Differences in cookie cutter shark-induced body scar marks between J and O stocks of common minke whales in the western North Pacific

Goto, M., Kanda, N., Pastene, L.A., Bando, T. and Hatanaka, H.

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

Contact email:goto@cetacean.jp

ABSTRACT
In this study the status of cookie cutter shark scars on the skin of common minke whales was examined to evaluate whether or not it is possible to identify the stock of origin of the individual animals based on such scars. The examination was made using samples of western North Pacific common minke whales collected by JARPNII. Assignments using the number of scars were not a full diagnostic for the minke whales of J and O stocks. However, at least there is a strong likelihood that animals which have no scars on the body were immature J stock animals. There were significant differences between suspected J and O stocks animals in the number of scar on their body. Further significant differences were found between mature and immature animals within both stocks in the number of scar as well.

KEY WORDS: COMMON MINKE WHALE, COOKIE CUTTER SHARK, SCAR, STOCK IDENTFICATION, JARPNII, NORTH PACIFIC

INTRODUCTION

Cookie cutter sharks (*Isistius brasiliensis*) live in the depths of all the oceans near the equator. As shown in Figure 1, this small shark is found in the western Atlantic Ocean from the Bahamas to the coast of southern Brazil. In the eastern Atlantic Ocean, it is found from Cape Verde, Guinea to Sierra Leone, southern Angola and South Africa including Ascension Island. The cookie cutter shark also lives in the waters of the Indo-Pacific from Mauritius to New Guinea, Lord Howe Island, New Zealand, Japan and the Hawaiian Islands. It is found off Easter Island and the Galapagos in the eastern South Pacific Ocean. Records of cookie cutter sharks off Australia include the waters off Queensland, New South Wales, Tasmania, and Western Australia (Compagno, 1984). Around Japanese water, this shark has been observed in the southern Pacific side of Japanese archipelago (sub-area 2) but no record has been made in the East China sea and Sea of Japan (Nakano, H., pers. com.).

Compagno (1984) also reviewed the food habits of cookie cutter shark as follows. Forming a suction cup with its mouth, the cookie cutter shark latches onto its prey. The top teeth are small, pointy and sharp to grasp hold of the prey's skin. Turning in a circle, this shark carves a round chunk of flesh out with its larger razor-sharp, serrated or saw-like bottom teeth. In a flash, the cookie cutter scoops out the meal. After attacking, its prey is left with an almost perfectly round mark that looks like someone used a round cookie cutter on its body. Cookie cutters bite chunks out of large billfish like marlins and tunas, large squid, seals, whales, dolphins, other sharks, and stingrays.

Most of the common minke whales taken by the JARPN/JARPNII survey in the Pacific side of Japan (known as O stock) have numerous white scars on the skin. However, a few of the sampled animals have no scar on the skin. Fujise *et al* (2001) examined relationship between genetically identified O or J stock animals and occurrence of scars, based on samples of minke whales taken by JARPN. Their results showed high correlations between occurrence of scar and each stock determined by genetic data. In this study scar marks in the body of common minke whale sampled by JARPN II (2002-2007) are examined to evaluate whether J and O stock common minke whales can be identified by taking into account the scar of the cookie cutter shark.

MATERIALS AND METHOD

Samples
A total of 1,062 western North Pacific common minke whales collected in the offshore and coastal components of JARPN II from 2002 to 2007 were examined. The scar types were categorized based on the number of scars as follows:

Type 1: No scar on the body
Type 2: 1-20 scars on a single side
Type 3: More than 20 scars on a single side

Number of scars was directly counted in Type 2 and Type 3 was not.

Kato (1992) estimated mean body length at the sexual maturity of the North Pacific minke whales to be 6.3 m for males and 7.1 m for females, so that we tentatively deal with animals less than 7m as immature and more than 7m as mature in this study.

Assignment of JARPN II minke whales to J and O stocks
Microsatellites analysis and a Bayesian method were used to assign individuals minke whales to either J or O stocks (see details in Kanda *et al*., 2009). The randomized chi-square Test of Independence (Roff and Bentzen, 1989) was used to investigate the extent of differences among scar mark types (Types 1, 2 and 3), stocks (J and O stocks) and sexual maturity of the animals by body length in each stock.

