PLASTIC INGESTION IN MARINE AND COASTAL BIRD SPECIES OF SOUTHEASTERN AUSTRALIA

JANN M. GILBERT[1,2], AMANDA J. REICHELT-BRUSHETT[2], ALISON C. BOWLING[3] & LES CHRISTIDIS[1]

[1]*National Marine Science Centre, Southern Cross University, Coffs Harbour, New South Wales 2450, Australia (janngilbert59@gmail.com)*
[2]*Marine Ecology Research Centre, School of Environment, Science and Engineering, Southern Cross University, Lismore, New South Wales 2480, Australia*
[3]*School of Health and Human Sciences, Southern Cross University, Coffs Harbour, New South Wales 2450, Australia*

Received 14 August 2015, accepted 29 October 2015

SUMMARY

Gilbert, J.M., Reichelt-Brushett, A.J., Bowling, A.C., Christidis, L. 2016. Plastic ingestion in marine and coastal bird species of southeastern Australia. *Marine Ornithology* 44: 21–26.

Plastic pollution is a significant problem in all oceans of the world and accounts for up to 90% of marine debris. Ingestion of plastic by seabirds and its effects are well documented, particularly in the Northern Hemisphere. However, fewer data exist for levels of plastic in seabird and coastal bird species in Australian waters or the southwestern Pacific. In this study, the stomach contents of a variety of seabirds and coastal birds (migratory and resident) were analysed for plastic. Nine (30%) of the birds sampled contained plastic. The median mass of plastic per bird was 41.7 mg and median number of pieces was 3.0. Shearwaters *Puffinus* spp. had significantly higher plastic mass and number of pieces than other species, and the most common type of plastic was manufactured. However, industrial pellets also contributed substantially. Plastics were primarily dark in colour. No clear indication of the influence of plastic ingestion on body condition could be found, however, internal physical damage and intestinal blockage was noted. Further assessment of the incidence and the effects of plastic ingestion in seabird and coastal bird species in Australian waters is required.

Key words: Australia, seabirds, coastal birds, shearwaters, marine pollution, plastic ingestion

INTRODUCTION

Plastic is a significant problem in all oceans of the world and accounts for up to 90% of marine debris (Derraik 2002, Rios *et al.* 2007, Barnes *et al.* 2009). It has well-documented impacts on a wide range of marine biota, primarily due to ingestion or entanglement (Laist 1997, Gregory 2009). Plastic ingestion by seabirds has increased significantly since the 1970s and parallels the increase in the amount and type of plastic in the world's oceans (Robards *et al.* 1995, Ryan 2008). Furthermore, greater numbers of species now ingest plastic, and the frequency of occurrence of plastic within those species has also increased (Robards *et al.* 1995, van Franeker *et al.* 2011, Lavers *et al.* 2014).

Seabirds in the order Procellariformes have some of the highest incidence of ingestion, with at least 80% of species reported to carry plastic loads (Robards *et al.* 1995, Ryan 2008, Acampora *et al.* 2014). Shearwaters *Puffinus* spp. are known to be particularly vulnerable (Vlietstra & Parga 2002) and in some species, e.g. Short-tailed *P. tenuirostris* and Flesh-footed *P. carneipes* shearwaters, the proportion of individuals ingesting plastic is reported to be 80%–100% (Hutton *et al.* 2008, Carey 2011, Cousin *et al.* 2015).

As wide-ranging foragers and marine predators, seabirds are also recognised as valuable bioindicators (Robards *et al.* 1997, Ryan 2008). Monitoring the incidence of ingestion and types of plastic ingested can provide a record of affected species and a basis for longer-term trends, as well as a cost-effective means to monitor plastic pollution levels in the ocean (Ryan *et al.* 2009, Tourinho *et al.* 2010). Ingestion of plastic in seabirds and its effects are well documented, particularly in waters of the Northern Hemisphere and around South America (e.g. Ryan 1990, Copello & Quintana 2003, van Franeker *et al.* 2011, Yamashita *et al.* 2011). Fewer data exist for Australian waters or the southwestern Pacific (Spear *et al.* 1995, Carey 2011), and there appears to be no information on plastic ingestion in coastal bird species in Australian waters.

