



# Plastic ingestion and body condition of Wedge-tailed Shearwaters in Vanuatu

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## Handling Editor:

Robert Davis

Received: 4 May 2026

Accepted: 24 May 2026

Published: 11 June 2026

**Cite this:** Borrelle SB *et al.* (2026) Plastic ingestion and body condition of Wedge-tailed Shearwaters in Vanuatu. *Pacific Conservation Biology* **32**, PC26045. doi:10.1071/PC26045

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## ABSTRACT

**Context.** Plastic pollution poses a serious, increasing hazard to many species and habitats. In the tropical marine environment, the Wedge-tailed Shearwater (*Ardenna pacifica*) has been the focus of numerous studies that have provided valuable insights into geographic and temporal variation in plastics exposure. **Aims.** We document the ingestion of macroplastics (>1 mm) in Wedge-tailed Shearwaters (known as koroliko in Vanuatu) in collaboration with the Traditional Custodians of the colony using a sample of birds taken during a traditional harvest on the remote island of Laika, Vanuatu. **Methods.** The harvest provided a random sample of 70 known-provenance birds and necropsies were conducted using standardised methodology for assessing plastic ingestion in seabirds. **Key results.** We found very low levels of plastic exposure in birds sampled during 2024 (frequency of occurrence: chicks 0%, fledglings 2.6%). Measurements of these birds indicated that they were in excellent condition, with mean fledgling body mass of  $487.6 \pm 37.0$  g. **Conclusions.** These results indicate that this population of Wedge-tailed Shearwaters is healthy and currently at low risk of plastic-associated impacts. **Implications.** This result highlights the value of seabirds as indicator species and the importance of sampling biomonitors across a broad area and over many years.

**Keywords:** baseline data, body condition, Indigenous science, monitoring, morphometrics, plastic pollution, seabirds, South Pacific, traditional harvest.

## Introduction

Plastic pollution is a significant environmental issue, with diverse, far-reaching impacts already documented in diverse habitats and throughout complex food webs (e.g. [Lavers \*et al.\* 2021a](#); [Charlton-Howard \*et al.\* 2023](#)). Marine birds (seabirds) are highly susceptible to plastic ingestion due to their foraging habits ([Caldwell \*et al.\* 2020](#)) and the pervasive presence of plastics in marine environments ([Zalasiewicz \*et al.\* 2016](#)). Procellariiformes, including Wedge-tailed Shearwaters (*Ardenna pacifica*, known as koroliko in Vanuatu), are surface foragers and rely heavily on olfactory cues to locate patchily distributed prey across vast oceanic foraging areas ([Nevitt 2008](#)). This olfactory-guided foraging strategy becomes problematic when plastic debris acquires a dimethyl sulfoxide signature through biofouling, a compound that is released by zooplankton that indicates productive zones in the oceans that seabirds use to locate natural prey ([Savoca \*et al.\* 2016](#)).

Among seabirds, trends in plastic ingestion across geographic regions and over time have been clearly demonstrated for only a few seabird species (e.g. [Lavers and Bond 2016](#); [Puskic \*et al.\* 2020](#); [Fayet \*et al.\* 2026](#)). In the tropics, the Wedge-tailed Shearwater has been the focus of numerous studies with data from 1978 to 2018 synthesised by [Lavers \*et al.\* \(2018\)](#). Results suggest that the proportion of Wedge-tailed Shearwaters ingesting plastic has generally increased over time ([Lavers \*et al.\* 2018](#)), with some exceptions. For example, birds sampled in the South Pacific during 2015–2019 had lower levels of ingested plastic (Table S1; [Berr \*et al.\* 2020](#); [Szabo \*et al.\* 2021](#)). Given the relative abundance of data for Wedge-tailed Shearwaters, these birds have been recommended as an indicator, or sentinel, of plastic pollution as the species breeds throughout the tropics (i.e. pantropical; [Lavers \*et al.\* 2018](#)).