RESULTS
Table 1 shows the number of samples used in the present study by type of scar mark, stock (as assigned by the genetic analysis), sub-area and the offshore and coastal components of JARPN II for the period 2002 to 2007. Individuals with no scars on their body (Type 1) were not detected in sub-area 7E, 8W, 8E, 9W and 9E.

Table 2 shows the number of samples used for the statistical analysis by stocks, body length and type of scar marks. In both stocks significant differences (P=<0.0001) were found between animals with more than and less than 7m in body length. Further there were significant differences (P=<0.0001) between J and O stocks animals with regard the number of scars as well.

It should be noted that most of J stock animals assigned by the genetic analysis were distributed within sub-area 7W except for one individual in the sub-area 9W. Figure 3 shows the geographic distribution of J stock animals within the sub-area 7W by type of scar mark. This figure shows no specific distribution by scar mark types in coastal waters in the Pacific side of Japan. Figure 4 shows the distribution of O stock animals by type of scar mark. There is no Type 1 animals assigned for O stock animals. Types 2 and 3 animals less than 7m in body length tend to distribute in coastal waters in the Japanese Pacific side. Although animals with more than 7m in body length distribute uniformity in the research area, animals having a larger number of scars tend to distribute in the northern part of the research area.

Figure 5 shows the frequency distributions of body length by types of scar marks and by J and O stocks as assigned by the microsatellite analysis. Regarding the J stock, no scars were observed in animals with body length less than 7m. Regarding the O stock, there is no animal with Type 1 scar mark. Further the frequency of Type 3 scar mark animals gradually increased with body length.

DISCUSSION
In this study scar marks on the body of common minke whale sampled by JARPN II (2002-2007) were examined in order to evaluate whether J and O stock common minke whales in the western North Pacific can be identified by using this non-genetic marker. The number of scars was not a full diagnostic character to assign individual minke whales to J and O stocks, because some J stock animals presented Types 2 & 3 scar mark which was dominant in the O stock animals. However our findings were that at least there was a strong likelihood that animals which have no scars on their body were J stock animals, and the number of scars in J stock animals is apparently less than that in O stock animals. Further, number of scars in J and O stocks animals is different by the body length, and smaller animals tend to have none or less number of scars. It is important to note that there were significant differences between suspected J and O stocks animals in the number of scars on their body, and such differences were found in both animals with more than and less than

7m in body length as well.

Although it was predicted that most of the J stock animals would have no scars by the previous results (Fujise *et al*., 2001), the present study showed that a large number of animals of the J stock have scars. One of the possible examinations for this is that scars are not diagnostic characters to assign individual minke whales to J and O stocks.

Other examination would be related to the migration pattern and distribution of J/O stock animals by its body length and habitat of the cookie cutter sharks. Cookie cutter sharks lives in the depth in the ocean. Around Japanese water, cookie cutter shark was detected in the southern Pacific side of Japanese archipelago (sub-area 2) and there is no record in the Sea of Japan and East China Sea (Nakano, H., pers. comm.).

Firstly, reason why many immature animals (tentatively less than 7m in this study) have no scar might be that they preferred to distribute in the shallow waters close to the Japanese coastal line, then they have no chance to meet cookie cutter sharks that lives in the depth in the ocean even if they migrate through sub-area 2. Indeed, Kanda *et al* (2009) reported that most of bycaught individuals taken in sub-area 2 were J stock animals and that average body length of the all animals bycaught on the set net fishery was 4.92 m, and all of the set nets were settled within 3 n.miles from the Japanese coastal lines. Migration route of common minke whale might be gradually shifted to the offshore area as they grown and this increased the chance to meet the cookie cutter sharks.

Secondly, regarding mature (tentatively more than 7m in this study) J stock minke whales, it was assumed that animals with no scars observed in the Pacific side of Japan would migrate from East China Sea and Sea of Japan to the Pacific through the Tsugaru or Soya straits, and that animals having scars migrate to the Pacific side through the sub-area 2. Under these assumptions, we will be able to estimate the migration pattern of J stock animals by observing the scar on the body. In this study two animals with body length more than 7m were detected. One animal (7.12m) was taken by the offshore component at off Kushiro in 2006 and the other (7.23m) was taken by coastal component in Sendai Bay. These animals might be migrated from Sea of Japan side to the Pacific through the northern straits and other animals through the sub-area 2 under these assumptions.

