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Fish oil disrupts seabird feather microstructure and waterproofing

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HIGHLIGHTS

- Little is known about effects of fish and other edible oils on seabirds.
- We conducted lab experiments and interviewed wildlife response experts.
- Lab experiments showed fish oil significantly disrupted feather microstructure.
- Feathers exposed to fish oil absorbed water and oil indicating loss of waterproofing.
- Experts agreed that fish oil is harmful to seabirds and requires intervention.

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ABSTRACT

Seabirds and other aquatic avifauna are highly sensitive to exposure to petroleum oils. A small amount of oil is sufficient to break down the feather barrier that is necessary to prevent water penetration and hypothermia. Far less attention has been paid to potential effects on aquatic birds of so called 'edible oils', non-petroleum oils such as vegetable and fish oils. In response to a sardine oil discharge by a vessel off the coast of British Columbia, we conducted an experiment to assess if feather exposure to sheens of sardine oil (ranging from 0.04 to 3 μm in thickness) resulted in measurable oil and water uptake and significant feather microstructure disruption. We designed the experiment based on a previous experiment on effects of petroleum oils on seabird feathers. Feathers exposed to the thinnest fish oil sheens (0.04 μm) resulted in measurable feather weight gain (from oil and water uptake) and significant feather microstructure disruption. Both feather weight gain and microstructure disruption increased with increasing fish oil thickness. Because of the absence of primary research on effects of edible oils on sea birds, we conducted interviews with wildlife rehabilitation professionals with experience rehabilitating sea birds after edible oil exposure. The consensus from interviews and our experiment indicated that physical contact with fish and other 'edible oils' in the marine environment is at least as harmful to seabirds as petroleum oils.

1. Introduction

It is well-known that petroleum oil discharges in oceans have negative impacts on seabirds (e.g., Leighton, 1991; Jenssen, 1994; Stephenson, 1997; Giese et al., 2000; Irons et al., 2000; Wiese and Robertson, 2004; Votier et al., 2005). Feather fouling from as little as 10 ml of petroleum oil can cause penetration of water and oil, result in loss of buoyancy, and significantly reduce thermoregulation in aquatic avifauna; these effects are particularly lethal in colder climates and for surface feeders and diving birds (Hartung, 1967; McEwan and Koelink, 1973; Levy, 1980; Lambert et al., 1982; Jenssen and Ekker, 1991; Camphuysen, 1998). Indeed, based on observations made in the field and results reported by O'Hara and Morandin (2010), trace quantities of oil impact feather integrity and water proofing ability. There is evidence that some marine birds, particularly those that spend some time on land, are able to 'self-clean' petroleum oil, without intervention from humans (Camphuysen, 2011); however, this likely does little to offset the large proportion of birds that are not able to recover on their own.

Much less is known about effects on seabirds of other types of oil such as fish and vegetable oils (sometimes termed 'non-petroleum oils', 'non-petrogenic oils', or 'edible oils'; we use the term edible oils throughout this paper, referring mainly to fish- and vegetable-based oils). We are aware of no previous studies measuring sensitivity of seabird feathers or whole birds to edible oils. It is vital to understand how edible oils impact feathers and birds since there is a perception that edible oils may be less detrimental to marine life than petroleum oils. However, observations of impacts of edible oils on seabirds suggest that they are as harmful, or more harmful than petroleum oils (Berry, 1976; McKelvey et al., 1980; Rigger, 1997; Bucas and Saliot, 2002).

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Many types of edible oils are formally recognized as harmful by The International Convention for the Prevention of Pollution from Ships (MARPOL; http://www.imo.org/About/Conventions/ListOfConventions/Pages/International-Convention-for-the-Prevention-of-Pollution-from-Ships-(MARPOL).aspx), which is reflected in national legislation (e.g., Canada: Canada Shipping Act: http://laws-lois.justice.gc.ca/eng/acts/C-10.15/; U.S.: U.S. Environmental Protection Act http://www2.epa.gov/emergency-response/vegetable-oils-and-animal-fats#frp). Indeed, in the U.S., the Environmental Protection Agency denied a request by various trade associations to amend restrictive Facility Response Plan rules and further differentiate between petroleum and edible oils in terms of potential environmental consequences in a worst case scenario (Federal Register 62 (202): 54508–54543: http://www.gpo.gov/fdsys/granule/FR-1997-10-20/97-27261). Despite clear legislation and upper level policy however, these oils and their impacts often are overlooked by response and enforcement personnel because edible oils are considered non-toxic, disregarding that the oil–feather interaction typically is the main reason for acute effects of oil exposure on marine birds.

Feathers are important for both insulation and buoyancy on water; feather microstructure, made up of barbs and barbules, creates an interwoven mesh structure with trapped air, which results in a waterproof barrier (Stephenson, 1997). It is this microstructure and the oleophilic nature of the structure that result in the water repellency of feathers (Rijke, 1970). A compromise of feather integrity can result in water penetrating plumage, displacing the layer of insulating air, which may result in hypothermia and death. In water birds, the structure within and between feathers is adapted to the specific (high) surface tension of unpolluted water (Swennen, 1978). In addition to disrupting the feather microstructure, oil and other materials lower surface tension of water resulting in feathers being less able to resist penetration (Swennen, 1978; Stephenson, 1997; Stephenson and Andrews, 1997).

