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Geospatial analysis of oil discharges observed by the National Aerial Surveillance Program in the Canadian Pacific Ocean

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A B S T R A C T

Oil pollution resulting from day to day human maritime activities contributes a high portion of the overall input into marine environments, constituting a major threat to marine ecosystems worldwide. In Canada, the National Aerial Surveillance Program (NASP) extensively monitors and collects information on oily discharges using remote sensing devices. Despite the availability of data from NASP and other surveillance programs internationally, there is a paucity of spatial analyses of oil pollution patterns, particularly in their association with human marine pursuits. The objective of this paper is to analyze the association between observed oily discharges and human maritime activities in the Canadian Pacific Ocean. This study used Poisson regression to spatially model detected oily discharges with marine traffic, coastal facilities and proximity to coast. Further, it developed localized ('regional') models to address spatial heterogeneity. The models identify recreational activities, passenger traffic, commercial traffic, fisheries, and proximity to the coast as predictors of observed oily discharges. The regional models yield more accurate and reliable estimates of local associations, and identify more parsimonious sets of predictors for each region. By identifying and accounting for human activities most associated with oily discharge patterns, the models developed in this study could be used to estimate pollution rates in areas with less surveillance, and identify areas where NASP coverage may need to be increased. Spatially explicit rates estimated by these models can be used to monitor the effectiveness of programs and policy aimed at reducing discharge rates of oily pollution. This study can be used as a model approach for extending the analysis to the other coasts of Canada, using available NASP data.

Introduction

Oil pollution is a major threat to marine ecosystems and coastal communities worldwide (Charlier, Fink, & Krystosyk-Gromadzinska, 2012). Extensive research has proven this true for seabirds, which are highly visible and considered one of the most vulnerable taxa to marine oil pollution (Burger & Fry, 1993; Camphuysen & Heubeck, 2001). There are many ways that oil can enter these ecosystems, including natural seeps, vessel accidents, terrestrial run-off, and as a result of day to day activities associated with thousands of human maritime pursuits (GESAMP, 2007 , 83 pp.; NRC, 2003 , 265 pp.). Oily discharges can occur intentionally (see Camphuysen & Heubeck, 2001; Wiese & Robertson, 2004), through negligence (i.e., poor maintenance for example), or purely by accident. In more extreme cases, oily discharges into marine environments can occur as a result of third party activities such as malicious (i.e., "interdictions" as per Church, Scaparra, & Middleton, 2004; see Anifowose, Lawler, van der Horst, & Chapman, 2012) or accidental (see Transport Safety Board of Canada, 2007) pipeline disruptions, or acts of war (see Iraq–Kuwait Conflict, p. 135 in NRC, 2003 , 265 pp.). Nevertheless, in most if not all cases, these discharges would be considered non-compliant with international standards (i.e., MARPOL) and therefore, illegal as defined by Canadian legislation. Although land-based activities (i.e., through terrestrial run-off) and natural seeps are considered the largest inputs of oil pollution into marine environments in terms of volume per year, (GESAMP, 2007 , 83 pp.; NRC, 2003 , 265 pp.), research and enforcement efforts have focused on human maritime activities as they are easier to quantify and associate with specifically identifiable oily discharges.

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Oil pollution from shipping accidents tends to be catastrophic, capturing much of the public attention; however, cumulatively oil pollution stemming from day to day activities ("operational discharges") contributes a higher rate of input into marine environments than pollution from shipping accidents (GESAMP, 2007 , 83 pp.; NRC, 2003 , 265 pp.). Most studies on impacts from operational discharges have focused on operational discharges and larger catastrophic spills from marine vessels (for example, see Camphuysen & Heubeck, 2001; Piatt, Lesink, Butler, Kendziorek, & Nysewander, 1990; Wiese & Robertson, 2004). However, day to day oily discharges also can be associated with outflows from terrestrial run-off, accidental spills from fuel docks, derelict vessels, coastal transfer facilities, pleasure craft, and fishery activities (GESAMP, 2007 , 83 pp.; NRC, 2003 , 265 pp.; NASP crew pers. comm.). Furthermore, size of discharge is not the only predictor of impact (Burger, 1993). Indeed, operational discharges can have devastating effects on highly mobile marine taxa such as seabirds, simply by virtue of timing and location. For example, over 50% of the global population of Cassin's Auklet (*Ptychoramphus aleuticus*) returns to Triangle Island (see Fig. 1) to breed. These breeding auklets tend to forage in relatively small areas of ocean over the shelf break approximately 60 km southwest or 80 northwest of Triangle Island (Boyd, McFarlane Tranquilla, Ryder, Shisko, & Bertram, 2008), which are areas also transited by vessels moving between the lower U.S. and Alaska or Prince Rupert in northern B.C, (O'Hara & Morgan, 2006). A single operational oily discharge from any of these vessels could have a major impact on Cassin's Auklet populations on a global scale. Camphuysen (1989) , 322 p. provided an empirical example of the importance of timing and location of a spill when he reported on a massive die-off of Common Scoters (*Melanitta nigra*) and Common Eiders (*Somateria mollissima*), species which tend to aggregate in flocks along the shoreline, from a small coastal spill in the North Sea. Clearly, when considered cumulatively, oil pollution from operational discharges is likely to have a big effect on marine ecosystems as these discharges occur at a much higher frequency and are extensive spatially (Serra-Sogas,