This paper examines the incidence of plastic ingestion, and the type and amount of plastic ingested, in a variety of the seabird and coastal bird species of southeastern Australia. Relationships between ingestion and a number of factors that may influence it, such as species, diet and migration pattern, were also considered.

METHODS

A sample of 30 birds — 11 species representing seven families and four orders (following Christidis & Boles 2008) (Table 1) — were examined. Samples were sourced from Australian Seabird Rescue (ASR), a WildlifeLink seabird and marine turtle rescue and rehabilitation organisation located in Ballina (28°84′S, 153°57′E) in northern New South Wales (NSW) on the east coast of Australia. Birds were found stranded (as a result of injury, illness or exhaustion) in various locations between Wooli (29°37′S, 153°29′E) and New Brighton (28°51′S, 153°55′E) and were brought into care at ASR but subsequently died. A variety of different species was chosen in order to identify whether plastic ingestion was prevalent in resident coastal species (e.g. Phalacrocoracidae and Charadriiformes) as well as in migratory species (e.g. Procellariformes) found on the north coast of NSW. While the sample size is small, it is novel in its inclusion of marine and coastal species, as well as migratory and resident birds found along the east coast of Australia. Samples were obtained from ASR over a period of 13 months (July 2011–August 2012) and kept frozen at -25 °C until necropsies were performed in August 2012.

Before necropsy, birds were thawed at room temperature, dried and weighed on an electronic balance (SECA, Chino USA); the beak and tarsus length were recorded for each individual. Necropsies were performed using general guidelines from Butcher & Miles (1993). Briefly, carcasses were plucked and dissected along the anteroposterior axis between the cloaca and the beak. Internal organs and anatomy were examined for haemorrhaging or other signs of internal trauma, which were recorded; where appropriate, samples were taken. Contents of the gizzard and proventriculus were examined for the presence of plastic or other foreign matter, and biological contents such as prey remains, grit or pebble fragments and parasites were also recorded (Auman *et al.* 1997, Carey 2011). Plastic items were removed, and the gizzard and proventriculus were examined for perforations, lacerations, ulceration or haemorrhage. Plastics were washed in Milli-Q ultra-pure water and dried in a fume hood. Items were counted, weighed on an AB204-S digital balance (± 0.1 mg), and classified by colour and type (industrial pellets or manufactured fragments) (Blight & Burger 1997, Ryan 2008), and size (according to Barnes *et al.* 2009).

Statistical analyses

Statistical analyses were performed with IBM SPSS Statistics version 22.0 (IBM Corporation, US). Because of the small sample size and the skewed distribution of the data, non-parametric statistical tests were applied. Mann–Whitney U tests were used to investigate differences in debris weight and number of pieces between species (shearwater and other), age classes (juvenile/adult, determined by plumage) and migration pattern (pairwise comparisons, trans-Pacific and equatorial/non-migrant). Correlations were used to investigate relationships between bird mass and plastic mass, and between bird mass and number of pieces. Given the use of non-parametric tests, medians are reported. “Incidence” is defined as a percentage of the total, i.e. for individuals of a species or group that contained plastic, and for types of plastic.

RESULTS

Overall, this study found that 10 of the 30 birds (33%) carried debris loads, with nine carrying plastic debris (30%). In total, 50 items were collected from 10 birds, 49 of which were plastic and one of which was metal. The metal item consisted of a gang hook (two hooks with attached metal tracer line, total weight 3.13 g), which had been ingested by a juvenile Australian Gannet

TABLE 1
Southeastern Australian marine bird species (resident and migratory) in this study, and usual habitats, residency and life-history stages

