AERIAL SURVEILLANCE AND OIL SPILL IMPACTS BASED ON BEACHED BIRD SURVEY DATA COLLECTED IN SOUTHERN BRITISH COLUMBIA

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SUMMARY

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The cumulative impact of maritime oil pollution resulting from frequent but typically small oil discharges (i.e. <1000 L) is a significant issue worldwide, but this issue is difficult to address because of the size of the oil spills involved relative to the size of the environment into which they are released. Here we compare oil-spill patterns and surveillance-flight effort of the Canadian National Aerial Surveillance Program (NASP) with the proportion of oiled carcasses and beaches documented by Beached Bird Survey (BBS) programs conducted in several regions of southern British Columbia. BBS results from two regions (west coast of Vancouver Island and the Strait of Georgia) support the contention that NASP surveillance over adjacent waters has played a role in reducing the cumulative impact of small oil spills on marine birds. However, the proportion of oiled carcasses documented in other regions (south Vancouver Island, Vancouver Harbour and Boundary Bay) provides no support for the deterrence effect of NASP. The absence of a deterrence affect suggests that predominant maritime activities in these regions are not affected by NASP presence, because these activities may not have been targeted as potential oil pollution sources in the past. Our comparisons not only provide some evidence of the impact of NASP on oil discharges at sea, but also can serve to inform NASP or other enforcement agencies concerning where future effort could be most beneficial.

Key words: Small oil spills, cumulative impact, oiled birds, Canadian National Aerial Surveillance Program, deterrent effect

INTRODUCTION

Some maritime oil pollution events do not trigger a "response" from local organizations or governments that addresses oil spills and associated impacts because constituent oil spills go undetected or unreported, or because they occur in areas in which they will dissipate before any response can be effective. Individual oil spills of this type are usually small (i.e. 1000 L or less), and point sources typically remain unidentified (i.e. "mystery spills"), which makes this issue particularly difficult to address. Nevertheless, oil spills in this category contribute a considerable amount of oil pollution to marine ecosystems worldwide (NRC 2003, GESAMP 2007). Although not clearly as destructive as large, catastrophic oil spills (e.g. *Exxon Valdez, Prestige, Erika*), smaller-scale oily discharges probably have a greater ecological impact per volume spilled because they occur more frequently and in more places (Burger 1993a). A very small amount of oil can kill a seabird (Wiese & Robertson 2004), and these small spills occur at scales comparable to the processes that drive distributions of potentially affected wildlife. For example, mesoscale oceanographic and bathymetric features have been shown to be important factors associated with dense seabird aggregations off the southwestern coast of Vancouver Island (Wahl *et al.* 1989, Burger 2003), where patch radii of seabirds and prey species have both been estimated at 10 km or less (Burger *et al.* 2004). Marine pollution from small-scale oil spills has been shown to have a cumulative effect on seabird populations particularly in areas in which seabird concentrations overlap with ship traffic (Wiese & Robertson 2004).

Beachcast as carcasses, or stranded and in distress, oiled wildlife (typically marine birds) is an obvious consequence of small-scale oil pollution that may otherwise go unnoticed. Incidental encounters with oiled beachcast wildlife and organized beach survey networks have increased public awareness of wildlife contaminated by oil pollution from unknown point sources. In North America, there are currently a number of organized networks of volunteers, often coordinated by non-governmental organizations, that survey Atlantic and Pacific beaches on a regular basis using broadly established protocols [Beached Bird Survey programs (BBSs)]. These programs provide critical information regarding the impact of oil pollution on marine wildlife. BBSs have been ongoing in British Columbia since 1986, except between 1997 and 2002 (see "Materials and Methods").

The Canadian National Aerial Surveillance Program (NASP) began in British Columbia in the early 1990s and continues to fly regular surveillance flights up to several times per week (Armstrong & Derouin 2002). Before 2007, flights were conducted mostly in a De Havilland Twin Otter (model DHC-6) and covered intense shipping routes through Georgia Strait, the Strait of Juan de Fuca and offshore just west of Vancouver Island. Oil spills documented between 1997 and 2006 occurred mostly throughout Georgia Strait and the Strait of Juan de Fuca, but hot spots (determined by spill rates, controlling for surveillance effort; Serra-Sogas *et al.* 2008) were identified inside the study area, including Howe Sound, Nanaimo, Boundary Bay (south of Vancouver), Southern Georgia Strait (east of Victoria, near the San Juan Islands), Barkley Sound and Cape Flattery in Washington State.

