Impact of marine debris on Antarctic fur seals *Arctocephalus gazella* at Cape Shirreff: diet dependent ingestion and entanglement
Preliminary results

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This report acknowledges the support provided by a range of organisations under the following project identifiers:

- Netherlands Ministry of Economic Affairs: BAPS project nr.: BO-11-018.02-044
  (Helpdesk reference: BO15 HD3563 Zwerfvuil_pelsrobb; IMARES Proj.nr. 431 28100 24)
- Netherlands Organisation for Scientific Research ALW-NWO Dossier nr.: 866.12.303
- Instituto Antártico Chileno INACH field season 2014: ECA 50: IN_02-12
- Instituto Antártico Chileno INACH field season 2015: ECA 51: IN_02-13
- British Antarctic Survey (BAS) – Bird Island field program 2014

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IMARES Wageningen UR

(Institute for Marine Resources & Ecosystem Studies)

Publication date: December 2015

Introduction

For several decades it has been known that plastics in the marine environment can harm marine organisms, most visibly birds, turtles and mammals (Shomura and Yoshida, 1985). These animals can become entangled in this synthetic debris and can ingest macro- and micro-plastics. Recently, increased awareness of plastic fragmentation into small persistent particles ('plastic soup') and the potential chemical hazards from ingestion have heightened the concern regarding the chemical impact on the marine food chains and ultimately the consequences for humans as end consumers (UNEP, 2011). UNEP listed plastic debris in the oceans as one of the three main emerging issues of concern for the global environment. Within the framework of the Commission for the Convention of Antarctic Marine Living Resources (CCAMLR) there has been attention to beached litter and seal entanglements, but little systematic work on the ingestion of plastic materials has been done. A recent study demonstrated the presence of micro-plastic debris in Southern Ocean sediments (Van Cauwenberghe et al. 2013) and there are several incidental reports on ingestion by seabirds (e.g. Van Franeker and Bell 1988, and Ainley et al. 1990). There is some information on plastic ingestion by seals. Plastic was found in faecal samples of three species of otariid seals at Sub-Antarctic Macquarie Island (Goldsworthy et al., 1997; McMahon et al., 1999; Eriksson and Burton, 2003). The studies qualitatively linked occurrence of the plastics to a diet of lantern fishes (Myctophidae). The tendency to ingest plastic particles among this type of fishes has been supported by recent studies in the North Pacific (Boerger et al., 2010; Davison and Asch, 2011). Plastic occurrence in scat samples at Macquarie Island was reported as a by-product of diet studies, without fixed protocols for recording presence or absence of debris and, therefore, no quantitative details are available. The first study to quantify plastic ingestion by a seal was in our paper on the North Sea harbour seal (*Phoca vitulina*) (Bravo Rebolledo et al. 2013).

In the first half of the nineteenth century Antarctic fur seals were hunted close to extinction (Bonner, 1968), populations have increased substantially in recent decades (Hucke-Gaete et al. 2004). Antarctic fur seals and closely related fur seal species have a circum-polar distribution. Thus, based on the seals, a circum-polar sampling protocol can be applied to obtain data on plastic occurrence across the Antarctic and the Sub-Antarctic.

The main fieldwork for this project (collecting scat samples, investigating entanglement rate and undertaking a beach litter survey for both macro- as micro-plastics) has been carried out on Cape Shirreff, Livingston Island, South Shetlands Islands in 2014 and 2015. Livingston Island contains the largest breeding colonies of Antarctic fur seals in the South Shetland Archipelago (Hucke-Gaete et al., 2004) and has been an important location for population, diet and foraging studies for this species (e.g. Casaux et al. 2004). Full cooperation with Chile for this project has been organised for transport logistics and fieldwork at the Chilean research station (Guillermo Mann Station (62°27' S; 60°47' W)) on Cape Shirreff for both years. Cooperation with the British Antarctic Survey (BAS) has been organised for scat collection on Bird Island, South Georgia in the austral summer of 2014. Figure 1 shows the sites where so far sampling has taken place.

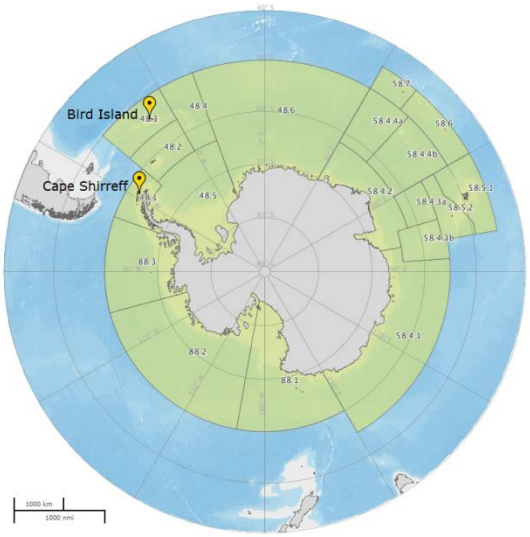

Figure 1. Overview of the Antarctic area with in green the CCAMLR regions. The sample areas are indicated in yellow symbols.