Common name	Scientific name (Order)	Habitat/Residency	n	Juvenile/Adult
Australian Gannet	*Morus serrator* (Suliformes)	Coastal and pelagic, migratory	6	6/0
Pied Cormorant	*Phalacrocorax varius* (Suliformes)	Coastal, resident	7	2/5
Australasian Darter	*Anhinga novahollandiae* (Suliformes)	Coastal, resident	2	0/2
Tropicbird	*Phaethon* sp. (Suliformes)	Pelagic, vagrant	1	1/0
Crested Tern	*Sterna bergii* (Charadriiformes)	Coastal, resident	1	1/0
Silver Gull	*Chroicocephalus novaehollandiae* (Charadriiformes)	Coastal, resident	2	0/2
Wandering Albatross	*Diomedea exulans* (Procellariformes)	Pelagic	1	1/0
Prion	*Pachyptila* spp. (Procellariformes)	Pelagic	1	1/0
Wedge-tailed Shearwater	*Puffinus pacificus* (Procellariformes)	Pelagic, migratory	2	0/2
Short-tailed Shearwater	*Puffinus tenuirostris* (Procellariformes)	Pelagic, migratory	5	0/5
Hutton’s Shearwater	*Puffinus huttoni* (Procellariformes)	Pelagic, migratory	2	0/2

TABLE 2
Total weight and number of pieces, and proportion of birds by species that had ingested plastic

Species	Total weight (mg; median, range[a])	Total pieces (median, range[a])	Incidence (%; proportion of n)
Short-tailed Shearwater	678.9 (164.8, 48.2–290.2)	31 (6, 3–12)	80 (4/5)
Wedge-tailed Shearwater	27.5	2	50 (1/2)
Hutton’s Shearwater	2.2	2	50 (1/2)
Pied Cormorant	9.1	3	14 (1/7)
Australasian Darter	41.7	10	50 (1/2)
Prion	1.4	1	100 (1/1)

[a]Where applicable.

Morus serrator. This metal debris was excluded from analysis of data relating to plastic ingestion. The size of most plastic items recovered, from visual observation (single observer), were categorised as micro (<5 mm), with only a small number of meso-sized items (5–20 mm). For the nine birds that carried plastic debris, the median number of plastic items per bird was 3.0 and median weight of plastic per bird was 41.7 mg (range 1.4–290.2 mg). However, it should be noted that 33% of birds carrying plastic carried >100 mg (median = 75.7 mg, range 164.8–290.2). The highest number of plastic items recorded in one sample was 12, and the greatest mass of plastic was 290.2 mg, both from Short-tailed Shearwaters. Four of the five Short-tailed Shearwaters had ingested plastic, with loads ranging from 48.2 mg to 290 mg, whereas, of the two Wedge-tailed Shearwaters *P. pacificus*, only one had ingested plastic and the load was much lower (27.5 mg) (Table 2). Overall, Short-tailed Shearwaters tended to carry more plastic than Wedge-tailed Shearwaters, but these differences were not significant. There were no significant correlations between bird mass and plastic mass (r = -0.19, $P > 0.05$) or bird mass and number of plastic items (r = 0.19, $P > 0.05$).

Shearwaters accounted for 67% of all birds that had ingested plastic, and they had ingested the highest number of pieces (35). Incidence of plastic ingestion was significantly higher in shearwaters (n = 9) compared with other species (n = 20) (67% and 15%, respectively, U = 43.5, P = 0.006), as was debris weight (106.5 and 9.1 mg, respectively; U = 37.5, P = 0.003) and total number of pieces (35 and 14, respectively, U = 41.5, P = 0.005). There were also significant differences between trans-Pacific migrants and non-migrants in incidence of plastic ingestion (67% and 18%, respectively, U = 33.0, P = 0.03), debris weight (170.2 and 5.6 mg, respectively; U = 25.0, P = 0.006), and number of pieces (8.0 and 2.5, respectively; U = 28.0, P = 0.01) but not between trans-Pacific and equatorial migrants (Fig. 1). There were no significant differences in incidence of plastic ingestion, debris weight or number of pieces between age classes (juvenile/adult, $P > 0.05$ in all cases) or foraging method (diver/surface, $P > 0.05$ in all cases).