NASP not only monitors and collects evidence of illegal discharges of oil into marine and aquatic environments, but also functions effectively as deterrence. NASP flies a brightly coloured aircraft that is clearly marked and often contacts maritime crews by radio. Although deterrence is a well-known outcome of sustained presence in a proactive policing and enforcement program, sustained presence is often questioned because of cost and the difficulty of measuring deterrence directly (Cook 1980, Sampson & Cohen 1988, Sherman & Weisburd 1995, Farrington & Welsh 2005).

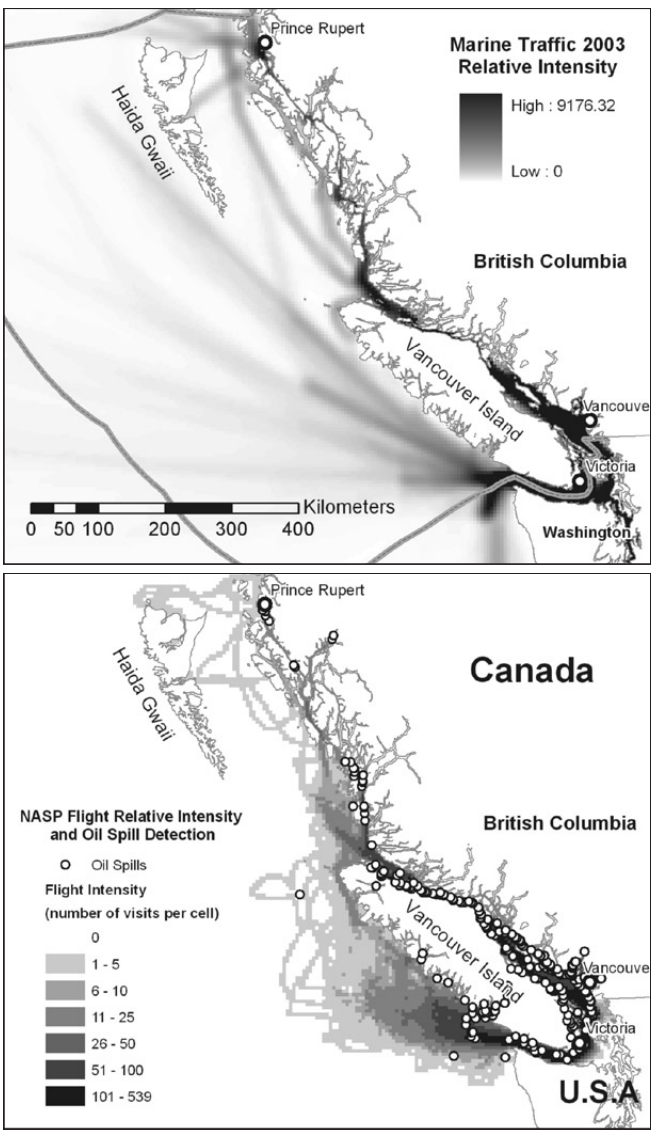

Fig. 1. Marine traffic relative intensity for 2003 (top panel), and National Aerial Surveillance Program (NASP) flight relative intensity and documented oil spills from 1997 to 2006 (bottom panel). Maps redrawn from O'Hara & Morgan (2006) and Serra-Sogas *et al.* (2008). NASP intensity was quantified as total number of flights per 5×5-km grid cell ("visits") from 1997 to 2006.

