Exploring the Deterrent Effect of Marine Pollution Monitoring in Canada's Pacific Region.

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Abstract

Off the Pacific coast of Canada, the number of detected small-scale oil discharges from vessel operations has moderately decreased since 2000 as a result of an increase in surveillance effort by Canada's National Aerial Surveillance Program (NASP). To explore the deterrence effect in the region, we investigated changes in the spatial distribution of NASP monitoring effort between early 1997 and late 2006, and differences between summer and winter seasons, using LISA cluster maps. In addition, we studied the spatial relationships between surveillance effort and different marine vessel traffic distributions, differentiating between seasons, and accounting for the presence of spatial autocorrelation in the variables. With this study we aim to generate hypothesis about the type of vessels targeted by NASP and, therefore, for specific deterrence effects from polluting.

Background and Relevance

Canada's National Aerial Surveillance Program (NASP) is the primary monitoring and deterrence tool for the enforcement of national and international pollution prevention regulations (Armstrong, 2004). Within Canadian Pacific waters, the number of NASP flights has varied since the beginning of the program in the early 1990s. Analysis of data provided by the NASP flight crew indicated that during the 1990s NASP surveillance effort declined reaching the lowest level in 1999/2000 fiscal year, followed by an increase of pollution surveillance hours to its peak in 2006/2007 fiscal year (Fig. 1). The number of detected oil spills per fiscal year also presented a notable decrease until 1999/2000, when it changed to a relatively constant number of detections (Serra-Sogas et al., 2008a).

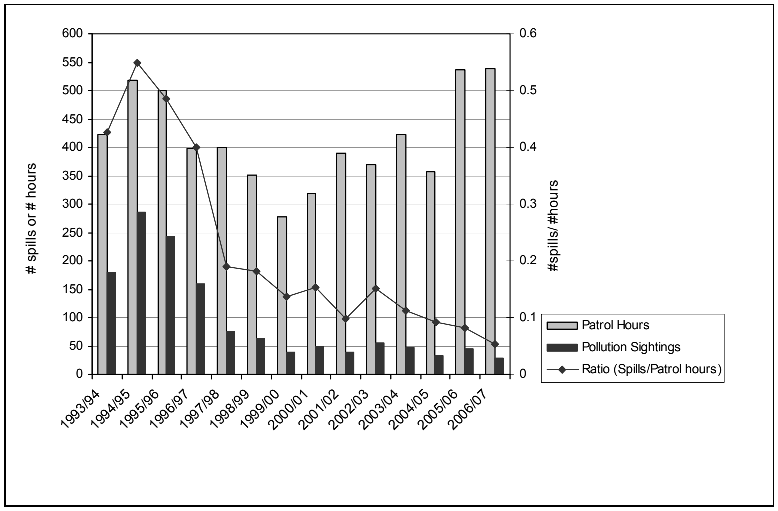

Fig. 1. Trends of total number of patrol hours and observed oil pollution events, and ratio number of spills by number of patrol hours from fiscal year 1993-1994 to 2006/2007 for Canada's Pacific Region.

Studies have shown that generally an increase in monitoring effort leads to a higher probability of detecting potential polluters, followed by an increase in compliance to pollution regulations due to a deterrence effect (Cohen, 2000). In order to investigate the deterrence effect of NASP to marine polluters, we first explore annual variations in the spatial distribution of surveillance effort from 1998 to 2005 in order to determine those areas that received higher surveillance effort and whether they remained the same over time and during different seasons (summer and winter). Next, in a more in depth analysis, we investigate vessels that have a higher probability to be monitored and, therefore, likely to be deterred from polluting, by quantifying the degree of correlation between surveillance effort and marine traffic densities for different vessel types. The analysis will be differentiating between summer and winter to capture seasonal differences in vessel traffic.

Data and Methods

The area considered in this study comprises the area surveyed by NASP between late 1997 and early 2006, and included within the Canadian Economic Exclusive Zone (Fig. 2).

Spatio-temporal information on individual patrol flights from late 1997 to early 2006 was obtained from the NASP flight crew. Surveillance effort was estimated from individual flight routes as the total area surveyed per unit of observation (one unit of observation is equal to 5 by 5 kilometers cell). Relative marine traffic densities for vessels larger than 20 m overall length, divided in type groups (e.g., tugs, ferries, tankers, carriers, cruise ships and fishing vessels) and seasons (e.g., summer and winter) were estimated from 2003 Vessel Traffic Operation Support System (VTOSS) dataset, courtesy of the Marine Traffic and Communication

Services (MCTS) of Transport Canada. 2003 is used as a representative year of shipping densities and distribution for the entire study period, knowing that the intensity of shipping movements in the Pacific Region were reasonably invariable from 2000 to 2006 (Canadian Coast Guard, 2001-2006).