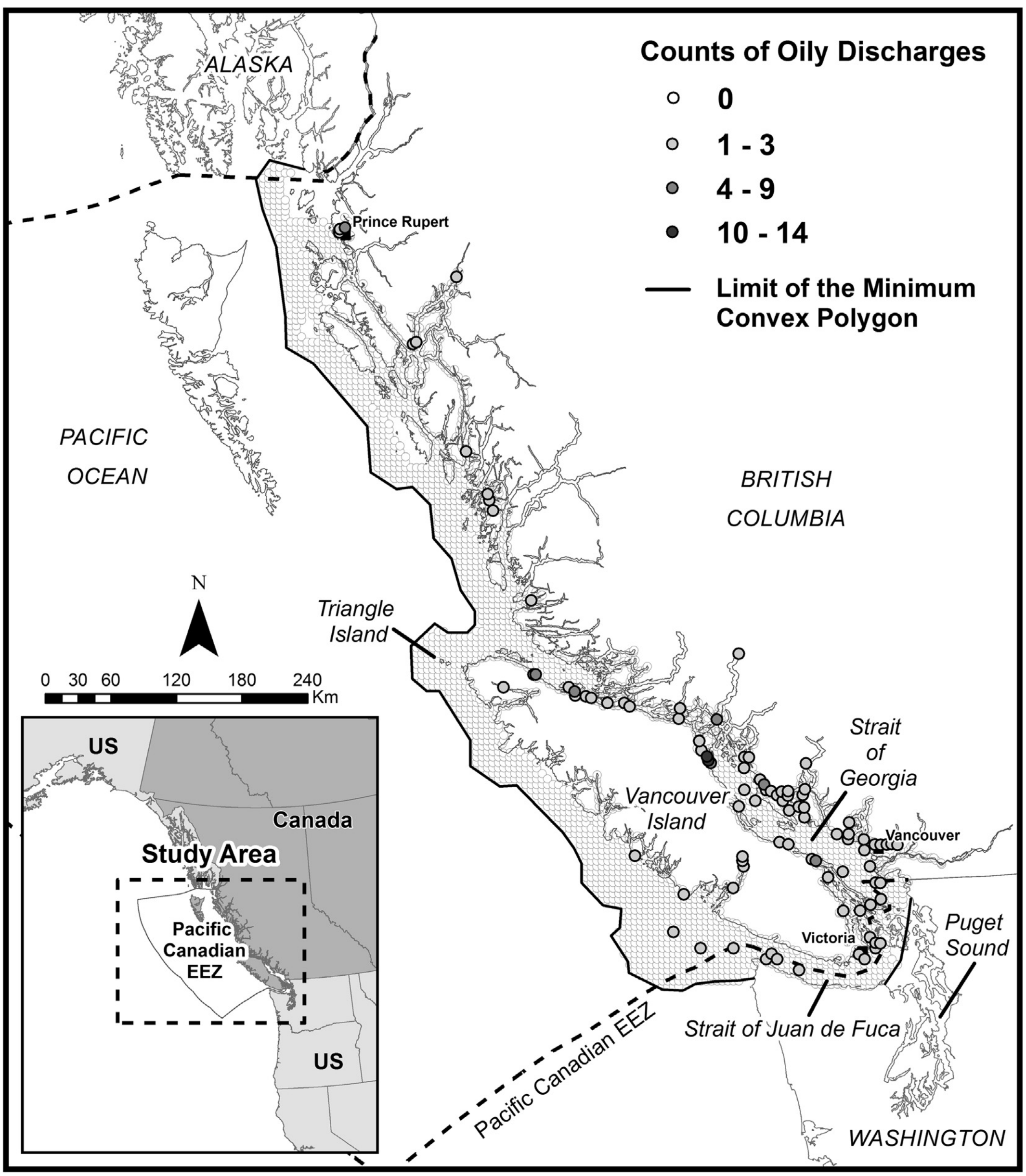

Fig. 1. Observed oily discharges in the Canadian Pacific region.