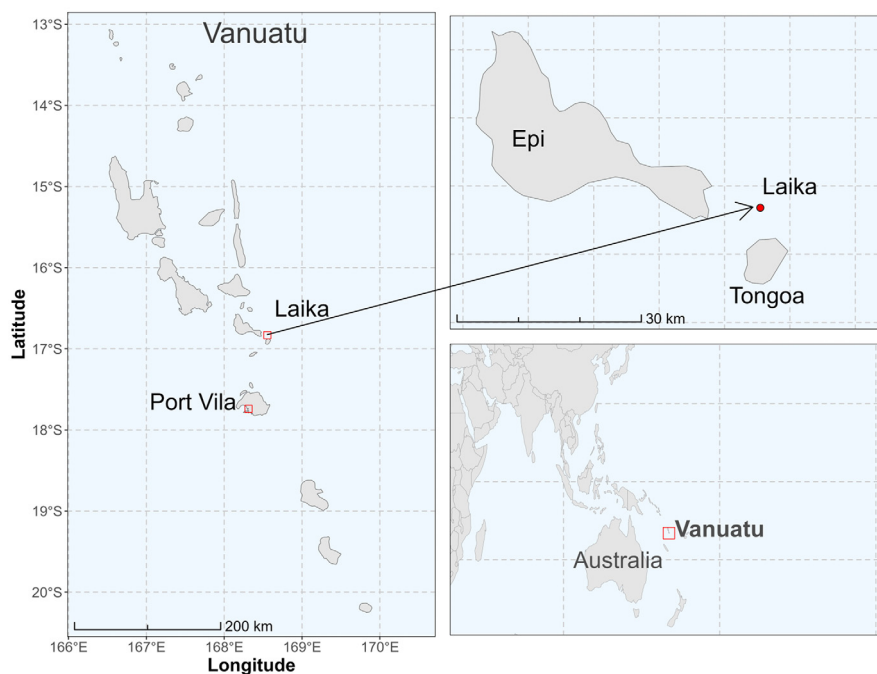
In the North Sea, the Northern Fulmar (*Fulmarus glacialis*) has been identified as a policy indicator for plastic pollution under the Convention to Protect the Marine Environment of the North East Atlantic (OSPAR 2008; van Franeker *et al.* 2021). Under the Convention, the Ecological Quality Objective (EcoQO) for marine plastics is defined as ‘less than 10% of Northern Fulmars having 0.1 g or less plastic in the stomach in samples from each of five different areas of the North Sea over 4 to 8 years’ (OSPAR 2008, p. 10). Northern Fulmars have also been used to evaluate and compare levels of plastic pollution in the eastern North Pacific, Canadian Arctic, Atlantic Canada, Svalbard and Iceland (e.g. Kühn and van Franeker 2012; Poon *et al.* 2017; Collard *et al.* 2022). While the Northern Fulmar often exceeds the EcoQO targets for plastic ingestion, this species-specific threshold provides a target for policy interventions and tracks exposure levels across space and time. The EcoQO has been adjusted for other species, such as the Sable Shearwater (*Ardenna carneipes*) (Lavers *et al.* 2014; Bond and Lavers 2024) but there has been no application of this threshold within the tropical Pacific region. Thus, extending the EcoQO to Wedge-tailed Shearwaters could enhance regionally specific conservation research efforts and plastics policy development (Farrelly *et al.* 2021) in a region already grappling with significant plastics-related issues (e.g. Nichols *et al.* 2021).

Most plastic ingestion studies are opportunistic (e.g. bycatch or beach-washed birds; Provencher *et al.* 2017), however recent data suggest that plastic loads in opportunistically sampled birds may be biased high and therefore not

reflect exposure across the entire population (Lavers *et al.* 2021b). We document the ingestion of macroplastics (particles >1 mm) in Wedge-tailed Shearwaters, hereafter koroliko, sampled from a traditional harvest on the remote island of Laika in Vanuatu (Fig. 1). This harvest provides a unique opportunity to examine the incidence of plastic ingestion from randomly sampled known-provenance birds from a putative healthy population within a specific geographical context.

