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Using JARPA and JARPAII platforms for investigating the occurrence of marine debris in the Indo-Pacific region of the Antarctic

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ABSTRACT

Records of marine debris and entanglements of whales in Antarctic waters are very limited. In this study, the information on marine debris and entanglements collected during JARPA/JARPAII and Japanese dedicated whale sighting surveys in the period 1987/88–2014/15, is summarized. The surveys were conducted in the Indo-Pacific sector, south of 60°S. Marine debris on the sea surface was recorded during systematic sighting surveys. A total of 163 pieces were found with buoys/floats being the most abundant (69% of all marine debris recorded). The highest density index (DI: number of marine debris observed per 100 n.miles) was recorded in Areas IV (70°E–130°E) and V (130°E–170°W) (DI: 0.15). The stomachs of 10,660 Antarctic minke whales, 16 dwarf minke whales and 17 fin whales caught under JARPA/JARPAII were also examined for the presence of debris. A total of 71 pieces were found in the stomachs of the three species. The number of plastic debris per 100 Antarctic minke whales was estimated at 0.08. Four cases of entanglement in a total of 10,660 Antarctic minke whales examined, were found. Given these low indices, the negative effects of marine debris on whales in the Antarctic is expected to be limited at present.

INTRODUCTION

The Antarctic is one of the most isolated places on earth, and the effects of human activities in this area is limited. However in recent years marine debris has been recorded in sub-Antarctic and Antarctic islands, but the information is limited (Barnes *et al.*, 2010; Ivar do Sul *et al.*, 2011).

JARPA/JARPAII conducted systematic monitoring of the Antarctic ecosystem for a long period of time, which included observation of marine debris in whales and their environment. The present study summarizes the observations on marine debris collected by JARPA/JARPAII and Japanese dedicated whale sighting surveys in the Indo-Pacific region of the Antarctic, over a period of more than 20 years. The relevance of this kind of survey is that marine debris could affect whales through ingestion and entanglements.

MATERIALS AND METHODS

Surveys

JARPA was conducted during the austral summer seasons (December–March) from 1987/88 to 2004/05 seasons, while JARPAII was conducted from 2005/06 to 2013/14. These long-term programs included sighting surveys and oceanographic surveys for management and monitoring purposes concurrently with whale sampling to study biological parameters (GOJ, 2005).

The present study on marine debris and entanglements was based on data collected by the JARPA/JARPAII and by a Japanese dedicated whale sighting survey conducted in the 2014/15 season. Details of the general methodology and survey procedures can be found in Nishiwaki *et al.* (2006) and Nishiwaki *et al.* (2014).

Research area

The research area comprised the Indo-Pacific region of the Antarctic, specifically the International Whaling Commission (IWC) Antarctic management Areas III (East) (35°E–70°E), IV (70°E–130°E), V (130°E–170°W) and VI (West) (170°W–145°W), south of 60°S.

Observation of marine debris on the sea surface

Marine debris (macro debris) observations on the sea surface were made from dedicated sighting vessels (Figures 1 and 2).

For each debris found, sighting date, sighting position and types of marine debris were recorded. Marine debris data was roughly sorted into three types of debris: metal, petrochemical products and others. The density index (DI: number of marine debris per 100 n.miles) was also

Figure 1. Sighting vessel from where the observations were made (left) and sighting activity of whale schools and marine debris (right).

Figure 2. Example of marine debris found on the sea surface. The buoy was observed at 67°S; 179°W during the 2013/14 season.