Scat samples

Information on abundance of plastic in the diet, and the diet of Antarctic fur seals was collected by scat sampling on Cape Shirreff, Livingston Island. Samples were collected from the 9th of January till 2nd of February 2014 and from the 7th of January till 5th of February 2015. We collected 200 scat samples from four different areas on Cape Shirreff (table 1), around suckling sites of female Antarctic fur seals. Furthermore, the BAS field team collected 100 scat samples on Bird Island, South Georgia in the austral summer of 2014 and in the austral winter of 2014.

AREA	Beach name
1	Playa Marko
	Playa Daniel
2	Maderas
	Cachorros
	Chugungo
	Ballena
3	Playa Alcàzar
	Playa Pinochet de la Barra
	Playa Antàrcticò
4	Playa Loberia

Table 1: The four different sample areas on Cape Shirreff

The analytical procedures for incidence of plastics followed the methods described in Bravo Rebolledo et al. (2013), and for the dietary analyses the methods given in Plötz et al. (1991) and Goldsworthy et al. (1997) were used. Scats were collected on two beaches designated as CCAMLR sample sites and on two non-CCAMLR beaches, with the reasoning that the higher human presence on CCAMLR beaches may bring along a higher chance to find debris on those beaches.

Micro-plastics are seldom reported in studies on seal scats. Rather than indicating a low prevalence, this could be because micro-plastics are difficult to see and identify, and typically are not considered – scat analyses are conducted primarily to investigate diet based on prey remains. Micro-plastics will pass through sieves that are normally used in dietary analyses of seal scats. Micro-plastics are too small to identify by the naked eye and are difficult to detect under a microscope, unless the researcher is trained to look for them. Even if plastics are seen, the observation might not have been documented. For instance, dietary studies on harbour seals have been carried out for decades in the Netherlands and plastics were occasionally noticed, but the study of Bravo Rebolledo et al. (2013) was the first to publish on the presence of plastics.

Photo 1: Antarctic fur seal faeces on Cape Shirreff (© Elisa Bravo Rebolledo)

Plastics in scat samples

First of all the scats were analysed for non-natural particles including plastic (industrial/user), other rubbish and industrial/chemical waste. Non-natural parts are found in nine of the 200 scats samples (4.5%) collected in 2014 on Cape Shirreff. We are still working on the analyses of the scat samples collected in 2015 on Cape Shirreff but so far we have one scat sample out of the 60 samples (that already have been processed) contained non-natural parts (1,67%).

From the samples collected on Bird Island ten of the 100 scats (10%) contained non-natural parts. All non-natural parts were photographed with a Zeiss camera stereoscope and their length and width were measured using Axiovision software (AxioVS 40 v. 4.8).

The non-natural particles found in the 2014 samples (both Cape Shirreff as Bird Island) were analysed with FTIR and EDX in collaboration with Shimadzu Europa GmbH and CARAT GmbH. With those techniques we try to identify the non-natural particle (if it is plastic yes or no) and if it is plastic of what type of the plastic. We are still working on the results from those tests but the first results show that of the 2014 Cape Shirreff samples at least five of the nine scats with non-natural parts have plastic particles. From the Bird Island samples at least six out of the ten scats with non-natural parts have plastic particles. Photo 2 shows examples of plastic particles found in the scat samples.

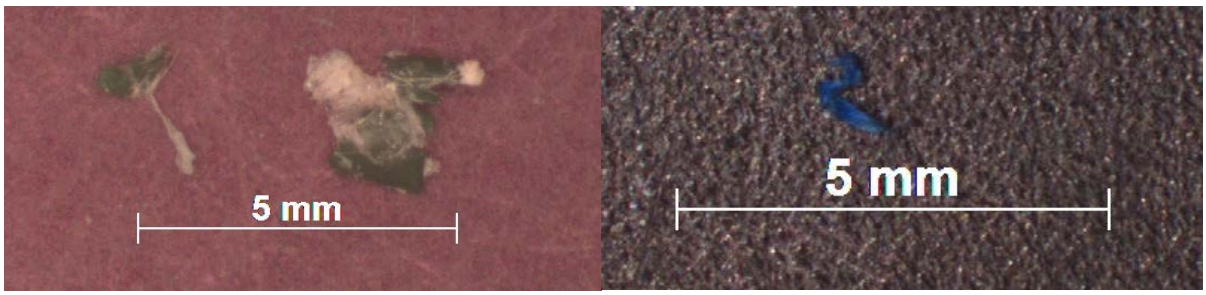

Photo 2: Examples of plastic particles found in Antarctic fur seal scat samples.

