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OFFSHORE HYDROCARBON AND SYNTHETIC HYDROCARBON SPILLS IN EASTERN CANADA: THE ISSUE OF FOLLOW-UP AND EXPERIENCE

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The Environmental Assessment (EA) process should involve the generation of testable predictions generated using clearly stated methods and followed by the collection of environmental monitoring data. Follow-up programs should aim to determine the accuracy of the initial predictions. We examined the follow-up process for six oil and gas extraction projects in eastern Canada with respect to assessing batch spill (<50 barrels of hydrocarbons and synthetic hydrocarbons) predictions. For three projects we compared oil spill frequency predictions to observed data. All three projects exceeded their predicted frequencies and two projects by ratios (actual to predicted) greater than six. Spill histories from earlier projects, clearly exceeding predictions of future projects, are not provided in subsequent oil and gas EAs for the region, when there were opportunities to do so. We provide recommendations on how to strengthen the quality of EAs and increase protection of the marine environment in Canada.

Keywords: Canadian Environmental Assessment Act; Canada-Newfoundland Atlantic Accord Implementation Act; Canada-Nova Scotia Offshore Petroleum Resources Accord Implementations Act; oil pollution; Northwest Atlantic.

Introduction

The Canadian Environmental Assessment Act (CEA-Act) was enacted in 1995 (CEA-Act, 1992) to evaluate the impact of human activities on the natural and social environments of Canada while promoting sustainable development. Approval for project proposals governed by the CEA-Act is based, in part, on an evaluation of the risk that the Project will cause undesirable environmental effects. Such EA predictions are inherently uncertain, making follow-up EA monitoring essential for an understanding of the environmental effects of a project (see Buckley, 1991; Arts *et al.*, 2001). The CEA-Act identifies follow-up programs as the determination of the effectiveness of mitigation and the verification of the accuracy of EA predictions. Worldwide, EA researchers have acknowledged the need for strong follow-up procedures (Sadler, 1996; Wood, 2003; Morrison-Saunders and Arts, 2004). In Canada, follow-up monitoring is a critical part of the EA process as outlined in the CEA-Act (s. 14 (c), s.16 (2c), s. 38), but many outstanding issues remain concerning the effectiveness of the process (see Storey and Noble, 2004).

To create a dynamic EA process, follow-up monitoring should be linked to feedback processes that can effectively address inaccurate EA predictions (Noble, 2000; Arts *et al.*, 2001; Storey and Noble, 2004). Feedback processes can be considered in two ways. The first is the identification of management actions for a project which exceeds EA predictions. The second is an examination of how the experience of on-going projects contributes to subsequent EAs of a similar nature. The CEA-Act's (1992) follow-up program definition (s. 2) does not include specific measures or guidelines for either of these issues. Both these types of feedback processes are critical for large scale industrial projects in regions which have multiple projects of a similar nature in highly dynamic environments, such as offshore oil and gas development in the Northwest Atlantic.

In this paper we examine how spills of hydrocarbons and synthetic hydrocarbons (hereinafter referred to as "oil") were handled in a series of EAs for two offshore regions of eastern Canada under the jurisdiction of joint Federal-Provincial Petroleum Boards. Specifically, we examined: (1) the accuracy of oil spill predictions in three offshore oil and gas EAs; (2) the Responsible Authorities' response where projects exceeded predictions; and (3) the evidence for whether local oil spill experience informed future EAs for four projects. From our analyses of this series of EAs, we provide recommendations on how regional experience may be used to strengthen both the management of the industry and the quality of oil spill predictions for offshore oil and gas EA in Canada.

In this paper we focus on small batch spills (< 50 bbl). The environmental effects of small batch spills in the NW Atlantic are not to be underestimated. Hydrocarbons persist for longer periods of time in cold water compared to warmer water (National Research Council, 1985) and thus remain biologically available for longer. While many different organisms may be negatively impacted by oil pollution, the NW Atlantic is home to tens of millions of migratory seabirds a large proportion of which are highly vulnerable to oil pollution (Wiese *et al.*, 2001); exposure to very small amounts of oil can compromise thermoregulatory capabilities and kill a diving bird (see Wiese and Ryan, 2003).

