

locality records of the introduced bridled goby, *Arenigobius bifrenatus*. New Zealand Journal of Marine and Freshwater Research 37, 105–112.

Walters, S., 1996. Ballast water, hull fouling and exotic marine organism introductions via ships—a Victorian study. Environment Protection Authority, Victoria Publication 494. 143 pp.

0025-326X/\$ - see front matter © 2003 Elsevier Ltd. All rights reserved.  
doi:10.1016/S0025-326X(03)00292-3

## Marine debris ingestion by Southern Giant Petrels and its potential relationships with fisheries in the Southern Atlantic Ocean

Sofía Copello<sup>a,\*</sup>, Flavio Quintana<sup>a,b</sup>

<sup>a</sup> Centro Nacional Patagónico (Conicet) Boulevard Brown S/N, 9120 Puerto Madryn, Chubut, Argentina

<sup>b</sup> Wildlife Conservation Society Southern Boulevard 2300, Bronx, 10460 New York, USA

The quantity of litter in the world's oceans has been steadily increasing over the years. Within the Southern Ocean, the amount of debris increased 100-fold during the early 1990s (Barnes, 2002) and fisheries appear to be the greatest single source (Burton and Riddle, 2001). The composition of floating debris has become dominated by anthropogenic plastics and polystyrenes, metals and glass (Burton and Riddle, 2001).

Seabirds ingest floating plastics and other foreign matter while feeding on the surface of the ocean (Ryan, 1987). The prevalence of plastic ingestion by seabirds has increased and is well documented in many families of Procellariiformes (Bourne and Imber, 1982; Ryan et al., 1988; Kinan and Cousins, 2000). The Southern Giant Petrel (*Macronectes giganteus*) is a wide ranging procellariiform which breeds in the coasts of Patagonia and forages throughout the Argentine continental shelf (Quintana and Dell Arciprete, 2002), and which often interacts with fisheries activities. Little is known about their diet and their extent of marine debris ingestion. To date, there is only one published reference of ingestion of marine debris by Southern Giant Petrel from Marion island at the Subantarctic Ocean (Nel and Nel, 1999). Here we evaluate the presence of marine debris in the diet of Southern Giant Petrels chicks at a colony on the Patagonian coast.

The study was conducted at Isla Arce (45°00'S, 65°50'W) on the Patagonian shelf, Argentina, in the South Atlantic Ocean, where about 350–400 Southern Giant Petrels breed annually (Yorio et al., 1998). As part of a wider study concerning the foraging ecology of Southern Giant Petrel, between 29 January and 4 April 2002 a total of 73 food samples were taken from 73

randomly selected chicks. Samples were obtained by upending chicks over a bucket plastic and massaging the stomach and throat. The sample was strained, the liquid drained off and all the samples preserved in 70% alcohol for later analysis. In the laboratory, each sample was thawed and drained, the remaining solid components were removed, and the presence and absence of different marine debris items computed. The litter were categorized as plastic (including plastics bags, caps, etc), plastic lines, vegetables (including peel of onions, potatoes, corn-cob), aluminum foil, paper, wood and others (including rubber foam, wire, rope and styrofoam). Each item was weighed to the nearest 0.01 mg using a digital balance. Frequency of occurrence (FO) refers to the number of samples in which a particular item appeared.

Seventy three percent of food samples ( $n = 73$ ) contained marine debris. Plastics were by far the most frequent item (FO = 66%), followed by plastic line (36%) and vegetables (34%). Other items such as aluminum foil, wood, paper and others were less frequent (less than 15%) (Cochran's test  $Q = 129.9$ ,  $df = 9$ ,  $p < 0.0001$ ) (Fig. 1). We extracted a total of 70.1 g of debris from the chicks' stomachs, composed by 37.0 g of plastics, 11.8 g of paper, 10.1 g of vegetables and 5.4 g of aluminum foil. The lightest items were wood, plastic lines and others items (all less than 1 g). The average weight of litter in each sample was  $2.0 \pm 3.4$  g ( $n = 73$ ).

The results indicate a high proportion of marine debris in the diet of Southern Giant Petrels from Isla Arce, plastics being the most frequent items. The literature on marine debris leaves no doubt that plastics make-up most of the marine litter worldwide, ranging between 60 and 80% of the total waste disposal at sea (Derraik, 2002). Although there have been several studies on the diet of *Macronectes* spp. in Subantarctic colonies (e.g. Hunter, 1983; Hunter and Brooke, 1992; Ridoux, 1994), the occurrence of marine debris has not been previously

\* Corresponding author. Tel.: +54-2965-451024; fax: +54-2965-451543.