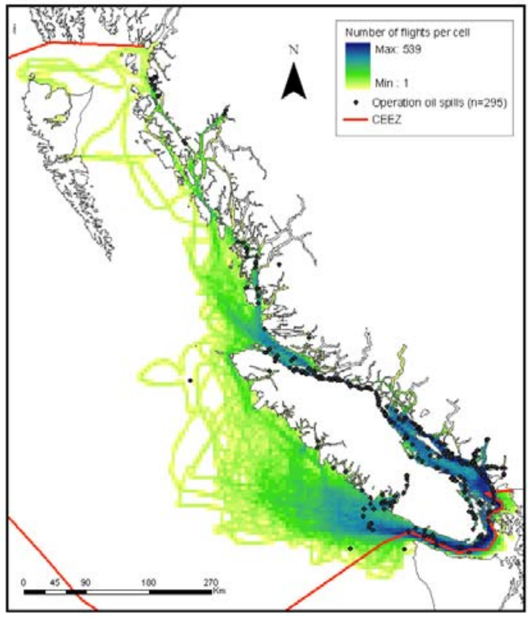

Fig. 2. Map of the spatial distribution of observed oil spills the estimated surveillance flight effort between 1997 and 2006.

Local measures of spatial autocorrelation, such as the local form of Moran's I or LISA, are appropriate to identify the location of high values (hot spots) and low values (cold spots) (Anselin, 1995; Boots, 2002). To estimate spatial autocorrelation indices, a weight matrix, which measures the potential interactions among spatial units, needs to be defined (Anselin, 1995). LISA cluster maps representing high values of surveillance effort per year and per season are constructed with GeoDa using a rook contiguity first order of neighbor's weight matrix (Anselin, 2005).

To explore the relationship between surveillance effort and marine traffic distributions, we quantify the relationship by estimating the Pearson's correlation index. In a previous study, both variables presented positive spatial autocorrelation (Serra-Sogas et al., 2008b). The presence of significant spatial autocorrelation in the variables, however, can affect statistical significance and interpretation of the correlation test (Legendre, 1993). Therefore, when testing the significance of correlation, the presence of spatial autocorrelation needs to be taken into account. Fortin and Fayette (2002) suggest a method that adjusts the number degrees of freedom proportionally to the amount of estimated spatial autocorrelation. This method is known as Dutilleul's adjustment t-test method (1993).

Results

Forthcoming results will provide: first the identification of areas that received higher density of pollution patrol flights and whether surveillance coverage was spatially consistent among years; and second, an understanding of monitoring bias and associated deterrence effects of NASP flights to potentially observed vessel types.

Conclusions

By exploring spatial changes of the NASP surveillance effort off the west coast of Canada and by recognizing bias on their monitoring planning we expect to draw inferences about the causal factors that lead to the observed declining pattern in detection rates. In addition, this analysis expects to provide relevant information for future analysis aimed to specify a model to predict detection and occurrence probabilities of vessel-source oil pollution.

References

Anselin, L. (1995). Local indicators of spatial autocorrelation - LISA. *Geographical Analysis, 27,* 93-115.

Anselin, L. (2005). *Exploring Spatial Data with GeoDA: A workbook*. Illinois: Spatial Analysis Laboratory, University of Illinois.

Armstrong, L., & Derouin, K. (2004). *National Aerial Surveillance Program 2001-2004. Final Report*. Transport Canada, Ottowa.

Boots, B. (2002). Local measures of spatial association. *Écoscience, 9*(2), 168.

Canadian Coast Guard (2001-2006). *Annual Statistics Report for the Pacific Region*. Safety & Environment Response Systems. Marine Communications & Traffic Services.

Cohen, M. A. (2000). Empirical Research on the Deterrence Effect of Environmental Monitoring and Enforcement. *The Environmental Law Reporter, 30*, 10245-10252.

Dutilleul, P., Clifford, P., Richardson, S., & Hemon, D. (1993). Modifying the t Test for Assessing the Correlation Between Two Spatial Processes. *Biometrics, 49*(1), 305-314.

Fortin, M.-J., & Payette, S. (2002). How to test the significance of the relation between spatially autocorrelated data at the landscape scale: A case study using fire and forest maps. *Ecoscience, 9*(2), 213-218.

Legendre, P. (1993). Spatial Autocorrelation: Trouble or New Paradigm? *Ecology, 74*(6), 1659.

Serra-Sogas, N., O'Hara, P. D., Canessa, R., Keller, P., & Pelot, R. (2008). Visualization of spatial patterns and temporal trends for aerial surveillance of illegal oil discharges in western Canadian marine waters. *Marine Pollution Bulletin, 56*(5), 825-833.

Serra-Sogas, N., O'Hara, P., Canessa, R., Bertazzon, S., & Gavrilova, M. (2008). Exploratory Spatial Analysis of Illegal Oil Discharges Detected off Canada's Pacific Coast. In *Computational Science and Its Applications – ICCSA 2008* (pp. 81-95).