In the present study, we compare encounter rates with oiled carcasses and incidence of oil found on beaches in southern British Columbia [Georgia Strait, Strait of Juan de Fuca and west coast of Vancouver Island (WCVI)] documented by BBSs conducted before and after the initiation of the regular NASP flights that occur throughout the study area. Although reductions in oiled carcasses documented in BBS surveys and aerial surveillance programs have been linked in European studies (Camphuysen & Heubeck 2001), this is the first

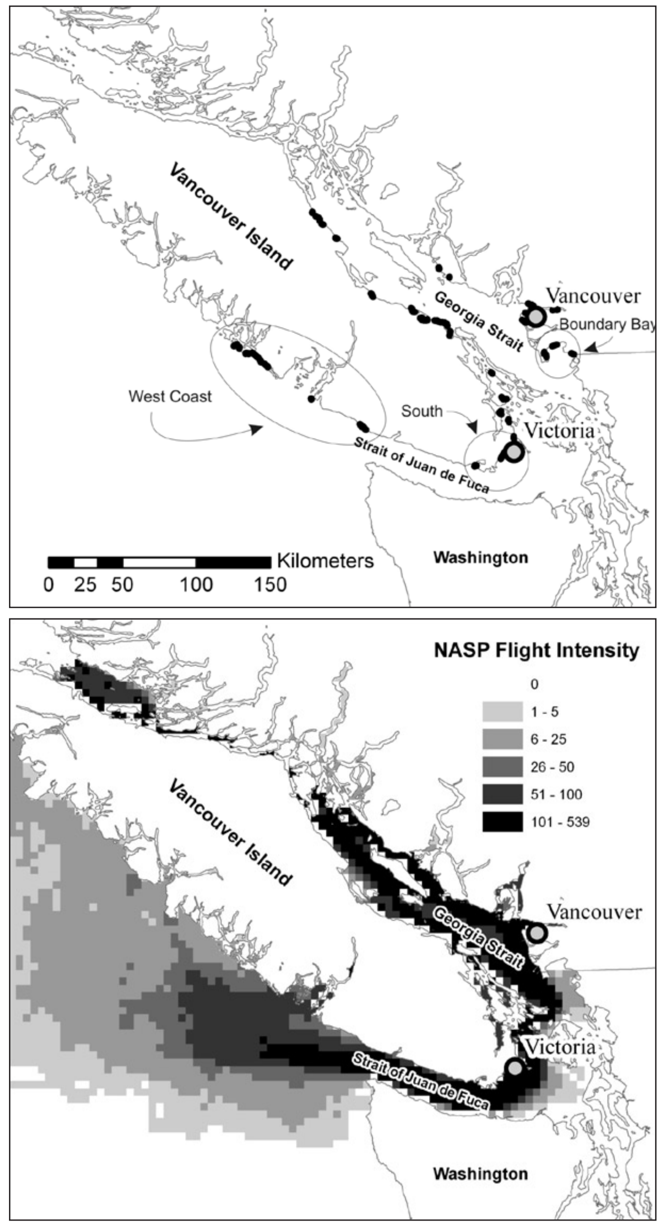

Fig. 2. Location of beached bird survey sites included in the present study (top panel), and National Aerial Surveillance Program (NASP) flight intensity (bottom panel). Encircled areas are regions mentioned in the text and in Table 1: Vancouver Island–West Coast ("West Coast"), Vancouver Island–South ("South"), and Boundary Bay sites. The "Vancouver" region in Table 1 refers to sites located near the city of Vancouver (excluding sites in the Boundary Bay region), and "Georgia Strait" includes sites along Georgia Strait and the Gulf Islands (southern Georgia Strait).

attempt at matching spatially explicit surveillance effort with BBS data at a scale that appropriately reflects interpretations of BBS data. The three main aims of this study are

- to estimate variation in the proportions of oiled carcasses documented in BBSs conducted in southern British Columbia since NASP initiation,
- to compare the foregoing variation with NASP effort, and
- to define areas in which NASP needs to concentrate more effort, based on variation in BBS results.