Plastic debris consisted of more fragments (including nylon fishing line remnants) than industrial pellets (60%, 31 pieces and 35%, 18 pieces, respectively), but the difference was not significant. Plastic fragments predominantly consisted of hard plastics degraded from larger items and some pieces of nylon line. Pellets made a noteworthy contribution to the total amount of plastic, with all four of the Short-tailed Shearwaters found to have ingested the same type of black coiled pellets; in two of the samples, the pellets were more highly degraded (Fig. 2). The colour of items ingested was predominantly black (67%) with dark colours (black, brown) accounting for 69% of items. The remaining 31% were of lighter colours (white, yellow and light blue).

Most plastic items were found in the gizzard (89%), with the exception of a piece of nylon line that was found in the small intestine of a prion (*Pachyptila* spp.). Three samples (33%) had plastic items completely blocking the pylorus (two Short-tailed and one Wedge-tailed shearwater), and ulceration and necrosis of the gizzard was evident in six of the nine samples that carried plastic (66%). With the exception of the two Australasian Darters *Anhinga novahollandiae* and two Silver Gulls *Chroicocephalus novaehollandiae*, all other birds were emaciated and most were less than half average normal weight (Vogelnest 2000). Only two birds (both Silver Gulls) had fat reserves. Few had any stomach contents apart from squid beaks, fish scales or other unidentified prey remains. Shellgrit and small pebbles were also relatively common, as was the presence of round and tapeworms.

DISCUSSION

While caution is required in interpreting results, given the small sample size and the variance in the data, we can report that plastic ingestion is prevalent in Australia's pelagic migratory seabird species, and also that ingestion is apparent in resident coastal species. The overall percentage of birds carrying plastic debris (30%) was lower than reported in other regional studies in eastern Australia (Hutton *et al.* 2008, Carey 2011, Acampora *et al.* 2013, Cousin *et al.* 2015). This is likely due to inclusion in the present study of coastal and near-shore species, which constituted over half of the samples (18 individuals). The results are, however, consistent with other studies that also included coastal and resident species, all of which reported lower overall incidence of plastic ingestion, with results between 11% and 40% (Ainley *et al.* 1989, Spear *et al.* 1995, Tourinho *et al.* 2010).

High incidence of plastic ingestion, and greater mass and number of items in shearwaters than in other species, has also been

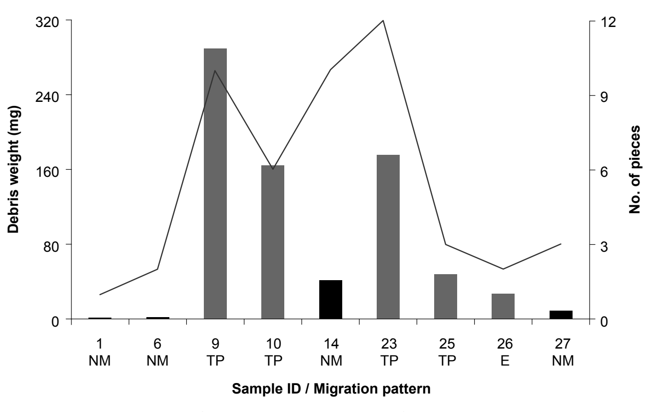

Fig. 1. Differences in debris weight and number of pieces by species (shearwaters and other species) and migration pattern (NM = non-migrant, TP = trans-Pacific, E = equatorial) for each of the nine birds that had ingested plastic. Bars represent total weight of plastic; the line represents the total number of pieces.

