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Post-release survival of surf scoters following an oil spill: An experimental approach to evaluating rehabilitation success

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ABSTRACT

Birds are often the most numerous vertebrates damaged and rehabilitated in marine oil spills; however, the efficacy of avian rehabilitation is frequently debated and rarely examined experimentally. We compared survival of three radio-marked treatment groups, oiled, rehabilitated (ORHB), un-oiled, rehabilitated (RHB), and un-oiled, non-rehabilitated (CON), in an experimental approach to examine post-release survival of surf scoters (*Melanitta perspicillata*) following the 2007 *M/V Cosco Busan* spill in San Francisco Bay. Live encounter-dead recovery modeling indicated that survival differed among treatment groups and over time since release. The survival estimate (±SE) for ORHB was 0.143 ± 0.107 compared to CON (0.498 ± 0.168) and RHB groups (0.772 ± 0.229), suggesting scoters tolerated the rehabilitation process itself well, but oiling resulted in markedly lower survival. Future efforts to understand the physiological effects of oil type and severity on scoters are needed to improve post-release survival of this species.

1. Introduction

Birds are often among the most affected vertebrate species in marine oil spills. For example, avian mortality rates after the 2010 *Deepwater Horizon* spill in the Gulf of Mexico showed the greatest increase compared to all other tetrapod vertebrate groups (Antonio et al., 2011). Such oil spill related mortality not only causes direct damage but can have profound impacts on marine bird population demographics (Votier et al., 2005; Henkel et al., 2012) including restricting survival and population recovery for many years afterwards, as was the case for sea ducks exposed to residual oil from the 1989 *Exxon Valdez* spill in Alaska (Esler et al., 2000, 2002). Given the large numbers influenced by oiling, marine birds have been frequent subjects of rehabilitation.

Wildlife rehabilitation plays a prominent public role and commands considerable resources during clean-up efforts after major marine oil spill events. While rehabilitation of oiled wildlife is common practice worldwide and mandated in California, its efficacy is often debated (Sharp, 1996; Estes, 1998; Jessup, 1998). Part of the controversy surrounding this practice centers on the survival of individuals released to the wild after treatment (Estes, 1998). Results of studies designed to evaluate avian post-release survival have been varied (Anderson et al., 1996; Sharp, 1996; Goldsworthy et al., 2000; Golightly et al., 2002; Altwegg et al., 2008), and several factors, including species, sex, body condition, degree of oiling, type of oil, and climatic conditions are known to play a role in survival outcomes (Goldsworthy et al., 2000). Recent advances in rehabilitative techniques (Mazet et al., 2002) have the potential to improve post-release survival, and continued experimental study is needed to evaluate their effects.

On 7 November 2007, the *M/V Cosco Busan* released 53,569 gallons of bunker oil into San Francisco Bay (SFB), California near the Oakland-San Francisco Bay Bridge. The surf scoter, (*Melanitta perspicillata*), a benthic-foraging sea duck, was the species most affected by the *Cosco Busan* spill (Hampton et al., 2008). Scoters are one of the most numerous waterfowl species wintering in this estuary, and SFB scoters comprise 39% of all those overwintering along the North American lower Pacific Flyway (1988–2009

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average; Accurso, 1992; USFWS, 2009). Scoter species (including surf, white-winged *M. fusca,* and black *M. americana* scoters) in North America have declined by as much as 50% over the past 30 to 50 years (Hodges et al., 1996; Dickson and Gilchrist, 2002; Nysewander et al., 2005). Long-lived waterfowl species with low reproductive potential such as scoters are particularly sensitive to changes in adult survival (Goudie et al., 1994) and may have the most difficulty recovering from oil spills (Samuels and Ladino, 1983/1984). Additionally, many sea ducks show high winter site fidelity and pair on wintering areas; thus, factors that affect survival rates in SFB could have disproportionate effects on local subpopulations (Esler et al., 2000).

Following the *Cosco Busan* spill, more than one thousand oiled scoters were treated by the Oiled Wildlife Care Network (OWCN) using a standardized marine bird protocol (OWCN, 2001). Post-rehabilitation survival of scoters had not been previously studied but was of particular interest given that they comprise a significant component of birds oiled in Pacific coast wintertime spill events (Savard et al., 1998; Hampton et al., 2003). We used an experimental approach to design a marked-bird study that compared survival of scoters externally oiled and rehabilitated (ORHB) with two control treatment groups: un-oiled, rehabilitated (RHB) and un-oiled, non-rehabilitated (CON). We predicted that oiling and the rehabilitation process itself could have effects on survival such that CON birds would have highest survival followed by RHB and then ORHB birds.

