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Are ocean conditions and plastic debris resulting in a 'double whammy' for marine birds?

Mark C. Drever[a,*], Jennifer F. Provencher[b], Patrick D. O'Hara[c], Laurie Wilson[a], Victoria Bowes[d], Carita M. Bergman[e]

[a] Environment and Climate Change Canada, Canadian Wildlife Service, Delta, British Columbia, Canada
[b] Acadia University, Department of Biology, Wolfville, Nova Scotia, Canada
[c] Environment and Climate Change Canada, Canadian Wildlife Service, Institute of Ocean Sciences, Sidney, British Columbia, Canada
[d] Animal Health Centre, Ministry of Agriculture, Abbotsford, British Columbia, Canada
[e] Gwaii Haanas National Park Reserve, National Marine Conservation Area Reserve, and Haida Heritage Site, Skidegate, British Columbia, Canada

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ABSTRACT

We report a mortality event of Red Phalaropes (*Phalaropus fulicarius*) that occurred from October to November 2016 on the north coast of British Columbia, Canada. All individuals were severely underweight and showing signs of physiological stress. The guts of all carcasses contained ingested plastics (100%, n = 9). Distribution modelling from pelagic bird surveys (1990–2010) indicated that Red Phalaropes are not typically found in the study area during fall months. Ocean conditions during fall 2016 were unusually warm, coinciding with reduced upwelling in the study area. eBird records since 1980 indicated Red Phalaropes are observed closer to shore during periods associated with reduced upwelling. These results suggest that distribution shifts of Red Phalaropes closer to shore, where plastic debris occurs in higher concentrations, may lead phalaropes to feed on plastic debris while in a weakened state, resulting in a combination of two adverse circumstances.

1. Introduction

The Red Phalarope (*Phalaropus fulicarius*) is a highly pelagic shorebird, spending up to 11 months each year on the ocean during non-breeding periods (Tracy et al., 2002). In western North America, Red Phalaropes migrate far offshore, and are rarely seen inland as they travel between breeding grounds in Alaska and northern Canada to non-breeding areas in waters off western South America (Tracy et al., 2002). Distribution at sea is associated with ocean fronts and areas of upwelling that concentrate zooplankton prey (Brown and Gaskin, 1988). Current population status of the species remains uncertain, although some evidence suggests long-term declines. Abundance of Red Phalaropes at Rasmussen Lowlands, Nunavut, Canada, in the mid-1990s was 76% lower relative to the mid-1970s (Gratto-Trevor et al., 1998). Similarly, Tracy et al. (2002) suggest the species became less common in early 2000s in the northern Gulf of Mexico relative to the 1960s and 1970s. Due to its pelagic nature and its breeding in remote Arctic regions, the Red Phalarope is understudied compared to other species. To understand potential drivers of these observed declines and to ensure protection for this species, better information about potential threats and sources of mortality is needed.

Large mortality events of Red Phalaropes can occur, consisting of emaciated migrants whose carcasses appear on beaches during migration and wintering periods, e.g., coastal California in 1934, 1969, and 2003/2004 (Miller, 1936; Bond, 1971; Nevins et al., 2005). Such events can result from changes in ocean-climate conditions, resulting from large scale phenomena such as El Niño-Southern Oscillation (ENSO) events that can lead to reduced availability of prey species. Breeding densities of Red Phalaropes at Prudhoe Bay, Alaska, decreased by > 50% in 1983 following the ENSO event in the non-breeding areas (Troy, 1996). Similarly, Red Phalaropes occurred commonly in offshore waters near Washington State in 1980, but declined during the 1982/1983 ENSO event, and returned to normal numbers in the following years, indicating perhaps a shift in distribution during these times (Wahl et al., 1993). ENSO events in the central (tropical) Pacific Ocean are linked with large scale changes in the northern Pacific Ocean through complex mechanisms (Di Lorenzo et al., 2010), and a strong ENSO signal may not always result in discernable changes in waters of more northern areas. In the eastern Pacific Ocean, influxes of warm water are associated with smaller size distributions of zooplankton (Chiba et al., 2015; Liu et al., 2015), and such shifts in preferred prey likely explain how ocean conditions affect Red Phalaropes, although

* Corresponding author.
E-mail address: mark.drever@canada.ca (M.C. Drever).

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further research is needed to identify the precise mechanism.

In addition to suffering effects of reduced prey, surface-feeding marine birds such as Red Phalaropes are also vulnerable to ingesting marine plastics pollution (Moser and Lee, 1992; Blight and Burger, 1997). Red Phalaropes are known to ingest plastic debris, presumably because plastics are mistaken as prey, and several studies have found high amounts of plastic debris in stomach contents. Bond (1971) reported that all 20 dead phalaropes found in November 1969 in southern California, United States, had plastic balls in stomachs, and all birds were emaciated (~50% of their normal body weights). Connors and Smith (1982) found that 85.7% of Red Phalaropes collected in 1980 from a flock of spring migrants in California had plastic pieces in gut contents, and that the amount of plastic and fat condition had a non-significant negative correlation, although sample size was small ($N = 7$). Moser and Lee (1992) found plastic in gut contents of 69.1% of Red Phalaropes collected at sea 5–60 km off the North Carolina coast, between 1975 and 1989 ($N = 55$). Despite these reports from US waters, plastics have not been previously recorded in Red Phalaropes in Canadian waters (Provencher et al., 2015). Therefore, any records of ingestion of plastics by phalaropes will inform the extent to which this exposure poses a threat to the species (Avery-Gomm et al., 2013).