Fig. 2. Plastic load collected from a Short-tailed Shearwater in which the black, coiled pellets (right) were completely blocking the pylorus. The image also shows the general mixture of pellets and fragments, and the predominance of dark or black plastic.

reported previously (Ainley *et al.* 1989, Spear *et al.* 1995, Ryan 2008, Tourinho *et al.* 2010). These studies also found low, or no, incidence of plastic ingestion in Charadriiformes or Phaethontidae (where the latter family was included), and suggested that differences in physiology may influence results. Shearwaters have a unique proventriculus, which restricts regurgitation of indigestible items (Furness 1985, Carey 2011, Acampora *et al.* 2014), and the absence of this in coastal species may help to explain the significant differences (Ainley *et al.* 1989, Tourinho *et al.* 2010). No other account of plastic ingestion in Phalacrocoracidae could be found.

Differences between other species and shearwaters could also be interpreted as a reflection of the different diets between the two groups. Azzarello & Van Vleet (1987) found that piscivores were less likely to ingest plastic, and Ryan (2008) suggested that more opportunistic foragers were unlikely to be very selective and, therefore, may be more prone to ingesting plastic inadvertently. The prey of shearwaters is composed of euphausiids, cephalopods, crustaceans and, to a lesser degree, small schooling fish (Lindsey 1986, Skira 1986), suggesting they are more opportunistic than coastal species such as the Australasian Darter and the Pied Cormorant *Phalacrocorax varius*, which are primarily piscivorous (Lindsey 1986).

Another explanation for the differences could be related to migration pattern (Ainley *et al.* 1989, Ryan 1990, Spear *et al.* 1995, Vlietstra & Parga 2002). As trans-Pacific migrants, Short-tailed Shearwaters cover vast areas of the Pacific Ocean during migration, and they are also known to forage at some distance from breeding colonies when resident (McDuie *et al*. 2015), crossing oceanic fronts in the process (Lindsey 1986, Skira 1986). Skira (1986), Ainley *et al.* (1989), Spear *et al.* (1995) and Vlietstra & Parga (2002), who compared longer-term data, noticed seasonal variations in the type and amount of plastic ingested, particularly in species with longer migration patterns. Specifically, Ainley *et al.* (1989) and Spear *et al.* (1995) found a higher incidence of ingestion in species that bred in the South Pacific and wintered in the North Pacific, and foraged at oceanic fronts or convergences, such as the Short-tailed Shearwaters in the present study. In contrast, non-migrant species, particularly in regional coastal areas where samples for the present study were collected, would have considerably less exposure to sources of plastic debris (Reisser *et al.* 2013).

The composition of plastic debris and predominance of plastic fragments found in birds in the present study have been reported in numerous other studies worldwide (e.g. Ryan 2008, Tourinho *et al.* 2010, Carey 2011). Surveys of plastic debris in Australian marine waters (Hardesty & Wilcox 2011, Reisser *et al.* 2013) also report the predominance of fragments from larger consumer items and of micro-plastics. Notably, the colour of debris found ingested in the present study (predominantly dark or black) was somewhat different from that reported elsewhere, with numerous studies reporting a predominance of light or bright colours (e.g. Vlietstra & Parga 2002, Carey 2011, Lavers *et al.* 2014, Cousin *et al.* 2015). Acampora *et al.* (2013), however, noted that Short-tailed Shearwaters in their study, which were adults on their southern migration, had consumed primarily dark- and clear-coloured plastics. This may help to explain the predominance of black fragments in samples from Short-tailed Shearwaters in this study, all of which were considered adults according to plumage and morphometrics (Vogelnest 2000). Ryan (2008) also reported that seabirds appeared to "prefer" darker or more conspicuously coloured debris. Alternatively, as Day (1980) suggested, shearwaters may show no colour preference, and ingestion of different colours may be a result of regional distribution patterns of plastic debris, or starving birds in poor body condition may be more likely to take anything (Day 1980).

The lack of a correlation between bird mass and plastic mass or number of items in the present study is notable, and has been regularly reported (Ainley *et al.* 1989, Robards *et al.* 1995, Ryan 2008), particularly in Short-tailed Shearwaters (Yamashita *et al.* 2011, Acampora *et al.* 2014, Cousin *et al.* 2015). While some authors have reported significant negative relationships in various species (Spear *et al.*, 1995, Auman *et al.*, 1997, and Vlietstra & Parga 2002, Lavers *et al.*, 2014), these are relatively rarely reported findings. As Vlietstra & Parga (2002) suggest, if plastic does have an adverse effect on body condition, then species that frequently ingest plastic should be the most likely to show negative effects on body condition, including reduced foraging success or starvation.