E-mail address: scopello@cenpat.edu.ar (S. Copello).

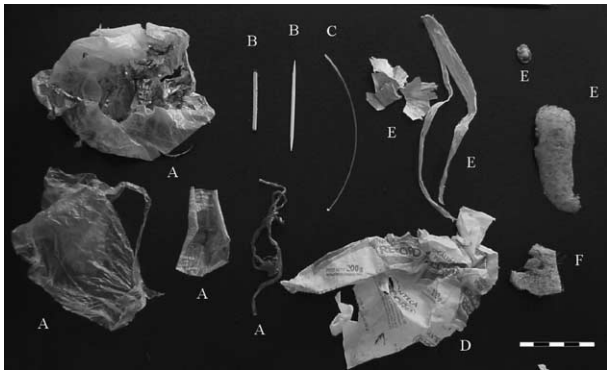


Fig. 1. Main waste disposal items found in the stomachs of Southern Giant Petrels chicks at Isla Arce, Patagonia, Argentina. (A) Plastics, (B) wood, (C) plastic line, (D) paper, (E) vegetables and (F) rubber foam (scale: 5 cm).

recorded. However, Nel and Nel (1999) described the presence of marine debris associated with Southern Giant Petrel nests. Although there are no previous studies on this species to compare with our results, other Procellariiformes species studies confirm the prevalence of ingested plastic (Connors and Smith, 1982; Bourne and Imber, 1982; Ryan et al., 1988).

Recent studies on hematology, biochemistry and disease serology of the Southern Giant Petrel in Patagonia, Argentina (Uhart et al., 2003) reported the healthy condition of adults birds at the two Patagonian colonies. However, the ingestion of plastics has been reported to cause deleterious effects on seabirds including: complicated its regurgitation (Pettit et al., 1981), clogged gizzards (Dickerman and Goelet, 1987), the concentration of toxic compounds (PCBs and pesticides) that can reduce breeding success (Sievert and Sileo, 1993), an increased risk of disease (Ryan, 1988), alteration of hormone levels and the formation of fat deposits (Connors and Smith, 1982), as well as direct mortality (Ryan et al., 1988).

Although we were not able to identify the sources of the marine debris recorded in diet samples of Southern Giant Petrel chicks, it is very likely that they derive from fishing activities. During the breeding season, the Southern Giant Petrels from Isla Arce and Gran Robredo travel 500 km daily over the Patagonian Shelf (Quintana and Dell Arciprete, 2002) and birds, particularly females, show a spatio-temporal overlap with fishing activities (Quintana et al., unpublished data). Southern Giant Petrels have often been observed feeding not only on fishing waste, but also on garbage thrown overboard. Marine debris appears to be more frequently derived from trawlers and/or jiggers rather than longliners operating on the Patagonian Shelf (i.e. hooks were not found around giant petrel nests, Copello and Quintana pers. obs.). The presence of items in the diet, such as squid and shrimp (Copello and Quintana, unpublished data) that can be obtained by scavenging on

trawler and jigger discards, emphasizes the association between petrels and these two fisheries. The by-catch in the Patagonian red shrimp fishery, for example, includes squid and fish that are discarded at sea (Pettovello, 1999). Trawlers and jiggers are also more numerous. Only 3–10 longline vessels (less than 1% of the total national fishing fleet) have been operating in Argentine waters in recent years (Bezzi et al., 2000), in contrast to 109–119 trawlers targeting several fish, 105–155 jiggers targeting squid, and 60 double-beam trawlers targeting Patagonian red shrimp. Furthermore, recent studies have reported there is either no incidental capture (Gandini and Frere, unpublished data) or low by-catch rate (4% of the total seabird captured) of Southern Giant Petrels by Argentine longline fisheries (Favero et al., 2001) in Argentina's Exclusive Economic Zone.

The interaction between Southern Giant Petrels and fisheries operating throughout the Patagonian shelf has not been fully assessed. Our study clearly demonstrates an association between these birds and high seas fisheries, most likely trawl vessels. The extent and consequences of this association will require further study in order to assess the costs of marine debris ingestion against the benefits of an alternative food supply in the form of fisheries waste.

### Acknowledgements

This research was funded by the Wildlife Conservation Society and Agencia Nacional de Promoción Científica y Tecnológica. We are grateful to Dr. Pablo Yorio for comments on earlier versions of the manuscript. We also thank Centro Nacional Patagónico (Conicet) for institutional support.