2. Methods

2.1. Treatment, radio-marking and data collection

We captured beached, oiled scoters by hand from several locations (Fig. 1) around SFB during 8–21 November 2007. We used netguns (Coda Enterprises, Inc., Mesa, AZ) from a 4 m Boston Whaler to capture birds in Central and San Pablo Bays during 30 November–16 December 2007 (Fig. 1) for the RHB and CON treatment groups. Captured scoters were placed in holding cages and brought to a U.S. Geological Survey (USGS) research field station in Vallejo, California or to the OWCN rehabilitation center in Cordelia, California for processing. We banded, weighed, and measured each captured scoter. We used a combination of plumage characteristics and cloacal examination to determine sex and bursal depth measurements to determine age (Mather and Esler, 1999). Coelomic radio transmitters with external whip antennas (18–19 g, model A2310, Advanced Telemetry Systems, Insanti, MN, USA) were surgically implanted (Olsen et al., 1992; Korschgen et al., 1996; Mulcahy and Esler, 1999) by experienced veterinarians in juvenile and after-second-year (ASY) male and female scoters. Implant transmitters were used because they have been shown to be less disruptive and cause fewer behavioral modifications than external attachment methods for some wild waterfowl (Rotella et al., 1993; Hupp et al., 2003). Coelomic implant transmitters are preferred for scoters relative to other transmitter types when data are collected over a long period of time (Iverson et al., 2006).

Scoters in ORHB and RHB groups underwent treatment and surgery at the OWCN facility. Birds in both groups were treated following established rehabilitative protocols (OWCN, 2001; Mazet et al., 2002) that included administration of charcoal and isotonic fluids, oil removal (ORHB group) and cleaning, assistance with thermoregulation, diagnostic blood work, rehydration, and nutritional supplementation. After rehabilitative treatments were administered, scoters in both groups were radio-marked and kept post-surgery at the facility until their feathers were deemed fully waterproofed and they exhibited normal buoyancy. Marked scoters in ORHB and RHB that died before release were not included in the study ($N = 6$ ORHB, $N = 6$ RHB). At the USGS field station, we radio-marked CON scoters within 24 h of capture and kept them up to 2 h following implant surgeries prior to release. Subcutaneous fluids were administered to CON birds every 4–5 h throughout the period of captivity to minimize the risk of dehydration. Two CON birds died immediately after surgery and were not included in the survival analysis. Marked scoters were released in the northern reach of SFB at the Carquinez Strait in Vallejo (ORHB and RHB), and from the Hercules shoreline (ORHB, RHB, and CON; Fig. 1). One marked ORHB scoter that escaped from the rehabilitation facility after processing was subsequently heard in the survey area and included in our analyses.

We conducted aerial telemetry flights in a fixed-wing aircraft 2–3 times a week for a total of 34 flights between 16 December 2007 and 7 May 2008 to determine location and status of all marked birds. We used a left–right switch-box system to isolate signals on either side of the airplane and determine locations (Gilmer et al., 1981). Each transmitter was equipped with a mortality sensor that doubled the pulse rate of the transmitter when motionless for 8 h. For each survey, we recorded whether a scoter was detected or not, and whether or not detected scoters were alive or dead. Identified mortalities were confirmed by recovery of the carcass or transmitter. The area monitored included bays and the coastline to the north and south of SFB from Bodega Bay to Monterey Bay, including all SFB sub-bays (South, Central, San Pablo, and Suisun), and adjacent wetlands (Fig. 1 inset – see survey area). Transmitters could be heard from 24 km away at an average flight altitude of 460 m; therefore, we identified a 24 km buffer zone around the flight path within which we assumed all transmitters could be heard. California Department of Fish and Game also conducted three extended telemetry flights along the California coast during March 2008 to listen for marked birds that might have left the study area. Dates and areas covered on these flights were: 24 March, Ventura north to Pismo Beach; 25 March, Pismo Beach north to SFB; 27 March, Point Arena north to the Oregon border (Fig. 1 inset).

2.2. Data analyses

We used a live encounter – dead recovery model (Burnham, 1993; Cooch and White, 2005) in Program MARK (White and Burnham, 1999) to estimate winter fates of scoters. This joint model extends standard Cormack–Jolly–Seber models of live capture–recapture data and estimates additional parameters (Burnham, 1993). The four parameters included in live encounter-dead recovery models are: S (the probability of surviving the interval), r (the probability of being dead and reported), F (the probability of fidelity to the sampling region or remaining in the sample), and p (the probability of detection or recapture, conditional on being alive and in the sampling region) (Cooch and White, 2005). This model was most appropriate for our data as detection probability (p) was less than one for individuals across treatments (Murray and Patterson, 2006). Live encounter-dead recovery models allow for the assumption that a bird not detected during one time interval could be either dead or alive and not resighted and does not censor that individual from the interval (Cooch and White, 2005).

We constructed a series of 14 *a priori* candidate models which were designed to evaluate S given all possible combinations of group and time effects, and we included models with body mass and sex as covariates. We did not adjust mass for structural size of each bird, because recent studies have shown little or no improvement with adjustments over body mass alone to predict body condition (Schamber et al., 2009). In all models, we set $F = 0.986$, based on data from un-oiled, non-rehabilitated surf scoters radio-marked from 2003 to 2005 in which only 2 of 149 individuals permanently emigrated from the study area during winter (De La Cruz et al., unpublished data). In all models, we assumed r and p varied among treatment groups but not with respect