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INGESTION OF MARINE DEBRIS AND EVIDENCE OF ENTANGLEMENTS INVOLVING ANTARCTIC MINKE WHALES (*BALAENOPTERA BONAERENSIS*) SAMPLED IN THE INDO-PACIFIC SECTOR OF THE ANTARCTIC

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Abstract

This study presents the results of an examination of marine macro debris ingested by Antarctic minke whales (*Balaenoptera bonaerensis*) in the Indo-Pacific sector of the Antarctic in the period 1987/88–2018/19. Whales used in this study were sampled by surveys of the former Japanese whale research programs under special permit in the Antarctic. Also, this study examines evidence of past and present entanglements around the body of the animals. Of a total of 11,992 whales examined, 19 had ingested macro debris (0.16%) such as polymer products and wood. Only four cases of entanglements were recorded in the 11,992 whales examined (0.03%). Of 5,215 whales examined from the period of 2005/06 onward, six whales presented body marks associated with past entanglements (0.12%). It was concluded that the frequency of macro debris ingested as well as the number of entanglement cases involving Antarctic minke whales sampled in the Indo-Pacific sector of the Antarctic are extremely low in comparison with whales in the North Atlantic. These low frequencies of ingested debris and entanglements are unlikely to have a negative effect on the conservation of the Antarctic minke whale populations in this sector of the Antarctic.

Key words: Antarctic, Antarctic minke whale, marine macro debris, ingestion, entanglements.

Marine debris is a kind of pollutant affecting marine wildlife. Among the marine debris types, plastics have a more negative impact on marine wildlife than others. Plastics include microplastic particles (with a diameter <5 mm, Arthur *et al.*, 2009) and macroplastic particles (>20 mm, Barnes *et al.*, 2009). Such marine debris could cause disease or be ingested and lead to starvation (Gregory, 2009). Recently, two workshops (Panti *et al.*, 2019; IWC, 2020) were held to discuss the current status of the interaction between marine debris and marine mammals. The objectives of the workshops were to identify negative effects on the animals; to identify possible areas of research to assess the impact of marine debris on this group of animals; and to propose ways to alleviate the problem. So far, detection of debris interactions in cetaceans has largely depended on data collected from small sample sizes provided by stranded animals. Therefore it has been difficult to determine the implications of debris interactions at a population level (Baulch and Perry, 2014).

The present study focuses on the Antarctic, one of the most isolated places on earth where the effect of human activities and the occurrence of marine debris are assumed to be limited (see also Isoda *et al.*, this issue). There is limited information regarding interaction between marine debris and whales in the Antarctic. This study investigates the occurrence of marine macro debris ingested by Antarctic minke whales (*Balaenoptera bonaerensis*) based on whales sampled over a period of more than 30 years in the Indo-Pacific sector of the Antarctic by surveys of the former JARPA/JARPAII (Japanese

Table 1. Number of macro debris ingested by Antarctic minke whales and frequencies (number of whales with debris ingestion per 100 Antarctic minke whales) in the Indo-Pacific sector of the Antarctic in the austral summer seasons 1987/88–2018/19 (JARPA, JARPAII and NEWREP-A). In parentheses are the numbers of marine debris found in the forestomach and main stomach when only those two compartments were examined in the 2005/06–2013/14 seasons (JARPAII).

