PRODUCED WATER FROM OFFSHORE OIL AND GAS INSTALLATIONS ON THE GRAND BANKS, NEWFOUNDLAND AND LABRADOR: ARE THE POTENTIAL EFFECTS TO SEABIRDS SUFFICIENTLY KNOWN?

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INTRODUCTION

Chronic oil pollution is a preventable yet persistent source of increased adult mortality and decreased fecundity for seabirds (Ford *et al.* 1982, Butler *et al.* 1988, Piatt *et al.* 1990), two serious problems for organisms that typically have a life-history strategy of high adult survival, low reproductive success, and delayed recruitment (e.g. Weimerskirch 2002, Wiese & Robertson 2004, García-Borboroglu *et al.* 2006). Sources of chronic oil pollution include discharges from marine vessels, runoff, and accidental spills and operational discharges from offshore oil and gas activities (National Research Council 1985, 2003).

Oiling of marine birds takes place at sea. Our knowledge of seabird populations has traditionally been obtained primarily on land from the study of birds at their breeding colonies. Beached bird surveys are the primary tool currently used to assess seabird mortality resulting from marine oil pollution (Furness & Camphuysen 1997). Resulting data demonstrate that oil pollution contributes to seabird mortality (e.g. Dalmann *et al.* 1994, Wiese & Ryan 2003, García-Borboroglu *et al.* 2006) and that oil-related mortality detectable by beached bird surveys varies by pollution source, season, geographic location and species sensitivity to oil pollution (Furness & Camphuysen 1997, Camphuysen 1998, Wiese & Ryan 1999, Camphuysen & Heubeck 2001, Wiese & Ryan 2003). The farther from shore that a bird is oiled, the less likely it is that that bird will reach a beach to be detected by a beached bird survey (Piatt *et al.* 1990, Wiese & Jones 2001).

Hunt (1987) and Piatt *et al.* (1990) suggest that chronic oil pollution could potentially affect seabird populations as severely as a single large oil spill. Wiese and Robertson (2004) demonstrate that the annual mortality of seabirds in Newfoundland and Labrador attributable to oiling is of a magnitude equivalent to that caused by the *Exxon Valdez* oil spill. Wiese *et al.* (2004) reports that chronic oil pollution in Newfoundland and Labrador reduces Thick-billed Murre *Uria lomvia* population growth. The magnitude of oiling-induced mortality in marine birds encountering marine oil pollution is partly a function of the number of birds encountering a given pollution event rather than of the volume or size of the oil discharge *per se* (Burger 1993). Small spills that overlap in space and time with large numbers of birds may kill substantially more birds than large spills that do not have that overlap. Thus, chronic sources of oil pollution (i.e. operational discharges such as produced water from offshore oil and gas platforms), while not as dramatic as an *Exxon Valdez,* are potentially significant sources of cumulative seabird mortality.

In this paper, we review how the potential environmental effects on marine birds of an operational oil discharge (produced water) from offshore oil and gas installations off Canada's most easterly province (Newfoundland and Labrador) have been assessed.

MARINE BIRDLIFE ON THE GRAND BANKS

The Grand Banks, off insular Newfoundland and Labrador, is an important place for the world's seabirds, with an estimated 40 million marine birds utilizing the region during the year (Montevecchi & Tuck 1987). The Important Bird Areas Program of Canada (2004) recognizes the global significance of 17 marine bird breeding colonies adjacent to the Grand Banks (see also Montevecchi & Tuck 1987, Lock *et al.* 1994). In addition to year-round residents, Arctic and Southern Hemisphere breeding species migrate into the region in the winter and summer months respectively (Lock *et al.* 1994). This region of the northwest Atlantic is particularly notable for high densities of auks. It is the chief wintering grounds for approximately four million Thick-billed Murres and fourteen million Dovekies *Alle alle,* and it hosts the largest breeding colonies of Atlantic Puffins *Fratercula arctica* and Common Murres *Uria aalge* in the western Atlantic (Lock *et al.* 1994). Thus, while the National Research Council (2003) considers offshore oil and gas installations to represent a small portion of the oil pollution in the world's oceans, the Grand Banks is a region where chronic oil pollution from oil and gas extraction could have significant cumulative effects on a variety of globally important seabird populations.

