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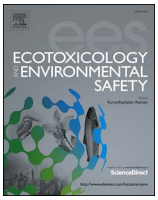

Trouble on takeoff: Crude oil on feathers reduces escape performance of shorebirds

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ABSTRACT

The ability to takeoff quickly and accelerate away from predators is crucial to bird survival. Crude oil can disrupt the fine structure and function of feathers, and here we tested for the first time how small amounts of oil on the trailing edges of the wings and tail of Western sandpipers (*Calidris mauri*) affected takeoff flight performance. In oiled birds, the distance travelled during the first 0.4 s after takeoff was reduced by 29%, and takeoff angle was decreased by 10° compared to unoiled birds. Three-axis accelerometry indicated that oiled sandpipers produced less mechanical power output per wingbeat during the initial phase of flight. Slower and lower takeoff would make oiled birds more likely to be targeted and captured by predators, reducing survival and facilitating the exposure of predators to oil. Whereas the direct mortality of heavily-oiled birds is often obvious and can be quantified, our results show that there are significant sub-lethal effects of small amounts crude oil on feathers, which must be considered in natural resource injury assessments for birds.

1. Introduction

Escaping predators is one of the main survival tasks for animals. Like most birds, migratory shorebirds have evolved behavioural tactics to minimize predation risk. Shorebirds can time migration in order to avoid the peak of migratory raptors on their journey (Ydenberg et al., 2004), and they travel in flocks using dilution or the confusion effect to reduce an individual's chance of being killed (Cresswell, 1994). To be effective, these behavioural tactics must be accompanied by the appropriate ability to fly and manoeuver. In particular, when an attack occurs, individuals that are slow or become separated from the flock are most vulnerable. Takeoff performance is therefore one of the major aspects of predation avoidance for migratory shorebirds and other flocking birds.

Difficulties during takeoff can occur when individual birds moult flight feathers (Swaddle and Witter, 1997; Swaddle et al., 1999), or when wing loading (the weight of the bird relative to its wing area) is high (Burns and Ydenberg, 2002; Ortega-Jiménez et al., 2010). External factors such as natural feather abrasion, breakage, or sun damage may also reduce feather quality and takeoff performance. Feathers can become contaminated with crude oil during oil spills, and whereas the inability of heavily-oiled birds to fly is often obvious, the potential for small amounts of oil to impair flight performance has not been studied.

During the 2010 Deepwater Horizon (DWH) oil spill in the Gulf of Mexico, about 3.2 million barrels of crude oil were discharged in the sea over an uninterrupted period of about three months (NOAA, 2015). The spill affected at least 25,000 km^2 of marine habitat and over 2100 km of coastal habitat (NOAA, 2015) in the Gulf of Mexico region. Both resident and transient birds, such as migratory shorebirds, were affected by the spill and their exposure to crude oil persisted long after the discharge from the compromised well was stopped (NOAA, 2015). Previous studies have typically only considered the acute effects of oil leading to rapid death, such as toxicity after ingestion and the reduced insulation of oiled feathers (Peakall et al., 1982; Fry and Lowenstine, 1985). During the DWH spill, tens of thousands of birds were estimated to have been directly killed, and several thousand live oiled birds were also observed (NOAA, 2015). The majority of these birds were assigned

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to “trace” or “light” oiled categories (less than 5% and 5–20% of body surface, respectively).

We quantified for the first time the effects of crude oil on takeoff ability of birds. We hypothesized that birds with lightly-oiled wing and tail feathers, as are commonly observed during oil spills, would have reduced takeoff performance (slower speed and lower takeoff angle). We studied the effects on wings and tail because these are the major surfaces involved in creating lift during flight (Thomas, 1997; Pennycuick, 2008), and we expect takeoff to be impacted when these surfaces are not fully functional, as in the case of oil contamination. We used high-speed video and three-axis accelerometers to quantify the effects of feather oiling on takeoff of western sandpipers. High-speed video is a standard method used to measure takeoff speed and angle (Lind et al., 2010). Accelerometers are used to measure parameters that are relevant to takeoff, such as overall dynamic body acceleration (ODBA), which has been shown to indicate mechanical power output in a variety of animal species, including birds (Wilson et al., 2006; Halsey et al., 2009; Elliott et al., 2013; Duriez et al., 2014). Measuring ODBA allowed us to deepen our understanding of the energy requirements of takeoff in birds with flight feathers contaminated by crude oil.

2. Materials and methods

2.1. Study birds

Western sandpipers (family Scolopacidae) winter in the Gulf of Mexico in large numbers (Morrison et al., 1993; Nebel et al., 2002), and were one of the species exposed to MC252 oil from the DWH spill (NOAA, 2015). They are representative of other birds of similar size and habitat requirements.

We captured western sandpipers near Roberts Bank and Boundary Bay in Delta, British Columbia, Canada (49°04’N; 122°58’W) in July 2012 and July 2013. Upon capture they were held for up to one week in animal facilities at Simon Fraser University (Burnaby, BC, Canada) before same-day shipment to Toronto, Ontario, Canada. They were then transported by vehicle to the Advanced Facility for Avian Research (AFAR) at the University of Western Ontario, London, Ontario, Canada and maintained in captivity until the experiments.