The general absence of this relationship has been a stumbling block in finding evidence for direct or indirect effects of plastic ingestion on body condition (Ryan 1990, Robards *et al.* 1995, Hutton *et al.* 2008, Carey 2011). As Ryan (1990) and others (Auman *et al.* 1997, Hutton *et al.* 2008) point out, there is the question of which is cause and which effect? Is the bird in poor condition due to plastic ingestion, or has starvation made it less discriminating and therefore more prone to plastic ingestion during foraging? In the case of stranded birds, has ingestion of plastic affected the ability to endure adverse weather and other conditions or, again, has starvation prompted indiscriminate ingestion of more plastic (Ryan 1990, Gregory 2009)? In the present study, all but two of the birds were classified as being in poor condition, but this could be considered an artefact, given that birds come into care at ASR generally because they are in poor condition.

Given the increasing amount of plastic and other debris in the oceans, and coastal and seabirds' reliance on marine ecosystems, they are likely to encounter marine debris throughout their lives. This makes them vulnerable to chronic effects from plastic accumulated over the long term (Ryan 1988, Colabuono *et al.* 2010, Rochman *et al.* 2013) and may add considerable stress to individuals (Ryan 1990, Vlietstra and Parga 2002), particularly if they are unable to successfully regurgitate all foreign matter (Ryan 1990, Mallory *et al.* 2006, Tourinho *et al.* 2010, Carey 2011). Vogelnest (2000) observed that this long-term exposure may have serious consequences for bird populations over time, however, a gradual decline in numbers may go unnoticed.

ACKNOWLEDGEMENTS

The assistance of Australian Seabird Rescue in providing samples and a necropsy lab is gratefully acknowledged; the project would not have been possible without this support. Thanks also to Southern Cross University lecturers and staff, who contributed their time and knowledge to the project. This study was undertaken as an Integrated Project in the third year of a Bachelor of Marine Science and Management degree at Southern Cross University, Lismore, Australia.

REFERENCES

ACAMPORA, H., SCHUYLER Q.A., TOWNSEND, K.A. & HARDESTY, B.D. 2014. Comparing plastic ingestion in juvenile and adult stranded short-tailed shearwaters (*Puffinus tenuirostris*) in eastern Australia. *Marine Pollution Bulletin* 78: 63-68.

AINLEY, D.G., SPEAR, L.B. & RIBIC, C.A. 1989. The incidence of plastic in the diets of pelagic seabirds in the Eastern equatorial Pacific region. In: SHOMURA, R.S. & GODFREY, M.L. (Eds). *Second International Conference on Marine Debris*. Honolulu, Hawaii: National Oceanic and Atmospheric Administration.

ANDRADY, A.L. 2011. Microplastics in the marine environment. *Marine Pollution Bulletin* 62: 1596-1605.

AUMAN, H.J., LUDWIG, J.P., GIESY, J.P. & COLBORN, T. 1997. Plastic ingestion by Laysan albatross chicks on Sand Island, Midway Atoll in 1994 and 1995. In: ROBERTSON, G. & GALES, R. (Eds). *Albatross Biology and Conservation*. Chipping Norton, Australia: Surrey Beatty & Sons.

BARNES, D.K.A., GALGANI, F., THOMPSON, R.C. & BARLAZ, M. 2009. Accumulation and fragmentation of plastic debris in global environments. *Philosophical Transactions of the Royal Society, B: Biological Sciences* 364: 1985-1998.

BLIGHT, L.K. & BURGER, A.E. 1997. Occurrence of plastic particles in seabirds from the Eastern North Pacific. *Marine Pollution Bulletin* 34: 323-325

CAREY, M.J. 2011. Intergenerational transfer of plastic debris by Short-tailed Shearwaters (*Ardenna tenuirostris*). *Emu* 111: 229-234.