Environmental impact assessments of offshore oil and gas activities on the Grand Banks have predicted no significant effects on marine bird populations from the discharge of oil in produced water (Mobil Oil 1985, Petro-Canada 1997, Husky Oil 2000). Three offshore platforms are currently producing oil on the Grand Banks, and new extraction projects are likely (e.g. LGL Limited 2005a; Fig. 1). We reviewed the approach used by the three existing environmental assessments (EAs) to predict the potential environmental effects on seabirds of chronic oil pollution resulting from produced water discharges.

Our objectives are

- to review the methods and data used to assess the potential environmental effects on seabirds of discharging produced water from offshore oil platforms into the sea
- to evaluate the public availability of data relevant to generating *a priori* impact assessment predictions for various seabird populations on the Grand Banks
- to apply the methodology used in the most recent offshore oil production EA in Atlantic Canada to auks as an example
- to provide recommendations on how to improve future offshore oil and gas EAs.

OFFSHORE OIL AND GAS ON THE GRAND BANKS

The Canada–Newfoundland and Labrador Offshore Petroleum Board (C-NLOPB; formerly Canada–Newfoundland Offshore Petroleum Board, C-NOPB) regulates offshore oil and gas activities in Newfoundland and Labrador. The C-NLOPB was formed under the Canada–Newfoundland Atlantic Accord Implementation Act (Government of Canada 1987). Currently, three oil production licenses are in operation: two Floating Production Storage and Offloading Facilities (FPSOs: Terra Nova and White Rose) and one fixed platform (Hibernia; e.g. C-NOPB 2006). Offshore oil and gas activity in the region is expanding (e.g. Orphan Basin; LGL Limited 2005a). In 2001, the C-NOPB estimated that only half of the potential oil reserves and three-quarters of the natural gas had been located. Between 2003 and 2005, 3 058 534 ha were licensed for exploration (C-NLOPB 2006; Fig. 1). In 2006, an exploratory drilling program was approved for the Orphan Basin (see LGL Limited 2005a).

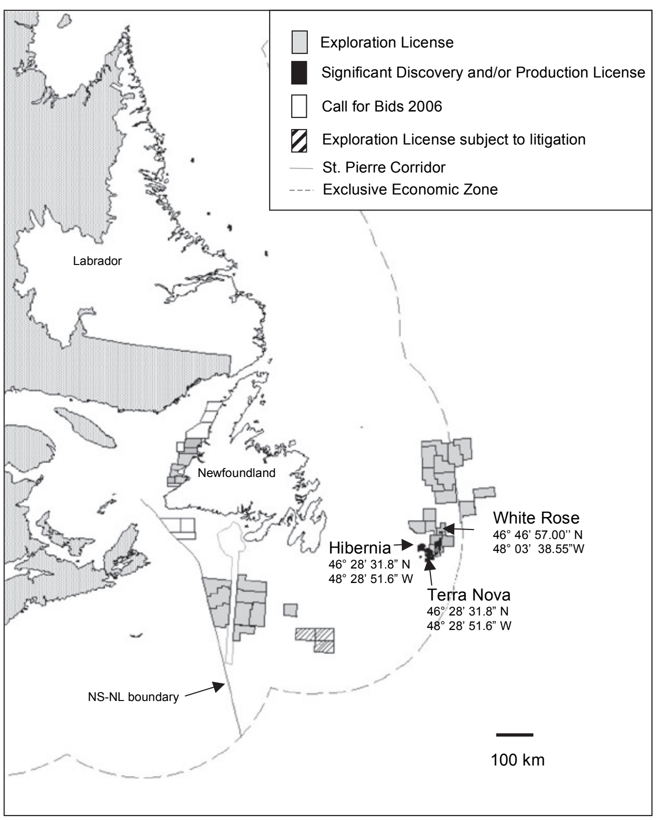

Fig. 1. Areas of offshore oil production, exploration activities and parcels of ocean up for bid in the jurisdiction of the Canada-Newfoundland and Labrador Offshore Petroleum Board (C-NLOPB 2006).