## Methods

The island Laika is part of the Shepherd Islands group located off the south-east coast of Epi, Shefa Province, Vanuatu (Fig. 1). There is a large colony of koroliko on Laika Island, estimated at 10,000–20,000 breeding pairs, making it the third largest colony of this species in the Pacific (O’Brien *et al.* 2024). Recent analysis of the impact of the traditional harvest on the population ( $\leq 5000$  birds per year) suggests that the removal of birds for sustenance is not impeding population growth (O’Brien *et al.* 2024) and the Kurumambe community, the Traditional Custodians of Laika Island, believe that the colony is expanding to other islands (J. Abel, Kurumambe Conservation Committee, pers. comm.). Upon arrival at Kurumambe village in the north of the island of Tongoa on 5 April 2024, a nasara (traditional formal welcome in Vanuatu) was conducted that included the Free, Prior and Informed Consent protocols, and permission to access the island was requested and granted.



**Fig. 1.** The islands of Tongoa and Laika (the sample collection site) are part of the Shepherd Islands group, Vanuatu. The capital city of Vanuatu, Port Vila, is also shown.

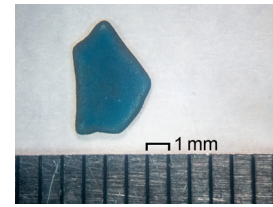
Koroliko were collected in association with Traditional Owners under local customary practices during the annual harvest, ensuring minimal disturbance to the population and adherence to traditional protocols. The bird carcasses were returned to the community for their use following necropsy. Several hundred birds are collected by the community on multiple occasions from April through May and we randomly collected 70 from these harvests on two occasions (6 and 24 April 2024). Upon collection, each bird was assigned a unique identification number and biometric data were collected, including body mass ( $\pm 10$  g), bill (culmen) length ( $\pm 1$  mm), and head + bill and tarsus length ( $\pm 1$  mm; Table 1). Birds collected on 6 April were classified as 'chicks' (age ~55 days), and plucked and frozen. Koroliko typically fledge at 90 days, thus the birds collected on 20 April were classified as 'fledglings' (age ~70 days) and frozen immediately. Adult birds were collected during both sampling periods and identified based on plumage characteristics (e.g. faded feathers with worn tips; Pyle 2009).

All birds were placed on ice and immediately transported to Port Vila where they were frozen at  $-20^{\circ}\text{C}$  pending processing. On 29–30 April 2024, the birds were thawed and necropsied. A midline incision was made from the cloaca to the sternum and the entire gastrointestinal tract, from the oesophagus to the cloaca, was carefully removed. Contents of the proventriculus and gizzard were recorded separately. All contents were emptied into a container and rinsed with fresh water prior to examination. Non-food items were categorised and recorded, with a particular focus on identifying any plastic debris. Plastic items were sorted into categories based on size and type (e.g. hard fragment, fibre, film (Provencher *et al.* 2019)). The number and total mass of ingested plastics were recorded for each bird, with individual plastics measured to the nearest 0.1 mm using calipers and weighed to the nearest 0.0001 g.

## Results

A total of 70 koroliko were collected for analysis during the harvest in April 2024 (Table 1).

Biometric measurements were recorded and are presented for adult, chick, and fledgling koroliko in Table 1. A single piece of hard blue plastic (i.e. a fragment; Fig. 2) was found in the proventriculus of one fledgling (frequency of occurrence 2.6%, mass of plastic 0.0071 g) and no plastic was recovered



**Fig. 2.** A single piece of blue plastic (hard fragment) was found in one koroliko/Wedge-tailed Shearwater fledgling measuring 5.2 mm  $\times$  3.4 mm.

from any other bird. The maximum length and width dimensions of the plastic item were 5.2 mm  $\times$  3.4 mm (Fig. 2).

## Discussion

We evaluated plastic exposure in koroliko across multiple age classes that were sampled within the same season. We also presented body size data for koroliko from a poorly documented region.