The birds were housed in specialized 2.4 m × 3.7 m shorebird rooms under 16L:8D (16 h of light, 8 h of darkness) light conditions at approximately 22 °C. They were fed an ad libitum diet of 80% Mazuri Waterfowl Starter (Purina, Agribrands Purina Canada, Woodstock, ON, Canada) and 20% trout chow (Aquamax Fingerling Starter 300, Grey Summit, MO, USA) supplemented with ~50 mealworms/20 birds every other day. During winter 2013 the light cycle was switched to 12L:12D to simulate conditions on the winter range. In mid-April 2013 the light cycle was changed to 14L:10D to photostimulate the birds into a migratory condition. The test in June 2013 was performed under these photoperiodic conditions. The birds captured in July 2013 were tested in September 2013 and the tests were performed when they were experiencing 16L:8D. During the winter 2013–2014 they went through the same photoperiodic changes described above, and additional tests were performed while the birds were experiencing 14L:10D.

2.2. Study design and schedule

The study was performed in three sessions: the first in June 2013 using birds caught in July 2012 (N = 10 oiled), the second in September 2013 using birds caught in July 2013 (N = 7 oiled, N = 7 controls), and the third in November 2014 (N = 7 oiled, N = 6 controls). In June 2013 and September 2013, the birds were tested sequentially over four days: baseline flight without accelerometer (video only), baseline flight with accelerometer, oiled (or sham) flight without accelerometer, and oiled (or sham) flight with accelerometer.

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Due to an unrecoverable data storage drive failure, the September 2013 videos were lost before they could be analyzed. We analyzed the accelerometer data from September 2013, but we waited until November 2014 to repeat the video recordings to allow the birds to replace their feathers, and to measure them while they were in a similar migratory state. We repeated the time-matched control experiment (see below) with the same individual birds that were studied in September 2013, except that in this case birds were measured over two days with the baseline followed by the experimental flight.

We followed a four-day protocol: all birds flew baseline flights (BF) on day one (video only) and two (video and accelerometer), and then were oiled or sham-treated on day three for their experimental flights (EF, video only). On day four they flew an additional flight carrying accelerometers. Between day three and four the sandpipers were held without access to bathing pools so their feathers remained oiled until tested on day four. In June 2013 all birds were oiled after their baseline flights. In September 2013 and November 2014 we added a time-matched control group to exclude the possible effect of habituation to the experimental schedule. Accelerometers were only deployed in June 2013 and September 2013.

2.3. Application of crude oil to feathers

The oil applied to the birds from the oiled group was MC 252 oil collected during the 2010 DWH Gulf of Mexico oil spill and artificially weathered (TDI-Brooks International, College Station, TX) prior to receipt for use in the studies. Birds from the oiled group were oiled on 25% of the total surface of wings and tail. Oil covered the tip of the primary feathers and tail feathers (Fig. 1). This level of oiling represented approximately 20% of the total body surface (light oiling) as determined from study skins in advance of the study, however, in a standing bird, this represented less than 5% of the visible body surface.

2.4. Takeoff experimental procedure

We conducted the takeoff flights in a large, brightly lit animal room that was sub-divided by temporary walls and white curtains into a test arena (length 500 cm, width 310 cm, height 290 cm). At a release point near a corner of the arena, each bird was placed in an opaque box 20 cm above the ground surface and approximately 30 cm from a wall to the bird's left side. A high-speed video camera (Motion Pro X4 plus, Integrated Design Tools, Inc.) was positioned perpendicular to the release point and recorded the takeoffs at 200 frames per second (fps). The researcher waited until the bird positioned itself facing the long dimension of the arena (perpendicular to a side-view video camera and away from the researcher). At this point, the box was removed and an external stimulus (clicking sound produced by a dog-training clicker, one to three clicks) was given to induce takeoff. The observer behind the bird used angle markers on the ground to estimate the angle of deviation from the straight line perpendicular to the camera to correct

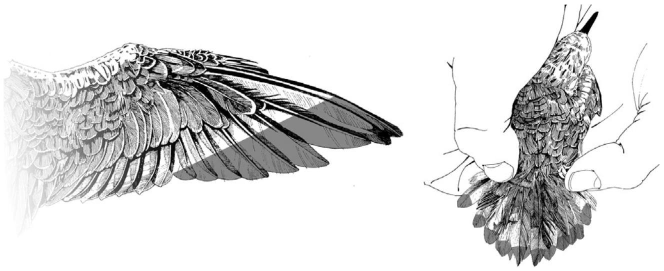

Fig. 1. Patterns of oiling for the experiments on Western sandpipers. Crude oil was applied to the trailing edge of the wing beginning 2.3 cm from the tip of the outermost primary feather to the tip of the 10th primary feather, and along a 0.7 cm margin of the tail. Sham treated birds were brushed in the same locations for the same duration with a dry paint brush. Illustration kindly provided by D.R. Smith.