Regarding the O stock animals, our results indicated that number of scar was different by the body length, and larger animals tended to have larger number of scar. The observation that the number of the less than 7m (mostly immature) O stock individuals distributed in the Japanese coast of the North Pacific side was well consistent to that illustrated by Hatanaka and Miyashita (1997). If the number of scars was reflect the length of stay at suspected breeding area where cookie cutter sharks distribute in the low latitude in the North Pacific, older animals would have more large number of scars. Figure 3 shows the animals have larger number of scar migrate to more northern part of research area. This indicates that older animals migrate to more northern area for feeding.

Fujise *et al*. (2001) examined the utility of three non-genetic markers (occurrence of scars, foetal length reflecting the conception date and accumulations of some pollutants) for stock identification in the western North Pacific minke whale. They found striking differences in these three markers between J and O stocks, and genetics and non-genetics markers matched almost perfectly. This means that a combination of several non-genetic markers would be useful for identification of these stocks. Therefore, we need to understand and recognize both the advantages and disadvantages of each biological marker, and determine stock identity by combining the information with genetic data. With this strategy it will be possible to identify stocks with more accuracy.

Regarding the number of scars unfortunately such information can not be obtained by observation of free ranging whales from sighting survey vessels because the distinction of scar on swimming whales is extremely difficult (Miyashita, T., pers. com.).

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Table 1. Number of samples used in the present study by type of scar, sub-area and stocks assigned by genetic data. Samples collected by the offshore and coastal components from JARPN II during 2002 and 2007.

			Microsatellite allocation		
		Type of scar	O	?	J
	1	None	0	4	35
7W	2	1-20 scars	19	10	39
Coastal	3	more than 21 scars	335	33	5
		Total	354	47	79
	1	None	0	1	2
7W	2	1-20 scars	38	4	13
Offshore	3	more than 21 scars	157	21	2
		Total	195	26	17
	1	None	0	0	0
7E	2	1-20 scars	1	1	0
Offshore	3	more than 21 scars	7	0	0
		Total	8	1	0
	1	None	0	0	0
8W	2	1-20 scars	8	0	0
Offshore	3	more than 21 scars	23	6	0
		Total	31	6	0
	1	None	0	0	0
8E	2	1-20 scars	20	2	0
Offshore	3	more than 21 scars	41	3	0
		Total	61	5	0
	1	None	0	0	0
9W	2	1-20 scars	19	3	0
Offshore	3	more than 21 scars	104	16	1
		Total	123	19	1
	1	None	0	0	0
9E	2	1-20 scars	4	1	0
Offshore	3	more than 21 scars	80	4	0
		Total	84	5	0
Grand total			856	109	97

Table 2. Result of the statistical analysis of frequency of scar type by body length in each stocks.

	J stock			O stock			
	Type 1	Type 2	Type 3	Type 1	Type 2	Type 3	P
Less than 7m	35	33	1	0	55	246	<0.001
More than 7m	2	17	4	0	47	485	<0.001
P		<0.001			<0.001		