Background

Regulatory bodies

In Atlantic Canada, offshore oil and gas activities are managed by joint Federal-Provincial Boards. In Nova Scotia, the Canada-Nova Scotia Offshore Petroleum Board (C-NSOPB) oversees offshore oil activities, while the Newfoundland and Labrador counterpart is the Canada-Newfoundland and Labrador Offshore Petroleum Board (C-NLOPB, formerly Canada-Newfoundland Offshore Petroleum Board, C-NOPB). The C-NSOPB and the C-NLOPB were formed under the Canada-Nova Scotia Offshore Petroleum Resources Accord Implementations Act (1988; hereinafter the Nova Scotia Accord) and the Canada-Newfoundland Atlantic Accord Implementation Act (1987; hereinafter the Atlantic Accord), respectively. Both Petroleum Boards have key roles in the environmental assessment process under the CEA-Agency (2004a, 2004b respectively) and are responsible for assessing proposals and administering the regulations as applied to approved projects. The Boards' obligations include environmental protection and enforcement of regulations (C-NLOPB, 2006a; C-NSOPB, 2005a). The Boards are both the Regulator and the Responsible Authority. Offshore oil and gas operators are required to report all oil spills to their respective Petroleum Boards (s. 166(1) Nova Scotia Accord, 1988; s. 161(2) Atlantic Accord, 1987; see also Fraser *et al.*, 2007). Thus, both compliance monitoring and EA monitoring of oil spills are fulfilled by a single commitment by the Regulators (see Arts and Nooteboom, 1999).

Offshore projects

Hibernia (Mobil Oil Canada Ltd., 1985), Cohasset-Panuke project (LASMO Nova Scotia Limited, 1990), Sable Offshore Energy Project (SOEP, 1997), Terra Nova (Petro Canada, 1997), White Rose (Husky Oil, 2000) and Deep Cohasset-Panuke (EnCana, 2006) represent a chronological series of EAs for offshore oil and gas production projects in eastern Canada (Fig. 1). We used this time series of projects as an opportunity to examine spill predictions and management strategies. Descriptive summaries for each project are provided in Table 1.

Oil spills in EAs

Offshore oil and gas projects are large scale projects requiring Comprehensive or Panel Review EAs in Canada (CEA-Act, 1992). Both EA procedures include a study of the project and public review, but Panel Reviews are more extensive and