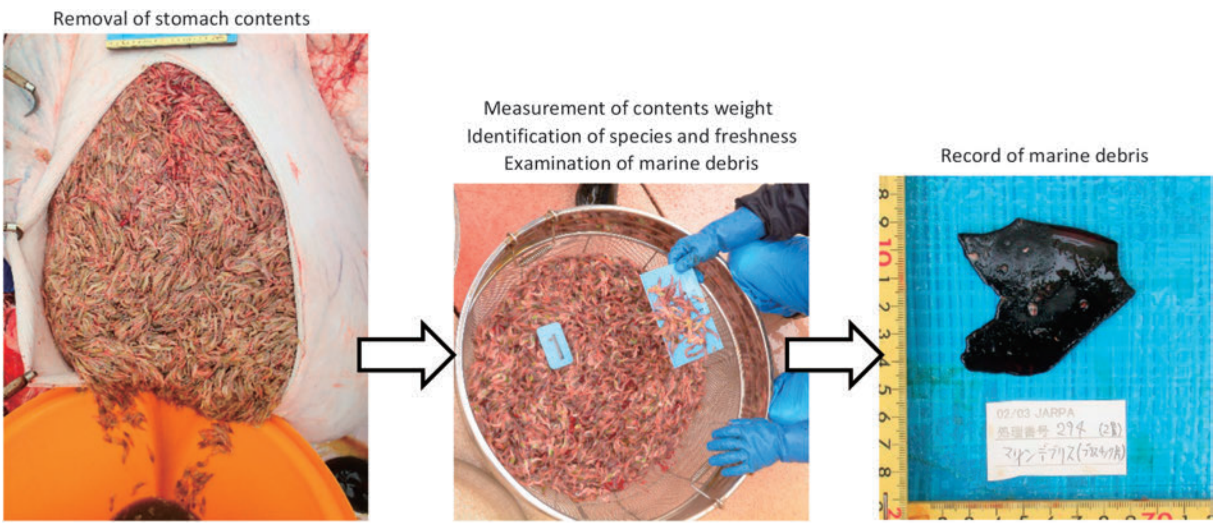

Figure 3. Examination of marine debris in whale stomachs onboard the research base vessel.

calculated in the period 1995/96–2014/15. No independent sighting surveys were conducted in the 2010/11, 2011/12 and 2013/14 seasons due to external interferences.

Observation of marine debris in whale's stomach

The stomachs of 10,660 Antarctic minke whales (*Balaenoptera bonaerensis*), 16 dwarf minke whales (*B. acutorostrata* subsp.) and 17 fin whales (*B. physalus*) were examined for the occurrence of debris.

The examination of whale stomachs was conducted onboard the research base vessel as shown in Figure 3. The three stomach chambers and the duodenal ampulla were examined macroscopically during the JARPA. Only the fore and main stomachs were examined during the JARPAII. Marine debris and objects other than preys were tabulated by five categories: feather, stone, wood, plastic and other. The sizes of solid objects (stone, wood and plastic) were estimated from photographic records.

The relationship between body length and body weight of Antarctic minke whales was compared between whales with and without debris in their stomachs (n=8,705). This was made to examine the body condition of the whales with debris in their stomachs.

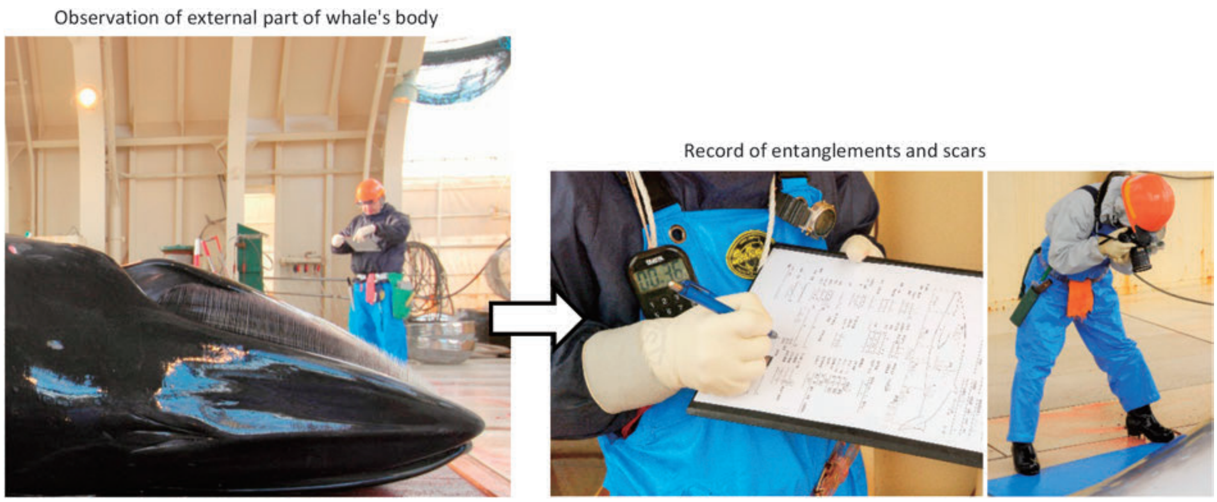

Figure 4. Observation of entanglements onboard the research base vessel.

Table 1
Summary of the sightings of marine debris on the sea surface in Areas III (East), IV, V and VI (West) during the JARPA (1991/92–2004/05), JARPAII (2005/06–2013/14) and Japanese dedicated whale sighting (2014/15) surveys.