Important to consider when assessing species vulnerability to marine plastics pollution is that plastic debris is not uniformly distributed on marine waters. Among coastal waters on the continental shelf of the northeast Pacific Ocean, high amounts of marine debris are found both near human population centers in the Salish Sea, as well as more remote areas such as Queen Charlotte Sound and specific fjords in the mainland coast of British Columbia, Canada (Williams et al., 2011). Similarly, Desforges et al. (2014) found microplastics were present throughout much of Pacific Ocean region of British Columbia, but with a strong spatial gradient wherein concentrations were lowest in offshore waters, and increased 6, 12 and 27-fold on the west coast of Vancouver Island, Strait of Georgia, and Queen Charlotte Sound, respectively. These elevated concentrations of microplastics near urban areas are consistent with land-based sources, whereas Desforges et al. (2014) suggest high concentrations of microplastics in Queen Charlotte Sound result from oceanographic currents that trap and concentrate debris. Once in the water, microplastics can concentrate along oceanic convergent and frontal zones associated with river plumes, tidal mixing and coastal upwelling (Auta et al., 2017). Given this spatial variance along the coast, a marine bird species' risk of exposure to marine plastic debris will depend on the amount of overlap between its distribution and the existing pools of plastic within ocean waters (Williams et al., 2011; Titmus and Hyrenbach, 2011). Given that phalaropes depend on frontal oceanic systems and their surface feeding foraging strategy, this species is especially vulnerable to plastic ingestion.

In the fall of 2016, the tug boat *Nathan E. Stewart* ran aground in Seaforth Channel, near Queen Charlotte Sound, British Columbia (Fig. 1), and shoreline assessments began as part of the emergency response. During this effort, several non-oiled Red Phalarope carcasses were found, providing a unique opportunity to document a mortality event of Red Phalaropes in a remote area of the species' range. Coincidentally, another Red Phalarope carcass was collected from Haida Gwaii during the same time period, and contributed to the sample after an unusual number of on and near shore sightings of Red Phalaropes were made by one of the authors (CMB) in Haida Gwaii. In this paper, we describe the physical conditions of the found bird carcasses from veterinary necropsy reports, and present stomach content analyses to quantify types and amount of food and ingested plastics. To better understand the oceanic conditions that may have led to this mortality event, the ocean conditions in the Queen Charlotte Sound during the fall of 2016 are also described and compared to normal conditions for the area. In addition, we collated the sparse information that was available on the distribution of Red Phalaropes during their southward migration (the time of annual cycle when this mortality event happened) on the Pacific northwestern coast of North America, based on pelagic surveys and eBird data. We use this information to gauge the frequency with which Red Phalaropes occur close to shore. These disparate sources of information are interpreted within the overall objective to place this unusual record of a mortality event within the larger context of conservation priorities for this pelagic shorebird.

2. Methods

2.1. Study area

Seaforth Channel lies near the Queen Charlotte Sound area within the Central Coast region of British Columbia, Canada (Fig. 1), and within the Canadian Pacific Exclusive Economic Zone (EEZ). The channel forms part of the marine highway ('Inside Passage') that connects ocean vessel traffic between Alaska with Washington State, United States. The area has rocky beaches set in complex shorelines and long fjords surrounded by coastal rainforest. The area is remote, with little road access, and the main population center is Bella Bella, also known as Wagisla (52.1605° N, 128.1456° W; Fig. 2), home to ~1500 people. The southern tip of the Haida Gwaii archipelago lies directly west of Seaforth Channel across Queen Charlotte Sound. Oceanographically, the study area is characterized as a transition zone where the Pacific Current bifurcates into the Gulf of Alaska Current flowing northward, and the southward flowing California Current (Thomson, 1981; Ware and McFarlane, 1989). The study area is characterized by upwelling features over the shelf-break during the summer (approximately May to September) and downwelling during the winter (Thomson, 1981).

On 13 October 2016, the tug *Nathan E. Stewart* ran aground while pushing a tanker barge in Seaforth Channel, approximately 20 km from Bella Bella (Fig. 1). The tug sank later that day, and an emergency oil spill response began. Clean-up efforts, coastline surveys, and wildlife monitoring continued daily (allowing for safe weather) from 15 October to 17 November 2017. During these efforts, eight dead Red Phalaropes were found from 28 October to 14 November 2017 (Fig. 1), approximately 2 weeks after the tug sank. In addition, on 22 November 2016, a Red Phalarope apparently foraging on the road (Hwy 16), was struck by vehicle approximately 20 km south of the city of Masset in Haida Gwaii (Fig. 1).

2.2. Necropsy and gut content analyses

All carcasses were shipped to the Animal Health Centre at the British Columbia Ministry of Agriculture for a necropsy by a professional avian pathologist (VB) who determined the cause of death. Post-mortem examination included measuring body weight, ranking body condition based on the degree of pectoral muscling and the extent of subcutaneous and visceral adipose stores. Body condition was scored as follows: 1, emaciated; 2, thin/poor; 3, fair; 4, good/very good; 5, excellent (Albert et al., 2010). Gender and sexual maturity was assessed by visualization of the gonads. Cause of death was recorded and the gastro-intestinal tract was removed for further examination.

Gut contents were later examined for all debris and diet items at the National Wildlife Research Centre in Ottawa. Gut contents were examined using techniques as applied to other seabirds to assess for plastics ingestion (Provencher et al., 2017; Poon et al., 2017). The stomachs (excluding the intestines) were opened and flushed with water to remove all items. All stomach contents were rinsed under a 1 mm sieve and examined using a binocular microscope. All plastics were enumerated and tabulated as recommended for marine birds in Provencher et al. (2017). Briefly, all debris was categorized as either industrial pellets or user debris (i.e., fragments, fibers, sheet, foam, wax and rubber; Provencher et al., 2017). Each individual piece of debris was measured using General model digital calipers. Both the length (the longest dimension) and width (the next longest dimension) of the debris items were measured, and the pieces were categorized into meso-