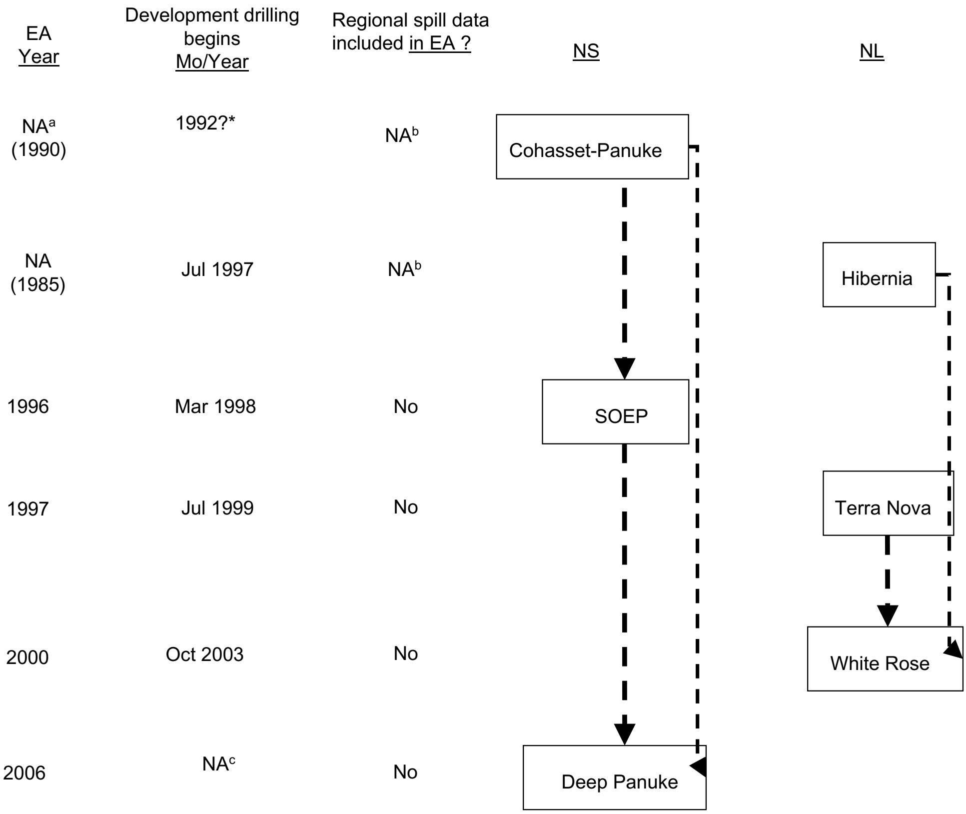

Fig. 1. A flowchart which describes the chronological order of oil and gas EAs and initiation of development drilling in eastern Canada. The dotted lines represent opportunities in which earlier projects' oil spill experiences could have informed later EAs. Each region is kept separate, although the reader may note that opportunities for information exchange between regions may have occurred.
[a]NA — not under CEAA
[b]NA — no prior experience in region to use in EA.
[c]NA — EA still in review (i.e., development drilling had not started March 2007).

include an independent panel of experts (see CEA-Agency, 2007). Accidental oil spills represent a significant environmental concern for this industry, thus attention to potential environmental effects, likelihood of occurrence, how oil behaves when spilled and history of spills for the industry, are among the topics addressed in the EAs. The literature on the environmental effects of oil spills is extensive and is not reviewed here (see Patin, 1999 and references therein). The early EAs (i.e., Hibernia and Cohasset-Panuke) do not provide specific spill predictions. SOEP, Terra Nova, White Rose and Deep Panuke (Table 2) provide spill predictions in the form of the probability of occurrence and number of spills for the lifetime of the project (except

Table 1. A summary of the offshore oil and gas projects in eastern Canada.

Project	EA date	Product extracted	Production date	Regulator
Hibernia[a]	1985	Oil	Nov 1997	C-NLOPB
Cohasset-Panuke[b]	1990	Oil	1992	C-NSOPB
Sable Offshore Energy Project[c]	1997	Gas	Dec 1999	C-NSOPB
Terra Nova[d]	1997	Oil	Jan 2002	C-NLOPB
White Rose[e]	2000	Oil	Nov 2005	C-NLOPB
Deep Panuke[f]	2006	Gas	N/A	C-NSOPB

[a]Project information from Mobil Oil Canada Ltd. (1985); C-NOPB (1998).
[b]Project information from LASMO Nova Scotia Limited (1990); C-NSOPB (1992).
[c]Project information from SOEP (1997); C-NSOPB (1998).
[d]Project information from Petro Canada (1997); C-NOPB (1998).
[e]Project information from Husky Oil (2000); C-NLOPB (2006).
[f]Project information from EnCana Corporation (2006)

SOEP which provides only probabilities). The spill probabilities are based on an extensive dataset maintained by the US. Mineral Management Services (see S.L. Ross Environmental Research Ltd., 1995; Husky Oil, 2000). We did not critique how the predictions were generated nor did we consider the environmental impacts of spills; rather we compared spill predictions to observations (see Buckley, 1991) for small batch spills (< 50 bbls). Batch spills vary in quantity and substance and occur in discrete events (as opposed to a continuous release of oil, as in a blowout; Patin, 1999). We also examined the Responsible Authorities' actions with regards to spill predictions in a post-EA framework.

Comparing Spill Observations with Spill Predictions within Projects

We compared spill observations from reported follow-up data with the predictions provided for a given Project's EA for batch (platform) spills for three projects (Terra Nova, White Rose, SOEP; Table 2). We assumed that all of the spills which occurred on the platforms were reported to the Boards. Deep Cohasset-Panuke was not yet in production (i.e., no spill experience in post-EA phase) and was excluded in the spill prediction: occurrence comparison analysis.