Research season	Sample size	Number of whales with debris ingestion	Marine debris*								Number of whales with debris ingestion per 100 Antarctic minke whales
			Wood		Polymer product		Others		Total		
1987/88	272	1	0	(0)	1	(0)	0	(0)	1	(0)	0.37
1988/89	236	0	0	(0)	0	(0)	0	(0)	0	(0)	0.00
1989/90	326	0	0	(0)	0	(0)	0	(0)	0	(0)	0.00
1990/91	323	0	0	(0)	0	(0)	0	(0)	0	(0)	0.00
1991/92	288	2	1	(0)	1	(0)	0	(0)	2	(0)	0.69
1992/93	327	2	1	(0)	1	(0)	0	(0)	2	(0)	0.61
1993/94	330	2	1	(0)	1	(0)	0	(0)	2	(0)	0.61
1994/95	330	0	0	(0)	0	(0)	0	(0)	0	(0)	0.00
1995/96	439	0	0	(0)	0	(0)	0	(0)	0	(0)	0.00
1996/97	440	0	0	(0)	0	(0)	0	(0)	0	(0)	0.00
1997/98	438	0	0	(0)	0	(0)	0	(0)	0	(0)	0.00
1998/99	389	2	1	(0)	1	(0)	0	(0)	2	(0)	0.51
1999/00	439	3	1	(0)	2	(0)	0	(0)	3	(0)	0.68
2000/01	440	3	2	(2)	1	(0)	0	(0)	3	(2)	0.68
2001/02	440	0	0	(0)	0	(0)	0	(0)	0	(0)	0.00
2002/03	440	2	0	(0)	1	(1)	1	(0)	2	(1)	0.45
2003/04	440	1	0	(0)	0	(0)	1	(1)	1	(1)	0.23
2004/05	440	1	1	(0)	0	(0)	0	(0)	1	(0)	0.23
2005/06	853	0	0	(0)	0	(0)	0	(0)	0	(0)	0.00
2006/07	505	0	0	(0)	0	(0)	0	(0)	0	(0)	0.00
2007/08	551	0	0	(0)	0	(0)	0	(0)	0	(0)	0.00
2008/09	679	0	0	(0)	0	(0)	0	(0)	0	(0)	0.00
2009/10	506	0	0	(0)	0	(0)	0	(0)	0	(0)	0.00
2010/11	170	0	0	(0)	0	(0)	0	(0)	0	(0)	0.00
2011/12	266	0	0	(0)	0	(0)	0	(0)	0	(0)	0.00
2012/13	103	0	0	(0)	0	(0)	0	(0)	0	(0)	0.00
2013/14	250	0	0	(0)	0	(0)	0	(0)	0	(0)	0.00
2014/15	-	-	-	-	-	-	-	-	-	-	-
2015/16	333	0	0	(0)	0	(0)	0	(0)	0	(0)	0.00
2016/17	333	0	0	(0)	0	(0)	0	(0)	0	(0)	0.00
2017/18	333	0	0	(0)	0	(0)	0	(0)	0	(0)	0.00
2018/19	333	0	0	(0)	0	(0)	0	(0)	0	(0)	0.00
Total	11,992	19	8	(2)	9	(1)	2	(1)	19	(4)	0.16

* All items found in stomach and duodenal ampulla except one polymer product found in the anus of one whale. Category 'others' includes one small black piece of carbonized object (research season: 2002/03) and one small rubber piece (research season: 2003/04).

Research Program under Special Permit in the Antarctic, Phases I and II) and NEWREP-A (New Scientific Whale Research Program in the Antarctic Ocean). The Antarctic minke whale is a small baleen whale species, which migrates between low latitude winter breeding grounds and high latitude summer feeding grounds in the Antarctic where it is widely distributed (Kasamatsu *et al.*, 1995). The species feed mainly on Antarctic krill (*Euphausia superba*) but also on ice krill (*E. crystallorophias*)

Fig. 1. A piece of polymer product found in the stomach of an Antarctic minke whale sampled during the 2002/03 austral summer season at position 76°S; 175°E (IWC Area V; CCAMLR sub-area 88.1).

Table 2. Ingestion of macro debris by Antarctic minke whales by sex and sexual maturity in the Indo-Pacific sector of the Antarctic in the austral summer seasons 1987/88–2018/19 (JARPA, JARPAII and NEWREP-A). In parentheses are the sample sizes examined by sex and sexual maturity.

	Female		Male		Total
	Immature	Mature	Immature	Mature	
Marine debris	(1,962)	(3,970)	(1,385)	(4,673)	(11,992)*
Wood	0	3	0	5	8
Polymer product	1	1	0	7	9
Others	0	0	1	1	2
Total	1	4	1	13	19

* Includes one male and one female of unknown sexual maturity status.

in some areas of the Antarctic (Ichii and Kato, 1991; Tamura and Konishi, 2009). It has been assumed that these whales ingested debris mixed in with food during the austral summer feeding period in the Antarctic waters.

This study also examines the body surface of the whales to identify entanglements, i.e., objects attached to the body (from the period of JARPA, JARPAII and NEWREP-A) or evidence from scars and marks of past entanglement events (from the period of JARPAII and NEWREP-A when more detailed photographic records were available). This is a unique study because it examines ingestion and entanglements in the Antarctic minke whale based on a series of surveys conducted over 31 years, and it is the first study to provide a summary of information regarding interaction between marine macro debris and whales in the Antarctic.

