RIWC 47:208-210). These sections are reproduced below for readers' convenience.

'7.3 Implications of new information

The implications of the above new information for structuring implementation trials were considered overall, in terms of the hypothesised three stocks and the hypothesised sub-stocks of each of these possible stocks.

The Group agreed that the new data, in conjunction with that reported previously, confirmed the distinction between the J and O stocks. Furthermore, the Group agreed that these data were compatible with a hypothesis of only one stock in sub-areas 7, 8, 9, 11 and 12 (with allowances for some J stock animals in sub-areas 7, 11 and 12 seasonally). The Group also agreed that these data were generally inconsistent with there being sub-stocks characterised by different levels of latitudinal migration. However, there were differences in the weight to be given to the different datasets, with the Group agreeing that the genetic, conception date and length and sex distribution data were the more informative about this question.

Furthermore, it was noted that the statistical power of the available data to distinguish among various hypotheses had not generally been calculated. However, it was noted that the power of the genetics data would necessarily be low for distinguishing a single stock from the alternative of two stocks with low rates of dispersal between them. Similarly, while the conception date data could help to confirm a two-stock hypothesis, it could not be used to reject it, as the lack of difference is not itself evidence for a single stock. The length and sex distribution data were judged to be potentially more useful, in that absence of certain age or sex categories from an area would suggest that the animals in that area were not a separate population.

7.3.1 The O and W Stocks

Comparing the monthly patterns of sightings and catches (SC/48/NP6) and length composition of the catches (SC/48/NP9), it was suggested that these data are consistent with the general patterns in Fig. 2. The pattern of male and immature female whales moving near the Pacific shore in sub-area 7S beginning in April is evident in the catch data (see discussion of SC/48/NP10 under Item 7.2.2). Sighting data show a low density of minke whales in central Honshu in May and from July onwards, although there were substantial catches from May to July. This is consistent with animals migrating through this area, but not residing to any degree, and therefore never being very abundant at any point in time. This applies also to sub-area 7N in September.

The catch data also show mature females in sub-area 11 beginning in April, but a decreasing proportion of females in this area as the season progresses. The sighting data suggest higher densities of whales around Hokkaido from July to September (a period when substantial catches have also been taken) and an absence of whales in October.

Kato interpreted these data as being consistent with the general pattern of spatial segregation of mature minke whales, and especially of females (Matsuura, 1936; Omura and Sakiura, 1956; Ohsumi, 1983; Wada, 1989; Kato *et al.*, 1992). This has also been reported in the North Atlantic (e.g. Jonsgard, 1951) and the Antarctic (Ohsumi *et al.*, 1970; Kato *et al.*, 1990). In these cases, mature females, and particularly pregnant females, probably migrate earlier, ultimately moving to higher latitudes than males and immature animals. He also suggested that the predominately male animals reflected in the catches from immediately south of Hokkaido in September migrate northward later.

The Group agreed that the genetic data implied sufficient dispersal between animals in sub-areas 7, 9 and 11 to maintain the observed degree of genetic homogeneity, but also noted that such homogeneity could be accomplished by relatively small numbers of animals dispersing between two populations in each generation.

While the Group agreed that no evidence was presented to support the hypothesis of a W stock, some members considered that the information did not exclude this possibility, in particular because of concerns about the ability of the available data to detect genetic differences. Some members considered that the hypothesis of a single O stock was more likely than the hypothesis of O and W stocks with low rates of dispersal, while others considered that neither hypothesis could be considered the more likely.

The Group also agreed that the low proportions of females and of smaller males in sub-area 9 was inconsistent with those samples representing a separate population. However, it was noted that the seasonal coverage of the samples from sub-area 9 did not include the period from April to May, that only a portion of sub-area 9 had been sampled (especially not the northern coastal area), and that large portions of areas 8 and 12 had not been sampled. Given these sampling limitations, it was suggested that the information does not preclude there being two stocks that are moving directly north and south, with low levels of east-west dispersal, in which animals from both or only the westernmost stock use the Okhotsk Sea.

It was suggested that observations in the size and sex composition of animals in sub-area 9 in the April to June period could potentially discriminate between the hypothesis of two stocks migrating north and south with low rates of interchange and the hypothesis of only one stock. However, even though the absence of females and young males in th earlier period would strengthen the case that the sub-area 9 animals were members of the O stock, alternate plausible hypotheses were developed which could not be resolved simply by that observation. For example, it was suggested that young animals of both the O and the putative W stock could be distributed along the Japanese coast in those months, only to segregate subsequently.

Several approaches were discussed in terms of how to structure *Implementation Simulation Trials* in the face of this uncertainty. Attention was drawn to the vulnerability of the RMP in the situation where the abundance information might be collected over a larger spatial area than is covered by the catching operations, when account is not taken of the possibility of multiple stocks (IWC, 1992a pp. 307-308). The approach of using abundance information only over the area of the catching operations was noted as being sufficient although its catch performance would be poor in the present case as the area in which historic catches were taken (within sub-areas 7 and 11) is so limited. The alternative suggested during the RMP development was to obtain information to measure mixing rates. This potential vulnerability of the RMP and the lack of direct observations on mixing rates alone may be sufficient grounds to consider a two-stock hypothesis in *Implementation Simulation Trials*.