Diet

Our data showed that most of the collected scats contained krill, most likely *Euphausia superba*.
In 2014 97.5% (195/200) of the scat samples collected on Cape Shirreff contained krill. In 24.5% (49/200) of the scats we found fish remains; 775 otoliths and 852 eye lenses, at least a total of 523 fishes. In 2.5% (5/200) we found squid remains. In 2015 91.67% (55/60) of the scat samples so far contain krill. In 16.67% (10/60) of the scat samples fish remains were found; 33 otoliths and 53 eye lenses, so a total of at least 32 fishes. Squid remains were found in 5% (3/60) of the scats.

For the samples collected on Bird Island 95% (95/100) contained krill. Fish remains were found in 54% (54/100) of the scats; 598 otoliths and 212 eye lenses, so at least 324 fishes. 2% (2/100) of the scats contained squid remains.

The otoliths collected from the scat samples still need to be identified and measured to have a complete overview of the diet of the Antarctic Fur seal scats that were collected. By measuring the length and width of the otoliths the fish length and mass can be estimated using a regression equation.

Entanglement

No entanglements were seen in 2014. In 2015 we recorded one female fur seal with marine debris around her neck (photo 3). The debris was identified as a nylon fishing rope. It was removed from the seals neck using a ski pole without capture of the seal. With an estimated local population of 21.190 fur seals at Cape Shirreff in 2001-2002 (SCAR, 2008), this is a low rate of entanglement (0.005%). No recent data on the number of the local population (only Cape Shirreff) is to our knowledge available. Recent data for Bird Island, South Georgia indicated entanglement rates of 0.016% of fur seals (Waluda & Staniland 2013).
The American NOAA field team 2015 found a chinstrap penguin with a half ingested rope (photo 3). They caught the penguin and were able to extract the rope from the bird's throat and oesophagus and released the bird in good condition (US Antarctic Marine Living Resources Program, 2015).

Photo 3: Left photo: Antarctic fur seal female entangled in a nylon fishing rope (© Piet-Wim van Leeuwen). Right photo: Chinstrap penguin with half ingested rope (© Wiley Archibald)

Beach Litter

In all four areas on Cape Shirreff where scat samples were collected, we conducted a beach litter survey in 2015. The beach litter survey followed the protocol of OSPAR (OSPAR 2010), to generate globally comparable data at a level of detail that allows presentation of results matching more simple protocols as e.g. applied by CCAMLR. Beach litter surveys normally provide information on debris, and macro-plastics.
In our Cape Shirreff study, also the occurrence of micro-plastics was investigated to assess the amount of small plastic particles in the environment. To assess the presence of micro-plastics in beach litter, samples of sediment from below the high tide line, on the high tide line and above the high tide line were collected in 2015 (photo 4). Perpendicular to the waterline 11 subsamples were taken, over a one meter line, with a 60 ml container. The samples were analysed in the lab, following methods described by Hidalgo-Ruz et al. (2012). No micro-plastics were found in the sediment samples of both 2014 as 2015.

Photo 4: Collecting sediment samples from area 4

Photos were taken from all the macro-debris found on the four beaches (photo 5). Where possible the debris was collected and brought back to the lab for further analyses. The analyses of the beach litter survey of macro- plastics is still in process.

Photo 5: Different types of macro-debris (© Piet-Wim van Leeuwen)

Further Research

To complete the dataset it is important to at least submit one more field season so different years can be compared. Also more samples from Bird Island should be preferable to have a better understanding in seasonal changes: samples of the austral winter of 2014 have been collected at Bird Island but still need to be analysed. The collection of scat samples at additional locations around the Southern Ocean would be valuable to evaluate geographical patterns. However, more funding is necessary to complete this research in its originally intended sense.

Acknowledgements

Special thanks go to the Instituto Antártico Chileno (INACH) for their great support, funding and logistics for both fieldwork seasons (INACH ECA 50: IN_02-12; INACH ECA 51: IN_02-13). Without the help of Jose Retamales, Veronica Vallejos and Javier Arata this project would not have been possible. In the Netherlands , we acknowledge in particular Martijn Peijs (Ministry of Economic Affairs) for his help with the funding for the travel and expenses related to the 2015 fieldwork and analyses of the collected samples (BAPS project nr.: BO-11-018.02-044). The 2014 field work was supported by the Netherlands Organisation for Scientific Research (ALW-NWO Dossier nr.: 866.12.303 Correspondence nr.: 2013/15174/ ALW). We are very grateful to Piet-Wim van Leeuwen (VOF Van Leeuwen), Suse Kuhn (IMARES), Jose Ojeda (INACH) and the NOAA field teams for their support during the fieldwork on Cape Shirreff. Steve Geelhoed and Peter Reijnders (IMARES) helped us with all the permits and preparation for the field trips. Last but not least we express our gratitude to the British Antarctic Survey (BAS), in particular Iain Staniland and the 2014 field team from Bird Island, for collecting fur seal scat samples and the transport of these samples to Cambridge.

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