### References

- Barnes, D.K.A., 2002. Invasions by marine life on plastic debris. *Nature* 416, 808–809.
- Bezzi, S., Akselman, R., Boschi, E., 2000. Síntesis del estado actual de las pesquerías marítimas argentinas y de la cuenca del plata. Años 1997, 1998. Con actualización 1999. Mar del Plata. INIDEP, SAGPyA. Contribución No 1129. p. 388.
- Bourne, W.R.P., Imber, M.J., 1982. Plastics pellets collected by prion on Gough Island, Central South Atlantic Ocean. *Marine Pollution Bulletin* 13, 20–21.
- Burton, H., Riddle, M., 2001. Marine debris in the Southern Ocean. *Australia Antarctic Magazine* 1(1), 51. Available at <http://www.aad.gov.au/information/magazine>.
- Connors, P.G., Smith, K.G., 1982. Oceanic plastic particle pollution: suspected effect on fat deposition in red phalaropes. *Marine Pollution Bulletin* 13, 18–20.
- Derraik, J.G.B., 2002. The pollution of the marine environment by plastic debris: a review. *Marine Pollution Bulletin* 44, 842–852.
- Dickerman, R.W., Goelet, R.G., 1987. Northern gannet starvation after swallowing styrofoam. *Marine Pollution Bulletin* 18, 293.

- Favero, M., Silva, M.P., Khatchikian, C.E., Arias, A., Cañete, G., 2001. Preliminary data on seabird by-catch along the Patagonian shelf by Argentine longline fishing vessels: period 1999–2001. In: Proceedings of the First South American Workshop for Conservation of Albatrosses and Petrels.
- Hunter, S., Brooke, M., 1992. The diet of Giant Petrels, *Macronectes* spp. at Marion Island, Southern Indian Ocean. Colonial Waterbirds 15, 56–65.
- Hunter, S., 1983. The food and feeding ecology of the giant petrels, *Macronectes halli* and *M. giganteus* at South Georgia. Journal of Zoology, London 200, 521–538.
- Kinan, I.T., Cousins, K.L., 2000. Abundance of plastic debris and ingestion by albatross on Kure Atoll, North-western Hawaiian Islands. Marine Ornithology 28, 136.
- Nel, D.C., Nel, J.L., 1999. Marine debris and fishing gear associated with seabirds at sub-antarctic Marion Island, 1996/97 and 1997/98: in relation to longline fishing activity. CCAMLR Science 6, 85–96.
- Pettit, T.N., Grant, G.S., Whittow, G.C., 1981. Ingestion of plastic by Laysan albatross. Auk 98, 839–841.
- Pettovello, A.D., 1999. By-catch in the Patagonian red shrimp (*Pleoticus mulleri*) fishery. Marine and Freshwater Research 50, 123–127.
- Quintana, F., Dell Arciprete, P., 2002. The foraging grounds of Southern Giant Petrels (*Macronectes giganteus*) on the Patagonian shelf. Polar Biology 25, 159–161.
- Ridoux, V., 1994. The diets and dietary segregation on seabirds at the subantarctic Crozet islands. Marine Ornithology 22, 1–192.
- Ryan, P.G., 1987. The effects of ingested plastic on seabirds: correlations between plastic load and body conditions. Environmental Pollution 46, 119–125.
- Ryan, P.G., 1988. Effects of ingested plastic on seabird feeding: evidence from chickens. Marine Pollution Bulletin 19, 125–128.
- Ryan, P.G., Connell, A.D., Gardner, B.D., 1988. Plastic ingestion and PCBs in seabirds: is there a relationship? Marine Pollution Bulletin 19, 174–176.
- Sievert, P.R., Sileo, L., 1993. The effects of ingested plastic on growth and survival of albatross chicks. In: Vernner, K., Briggs, K.T., Morgan, K.H., Siegal-Causey, D. (Eds.), The Status, Ecology and Conservation of Marine Birds of the North Pacific. Canadian Wildlife Service. Special Publication, Ottawa, pp. 212–217.
- Uhart, M., Quintana, F., Karesh, W., Braselton, W.E., 2003. Baseline hematology, biochemistries and disease serology of the Southern Giant Petrel in Patagonia, Argentina. Journal of Wildlife Disease 39 (2), 359–365.
- Yorio, P., Frere, E., Gandini, P., Harris, G., 1998. Atlas de la distribución reproductiva y abundancia de aves marinas del litoral patagónico Argentino. Plan de Manejo Integrado de la Zona Costera Patagónica. Fundación Patagonia Natural and Wildlife Conservation Society.