Type of marine debris	Metal (Total number=14)				Petrochemical products (Total number=148)														Other (Total number=1)				
	Can		Drum (≦200 L)		buoy /float*		Bottle		Container		Fender		Net		Other plastic products		Styrofoam products		Other products*		Sub total		Total
AREA / Type of searching effort	on	off	on	off	on	off	on	off	on	off	on	off	on	off	on	off	on	off	on	off	on	off	
AREA III (East)			1		4		1	1									1				7	1	8
AREA IV			2	4	37	10			1				1		1	1	8	4	1		51	19	70
AREA V	2		1	3	35	14	3		2		5	3	2		1		1				52	20	72
AREA VI (West)			1		7	5															8	5	13
Total	2	0	5	7	83	29	4	1	3	0	5	3	3	0	2	1	10	4	1	0	118	45	163

Buoys/floats /fenders were floating as single object, however, at least in six cases, several buoy/fenders were observed; those cases were counted as a single observation. Other plastic products were rope and ball. Other products were unknown material square boxes.
*Material of buoys/floats was considered to be plastic, in addition to Styrofoam and rubber.

Entanglements

Observations of the external part of the bodies of the whales were made onboard the research base vessel as shown in Figure 4. All cases of entanglements (attached objects) in Antarctic minke whales sampled by the JARPA and JARPAII (n=10,660) were recorded. Furthermore scars and marks in the body of whales possibly produced by entanglements was examined for whales sampled under the JARPAII (n=3,883). The latter analysis was based on JARPAII surveys, when more detailed body observations, supported by the use of digital cameras, started.

The relationship between body length and body weight of Antarctic minke whales was compared between whales with and without entanglements (n=8,705). This was made to examine the body condition of the whales with entanglements.

RESULTS

Marine debris on the sea surface

A total of 163 records of marine debris were made (14 metals, 148 petrochemical products and one other) on the sea surface (Table 1). Buoys/floats (petrochemical) accounted for 69% of all marine debris. Debris was found throughout all research areas; however, the DI was higher in Areas IV and V particularly during the JARPAII period (Table 2, Figures 5a and 5b). The most southerly debris was a buoy found in area V (Ross Sea) at 74°S, 176°W.

The highest DI was recorded in Area IV and V (DI: 0.15). The average DI in the four Areas was 0.13 (Table 2). DI for buoys/floats ranged from zero to 0.35 and these increased suddenly in Areas IV and V after the 2005/06 season and it peaked at the 2007/08 season and then decreased (Figure 6).

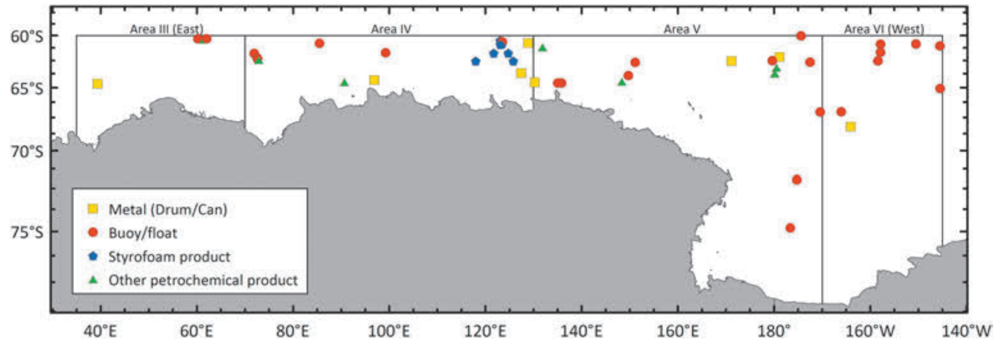

Figure 5a. Distribution of marine debris found during the JARPA surveys (1987/89–2004/05).

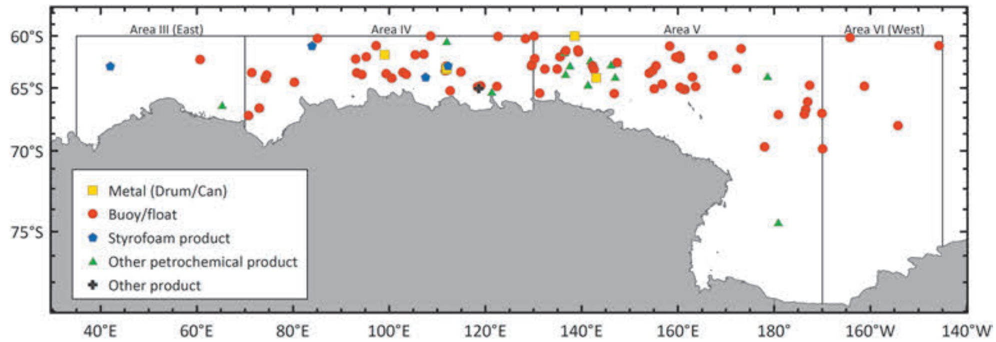

Figure 5b. Distribution of marine debris found during the JARPAII (2005/06–2013/14) and Japanese dedicated whale sighting (2014/15) surveys.