Sable offshore energy project

We compared EA oil spill predictions with spill observations for the SOEP based on data requested and provided by the C-NSOPB 1998–2004 (C-NSOPB, 2005b). As of 2004, the SOEP reported a cumulative total of 57 spills under 50 bbl in which exact spill volumes were provided: (diesel [9], condensate [9], "hydrocarbons" [8], light oil [5], hydraulic oil [3], hydraulic fluid [2], synthetic based muds [4], oil based

Table 2. Predicted and observed platform small batch spill events (hydrocarbons, synthetic hydrocarbons and condensate) for offshore gas development and production activities for four projects in Nova Scotia and Newfoundland and Labrador.

Project (dates of coverage for observed spill data)	Annual probability (spill < 50 bbl)	Lifetime predicted spills (< 50 bbl)	Number of observed spills (< 50 bbl) as reported by Boards (total spilled bbl)
Sable Offshore Energy Project (NS) (1994–2004)	One in 2	(8.5)[a]	57 spills (67.2 bbl): 52 < 1 bbl 1 bbl < 6 spills < 49 bbl
Terra Nova (NL)[b] ([July] 1999–2006)	One in 5 100 ("once every 5 years")[c]	5.3	33 (122.5 bbl): 16 < 1 bbl 1 bbl < 17 spills < 49 bbl
White Rose (NL) (2003–2007)	One in 5	2.38 (1–49 bbl)[d]	3 (47.9 bbl)[e] [33 spills < 1 bbl][d]
Deep Panuke (NS) (project not yet in development or production)	One in 16	1.12 (1–49 bbl)	No data yet available

[a] A lifetime prediction was not provided by SOEP. We calculated the lifetime spill prediction based on probability and projected lifetime of the project.
[b] As reported by the C-NLOPB (2006b). Data includes all spills associated with project (i.e., spills during development drilling from drilling rigs and spills during production from drilling rigs and the FPSO) after EA approval.
[c] The term "oil" in the context of spills is not explicitly limited to crude in EA (Petro Canada, 1997).
[d] White Rose prediction for small batch spills was for 1–49 bbl; prediction excludes spills < 1 bbl.
[e] As reported by the C-NLOPB (2006b). Data includes all spills (1–49 bbl) associated with project after EA approval. The term "oil" refers to all hydrocarbons (Husky Oil, 2000).

muds [3] and miscellaneous hydrocarbons [14]). Six out of 57 spills were over one bbl (1 bbl = 159 l; Table 2).

The SOEP (1997) EA had predicted a "one in two" (0.5) probability of a platform spill less than 50 bbl occurring annually (Table 2). The lifetime number of predicted spills under 50 bbl is 8.5; which we calculated using the annual spill probability and the estimated project's lifetime of 16–17 years. The observed average annual spill rate for < 50 bbl between 1998 and 2004 was 9.6 spills per year. Six years into production the total number of spills (57) exceeds the project's lifetime prediction of 8.5 spills < 50 bbl.

Terra Nova

We compared EA oil spill predictions with spill observations for the Terra Nova project from data provided on the C-NLOPB's website (C-NLOPB, 2006b).

Between 1999 (July) and 2006 the Terra Nova project reported 33 spills < 50 bbl of which 17 spills were between 1–49 bbl. Of the 33 small batch spills, the substances constituted a variety of hydrocarbons: "condensate" [4], "crude" [9], "hydraulic oil" [6], "synthetic based muds" [9] and miscellaneous hydrocarbons [5]. The other 16 spills were < 1 bbl.

The Terra Nova EA provided annual predicted spill probabilities and predicted the number of events for batch spills < 50 bbl (Table 2; Petro Canada, 1997). The observed average annual rate was 5.4 spills per year. The predicted number of spills < 50 bbl for the lifetime of the project was 5.3 (Table 2; C-NLOPB, 2006b). Thus, the lifetime predicted number of spills was, on average, exceeded in each year of operation.