We found only one small fragment of plastic in one individual (Fig. 2) among the 70 koroliko necropsied during the traditional harvest on the island of Laika. This was unexpected given that ingested plastic has been consistently reported in at least 10% of juvenile koroliko sampled at 11 sites since the early 1980s (Table 2). The absence of plastic in all but one fledgling koroliko on Laika Island offers valuable insights into regional variation in marine pollution.

For example, while plastic is widely distributed throughout the South Pacific Ocean, particle concentrations vary, with the highest densities found east of Laika Island (Eriksen *et al.* 2013) in an area that is largely outside the preferred foraging area of koroliko. Recent tracking data indicate that adult koroliko travel 300–400 km south of Laika Island during foraging trips in February, ~20 days post hatching (study authors, unpubl. data). Marine pollution in this area may be lower than in other regions, and this could explain the low levels of plastic ingestion in birds on Laika Island.

There is also evidence that some seabird species demonstrate species-specific behaviours that may reduce plastic exposure to chicks in the South Pacific Ocean. For example, in the Pitcairn Islands, lavage of Christmas Shearwater (*Puffinus nativitatis*) fledglings found relatively high amounts of ingested plastic (max 0.253 g; Lavers and Bond 2024) while Kermadec Petrel (*Pterodroma neglecta*) fledglings (lavage)

**Table 1.** Biometric data (mean  $\pm$  standard deviation) for adult, chick, and fledgling koroliko/Wedge-tailed Shearwaters sampled on Laika Island, Vanuatu in April 2024.

| Age       | n  | Sex | Body mass (g)    | Head + bill length (mm) | Bill length (mm) | Bill depth (mm) | Tarsus length (mm) |
|-----------|----|-----|------------------|-------------------------|------------------|-----------------|--------------------|
| Chick     | 14 | Unk | 445.5 $\pm$ 56.2 | 83.3 $\pm$ 2.1          | 38.6 $\pm$ 3.4   | 12.6 $\pm$ 0.7  | 49.3 $\pm$ 3.0     |
| Fledgling | 38 | Unk | 487.6 $\pm$ 37.0 | 83.5 $\pm$ 2.1          | 38.3 $\pm$ 2.5   | NR              | 49.6 $\pm$ 1.3     |
| Adult     | 10 | M   | 401.1 $\pm$ 59.0 | 87.7 $\pm$ 4.3          | 41.3 $\pm$ 4.7   | 13.4 $\pm$ 0.5  | 49.6 $\pm$ 1.1     |
|           | 8  | F   | 377.2 $\pm$ 45.7 | 84.8 $\pm$ 1.6          | 39.5 $\pm$ 4.0   | 13.3 $\pm$ 0.2  | 49.4 $\pm$ 1.2     |

NR, not recorded; n, sample size; Unk, unknown.