Table 2
The density indices (DI, number of marine debris per 100 n. miles) during JARPA (1995/96–2004/05), JARPAII (2005/06–2013/14) and Japanese dedicated whale sighting survey (2014/15).

Area (95/96–14/15)	Searching distance (n.miles)	Number of marine debris (on effort)	Density index (number of marine debris per 100 n.miles)
Area III (East)	14,570	7	0.05
Area IV	34,638	51	0.15
Area V	34,554	52	0.15
Area VI (West)	10,096	8	0.08
Total	93,857	118	0.13

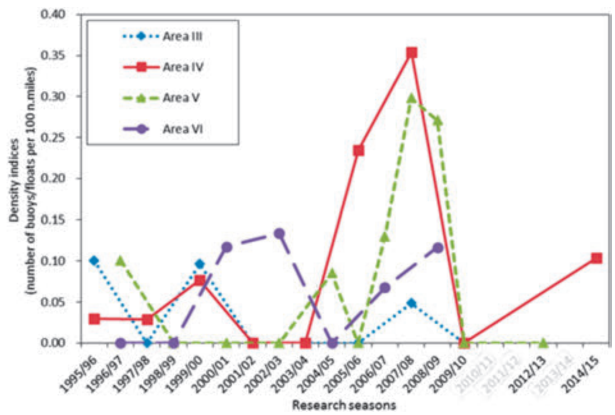

Figure 6. Density indices by season/area of sighted buoys/floats during JARPA (1995/96–2004/05), JARPAII (2005/06–2013/14) and Japanese dedicated whale sighting (2014/15) surveys.

Observation of debris in whale's stomachs

A total of 69 out of the 10,660 Antarctic minke whales examined had ingested marine debris and objects other than prey (Table 3). Feathers accounted for 44 cases, stones in six cases, pieces of wood in eight cases and plastics in nine cases. In 36 cases, debris and objects other than prey was found in the fore and main stomach.

The occurrence of plastic debris in body of whales per 100 Antarctic minke whales examined was calculated at 0.08. The size of solid objects (stone, wood, plastic) was less than 100×100 mm (Figure 7). There were two occurrences (one plastic bag and one small wood scantling) in which the size of the objects was more than 100×100 mm.

There were no differences in the relationship between body length and body weight of Antarctic minke whales with or without debris in their stomachs (Figure 8).

No debris and objects other than prey was found in the stomachs of the 16 dwarf minke whales examined. In the case of the fin whales, only one animal had ingested objects other than prey (two pieces of feathers).

Table 3
Marine debris and objects other than prey ingested by the Antarctic minke whales sampled by JARPA and JARPAII surveys (1987/88–2013/14).