White Rose

We compared EA oil spill predictions with spill observations for the White Rose project from data provided on the C-NLOPB's website (C-NLOPB, 2006b). Between 2003 and 2007 the White Rose project reported 36 spills < 50 bbl, three of which were between 1–49 bbl (the remaining 33 were < 1 bbl; Table 2). Of the 36 spills the substances were "hydraulic oil" [20], "crude" [7] and synthetic based muds [5], "lubricating oil" [2], "oily water" [1] and diesel [1].

The White Rose EA predictions for spills < 50 bbl did not include spills less than one bbl, nor did they provide predictions for spills < 1 bbl (Husky Oil 2000; Table 2). The predicted number of events for the lifetime of the project was 2.38 for spills 1–49 bbl, thus, in four years of development and production the lifetime prediction is exceeded (Table 2).

Regulators' Responses to the Exceeded Value of Spill Predictions

All three of the projects considered above exceeded their predictions for batch spills < 50 bbl. We posed the question: Did the Regulators acknowledge the exceeded spill predictions in their publicly available annual reports?

Sable offshore energy project

We examined C-NSOPB annual reports from 1999–2005 under the Chairman's remarks, the Sable Offshore Development Project, Environment and Waste Treatment Guideline headings. The fiscal year 1999–2000 was our starting point because it was the year the C-NSOPB began reporting summary oil spill statistics in their annual reports. (The C-NSOPB does not report oil spill statistics on a per-project basis; see C-NSOPB, 2007.) We found no specific reference to the issue of EA spill exceedance in the annual reports. We found one reference to EA predictions in the context of Environmental Effects Monitoring, but it was in regards to drilling wastes and produced water (C-NSOPB, 2003).

Terra Nova & White Rose Projects

We examined C-NLOPB annual reports from 1999–2006 under Chairman's report, Terra Nova Project, White Rose Project and Environment sections. We found no reference to the issue of EA spill predictions and observed data for either project.

EA Predictions with Respect to Ongoing Projects

We posed the question: Did the Regulators (i.e., the Boards) have an opportunity to require a section in EAs which considers regional spill experiences and if yes, was a section provided? Two projects, Cohasset–Panuke (LASMO Nova Scotia Limited, 1990) and Hibernia (Mobil Oil Canada Ltd., 1985) were the first offshore oil and gas projects in NS and NL, respectively, and thus provided the starting point for our analysis. While both of these earlier projects' EAs were conducted prior to the CEA-Act (1992), their experience nonetheless is important in considering lessons learned for the regional production of oil and gas. We examined subsequent EAs: Sable Offshore Energy Project (SOEP, 1997), Terra Nova (Petro Canada, 1997), White Rose (Husky Oil, 2000) and Deep Cohasset-Panuke (EnCana, 2006). In our approach, we consider if each project's experience contributed to the quality of the next chronological EA within each jurisdiction.

Nova Scotia (C-NSOPB)

The Cohasset–Panuke project was four years into oil production when the SOEP EA process occurred (Figure 1; C-NSOPB, 1998). During the first two years of production (1994–1996) Cohasset-Panuke experienced 12 spills (total volume 58.56 bbls, average $\pm$ SD, 5.32 $\pm$ 6.41 bbls, range 0.01–14.97 bbls; C-NSOPB, 2005b), six of which were over 1 bbl. Thus, Cohasset-Panuke exceeded SOEP's lifetime spill prediction for spills < 50 bbl (8.5 spills) in the first two years of production and prior to the SOEP EA approval (see Comparing Observed to Predicted Spills within Projects; Table 2). The SOEP EA notes "… experience in developing the Cohasset/Panuke fields near Sable Island has been considered and has benefited this assessment" (SOEP, 1997; pp. 1–4) yet no regional spill data are considered in the EA (SOEP, 1997; section 3.5).