Produced water

Produced water is formation water from the oil-bearing substrata brought to the surface with the oil and gas, or seawater injected into the reservoir during the production phase of oil or gas extraction (Patin 1999). The offshore oil and gas industry generates hundreds of thousands of litres of produced water daily, most of which is discharged into the ocean and represents most of the waste discharged from offshore oil extraction production facilities (e.g. Patin 1999, Veil *et al.* 2004; Table 1). Produced water consists of substances that vary widely among oil fields [see Patin 1999, Canadian Association of Petroleum Producers (CAPP) 2001, Veil *et al.* 2004 for reviews on produced water]. Generally, it includes trace heavy metals, radionuclides, sulfates, treatment chemicals, produced solids and hydrocarbons (e.g. Patin 1999, Veil *et al.* 2004).

Various aspects of the potential environmental effects of produced water have been studied, with topics ranging from technological solutions to tracking the fate of the various components (e.g. Ray & Engelhardt 1992, Reed & Johnsen 1996). The organic components of produced water include three different types of oil: dispersed, dissolved and free (Yang & Tulloch 2002). Dispersed oil refers to small droplets suspended in an aqueous phase. The components of dissolved or soluble oil (organic acids, polycyclic aromatic hydrocarbons, phenols and volatiles) are not readily removed from produced water and contribute to its toxicity (Veil *et al.* 2004). Free oil is oil separate from the aqueous phase. The dispersed and soluble oils not removed by the treatment process are usually discharged into the ocean; free oil is usually removed (C-NOPB 2002).

A produced water plume may rise from a below-surface discharge to the surface (depending on temperature; Petro-Canada 1997, Husky Oil 2000), where rapid dilution and evaporation (of volatiles) takes

TABLE 1
Approximate oil volumes associated with projected produced water daily discharges for three projects on the Grand Banks, Newfoundland and Labrador

	Daily produced water discharge estimates (m^3/day)	Volume of oil discharged in produced water (m^3/day) per day[a]
Hibernia[b]	14 300	1.2
Terra Nova[c]	11 000	0.44
White Rose[d]	30 000	0.572

[a] Discharges are reported in cubic metres per day and oil content (milligrams per litre) in the Offshore Waste Treatment Guidelines (C-NOPB 2002). To calculate the volume of oil (not oil and water), we used these calculations:
m^3/day × (1000 L/1 m^3) = litres/day
Litres/day × 0.04 g/L = grams/day oil
Kilograms/day oil × (1 m^3/1000 kg) = m^3/day oil.

[b] Mobil Oil (1985).

[c] Petro-Canada (1999).

[d] Husky Oil (2000).

place (e.g. CAPP 2001, Veil *et al.* 2004). Dilution of the produced water plume for the Hibernia platform was predicted to occur by a factor of 1000 at 500 m from the discharge site (Mobil Oil 1985). For the Terra Nova platform, dilution by a factor of 1000 at 50 m and by 3000 at 250 m from the discharge site has been predicted (Petro-Canada 1997). Husky Oil (2000) predicted dilution of 40:1 at the FPSO, but 1000:1 at 10–15 km. Husky Oil (2000: 377) also predicted surface sheens of 0.2 mg/L occurring within a "few hundred meters" of the discharge site "at least one percent of the time."