CHRISTIDIS, L. & BOLES, W.E. 2008. *Systematics and taxonomy of Australian birds*. Collingwood, Victoria: CSIRO.

COLABUONO, F.I., TANIGUCHI, S. & MONTONE, R.C. 2010. Polychlorinated biphenyls and organochlorine pesticides in plastics ingested by seabirds. *Marine Pollution Bulletin* 60: 630-634.

COPELLO, S. & QUINTANA, F. 2003. Marine debris ingestion by Southern Giant Petrels and its potential relationships with fisheries in the Southern Atlantic Ocean. *Marine Pollution Bulletin* 46: 1513-1515.

COUSIN, H.R., AUMAN, H.J., ALDERMAN, R. & VIRTUE, P. 2015. The frequency of ingested plastic debris and its effects on body condition of short-tailed shearwater (*Puffinus tenuirostris*) pre-fledgling chicks in Tasmania, Australia. *Emu* 115: 6-11.

DAY, R.H. 1980. *The occurrence and characteristics of plastic pollution in Alaska's marine birds*. MS thesis, Fairbanks, AK: University of Alaska.

DERRAIK, G.B. 2002. The pollution of the marine environment by plastic debris: a review. *Marine Pollution Bulletin* 44: 842-852.

FURNESS, R.W. 1985. Ingestion of plastic particles by seabirds at Gough Island, South Atlantic Ocean. *Environmental Pollution Series* 38: 261-272.

GREGORY, M.R. 2009. Environmental implications of plastic debris in marine settings — entanglement, ingestion, smothering, hangers-on, hitch-hiking and alien invasions. *Philosophical Transactions of the Royal Society B: Biological Sciences* 364: 2013-2025.

HARDESTY, B.D. & WILCOX, C. 2011. Understanding the types, sources and at-sea distribution of marine debris in Australian waters. Canberra, Australia: CSIRO.

HUTTON, I., CARLILE, N. & PRIDDEL, D. 2008. Plastic ingestion by flesh-footed (*Puffinus carneipes*) and wedge-tailed (*P. pacificus*) shearwaters. *Papers and Proceedings of the Royal Society of Tasmania* 142(1): 1-6.

LAIST, D.W. 1997. Impacts of marine debris: Entanglement of marine life in marine debris including a comprehensive list of species with entanglement and ingestion records. In: COE, J. & ROGERS, D.B. (Eds). *Marine Debris: Sources, Impacts and Solutions*. New York: Springer-Verlag.

LAVERS, J.L., BOND, A.L. & HUTTON, I. 2014. Plastic ingestion by Flesh-footed Shearwaters (*Puffinus carneipes*): Implications for fledgling body condition and the accumulation of plastic-derived chemicals. *Environmental Pollution* 187: 124-129.

LINDSEY, T.R. 1986. *The Seabirds of Australia*. Sydney, Australia: Angus & Robertson.

MALLORY, M.L., GREGORY, G.J. & MOENTING, A. 2006. Marine plastic debris in northern fulmars from Davis Strait. *Marine Pollution Bulletin* 52: 800-815.

McDUIE, F., WEEKS, S.J., MILLER, M.G.R. & CONGDON, B.C. 2015. Breeding tropical shearwaters use distant foraging sites when self-provisioning. *Marine Ornithology* 43: 123-129.

MOORE, C.J. 2008. Synthetic polymers in the marine environment: A rapidly increasing, long-term threat. *Environmental Research* 108: 131-139.

REISSER, J., SHAW, J., WILCOX, C., HARDESTY, B.D., PROIETTI, M., THUMS, M. & PATTIARATCHI, C. 2013. Marine plastic pollution in waters around Australia: characteristics, concentrations, and pathways. *PLoS ONE* 8(11): e80466. doi:10.1371/journal.pone.0080466.