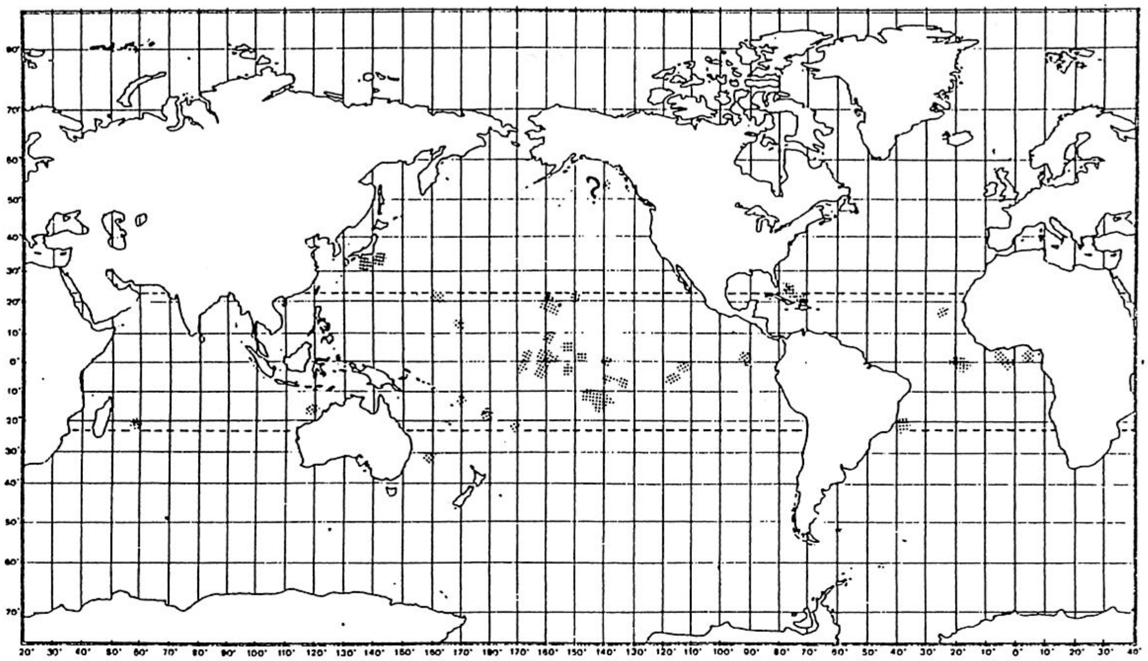

Fig.1. Geographical distribution of Cookie-cutter shark (after Compagno, 1984).

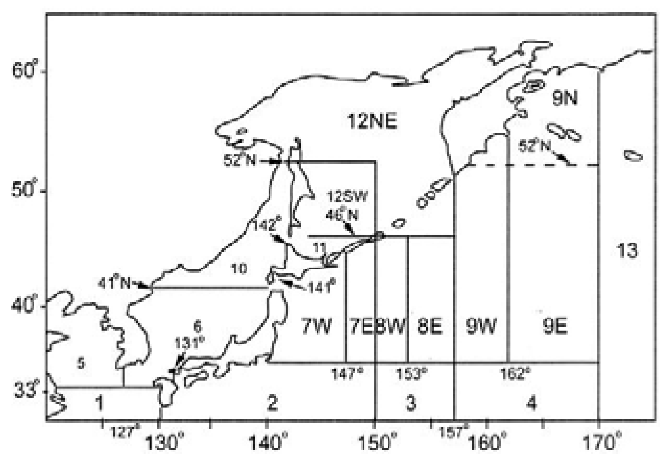

Fig. 2. The 18 sub-areas used for the *Implementation Simulation Trials* for North Pacific minke whales.

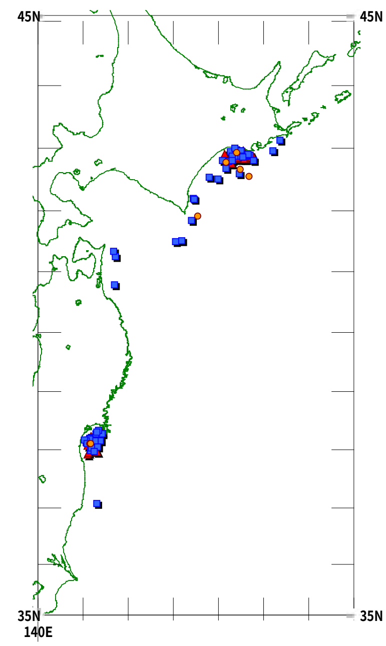

Fig.3 Distributions of J type animals by Type of scar. ▲ : None, ■; 1-20 scars and ●; more than 21 scars.

