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Low incidence of plastics in food loads delivered to nestlings by a zooplanktivorous seabird over a 21-year period

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ABSTRACT

We quantified the amount of plastic found in food loads delivered to nestlings in Cassin's Auklet (*Ptychoramphus aleuticus*), a small, zooplanktivorous seabird, on Triangle Island, British Columbia, in 1996–2016. The density of plastic in surrounding waters is moderately high, yet few food loads contained any plastic (3 of 850), and none more than two pieces. That result accords well with previous observations on the other four North Pacific auklets (*Aethia* spp.), leading us to conclude that true auklets rarely transfer plastic to nestlings. However, many hatch-year Cassin's Auklets found dead in coastal British Columbia, Washington and Oregon during the mass mortality event of fall and winter 2014–15 had plastic in their ventriculi. We suggest that these plastic particles would have been obtained at sea after fledging, perhaps while the birds transited south through a region of high plastic density off the west coast of Vancouver Island, Washington and Oregon.

1. Introduction

There is growing awareness that plastics in the ocean pose a serious threat to a wide variety of marine biota (Watts et al., 2015; Sussarellu et al., 2016). The threat may be especially acute for seabirds, a large, taxonomically diverse avian group widely distributed across all of the world's oceans, and for which exposure to plastics is expected to increase in future years (Wilcox et al., 2015). Among the reported deleterious effects of plastic ingestion on seabirds are starvation due to gut blockage (Fry et al., 1987; Pierce et al., 2004), reduced body condition (Ryan, 1987; Spear et al., 1995), and elevated toxicological loads (Yamashita et al., 2011; Tanaka et al., 2013). All of these effects can lead to the impairment of self-maintenance and reproductive functions in adults. Further, the transfer of plastics from adults to dependent offspring can compromise the fitness of those offspring (Lavers et al., 2014). However, the prevalence and severity of the latter issue, and its relationship to ecological factors such as trophic level and foraging range, remain poorly resolved at present.

We examined the transfer of plastics in food loads delivered by adult Cassin's Auklets (*Ptychoramphus aleuticus*; a small (190 g), zooplanktivorous North Pacific seabird) to their nestlings over a 21-year period (1996–2016). The transfer could include plastic consumed directly by the adult birds, and very small pieces (< 1 mm) that the adults obtain passively when they consume large zooplankton (Desforges et al., 2015). Our study took place on Triangle Island, British Columbia, Canada, where an estimated 40% of the world's population of this species breeds (Rodway, 1990). In Cassin's Auklet, as in all true auklets (the tribe Aethiini, of the family Alcidae), provisioning adults load zooplankton in a gular pouch – an extension of the buccal cavity extending alongside the esophagus and trachea that develops prior to breeding (Speich and Manuwal, 1974) - for delivery back to offspring in the nesting burrow. It is a simple matter to intercept provisioning adults when they return to the colony just after dark, and induce them to regurgitate the contents of the pouch. Samples thus collected consist primarily or entirely of prey captured within the previous few hours. During the mass mortality event of fall and winter 2014–15, 47% of hatch-year Cassin's Auklets found dead on beaches along the Oregon and Washington coasts had plastic in their ventriculi (also called the gizzard). The plastic loads present in these birds averaged 5.4 pieces and weighed 87.6 mg (Floren and Shugart, 2017). However, whether the plastics were off-loaded to nestlings by their parents at the colony, or were actively consumed at sea after the young bird had fledged, is unknown.

Exposure to plastic predicts ingestion frequency in seabirds, and exposure has increased globally in recent decades (Wilcox et al., 2015). That observation, combined with the moderately high density of plastics (~2000 particles m^{-3}; Desforges et al., 2014) occurring in the primary offshore foraging areas used by provisioning Cassin's Auklets

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on Triangle Island (Boyd et al., 2008), leads logically to *a priori* predictions of both a high incidence of plastic in the regurgitate samples and an increasing incidence over the 21-year study period. However, Bond et al. (2010) examined plastics in food loads delivered to nestlings of the four *Aethia* auklets in the Aleutian Islands, AK, over a 14-year period (1993–2006), finding plastic in only one food load obtained from a Whiskered Auklet (*Aethia pygmaea*) gular pouch. Although the density of plastics in sea-water in the Aleutians was unknown, that result led those authors to hypothesize generally that the zooplanktivorous auklets rarely off-load plastics to nestlings. Here, we test the validity of these two competing hypotheses in the fifth species of true auklet.

2. Materials and methods

In each year from 1996 to 2016, 14 to 80 adult Cassin's Auklets were captured between 15 May and 30 June while returning to the colony at night to provision offspring. That six-week sampling period corresponds to the peak of provisioning at Triangle Island (Hipfner et al., 2010). Most birds were caught in pheasant nets erected between 2 large poles, while others were caught by hand on the ground. Upon capture, we gently massaged the adults' gular pouches to induce them to regurgitate full or partial food loads through a funnel into a small, preweighed, screw-top plastic bottle. Each bottle was reweighed, this time including the regurgitate, then filled with 14% formalin buffered with Borax for transport back to the laboratory.