Both Cohasset–Panuke's and SOEP's experiences could have been incorporated within the Deep-Panuke EA (EnCana, 2006). The Deep-Panuke EA (EnCana 2006, volume 4, pp. 3–4) notes that "the project's design will build upon lessons learned from previous spill events in order to minimize potential risk for spills" yet do not discuss SOEP or Cohassett-Panuke spill experiences. The Deep-Panuke EA (EnCana 2006, volume 4, pp. 3–5) predicts an annual probability of one in sixteen and 1.12 spills for the lifetime of the project for spills between 1–49 bbl. From 1998 to 2004, SOEP experienced 6 spills (> 1 bbl; or 1.0 spills per year) and from 1994–1999, Cohasset–Panuke experienced 8 batch spills (> 1 bbl; 1.6 spills per year; C-NSOPB, 2005a). Both projects provide data which suggests the Deep-Panuke EA's prediction for small spills is not supported by the observed data.

Newfoundland and Labrador (C-NLOPB)

The Terra Nova EA occurred in 1997. The timing of the EA process was such that prior experience at Hibernia could not be considered (development drilling at Hibernia started in 1997; C-NOPB, 1998; Figure 1).

The White Rose EA was initiated in October 2000 (Husky Oil, 2000), submitted by the C-NLOPB to the Federal Minister in April 2001 and approved in June 2001 (C-NOPB, 2002). The timing of this EA permitted a consideration of both the Hibernia and Terra Nova projects. In the first two years of oil production (1997–1999), Hibernia experienced 31 spills < 50 bbl (total volume $= 26.96$ bbl, range, 0.01–12.58 bbl; average $\pm$ SD, 0.84 ± 2.46 bbl; C-NLOPB, 2006b); five spills were > 1 bbl. Terra Nova started development drilling in July 1999 (C-NOPB, 2000). From July 1999 to Jan 2001, the Terra Nova project experienced seven platform spills < 50 bbl (total volume $= 75.48$ bbl, range, 0.19–31.45 bbl; average $\pm$ SD, 10.78 ± 12.39 bbl; C-NLOPB, 2006a); five spills were > 1 bbl.

The White Rose EA predicted 2.38 spills 1–49 bbl for the lifetime of the project (Table 2); an estimate clearly exceeded by both Hibernia and Terra Nova in a period prior to the approval of the White Rose EA. There was no specific reference to local spill experience in the White Rose EA (Husky Oil, 2000).

Discussion

Our research identifies three weaknesses in the management of offshore oil and gas activities in eastern Canada. The spill frequency predictions provided for small batch spills do not reflect observed frequencies for three projects. The Boards did not publicly respond to the issue of the observed data exceeding predicted estimates for each project. Further, the Boards, as Responsible Authorities, did not address this issue in subsequent EAs, even though opportunities to do so were presented.

Projects requiring an EA are approved partially on the perceived quality of their environmental effects predictions. Our examination of the data available shows that EA predictions for batch spills in eastern Canada's offshore have underestimated the risks of spills less than 50 bbls, two by an order of magnitude. The spill predictions provided in the EAs reviewed are very precise and as precision increases, accuracy decreases (Storey and Noble, 2004). What constitutes a realistic estimate is difficult to determine as EAs do not typically provide an acceptable level of error (Buckley, 1981; Storey and Noble, 2004). We would assume that the observed number of spills of 57 versus the lifetime prediction of 8.5 for SOEP (magnitude of actual to predicted frequency 6.7; Buckley, 1991), and observed number of spills of 33 versus the lifetime prediction of 5.3 for Terra Nova (magnitude 6.22) is an unacceptable level of accuracy; enough to warrant a re-evaluation of the methods used to model spill probabilities and for future offshore oil and gas production EAs to identify an acceptable level of error for spill predictions. Perhaps the inaccuracy of a spill category < 50 bbl is one reason why the White Rose project (Table 2) modified their spill predictions to exclude spills < 1 bbl, but reasons for the change were not provided (Husky Oil, 2000).