**Table 2.** Summary of plastic ingestion studies for fledgling koroliko/Wedge-tailed Shearwaters.

| Year      | Location              | Age | n   | FO   | Mean pieces<br>( $\pm$ s.d.) | Range | Mean<br>mass (g) | Range (g) | Sampling method <sup>A,B</sup>         | Source                        |
|-----------|-----------------------|-----|-----|------|------------------------------|-------|------------------|-----------|----------------------------------------|-------------------------------|
| 1978–1980 | Hawai`i, USA          | F   | 47  | 0.0  |                              |       |                  |           | Spontaneous regurgitations             | Harrison <i>et al.</i> (1983) |
| 1984      | Manana Island, USA    | F   | 20  | 60.0 |                              | 0–12  |                  |           | Destructive and opportunistic/Necropsy | Fry <i>et al.</i> (1987)      |
| 1986      | Midway Atoll, USA     | F   | 11  | 27.0 |                              |       |                  |           | Opportunistic/Necropsy                 | Sileo <i>et al.</i> (1990)    |
| 1987      | Kaua`i, USA           | F   | 7   | 29.0 |                              |       |                  |           | Opportunistic/Necropsy                 | Sileo <i>et al.</i> (1990)    |
| 1984–1991 | Tropical Pacific      | F   | 5   | 20.0 |                              |       |                  |           | Destructive/Necropsy                   | Spear <i>et al.</i> (1995)    |
| 2005      | Lord Howe Island      | F   | 22  | 13.6 |                              |       | 5.83             | 0.0–11.0  | Opportunistic/Necropsy                 | Hutton <i>et al.</i> (2008)   |
| 2005      | Lord Howe Island      | F   | 30  | 43.4 |                              |       | 0.70             |           | Random sample/Lavage                   | Hutton <i>et al.</i> (2008)   |
| 2006–2013 | Tern Island, USA      | P   | 4   | 75.0 |                              |       |                  |           | Opportunistic/Necropsy                 | Rapp <i>et al.</i> (2017)     |
| 2012      | Heron Island, AU      | F   | 24  | 20.8 | 3.2                          | 0–5   | 0.06             | 0.0–0.11  | Random sample/Lavage                   | Verlis <i>et al.</i> (2013)   |
| 2011–2012 | SE Australia          | F   | 2   | 50.0 | 1.0                          | 0–2   | 13.8             | 0.0–27.5  | Opportunistic/Necropsy                 | Gilbert <i>et al.</i> (2016)  |
| 2011–2014 | Kaua`i, USA           | F   | 13  | 76.9 | 2.38 $\pm$ 1.94              | 0–31  | 0.03 $\pm$ 0.03  | 0.0–0.13  | Opportunistic/Necropsy                 | Kain <i>et al.</i> (2016)     |
|           |                       | A   | 19  | 42.1 | 3.68 $\pm$ 9.29              | 0–40  |                  |           |                                        |                               |
| 2013      | Eastern Australia     | P   | 28  | 14.3 | 0.46                         |       |                  |           | Opportunistic/Necropsy                 | Roman <i>et al.</i> (2016)    |
| 2013      | Lord Howe Island      | F   | 70  | 44.3 | 1.04 $\pm$ 1.76              | 0–9   | 0.11 $\pm$ 0.28  | 0.0–1.39  | Opportunistic/Necropsy                 | Lavers <i>et al.</i> (2018)   |
| 2013      | Lord Howe Island      | F   | 154 | 31.2 | 1.01 $\pm$ 3.68              | 0–15  | 0.07 $\pm$ 0.24  | 0.0–0.97  | Random sample/Lavage                   | Lavers <i>et al.</i> (2018)   |
| 2015–2018 | New Caledonia         | F   | 18  | 11.1 | 0.17 $\pm$ 0.51              | 0–2   | <0.1             | 0.0–0.50  | Opportunistic/Necropsy                 | Berr <i>et al.</i> (2020)     |
|           |                       | A   | 34  | 5.9  | 0.09 $\pm$ 0.38              | 0–2   | 1.1 $\pm$ 4.7    | 0.0–23.9  |                                        |                               |
| 2019      | Lord Howe Island      | F   | 42  | 21.4 |                              |       | 0.15             |           | Opportunistic/Necropsy                 | Szabo <i>et al.</i> (2021)    |
| 2024      | Laika Island, Vanuatu | A   | 18  | 0.0  | 0.00                         |       | 0.00             |           | Random sample<br>(Harvest)/Necropsy    | This study                    |
|           |                       | C   | 14  | 0.0  | 0.00                         |       | 0.00             |           |                                        |                               |
|           |                       | F   | 38  | 2.6  | 0.01                         | 0–1   | 0.0071           |           |                                        |                               |

A, adult; F, fledgling; P, age classes pooled; N, sample size; FO, frequency of occurrence (%).

<sup>A</sup>Necropsy of deceased birds (proventriculus and gizzard).