The surveys were conducted during the austral summer seasons from 1987/88 to 2018/19. Table 1 shows the details of the survey years and the number of samples for each year. The research area comprised the Indo-Pacific sector of the Antarctic, specifically the International Whaling Commission (IWC) Antarctic Management Areas III East (IIIE) (35°–70°E), IV (70°–130°E), V (130°E–170°W) and VI West (VIW) (170°–145°W), south of 60°S (JARPA and NEWREP-A) and south of 62°S (JAR-

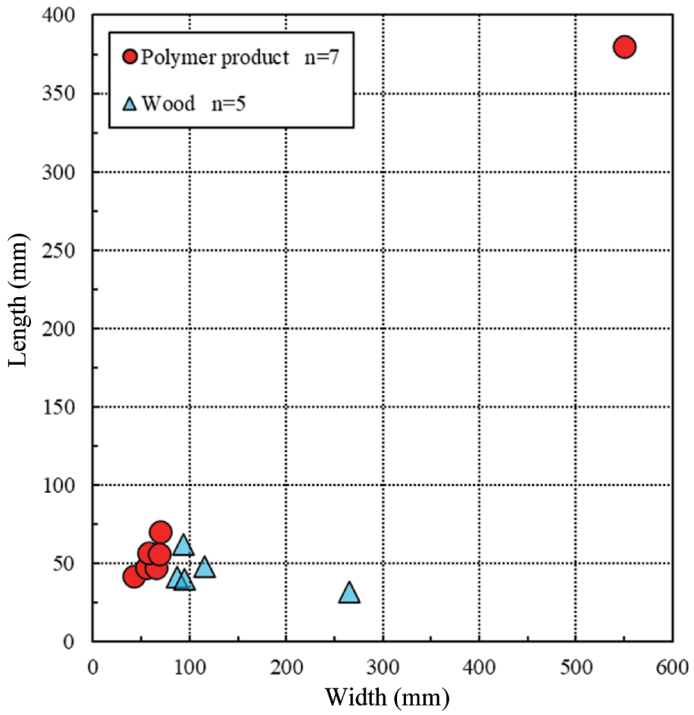

Fig. 2. Size of marine debris ingested by Antarctic minke whales in the Indo-Pacific sector of the Antarctic (1987/88–2004/05). The sample size of debris in this figure is different from that in Table 1 (no size information was available for two polymer products and three wood pieces).

PAII). These areas overlap partially with the Convention Areas of the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR): Area IIIE with Divisions 58.4.2–4, Area IV with Divisions 58.4.1–3, Area V with Division 58.4.1 and sub-area 88.1, and Area VIW with sub-area 88.2.

In order to obtain samples representative of the populations, Antarctic minke whales were sampled randomly on predetermined track-lines (Nishiwaki *et al.*, 2006; Nishiwaki *et al.*, 2014). Sampled whales were examined onboard of the research base vessel where several biological measurements and samples were collected. Body length was measured to the nearest 1 cm from the tip of snout to the deepest part of the notch of the flukes along a straight line parallel to the body axis. Body weight was obtained using a large weighing scale installed on the flensing deck. Sex of the whales was determined by researchers on board. Sexual maturity in females was determined by the presence of at least one corpus luteum or albicans in the ovaries and for males a single testis weight of 400 g or more was used as a criterion (Kato, 1982).

The stomachs of 11,992 Antarctic minke whales were examined. Examination of macro debris was conducted during the routine analysis of stomach contents following established protocols (Tamura and Konishi, 2009). The three stomach chambers and the duodenal ampulla were examined macroscopically during the period 1987/88–2004/05 (JARPA) and 2015/16–2018/19 (NEWREP-A). Only the fore and main stomachs were examined during the period 2005/06–2013/14 (JARPAII). Macro debris and objects other than preys were recorded. The sizes of solid objects were estimated from scaled photographic records.

Out of the 11,992 Antarctic minke whales examined, a total of 19 whales had ingested macro debris (Table 1). None of the whales had multiple marine debris in their stomachs. Fig. 1 shows an example of marine debris (polymer product) found in the stomach of an Antarctic minke whale. There were nine cases of polymer product ingestion and eight cases of wood ingestion. Macro debris ingestion was not observed after the 2005/06 season and there was no temporal increasing trend over the re-

Table 3. List of entanglement cases in the Antarctic minke whales in the Indo-Pacific sector of the Antarctic in the austral summer seasons 1987/88–2018/19 (JARPA, JARPAII and NEWREP-A) (see Fig. 3).