Produced water and oil sheens

The relationship between the discharge of produced water and the occurrence of oil sheens is not well understood (ERIN Consulting Ltd. & OCL Services Ltd. 2003). Oil sheens are a thin (less than 2 or 3 microns) film visible on the water's surface (ERIN Consulting Ltd. & OCL Services Ltd. 2003). ERIN Consulting Ltd. and OCL Services Ltd. (2003) note that the phenomenon of sheen formation has been studied very little.

The formation of sheens may be related to the characteristics of the receiving waters, the rate and depth of discharge, and the characteristics of the produced water such as temperature, the quantity of solids, the type of hydrocarbon, oil droplet size or the presence of certain types of metals such as iron (ERIN Consulting Ltd. & OCL Services Ltd. 2003). Veil *et al.* (2004) suggest that dispersed oil and soluble components of medium-to-high molecular weight hydrocarbons, which are not easily removed from produced water, contribute to sheen formation. Although the discharge of produced water may be continuous, it is unclear whether sheens are also continuous, partly because sheens may be present but not visible. Reports of sheens from offshore operators are episodic (ERIN Consulting Ltd. & OCL Services Ltd. 2003, Department of Trade and Industry 2006a; Table 2). For the present paper, we assumed that sheens are at least partly related to the oil content of the produced water stream when released (e.g. dispersed hydrocarbons). Of seminal importance for the study is the fact that contact with hydrocarbons compromises the feather structure and thermoregulatory function of pelagic seabird plumage. In cold waters such as those addressed herein, the deleterious effect is heightened, because compromised plumage results in death from hypothermia, particularly for diving birds (Leighton 1985, Stephenson 1997), as will be discussed shortly.

Waste treatment guidelines for produced water

Regulators provide guidelines for pollutant discharges to offshore operators based on the best available technology (BAT). The BAT for the treatment of produced water removes most free oil before discharge (National Research Council 2003; discussion to follow); therefore, much of the oil that remains is discharged into the ocean in dispersed and dissolved forms (Otto & Arnold 1996, CAPP 2001, Neff 2002, Veil *et al.* 2004).

The oil content of produced water is primarily the aliphatic (straight-chain) component of dispersed oil (Yang & Tulloch 2002). The most common method used offshore for reducing the oil content of produced water before discharge is a gravity-based separation technique with gas flotation or hydrocyclones (CAPP 2001, ERIN Consulting Ltd. & OCL Services Ltd. 2003; see CAPP 2001 for a review of waste management of produced water). Discharge concentrations of oil and grease vary depending on at least eight different factors (e.g. temperature, pressure, oil type, flow rate, and so on), which will affect oil concentrations achieved using the BAT (International Association of Oil and Gas Producers 2002). Veil *et al.* (2004) notes that use of the BAT results in average oil concentrations of 23.5 mg/L (no variance provided).

The Oslo–Paris Commission (OSPAR 2001) set recommended waste treatment guidelines for produced water discharges of hydrocarbons in the North Sea at a monthly average of 30 mg/L, effective beginning in 2006 (no exceptions threshold noted). As of June 2006, the United Kingdom's regulatory limit of 30 mg/L weighted average was in effect, although the industry had been achieving this level voluntarily for several years [Department of Trade and Industry (DTI) 2006]. The current guideline for hydrocarbon concentrations in produced water for the United States is an average of 29 mg/L per month for the outer continental shelf region (e.g. Environmental Protection Agency 2004). The U.S. regulations further specify a maximum (average) of 42 mg/L daily (see also Otto & Arnold 1996). The Offshore Waste Treatment Guidelines for Atlantic Canada (C-NOPB 2002) recommend that oil concentrations in produced water not exceed a monthly average of

TABLE 2
Produced water sheen[a] reports from offshore oil and gas operators in the United Kingdom from 2002 to 2005[b]

	2002	2003	2004	2005
Installations discharging oil (*n*)	74	85	78[d]	77[d]
Non-upset discharge (*n*)[c]	48	78	84	64
Average oil (ppm)	28.97±17.01	40.16±25.07	40.36±19.89	36.63
<40 ppm	4	2	5	0
<100 ppm	0	0	10	3
ppm Not reported	10	6		
Upset discharge (*n*)[c]	15	14	15	25
Average oil (ppm)	61.65±26.24	43.86±18.68	194.23±506.64	52.32
>100 ppm	0	0	3	
ppm Not reported	5	0	1	