Antarctic minke whale		Marine debris and objects other than prey										Total	
Research season	Sample size	Feather		Stone		Wood		Plastic		Others			
1987/88	272	—	—	—	—	—	—	1	(0)	—	—	1	(0)
1988/89	236	—	—	—	—	—	—	—	—	—	—	—	—
1989/90	326	—	—	—	—	—	—	—	—	—	—	—	—
1990/91	323	—	—	—	—	—	—	—	—	—	—	—	—
1991/92	288	—	—	—	—	1	(0)	1	(0)	—	—	2	(0)
1992/93	327	2	(2)	—	—	1	(0)	1	(0)	—	—	4	(2)
1993/94	330	—	—	—	—	1	(0)	1	(0)	—	—	2	(0)
1994/95	330	—	—	—	—	—	—	—	—	—	—	—	—
1995/96	439	—	—	—	—	—	—	—	—	—	—	—	—
1996/97	440	8	(7)	1	(0)	—	—	—	—	—	—	9	(7)
1997/98	438	4	(0)	—	—	—	—	—	—	—	—	4	(0)
1998/99	389	1	(0)	1	(1)	1	(0)	1	(0)	—	—	4	(1)
1999/00	439	—	—	—	—	1	(0)	2	(0)	—	—	3	(0)
2000/01	440	—	—	—	—	2	(2)	1	(0)	—	—	3	(2)
2001/02	440	1	(0)	1	(0)	—	—	—	—	—	—	2	(0)
2002/03	440	2	(1)	—	—	—	—	1	(1)	1	(0)	4	(2)
2003/04	440	4	(3)	1	(0)	—	—	—	—	1	(1)	6	(4)
2004/05	440	8	(3)	1	(0)	1	(0)	—	—	—	—	10	(3)
2005/06	853	11	(11)	—	—	—	—	—	—	—	—	11	(11)
2006/07	505	—	—	—	—	—	—	—	—	—	—	—	—
2007/08	551	—	—	—	—	—	—	—	—	—	—	—	—
2008/09	679	—	—	1	(1)	—	—	—	—	—	—	1	(1)
2009/10	506	2	(2)	—	—	—	—	—	—	—	—	2	(2)
2010/11	170	—	—	—	—	—	—	—	—	—	—	—	—
2011/12	266	1	(1)	—	—	—	—	—	—	—	—	1	(1)
2012/13	103	—	—	—	—	—	—	—	—	—	—	—	—
2013/14	250	—	—	—	—	—	—	—	—	—	—	—	—
Total	10,660	44	(30)	6	(2)	8	(2)	9	(1)	2	(1)	69	(36)

All items were found in the stomach and duodenal ampulla except for three feathers, one small stone and one plastic piece found in the oral cavity, small intestine and anus respectively. The 'Others' includes one small rubber piece and one small mineral matter such as coal. (Number in parentheses): number of marine debris and objects other than prey found in the fore stomach and main stomach.

Entanglements

Only four cases of entanglements were found in a total of 10,660 Antarctic minke whales examined (Table 4, Figure 9). Those involved fishing hooks, monofilament fishing lines, ropes and packing bands. There were no differences in the relationship between body length and body weight of Antarctic minke whales with or without entanglements (Figure 8). At least five out of 3,883 Antarctic minke whales examined in JARPAII had scars presumably derived from entanglements (Figure 10).

DISCUSSION

Evidence from remote oceanic islands suggested a southward-decreasing, strong latitudinal gradient in litter densities from subtropical and temperate waters through the subtropical convergence to polar front and beyond (i.e. there is a clear trend in marine debris accumulation with latitude) (Barnes, 2005; Gregory and Ryan, 1997).

Matsumura and Nasu (1997) reported the results of sighting surveys showing the distribution of floating marine debris in the North Pacific Ocean and its adjacent

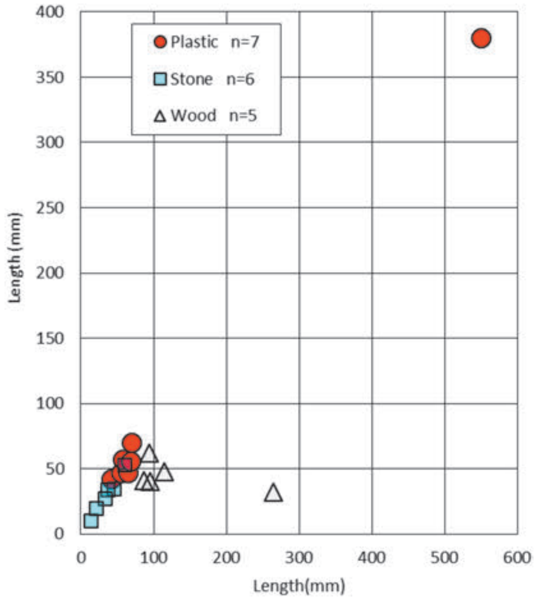

Figure 7. Size of marine debris ingested by Antarctic minke whales sampled by JARPA and JARPAII surveys (1987/88–2013/14).

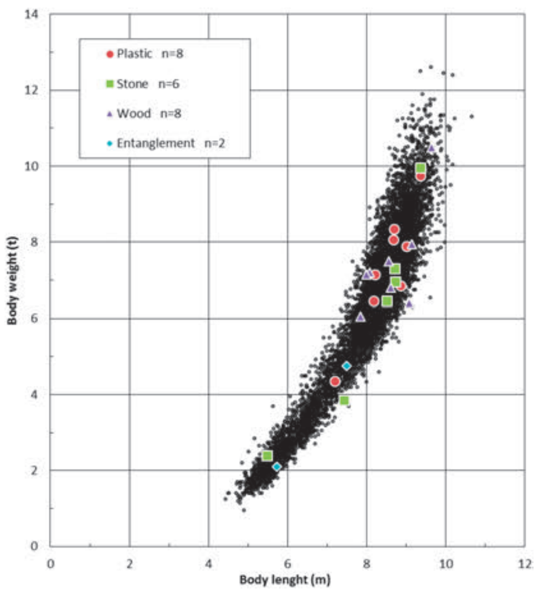

Figure 8. Relation of body length and body weight in Antarctic minke whales (n=8,705) for whales with and without debris in their stomachs (or entanglements).