Research season	Date	Latitude	Longitude	Body length(m)	Body weight(t)	Sex	Stomach contents	Entanglement objects	Fig. 3
1995/96	22 Dec. 1995	62°48'S	68°55'E	7.5	4.7	M	Empty	Fishing hook	a
2003/04	10 Dec. 2003	63°10'S	54°56'E	5.7	2.1	M	Krill	Monofilament fishing line	b
2005/06	6 Jan. 2006	64°26'S	72°40'E	7.8	N/A	F	Krill	Rope	c
2005/06	5 Mar. 2006	63°56'S	103°46'E	5.7	N/A	M	Krill	Packing band	d

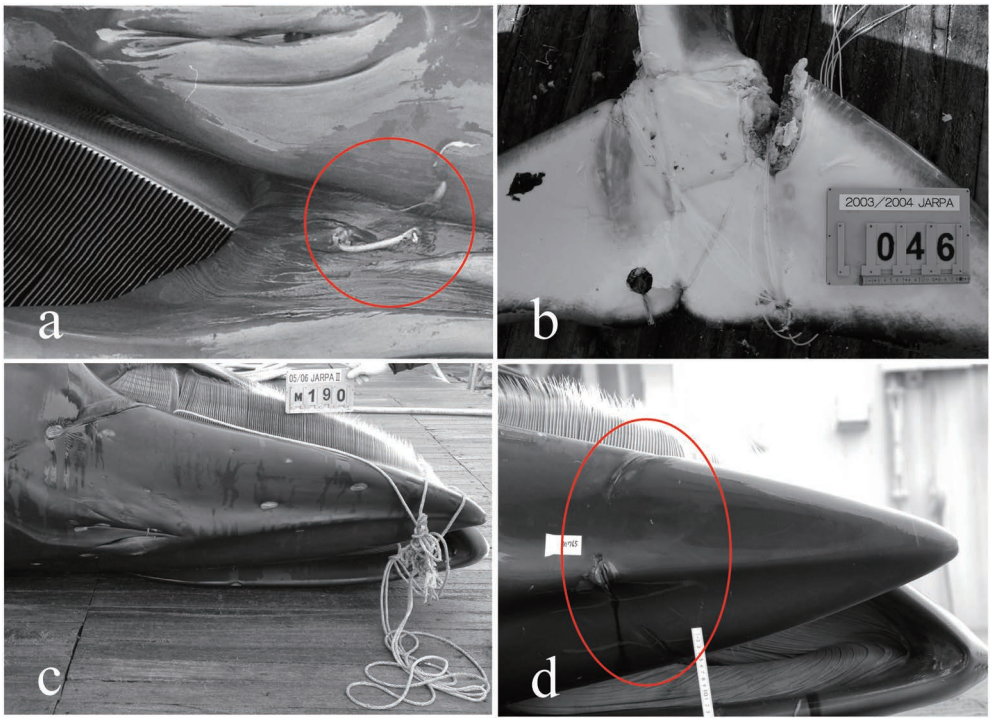

Fig. 3. Four cases of entanglement in the Antarctic minke whales in the Indo-Pacific sector of the Antarctic in the austral summer seasons 1987/88–2018/19 (JARPA, JARPAII and NEWREP-A). **a**: fishing hook; **b**: monofilament fishing line; **c**: rope; **d**: packing band (the band was lost when the whale was transported to the research base vessel).

search period. The frequency of stomachs with debris per 100 Antarctic minke whales examined was very low (0.16%) and the frequency of polymer products was 0.08%. Around 68.4% of all macro debris was ingested by mature males (Table 2). Most macro debris (75.0%) was less than 100 mm in size (Fig. 2). There were three debris, one polymer bag and two small wood pieces with sizes of more than 100×100 mm. Apart from debris, stones were found in six whales (in six austral seasons) and feathers in 37 whales (in thirteen austral seasons).

The frequency of ingested debris per 100 Antarctic minke whales was very low in comparison with debris found in whales from the North Atlantic. For example, six of 82 Icelandic fin whales (*B. physalus*) examined had debris in their stomachs while on the eastern coast of the United States, three of 19 mysticetes examined contained synthetic objects in their gut (Sadove and Morreale, 1990). The frequencies of marine debris ingestion obtained from stranded animals 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). For the Indo-Pacific sector of the Antarctic, our study found that only 19 Antarctic minke whales out of 11,992 examined had macro debris in their stomachs (0.16%).