RIOS, L.M., MOORE, C.J. & JONES, P.R. 2007. Persistent organic pollutants carried by synthetic polymers in the ocean environment. *Marine Pollution Bulletin* 54: 1230-1237.

ROBARDS, M.D., GOULD, P.J. & PIATT, J.F. 1997. The highest global concentration and increased abundance of oceanic plastic debris in the North Pacific: evidence from seabirds. In: COE, J.M. & ROGERS, D.B. (Eds). *Marine Debris: Sources, Impacts and Solutions*. New York: Springer-Verlag.

ROBARDS, M.D., PIATT, J.F. & WOHL, K.D. 1995. Increasing frequency of plastic particles ingested by seabirds in the subarctic north Pacific. *Marine Pollution Bulletin* 30: 151-157.

ROCHMAN, C.M., BROWNE, M.A., HALPERN, B.S., HENTSCHEL, B.T., HOH, E., KARAPANAGIOTI, H.K., RIOS-MENDOZA, L.M., TAKADA, H., TEH, S. & THOMPSON, R.C. 2013. Policy: Classify plastic waste as hazardous. *Nature* 494: 169-171.

RYAN, P.G. 1988. Effects of ingested plastic on seabird feeding: Evidence from chickens. *Marine Pollution Bulletin* 19: 125-128.

RYAN, P.G. 1990. The effects of ingested plastic and other marine debris on seabirds. In: SHOMURA, R.S. & GODFREY, M.L. (Eds). Second International Conference on Marine Debris. Honolulu, Hawaii: National Oceanic and Atmospheric Administration,.

RYAN, P.G. 2008. Seabirds indicate changes in the composition of plastic litter in the Atlantic and south-western Indian Oceans. *Marine Pollution Bulletin* 56: 1406-1409.

RYAN, P.G., MOORE, C.J., VAN FRANEKER, J.A. & MOLONEY, C.L. 2009. Monitoring the abundance of plastic debris in the marine environment. *Philosophical Transactions of the Royal Society B: Biological Sciences* 364: 1999-2012.

SKIRA, I. 1986. Food of the Short-Tailed Shearwater, *Puffinus tenuirostris*, in Tasmania. *Wildlife Research* 13: 481-488.

SPEAR, L.B., AINLEY, D.G. & RIBIC, C.A. 1995. Incidence of plastic in seabirds from the tropical Pacific, 1984-91: relation with distribution of species, sex, age, season, year and body weight. *Marine Environmental Research* 40: 123-146.

TOURINHO, P.S., IVAR DO SUL, J.A. & FILLMANN, G. 2010. Is marine debris ingestion still a problem for the coastal marine biota of southern Brazil? *Marine Pollution Bulletin* 60: 396-401.

VAN FRANEKER, J.A., BLAIZE, C., DANIELSEN, J., FAIRCLOUGH, K., GOLLAN, J., GUSE, N., HANSEN, P-L., HEUBECK, M., JENSEN, J-K., LE GUILLOU, G., OLSEN, B., OLSEN, K-O., PEDERSEN, J., STIENEN, E.W.M. & TURNER, D. 2011. Monitoring plastic ingestion by the northern fulmar Fulmarus glacialis in the North Sea. *Environmental Pollution* 159: 2609-2615.

VLIETSTRA, L.S. & PARGA, J.A. 2002. Long-term changes in the type but not amount of ingested plastic particles in short-tailed shearwaters in the southeastern Bering Sea. *Marine Pollution Bulletin* 44: 945-955.

VOGELNEST, L. 2000. Veterinary Management of Seabirds. In: HOWEY, W.P. (Ed). *Marine Wildlife*. Sydney, Australia: Post Graduate Foundation, Veterinary Science, University of Sydney.

YAMASHITA, R., TAKADA, H., FUKUWAKA, M.A. & WATANUKI, Y. 2011. Physical and chemical effects of ingested plastic debris on short-tailed shearwaters, *Puffinus tenuirostris*, in the North Pacific Ocean. *Marine Pollution Bulletin* 62: 2845-2849.