<sup>B</sup>Lavage on live birds sampled using stomach flushing (proventriculus only).

contain very low amounts (max 0.018 g; Lavers *et al.* 2026). On Lord Howe Island in eastern Australia, koroliko and Sable Shearwaters breed sympatrically and forage in broadly similar locations. Yet plastic exposure differs markedly in these two species with koroliko containing an average of 1.04 pieces of plastic (Lavers *et al.* 2018) while Sable Shearwater fledglings frequently contain >300 plastic items (J. L. Lavers, A. M. de Jersey, J. Rivers-Auty, A. L. Bond, unpubl. data.). These interspecific differences suggest that inherent behavioural adaptations or selective foraging behaviours may significantly influence plastic exposure risk, even among closely related species foraging in similar environments (N. Potapova, S. Avery-Gomm, C. Potter, A. L. Bond, S. B. Borrelle, J. L. Lavers, S. Portugal, H. P. Possingham, J. P. Provencher, N. Cooper, unpubl. data). However, which behaviours drive these outcomes is unclear as our understanding of how factors such as plastic abundance, colour, shape or smell influence seabird choice are not fully understood (Savoca *et al.* 2016; Hidalgo-Ruz *et al.* 2021; Clark *et al.* 2023).

Beyond plastics, the condition of koroliko fledglings on Laika Island appears excellent with body mass and head measurements being slightly larger than what has been reported at other

breeding sites within the South Pacific. For example, on Lord Howe Island, mean body mass and head + bill length of koroliko fledglings sampled at the same time of year (late April 2024) were  $271 \pm 79$  g and  $80.2 \pm 20.8$  mm, respectively (J. L. Lavers, unpubl. data). Thus, on average, koroliko fledglings on Laika Island appear to be 10–15% larger than those on Lord Howe Island. This could be due, in part, to the higher rate of plastic ingestion on Lord Howe Island where 25–45% of fledglings contain plastic (Table S1; Lavers *et al.* 2018). The consumption of plastic has been linked with smaller body size in shearwaters (Lavers and Bond 2023). Taken together, the excellent body condition and very low plastic exposure on Laika Island suggests that the Vanuatu population of koroliko is ‘bucking the trend’ with regards to plastic exposure levels at other sites.

## Conclusion

The frequency of occurrence of ingested plastic in koroliko on Laika Island is the lowest recorded for this species since 1978 (0%; Table 2), providing a valuable baseline for monitoring plastic pollution across the Pacific. While sampling from the

harvest on Laika Island provides a unique opportunity to assess plastic ingestion in known provenance birds, future monitoring must address the correlation between harvested and opportunistically sampled birds, particularly given that sampling from harvests is unlikely to be feasible across the species' distribution. As global plastics production and ocean pollution increase and marine conditions change (Borrelle *et al.* 2020; J. L. Lavers, A. M. de Jersey, J. Rivers-Auty, A. L. Bond, unpubl. data), it will be essential to develop a more pragmatic monitoring system based on opportunistically sampled individuals. We also recommend ecotoxicology testing for koroliko to ensure that chemical pollutants are not posing a risk to this species (e.g. organochlorine pesticides, per- and polyfluoroalkyl substances and heavy metals; Philpot *et al.* 2019) or the health of the custodians who have relied on these birds as a source of food for centuries (Lavers and Bond 2013; O'Brien *et al.* 2024). Collaboration with the Kuramambe community remains critical for both monitoring koroliko population health and understanding the impacts of plastic pollution on traditional harvesting practices.

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**Data availability.** All data are presented in the paper.

**Conflicts of interest.** All authors declare that they have no conflicts of interest.

**Declaration of funding.** Funding for this research was generously provided by the European Union through the Pacific Biodiversity and Sustainable Land-Seascapes (Pacific BioScapes) Programme implemented through the Secretariat of the Pacific Regional Environment Programme (SPREP; grant no. AP\_2/43). The study was conducted with approval from the Vanuatu Government (permit no. VAN-ENV-04223).

**Acknowledgements.** We extend our gratitude to Chief Isaiah Serere, the Kuramambe Community, Kingsley Baereleo, Trevor Ledoro, Josephine Laloyer, Ana Ciriwaya, and Edin Whitehead for their friendship and assistance. We are thankful for comments received from the reviewers who generously volunteered their time to improve the manuscript.

**Author contributions.** SBB designed the study, and SBB, EM, DKM, KAB and JLL collected data. JLL and SBB drafted the manuscript. All authors reviewed and approved the submission.

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