While accidental spills are clearly the responsibility of the operators, the Regulators nonetheless also have responsibility of providing an analysis of the causes of the spills, the corrective measures implemented to reduce the chances of future occurrences and the effectiveness of the corrective measures across projects. Due to the historical (for NL; Fraser and Ellis, in press) proprietary nature of oil spill information, only the Boards were in possession of all of the data required to conduct such an analysis. Therefore only the Boards were capable of understanding how to minimize future oil spills in the context of observed data across projects. Our review indicates there was no public acknowledgement of the inaccuracy of small batch oil spill predictions by the Boards across several projects. Further this information was not used to increase the accuracy of predictions in subsequent EAs.

The petroleum Boards need clear guidelines on how to respond to Projects known to have exceeded the predictions on which their EA approvals were based. The distinction between the proponents' and the Responsible Authorities' obligations is important in the follow-up process (Arts *et al.*, 2001; Storey and Noble, 2004). Predictions based on clear hypotheses require the Boards to articulate what triggers a response (CEAA, 1999). These guidelines should be part of the post EA process. Several researchers (e.g., Storey, 1991; Storey and Noble, 2004) offer guiding principles for follow-up practices specific to the Canadian EA process including a commitment to action; the Responsible Authority must be able to implement change when faced with unanticipated results.

As part of a review of the effectiveness of the CEA-Act, the CEA-Agency (1999) made several recommendations regarding follow-up monitoring processes including increasing public knowledge and verification of predictions. Currently, there is no formal feedback mechanism in place requiring the incorporation of local oil spill experience in future EA predictions. The lack of feedback in management approaches is reinforced in the Regulatory Roadmaps Project (Erlandson Consulting and Petroleum Research Atlantic Canada, 2004), which outlines the EA process for oil and gas projects in eastern Canada but provides no discussion on feedback management practices. The Responsible Authority needs to create links among pre-EA and post-EA processes for individual projects, as well as for future EAs (Morrison–Saunders and Arts, 2004).

We have several recommendations all of which would increase the quality of future EAs in Canada (CEA-Agency, 2001). We hope that these recommendations provide support for the implementation of follow-up best practices in the environmental management of oil spills from offshore oil and gas production in Canada (see Arts and Morrison–Saunders, 2004).

(i) Where possible (as is the case for batch spills less than 50 bbls predictions), EAs should state testable hypotheses in clear terms for which follow-up data are collectable (Lawrence, 2003). These hypotheses should also include predictions of the numbers of marine birds estimated killed in relation to amount of oil spilled, as they are the organisms most vulnerable to oil pollution in these regions (Wiese *et al.*, 2001).

(ii) The EA should provide detailed information for environmental effects monitoring (EEM) programs for all hydrocarbon spills over 1 bbl. These would include specific methods on how spill impacts will be assessed, including drift block (Wiese and Jones, 2001) and beached bird survey (see Wiese and Robertson, 2004) designs for estimating marine bird mortality. (Currently, information on EEM programs are not publicly available; Fraser and Ellis, in press.)

(iii) The EAs should include a section which discusses local spill experiences, including specific causes of past spills, the corrective measures employed and the effectiveness of corrective measures.

(iv) The EAs should include data on how the environmental impacts of past oil spills were assessed, describe any problems with the assessments and how these problems will be addressed in future spill situations.

(v) The EAs should address the issue of cumulative effects from the exceeded values of predictions of small platform spills from multiple platforms. The cumulative effect of chronic oil pollution on marine bird populations from offshore oil and gas platforms remains undetermined in this region (see Hatch Associates Ltd and Griffiths Muecke Associates, 2000; CEA-Agency, 2001).

The NW Atlantic is an extreme environment with respect to wind, sea and ice conditions. It includes high densities of marine bird assemblages which are extremely vulnerable to even small amounts oil pollution (e.g., Wiese *et al.*, 2001; Wiese and Ryan, 2003). Local experience should be incorporated into future EA spill predictions. Inaccurate spill predictions, coupled with an apparent lack of feedback management approaches from the two Petroleum Boards undermine protection of the marine environment. With the growth of offshore oil exploration and production in the NW Atlantic and elsewhere in Canada, the implementation of a feed-back management process that responds to the results of EA monitoring is vital.

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