The Antarctic minke whale is a filter feeder species with swallowing behavior (Nemoto, 1970), and

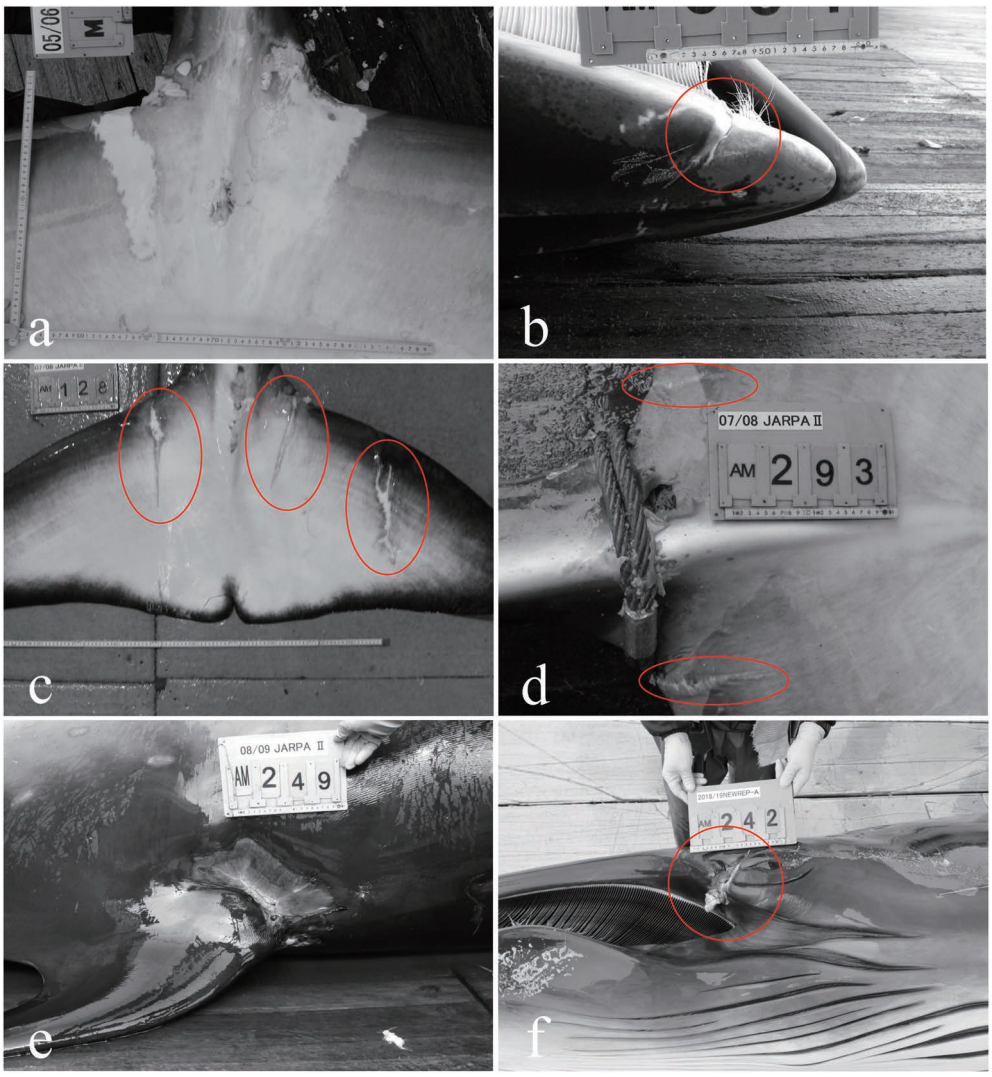

Fig. 4. Six cases of Antarctic minke whales in the austral summer seasons 2005/06–2018/19 (JARPAII and NEWREP-A) presenting marks and scars possibly produced by past entanglements. **a**: healed injury of flukes; **b**: healed injury of snout; **c**: healed injury of flukes; **d**: healed injury of flukes (rope used in the whale processing is also shown); **e**: healed injury of dorsal fin; **f**: unhealed injury of head.

this foraging behavior of Antarctic minke whales is associated with shallow waters (less than 100 m in depth) (Friedlaender *et al.*, 2014), which increases the chance of ingesting debris floating on the surface or in layers just under the surface.