[a]Sheens were described in many different forms including rainbow, blue, blue/gray, silvery/grey, silvery, and discoloration.
[b]Source: Department of Trade and Industry (2006).
[c] Systems were identified "upset," "problem," "instability" or specifically noted malfunction.
[d] Identified as produced water discharges only (J. Duguid, DTI, unpubl. data).

40 mg/L and a daily average of 60 mg/L. Beginning 31 December 2007, offshore production installations will be expected to meet a new monthly average limit of 30 mg/L (C-NOPB 2002). For comparison, International Maritime Organization (1973) regulations limit oil concentrations to 15 mg/L for the instantaneous discharge of oily bilge from a ship, a concentration at which oil sheens do not occur (see ERIN Consulting Ltd. & OCL Services Ltd. 2003). For onshore oil extraction operations, the BAT can achieve hydrocarbon concentrations as low as 5 mg/L. However, offshore operators are limited in their capacity to use comparable technology for both onshore operations and bilge water treatment primarily because of space constraints at sea (Wills 2000, ERIN Consulting Ltd. & OCL Services Ltd. 2003).

Despite regulatory guidelines based on the BAT, oil sheens are, in practice, often associated with produced water discharges (Stephenson 1992, Wills 2000, ERIN Consulting Ltd. & OCL Services Ltd. 2003, DTI 2006; Table 2). Oil sheens at platforms in the North Sea are noted as "the norm" (ERIN Consulting Ltd. & OCL Services Ltd. 2003, see also Stephenson 1992). Wills (2000) notes that at offshore installations in the North Sea, sheens occur even at 25 mg/L on calm days. DTI (2006) provides information on the number of sheens reported by operators in the North Sea (Table 2). Sheens are reported by operators in the United Kingdom even when concentrations are well under the maximum permissible oil content (ERIN Consulting Ltd. & OCL Services Ltd. 2003; J. Duguid, unpubl. data; Table 2).

Oil sheens also occur with produced water discharges in Atlantic Canada (Alder Institute 2001a, ERIN Consulting Ltd. & OCL Services Ltd. 2003). The daily limit on oil content in produced water of 60 mg/L (Waste Treatment Guidelines–permissible 24-hour arithmetic average) does not place a limit on the concentration of oil that it is permissible to discharge on an instantaneous basis (i.e. not averaged). Nor do the guidelines limit the cumulative total volume of oily water that may be discharged into the marine environment (C-NOPB 2002). Events exceeding guideline limits of oil concentrations, which may cause sheens, are permitted, as long as the monthly weighted average (40 mg/L) is achieved (i.e. the volume of water associated with the effluent stream can be increased to bring the average within acceptable limits, even though for brief periods of time the limit may have been exceeded; Clarke 2001). However, the operators are required to report daily oil concentrations when they exceed the permissible guidelines of 60 mg/L (C-NOPB 2002). Thus, discharges causing sheens can occur while current guidelines are being complied with. Although the occurrence of sheens at platforms on the Grand Banks has been reported by independent observers (Montevecchi & Burke 2004 and references therein), the cause of the sheens was unknown.