MATERIALS AND METHODS

Shipping information was summarized for the calendar year 2003 based on data provided by the Canadian and US Coast Guards (Fig. 1), which coordinate and direct shipping traffic through the Canadian and US exclusive economic zones (extending to 200 nautical miles from the coast). These data include all ships above 20 m length and are summarized as total numbers per cell in a grid of 5×5-km cells (see O'Hara & Morgan 2006 for details). Similarly, flight intensity (Figs. 1 and 2) was summarized as number of flights visiting each 5×5-km cell over the entire study period. All oil spills documented (Fig. 1) were detected by eye and documented by NASP crew members during surveillance flights between 1997 and 2006 (for details see Serra-Sogas *et al.* 2008). The relative probability of oil detection was modelled using a kernel estimator for density estimation with an adaptive bandwidth (for details see Serra-Sogas *et al.* 2008). This method allows for visualization of oil spill occurrence, controlling for variation in surveillance effort and emphasizing areas of higher relative oil spill intensity or "hotspots" (Fig. 3, adapted from Serra-Sogas *et al.* 2008).

BBS data were collected during surveys coordinated by A.E. Burger (University of Victoria) from 1987 to 1996 and surveys coordinated by Bird Studies Canada (BC Program) from 2002 to 2007 (Fig. 2). Surveys were conducted using standardized and similar protocols, which facilitates comparisons of proportions of carcasses exhibiting exposure to oil pollution. Skilled volunteers conducted surveys along predefined stretches of beach once per month, on approximately the same day (1986–1997) or in the last week of the month (2002–2005). The number and identification of all carcasses encountered was recorded, with identification made to the lowest taxonomic level possible, using beached bird identification guides (Ainley *et al.* 1980, Hass & Parrish 2002). All carcasses were examined for traces of oil or other possible causes of mortality (i.e. starvation or fishing gear entanglement) and were either removed from the beach or tagged for identification in future surveys. Presence and type of oil on the beach was also recorded on every survey. Impacts from maritime oil pollution were indexed using

- proportion of intact carcasses (>90% of carcass remaining; incomplete carcasses were not included in this analysis) found with oil, and
- proportion of surveys with oil contaminating the beach route.

BBS volunteers did not examine carcasses for exposure to any type of clear petroleum oil (i.e. diesel or kerosene) or vegetable oils such as canola or palm oil derivatives.

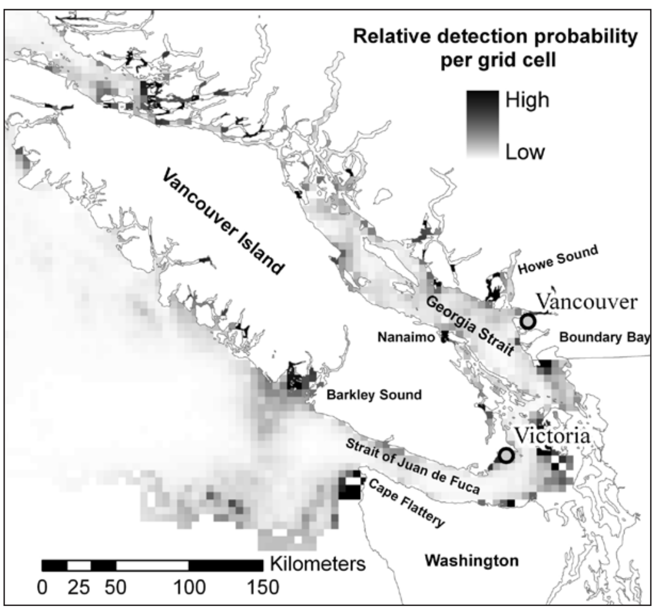

Fig. 3. Probability of detecting oil pollution per flight per 5×5-km grid cell using kernel estimation with adaptive bandwidth based on National Aerial Surveillance Program (NASP) data collected in the study area (Georgia Strait, Vancouver, Boundary Bay and South and West Coast Vancouver Island). Map redrawn from Serra-Sogas *et al*. (2008).

RESULTS AND DISCUSSION

Between the first (1987–1996) and second (2002–2007) BBS periods, the proportion of oiled carcasses and oiled beaches changed most on survey routes along the WCVI region (Table 1). Proximity to intense shipping traffic (Fig. 1) and nearby oil spill detection hotspots (Fig. 3) may explain high rates of oiled carcasses found in the WCVI region. NASP surveillance flights were concentrated southwest of survey beaches in this region, where shipping traffic funnels into the mouth of the Strait of Juan de Fuca. This area is also a likely source of carcasses beachcast on WCVI beaches, given prevailing wind conditions, especially during the period October to April (O'Hara & Morgan 2006). A less dramatic change in the proportion of oiled carcasses encountered was also observed in the Strait of Georgia. The reduction in the proportion of beachcast carcasses oiled and of oily tar balls found on beaches since the onset of the NASP program provides correlative evidence of the deterrence effect that the NASP presence has had on rates of oily discharge west of the entrance to the Strait of Juan de Fuca. Declines in oil spill detection rates by NASP are consistent with deterrence (Serra-Sogas *et al.* 2008), but it is unclear if this decline is occurring similarly in all regions.