Regarding entanglements, only four cases were found in the total sample of 11,992 whales (0.03%) (Table 3, Fig. 3). These included a fishing hook, a monofilament fishing line, a rope and a packing band. Six out of 5,215 Antarctic minke whales examined from the period of 2005/06 onward presented scars and marks likely to be associated with past entanglements (0.12%) (Fig. 4). It was assumed that scars were healed injuries (five cases) while unhealed marks were considered as injuries (one case). The unhealed injury was observed during the most recent survey under NEWREP-A. The possibility of these scars being produced by attacks from killer whales (*Orcinus orca*) is low. Scars observed in the present study were not consistent with the dentition of killer whales which comprise linear, parallel scars spaced 2.5–5.0 cm apart (Naessig and Lanyon, 2004). As in the case of debris, cases of entanglements with dangerous objects were extremely low in the Antarctic minke whales from the Indo-Pacific sector of the Antarctic when compared to the North Atlantic. For example, along the eastern coast of the United States and Canada during 2002–2006, 27 and 77 cases of entanglements

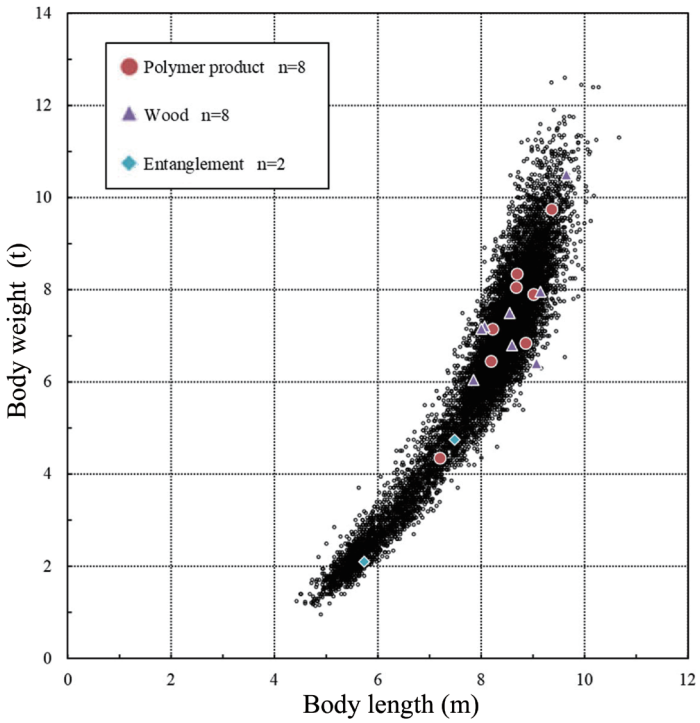

Fig. 5. Relationship between body length and body weight in the Antarctic minke whales (n=10,037) including whales ingesting debris and cases of entanglement. The sample size in this figure is different from those in Tables 1 and 3 (no body weight was available for one animal that ingested polymer product and two entangled animals).

were reported for common minke whales (*B. acutorostrata*) and humpback whales (*Megaptera novaeangliae*), respectively (Glass *et al.*, 2008). In Iceland, five of 95 fin whales examined showed signs of previous entanglements (Sadove and Morreale, 1990). It was reported that 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). Similar cases were reported for common minke whales in the Atlantic (Gill *et al.* 2000). In the present study, one of the four cases of entanglement in the Antarctic minke whale was from a packing band (Fig. 3d). CCAMLR has prohibited the discharge of plastics and restricted the use of packing bands on fishing vessels through Conservation Measure 26–01 (CCAMLR, 2006). Fishing gear is the most significant source of entanglements for whales and such entanglements have been reported in various waters (Laist, 1997; Simmonds, 2012). In the Antarctic, reports of mortality of whales attributed to entanglements related to fisheries operations are rare. One of those reports informed of the mortality of a sperm whale and another one possibly of an Antarctic minke whale (SC-CAMLR 2004; 2012). In the present study, only three cases of entanglements occurred, possibly from fishing gears (derelict or active) (Fig. 3).

In the cases involving both macro debris ingested and entanglements, it was shown that whales were not emaciated according to the usual body-length-weight relationship (Fig. 5). In conclusion the frequencies of marine macro debris ingested as well the cases of entanglements involving Antarctic minke whales in the Indo-Pacific sector of the Antarctic are extremely low, and much lower in comparison with cases reported in the North Atlantic. These low frequencies of ingested debris and entanglements are unlikely to have a negative effect on the conservation of the populations of Antarctic minke whales in the Indo-Pacific sector of the Antarctic.

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