waters in the period 1987–1991. These surveys covered approximately 926,000 n.miles and counted 136,338 pieces of marine debris (including natural objects). About 60% of marine debris accounted for petrochemical debris (e.g. fishing gear, styrofoam, other plastic products). Total debris densities in coastal waters were 20–40 objects per square n. mile, while the density in the north equatorial current area (5° to 15°N, across the central Pacific) was about 0.2 objects per square n. mile, and 1–3 objects per square n. mile in the subarctic boundary area (35° to 45°N) (Matsumura and Nasu, 1997).

The DI in our study (Table 2) was compared with the results by Matsumura and Nasu (1997). The DI in the Antarctic is lower by two orders of magnitude in comparison with the North Pacific Ocean and its adjacent waters. Thus our observations prove that the Antarctic waters have a very low density of marine debris on the sea surface.

Sources of marine debris in the Antarctic include fishing, and research/tourism vessels, but also global oceanic debris drifting across the Polar Front. Fishing operations are important sources of marine debris in the Antarctic, contributing not only with direct fishing-related debris but also miscellaneous items (Ivar do Sul *et al.*, 2011). According to our results, fishing buoys/floats accounted for about 69% of all sighted marine debris on the sea surface. Barnes *et al.* (2010) recorded three pieces of marine debris in the Durmont D′Urville and Davis Seas (i.e. Areas IV and V): a plastic cup and two fishing buoys.

The assumption that all buoys/floats observed in the Antarctic were transported from lower latitudes is unreasonable in consideration of the barrier effects of the Polar Frontal Zone, even if it is weak. Webber and Parker (2012) showed fishing gear loss of bottom longline fisheries targeting Antarctic toothfish (*Dissostichus mawsoni*). Since 2004/05, licensed longline vessels have conducted exploratory fishery for *Dissostichus* spp. (target species is Antarctic toothfish) in CCAMLR division subarea 58.4.1 (which overlaps with Areas IV and V), and

Table 4
List of entangled whales observed during JARPA and JARPAII surveys (1987/88–2013/14).

Research season	Specimen No.	Date	Latitude	Longitude	Body length (m)	Body weight (t)	Sex	Stomach contents	Entanglement objects	Figure 9
1995/96	065	22/12/1995	62°48′S	68°55′E	7.5	4.7	M	Empty	Fishing hook	a
2003/04	046	10/12/2003	63°10′S	54°56′E	5.7	2.1	M	Krill	Monofilament fishing line	b
2005/06	190	6/1/2006	64°26′S	72°40′E	7.8	NA	F	Krill	Rope	c
2005/06	765	5/3/2006	63°56′S	103°46′E	5.7	NA	M	Krill	Packing band	d