Cassin's Auklet regurgitate samples were washed over a 0.063 mm mesh to remove the formalin, which was captured for neutralization treatment and disposal. Using a Wild M420 dissecting microscope (www.leica-microsystems.com) with 20× oculars and 6.3–32 zoom capability, the prey items found in the food loads were counted, the life stage of each prey item was determined, and the item identified to the lowest taxonomic level possible. Any plastic particles found were separated out, enumerated, then weighed.

3. Results

A total of 850 food loads destined for nestling Cassin's Auklets was collected on Triangle Island over the 21-year study period (Table 1). Those food loads included a total of 297,697 examined prey items, most of which (75.0%) were the large, subarctic copepod *Neocalanus cristatus*; other taxa present in appreciable numbers (≥1.0% of the total) were the euphausiids *Thysanoessa inspinata* (7.2%), *T. spinifera* (5.6%), and *Euphausia pacifica* (3.3%), as well as various amphipods (2.9%), decapods (2.3%), and larval fish (1.3%). However, only 4 plastic particles were recovered in the 850 food loads: 3 in two loads in 2010 (one load comprised of 92.9% *N. cristatus* by number, the other of > 99% decapods) and one in 2011 (comprised of 61.1% *N. cristatus* and 38.9% *E. pacifica*). The four plastic particles ranged in mass from 0.0045 g to 0.1411 g; we did not record the colour or type of plastic.

Table 1
Prevalence of plastic particles in food loads delivered to nestling Cassin's Auklets on Triangle Island, British Columbia, between 15 May and 1 July of 1996–2016.

Year	No. food loads	No. prey items	No. plastic particles (no. food loads)
1996	55	20,324	0
1997	47	21,765	0
1998	50	16,282	0
1999	46	18,838	0
2000	36	10,577	0
2001	80	26,768	0
2002	40	16,371	0
2003	44	13,860	0
2004	50	17,874	0
2005	40	15,670	0
2006	43	10,730	0
2007	37	15,270	0
2008	36	14,976	0
2009	43	23,017	0
2010	39	10,739	3 (2)
2011	39	12,076	1 (1)
2012	31	12,274	0
2013	40	11,951	0
2014	20	3267	0
2015	14	2037	0
2016	20	3031	0
All years	850	297,697	**4**

4. Discussion

We found very few plastic particles (just 4 in total) in 850 food loads delivered by adult Cassin's Auklets to their nestlings on Triangle Island, and no suggestion of an increasing trend over the 21 years of our study. Those results seem surprising, given the species' zooplanktivorous diet, the moderately high density of plastics in waters around Triangle Island (Desforges et al., 2014), and the increasing amount of plastic that has polluted the ocean over recent decades (Wilcox et al., 2015). The results do however support the hypothesis of Bond et al. (2010) that the true auklets rarely off-load plastics to their offspring. In contrast, Amelineau et al. (2016) found that Little Auks (*Alle alle*), the North Atlantic's ecological counterpart to the North Pacific auklets, had on average 10 (2005) and 9 (2014) plastic particles per gular pouch in West Greenland, where the at-sea density of plastics was low. The difference between study species occurred despite the fact that the Little Auk shares with the true auklets a suite of morphological traits, notably small body size and gular pouch as storage organ for provisioning offspring; and also ecological traits including zooplanktivory, with large copepods as primary prey. The difference also highlights how little we know about the ecological and behavioural factors that determine the extent of off-loading of plastic to nestling seabirds. In species in which provisioning adults do off-load large quantities of plastics, impacts on offspring survival can be so severe as to raise long-term conservation concerns (Lavers et al., 2014).

Light-level geolocator tags deployed on Cassin's Auklets on two large colonies in British Columbia (Triangle and Frederick islands) during the 2014 breeding season (K.R. Studholme, unpubl. data) showed that many of these birds were present along the southern British Columbia, Washington and Oregon coasts at the height of the mass mortality event in fall and winter of 2014–15. This was expected, given that ~75% of the world's population of Cassin's Auklets breeds on colonies in British Columbia, including ~40% on Triangle Island alone (Rodway, 1990). Many (47%) of the hatch-year birds collected dead on beaches during this mortality event had considerable quantities of plastic in their ventriculi (Floren and Shugart, 2017). The results of our study suggest that the vast majority of these plastics would have been acquired in the post-fledging period, during which birds transited in a southerly direction off the west coast of Vancouver Island, Washington and Oregon – of which the former, at least, is a region of high plastic density compared to offshore areas around Triangle Island (Desforges et al., 2014).

Floren and Shugart (2017) suggested that there was no direct causal link between the plastics and the mass mortality in 2014–15. Given that zooplanktivorous seabirds are thought to consume plastic which they mistake for their natural prey (Amelineau et al., 2016), and that the mortality was linked to starvation caused by the preponderance of small, lipid-poor, southerly zooplankton species within the Cassin's Auklet wintering areas (Jones et al., in review), it is nonetheless possible that the ingestion rate of plastics was especially high leading up to and during the event. In addition to the hatch-year birds, many sub-adult (54%) and adult (35%) Cassin's Auklets found dead had also ingested plastics (Floren and Shugart, 2017), with both values generally higher than reported for the species in previous studies (40% (N = 10) in Day, 1980; 11% (N = 35) in Robards et al., 1995; 0% (N = 1) in Avery-Gomm et al., 2013). We suggest that the relationship between

plastic ingestion rates and the nutritional state of foraging seabirds is a topic in need of further investigation.

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