Another approach suggested for handling the uncertainty was to assess the likelihood of the various hypotheses, either as a qualitative or quantitative judgement or by incorporating the information in the conditioning process. The former calls for subjective judgements, and it is unclear how such judgements might be used in the process of evaluating the results of any *Implementation Simulation Trials*. The latter might be done by incorporating the information supportive of two stocks, specifically the lower proportions of mature animals in sub-area 11 in the period 1977-1987, directly into the conditioning process. This would necessarily discount the possibility of these changes being related to environmental factors (e.g. prey availability), would require assumptions about the representativeness of the catch data and may require arbitrary judgments about process error. The latter might be seen as logically parallel to making judgments at the outset on the relative likelihood of competing hypotheses.

7.3.2 Sub-stocks

The Group agreed that on the Pacific side of Japan, differential migration patterns by sex and by maturity are evident when the length and sex frequency data from the commercial catches are interpreted in conjunction with sightings data. These patterns precluded animals in either sub-area 7 or sub-area 11 being separate sub-stocks. Indeed, these coastal regions appear to be migratory corridors (see Item 7.3.1).

Sighting surveys of varying portions of the Sea of Japan along the Japanese west coast have been conducted in June, August, September and October. These surveys have shown mostly continuous distributions over the areas surveyed in August and September. In June, however, there were markedly fewer sightings in the southern half of Honshu. These continuous distributions do not suggest the existence of local aggregations, either corresponding to the land stations or otherwise, that had been hypothesised as a basis for the proposed sub-stocks. Thus the Group agreed that whales in the Sea of Japan east of Korea are best considered as one stock.

The few sightings along southern Honshu in June suggest that minke whales are more abundant in the northern parts of the Sea of Japan by June, although they do occur in the southern Sea of Japan, at least in low numbers, at this time. This is consistent with Sea of Japan animals identified through genetic analyses of samples from sub-area 11 in April. The few sightings made during an October survey all along the west coast of Japan were in the central and southern regions. Thus minke whales may be more abundant in the southern Sea of Japan than in the north from September, the beginning of their calving and breeding season. There is no evidence whether these animals regularly move south out of the Sea of Japan for calving and breeding, or complete their annual cycle within the Sea of Japan.

There is little information about the relationship of the animals in the Sea of Japan to animals which have been subject to fisheries in sub-area 5. Chinese catches from the north of the Yellow Sea were reported from 1955 to 1979. Partial data for the period between 1958 and 1965 show that catches occurred primarily from March to July, with a few animals reported taken in January and February. Korean catches from the area immediately west of Korea from 1972 to 1986 occurred between March and September. These months are similar to those for the Korean catches just east of the Korean Peninsula (sub-area 6), which are reported primarily from May to October, with lesser numbers in March and April.

The 30 genetic samples used in SC/48/NP5 include one from sub-area 5. SC/48/NP21 presented results from Wada (1991), with 45 animals labelled as being from sub-areas 5 and 6. The mixture is unknown, but is likely to include few sub-area 5 animals. Thus, there is little genetic information available for animals to the west of Korea.

The catches from the northern Yellow Sea may have declined markedly over the 1970s (PRC, 20 Sept 1987), with a corresponding decrease in average body weight from 3.2 to 2.2 tons over the 1970s. The CPUE data for the Korean fishery in sub-areas 5 and 6 suggests a marked decline in abundance between 1965 and 1985 (Gong, 1987; IWC, 1984 p.107; 1988 p. 97). In 1987, the Scientific Committee concluded that the animals in the then defined Sea of Japan-Yellow Sea-East China Sea stock had been reduced to about 18-43% of initial levels (IWC, 1988 p.97). The length-frequency data suggest that all size-classes are present in both sub-areas 5 and 6.

Sightings surveys have been extremely limited, with 39 hours of effort reported by Korea in the Yellow Sea in April 1987 (1 animal sighted, IWC, 1988 p. 97) and fishermen's visual surveys in the northern Yellow Sea reported by China (PRC, 20 Sept 1987). The latter was noted to confirm that the whale resources in this region have been heavily depleted.

The Group considered whether it was appropriate to assume that the animals in sub-area 5 formed part of the J stock. Evidence in this regard is very sparse. In view of this, the Working Group decided to examine two scenarios regarding the relationship between the catches in sub-area 5 and the animals normally found in sub-areas 6 and 10. It decided that the catches from west of Korea (sub-area 5) would be assumed to have been taken from the J stock for the base-case trials. A set of sensitivity tests will examine the implications of ignoring the catches in sub-area 5. The catches from sub-area 1 will be assumed to have been taken from the J stock in both scenarios.'