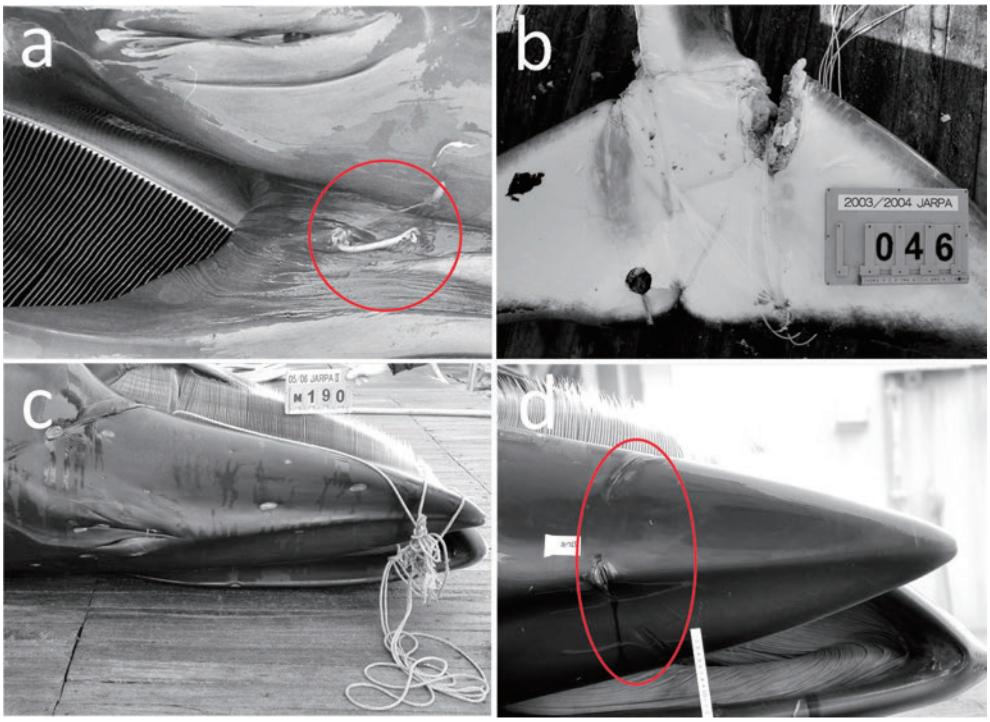

Figure 9. Four entangled Antarctic minke whales observed during JARPA and JARPAII surveys (1987/88–2013/14). (a) Fishing hook, (b) Monofilament fishing line, (c) Rope, (d) Packing band, (d) Loose packing band when a whale was being transported on the way to research base vessel.

there are high levels of IUU (illegal, unreported and unregulated) fishing conducted outside CCAMLR regulations (SC-CAMLR, 2011). The number of licensed vessels in the exploratory fishery in subarea 58.4.1 was four to seven in 2004/05 to 2007/08 seasons, however it was decreased to one to three in 2008/09 to 2014/15 seasons (SC-CAMLR, 2012a; CCAMLR, 2013; 2014; 2015). The number of sighted buoys/floats suddenly increased in Areas IV and V after the 2005/06 season and peaked at 2007/08 seasons, and then decreased. This pattern coincides with the fluctuation of longline fisheries operations (include IUU fishing).

In Iceland, six of 82 examined fin whales (commercial whaling) and in the New York area, three of 19 examined mysticetes (stranding) contained synthetics in the gut (Sadove and Morreale, 1990). The occurrence rates of marine litter ingestion obtained from stranded animals examined in the UK were 2.2% in the harbour porpoise (*Phocoena phocoena*) and 2.3% in the short-beaked common dolphin (*Delphinus delphis*) (Deaville and Jepson, 2010). We found 60 individuals with 69 pieces of marine debris and objects other than prey out of 10,660 Antarctic minke whales sampled in the Antarctic (0.56%). Among them, there were only nine cases of plastics, which is an extremely low frequency (0.08%) in comparison with other oceanic basins. Given this low frequency the effect of marine debris on whales is expected to be low.

Entanglement of Antarctic fur seals (*Arctocephalus gazella*) was caused mostly by loop shaped debris such as packing bands (Croxall *et al.*, 1990; Arnould and Croxall, 1995). CCAMLR has prohibited and restricted the use of packing bands on fishing vessels in Conservation Measure 26-01. In this study, some entangled whales strapped with packing bands around their upper rostrums were found (Figures 9-d). Similar cases were reported in common minke whales (*B. acutorostrata*) in the Atlantic (Gill *et al.*, 2000). It has been indicated that loop shaped debris causes the entanglement of whales as well pinnipeds.

Fishing gear is the most significant source of entanglements for whales and those entanglements were reported in various waters (Laist, 1997; Simmonds, 2012). Documented interaction between whales and fisheries in the Southern Ocean included killer (*Orcinus orca*) and sperm whales (Kock *et al.*, 2006), however entanglement mortalities recorded in the case of sperm whales and possibly minke whales (SC-CAMLR, 2004; 2012b) were low. In this study, only three cases of entanglements (probably by fishing gear) were found among the 10,660 Antarctic minke whales examined.