Beaches surveyed in the South Vancouver Island and Boundary Bay regions showed small increases in the proportion of oiled carcasses documented between BBS periods. This finding suggests that sources of oil pollution in these regions are unaffected by the NASP presence. Until recently, NASP has focused on larger seagoing vessels, ferries and tugs. Pleasure craft, commercial fishers and marinas have not been as scrutinized with respect to oily discharges, but this may change. NASP in the Pacific region of Canada has started to focus on these categories of maritime use and has been documenting oil spills associated with the activities of these craft (P.D. O'Hara pers. comm. with NASP personnel). The high proportion of oiled carcasses found along beaches in the Vancouver region has also raised public awareness of smaller oil spills, despite the lack of surveys in the first BBS period. It should also be pointed out that many of the beached bird carcasses found in Boundary Bay have been linked to the gillnet fishery in the area (Hamel *et al.* 2009), and that effect would result in a lowering of the proportion of mortality attributable to cumulative-impact oil pollution.

Two major oil spills occurred that may have affected early BBS results in our study. The fuel barge *Nestucca* sank in December 1988, releasing fuel oil that killed an estimated 56 000 birds and that affected most of the beaches along the WCVI (Rodway *et al.* 1989, Ford *et al.* 1991, Burger 1993b, Burger 2002). The M/V *Tenyo Maru* sank in July 1991 and killed many seabirds as well, but most of the oil apparently moved south along the Washington coast (Burger 1992, Venkatesh & Crawford 1993). Birds known to have been killed by these spills were not included in the BBS dataset, but oil, which persisted for many months after the spills, might have contributed to some of the oil reported on the beaches (Burger 2002).

Although far from conclusive, BBS data provide potentially important evidence supporting the role that NASP can play in deterring oil spills affecting seabirds, particularly over the continental shelf off southwestern Vancouver Island and near the mouth of the Strait of Juan de Fuca, which is considered an important foraging area that tends to concentrate seabird species from around the world (Morgan *et al.* 1991, Wahl *et al.* 1993, Burger 2003), and also within the Strait of Georgia. In other regions, NASP appears to have had little effect, but may take on a bigger role as it continues to document oil spill occurrence. Perhaps it can provide the impetus for redirecting on-the-ground enforcement efforts. Results from the present study not only provide much needed evidence of the effectiveness of deterrence of an aerial surveillance program, but can also help to direct future surveillance and enforcement efforts. The small increases in encounter rates of oiled carcasses found by BBSs in the southern Vancouver Island and Boundary Bay regions suggest that sources of oil pollution in those areas are currently enjoying some degree of impunity despite the regular presence of NASP. Current management and enforcement efforts may consider shifting their focus from shipping and fishing to other commercial and private maritime industries and activities.

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TABLE 1
Bird carcasses found (n) and proportion contaminated with oil (%), and beach surveys conducted (n) and proportion with oil (%) found during the first (1986–1997) and second (2002–2005) programs of beached bird surveys conducted in British Columbia[a]

Region	Oiled carcasses				Oiled beaches			
	1986–1997		2002–2007		1986–1997		2002–2007	
	(%)	(n)	(%)	(n)	(%)	(n)	(%)	(n)
Boundary Bay	0	182	3	60	4	162	0	93
Vancouver[b]		14	14		7	201		
South Vancouver Island	12	32	19	32	2	389	0	289
Georgia Strait	12	33	0	19	5	314	<1	419
West Coast Vancouver Island	56	54	1	133	17	422	1	239

[a] Refer to Fig. 3 for regions.

[b] Vancouver sites were not surveyed before 2002.

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