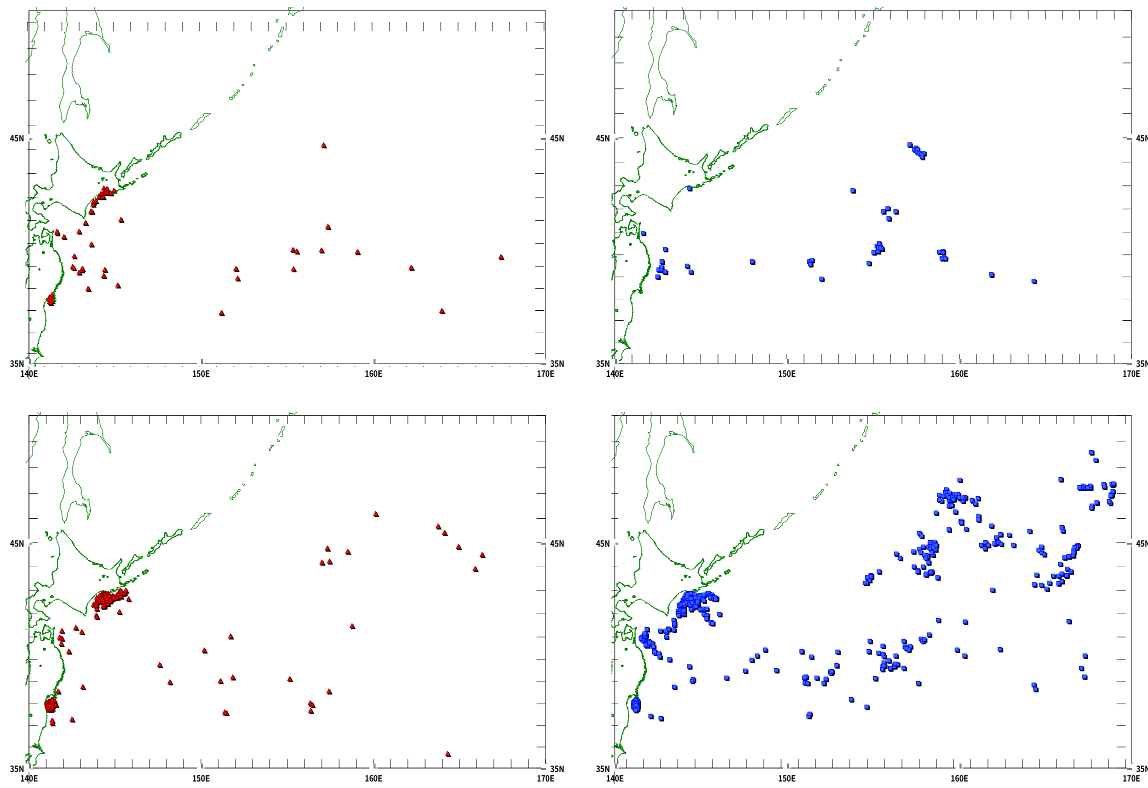

Fig.4. Distributions of O type animals by type of scar and body length. Upper left: Type 2 and less than 7m, upper right: Type 2 and more than 7m, lower left: Type 3 and less than 7m, lower right: Type 3 and more than 7m.

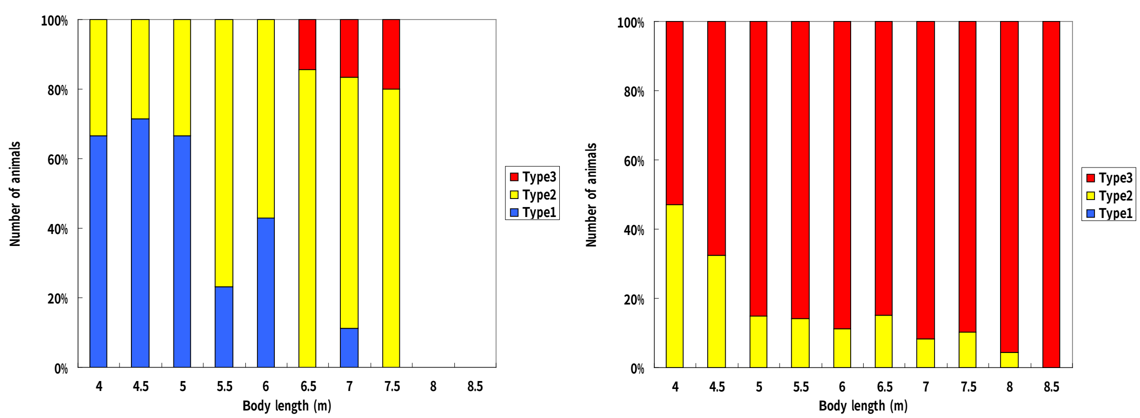

Fig.5. Frequency distributions of body length by types of scar and by J and O stock animals assigned by microsatellite. The left figure correspond to J stock animals and the right figure to O stock animals.