Studies on the effects of petroleum oils on feather microstructure are sparse yet show that oils and other pollutants disrupt feather microstructure by collapsing the interlocking structure of barbs, barbules, and hooks, resulting in the penetration of water and oil, displacing air (Hartung, 1964; Jenssen and Ekker, 1988; Jenssen, 1994; O'Hara and Morandin, 2010). Evidence linking fish and other edible oils with negative impacts on feathers and whole birds is largely anecdotal at this point. Consequently, management and enforcement policy often overlooks edible oils in addressing potential ecological consequences associated with discharged oil.

This study was initiated in response to a July, 2010 discharge of approximately 940 l of crude sardine oil, into the marine environment from a vessel 220 km west of Vancouver Island. The discharge and resultant sheen was observed by a Transport Canada National Aerial Surveillance Program (NASP) aircraft and was reported to be approximately 25 km^2 with a silver grey appearance (pers. comm. Ralph Hilchie, NASP; incident report to enforcement agencies for both Transport Canada and Environment Canada). The effects of this spill on wildlife were not directly measured at the time.

This study is composed of two main components: 1. An experiment to assess the impacts of fish oil on seabird feather microstructure, and water and oil uptake with varying surface oil thicknesses; and 2. Interviews with researchers, rehabilitation professionals, and veterinarians on their experiences with seabirds and edible oils. For the experiment portion, we adapted a protocol from a previous experiment we conducted on petroleum oils (O'Hara and Morandin, 2010). In the previous experiment, we found that there was a significant weight increase in feathers exposed to crude oil sheens 3 μm and greater, and a significant change in feather microstructure with crude oil sheens of 0.1 μm and greater. We expected that fish oil would cause a similar feather microstructure disruption and weight gain as petroleum oil, with the thinnest sheens causing no measurable effect, and an increasing disruption and weight gain with increasing sheen or slick thickness. The purpose of the interviews was to establish the extent to which whole birds are affected by exposure to fish oil and their ability to preen these oils out. Because edible oils are less toxic to seabirds, an ability to rapidly and efficiently preen the oils from feathers would support the case for edible oils being less harmful than generally toxic petroleum oils.

2. Feather exposure experiment

2.1. Materials and methods

Upper breast feathers were sampled from 10 frozen common murre (*Uria aalge*) and 10 rhinoceros auklet (*Cerorhinca monocerata*) carcasses collected from fisheries incidental take in British Columbia waters. Carcasses were stored in a freezer at −10 °C. Unprocessed, crude sardine oil was acquired from Investigations (Environment Canada) from the Vancouver Port reception facility that received crude fish oil from the vessel associated with the discharge event documented by the NASP and described in the introduction to this study. The fish oil was stored in a clean brown glass bottle in a refrigerator at approximately 3 °C.

Fish oil treatments were chosen to encompass the thickness corresponding to a silver or grey sheen, which was the observed colour of the sardine oil slick observed by the NASP; a silver/grey sheen corresponds to 0.04 μm to 0.3 μm for petroleum oil on seawater. However, these sheen and slick thicknesses are estimated based on a visual assessment of colours calibrated for petroleum oils, and this technique may not be accurate for estimating the thickness of other oils. We chose four treatment levels of 1) control: no oil added, 2) low estimate silver/grey: 0.04 μm, 3) mid-estimate silver/grey sheen: 0.1 μm, and 4) rainbow colour sheen: 3.0 μm (http://response.restoration.noaa.gov/sites/default/files/OWJA_2012.pdf). These sheen thicknesses also corresponded to the thicknesses of petroleum oil used in O'Hara and Morandin (2010). Initially we included a fifth treatment level, a positive control of 25 μm thickness; however, preliminary tests showed that this thickness completely saturated the feathers with oil and there was no calculable amalgamation index (see below). Sheen treatments were created by calculating the amount of oil required to create the designated thickness given the surface area of the Petri dish using the formula, volume of oil added = πr2x (where r = radius of the Petri dish, and x = oil thickness).

Seawater was cooled in the refrigerator to approximately 10 °C to simulate typical summer seawater surface temperatures off the coast of Vancouver. 140 ml Petri dishes were filled with 77 ml (5 mm height) of the cooled seawater. One replicate of each treatment was prepared at a time, so that there were four dishes prepared at once, and appropriate volumes of oil (based on formula above) were pipetted onto the surface using a calibrated micropipette. In each experimental round of four Petri dishes, dishes were randomly assigned to an oil treatment and dishes were used from left to right. After oil was deposited on the surface of the seawater, it was gently stirred with the tip of the pipette. Before being exposed to the oil sheen, a feather was picked up by the calamus (Fig. 1) with clean tweezers and weighed on a Scaltec SBC 22 analytical balance (Heilingenstadt, Germany, accuracy class I) to 0.0001 g.

The feather was placed with the convex side up on a microscope slide and photographed under 60× magnification. Two images were taken on each side of the rachis for a total of four images of each feather. Image locations were chosen semi-randomly, in areas that did not contain large anomalies such as splits between barbs (Fig. 2). The feather was then placed on the water, in the centre of the Petri dish, convex side down, for 15 s. The feather was swiped three times across the surface of the water, the full diameter of the Petri dish, and then left stationary on the water surface for an additional 15 s.

The feather was weighed a second time and then again placed onto a glass slide, convex side up, leaving the convex feather surface untouched after treatment. During this process, the feather was grasped by the calamus only, with no disturbance of the barbs and barbules other than the treatment. The process was repeated 10 times (rounds) for each species with washed and freshly prepared Petri dishes. For each of the 10 treatment rounds per species, a different individual bird