At least five out of 3,883 Antarctic minke whales examined in JARPAII had scars presumably derived from entanglements (see Figure 10). Those scars suggested

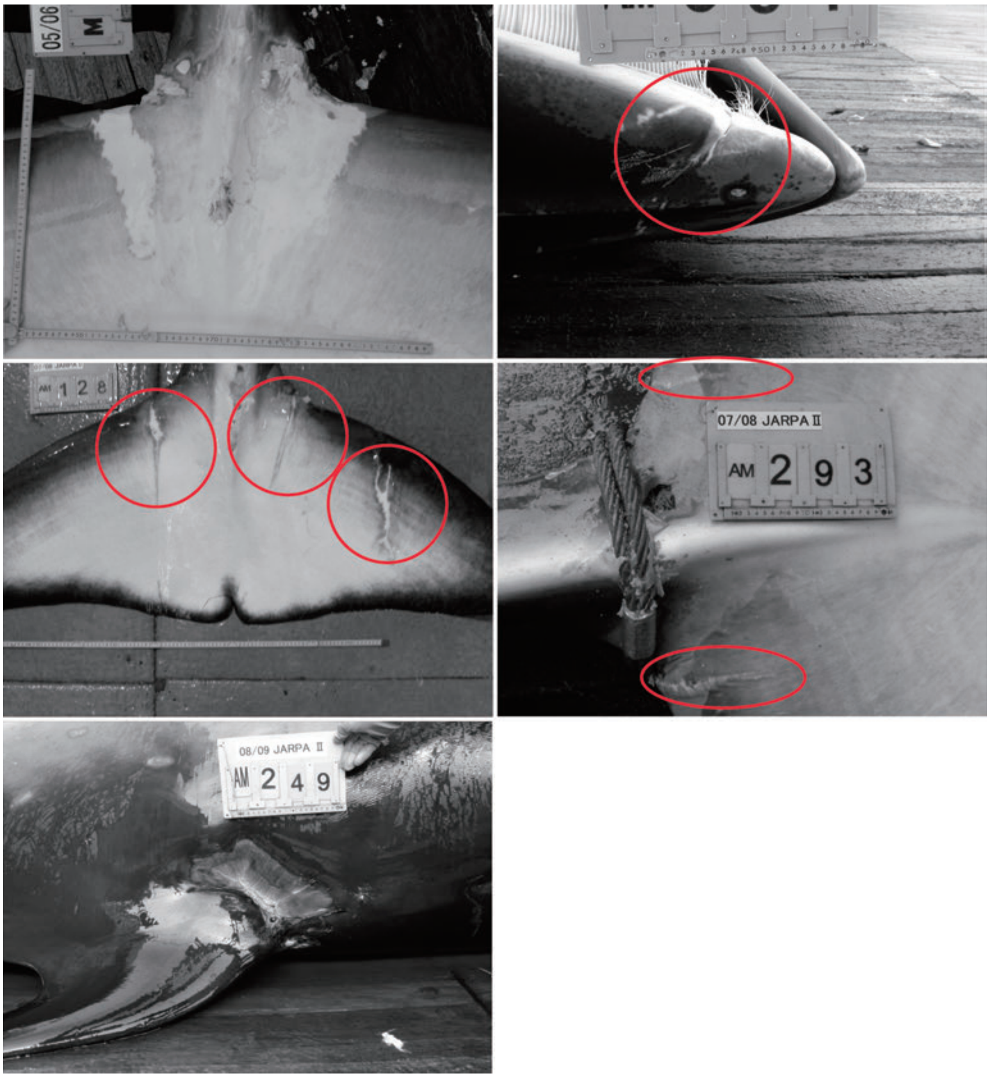

Figure 10. Five cases of Antarctic minke whales with scars probably derived from entanglements observed during JARPAII surveys (2005/06–2013/14). In the middle right-hand picture the wire rope used in the processing is also shown.

that the entanglements occurred in previous cases, but that they escaped from the obstructive objects and survived. Entanglements along the eastern seaboard of the United States and Canada during a five year period were reported as 27 cases of minke whales and 77 of humpback whales (Glass *et al.*, 2008). In Iceland, five of 95 fin whales examined showed signs of previous entanglement (Sadove and Morreale, 1990). The entanglements of Antarctic minke whales are less frequent. Therefore the level of impact of entanglements on Antarctic minke whales would be low in comparison with other oceanic basins.

CONCLUSIONS

This study provided the first comprehensive quantitative approach of examining marine debris on the sea surface and ingestion of marine debris and entanglement of whales in the Antarctic. Given the low frequencies and indices, the impact of marine debris on whales in the Antarctic is expected to be limited. Our study provides some evidence that some degree of interaction between whales and fishery exist in the Antarctic. Webber and Parker (2012) recommended that fishing vessels and/or the CCAMLR observer should record the detailed gear loss, for estimating unaccounted fishing mortality and to reduce the loss of fishing gear. That information is also essential to understand the interaction between whales and fisheries and marine debris. Long-term surveys conducted by JARPA and JARPAII proved very useful for examining the occurrence of marine debris and entanglements in the Antarctic.

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