PREDICTIONS FROM ENVIRONMENTAL EFFECTS ASSESSMENT

Throughout the 20-plus years of offshore oil and gas activities on the Grand Banks, the high vulnerability of seabirds to accidental oil spills has been acknowledged (Mobil Oil 1985, Petro-Canada 1997, Husky Oil 2000). However, all three oil and gas EAs on the Grand Banks concluded that the potential effects on seabirds from oil in produced water discharges are "negligible" (Mobil Oil 1985, Petro-Canada 1997) and "non-significant" (Husky Oil 2000). Mobil Oil (1985) and Petro-Canada (1997: 5–8) defined "negligible" as "impacts with essentially no effects." The basis of that prediction is an assumption that the dilution potential of the ocean as a receiving environment makes ocean discharge an effective waste treatment method for produced water and thus eliminates any potential harm to birds (Mobil Oil 1985, Petro-Canada 1997). No evidence to support this assumption was presented. Because the White Rose project (Husky Oil 2000) was the only EA to provide a somewhat quantitative approach for determining the impact on birds from ocean discharge of produced water, the remainder of this paper will focus on the methods used in the White Rose EA. (Husky Oil is the operator of the White Rose Project and holds a 72.5% working interest; Husky Energy 2006.)

Husky Oil (2000: section 4.2.5, 284) identified a significant impact as "one having a high or medium magnitude, for a duration of greater than one year, over an area greater than 100 km^2." All three criteria have to be met for a significant effect. Magnitude was defined as negligible ("essentially no effect"), low (affects 0%–10% of individuals in the affected area), medium (affects 10%–25% of individuals in the affected area) and high (affects >25% of individuals in the affected area; Husky Oil 2000: section 4.2.1). Produced water discharges were rated as nonsignificant for the environmental effects assessment on marine birds. The basis of that prediction was a magnitude rating of negligible and a spatial extent of less than 1 km^2 (the frequency of discharges was "continuous" and occurring for >72 months; Husky Oil 2000). The spatial extent was based on produced water dilution models. No seabird data were provided for the magnitude criterion (Husky Oil 2000). Species-specific models were not presented. Nonetheless, the scientific certainty of the prediction was rated as "high" (Husky Oil 2000). Husky Oil (2000: section 4.4.2.4, 377) specifically noted: "Birds may come in contact with the surficial sheen, however, it will be so dilute it will not effect the thermoregulatory capability of the birds."

DATA REQUIREMENTS FOR AN *A PRIORI* ENVIRONMENTAL EFFECTS ASSESSMENT

Marine birds overlap spatially with oil pollution from produced water when such pollution is present on or near the ocean surface. We focus on surface sheens resulting from produced water discharges as indicators of discharge events potentially harmful to seabirds. To quantitatively predict the environmental effects of oil sheens on seabird populations, data relevant to oil sheen dynamics and various seabird parameters are required.

Data on oil sheens in Atlantic Canada

Produced water is continuously discharged throughout the time a platform is producing oil. Oil sheens may therefore occur at any time, but they are most likely to be observed during daylight hours, under calm conditions (ERIN Consulting Ltd. & OCL Services Ltd. 2003). For *a priori* environmental effects models, either historical data or estimates based on clear assumptions and modeling relating to the location, frequency, surface area, trajectory and persistence of oil sheens originating from disposal sites are required.

Since 2003, the C-NLOPB has requested offshore oil and gas operators to report oil sheen occurrences from produced water discharges from the Hibernia, Terra Nova and White Rose platforms (D. Burley, C-NLOPB, pers. comm.). This recent requirement covers produced water discharges falling within the standards outlined in the Offshore Waste Treatment Guidelines. Sheens occurring when the treatment guidelines have been exceeded (>60 mg/L) and those resulting from accidental spills are of a different category, which operators have always been required to report to the Responsible Authority (C-NOPB 2002).

We tested the public availability of these data by requesting from the C-NLOPB copies of the operator-generated oil sheen reports in January 2004. Our request was denied. In April 2006, we placed a similar request for the same data through Environment Canada under the *Access to Information Act* (Government of Canada 1985). This request was also denied based on Personal Information, Third-Party Confidentiality, Accounts of Consultations with Government Employees, and Statutory Prohibitions (*Access to Information Act,* sections 19(1), 20(1)(b), 21(1)(b) and 24(1), respectively; Office of the Information Commissioner, Environment Canada, 14 June 2006). Therefore, the historical data relevant to assessing the frequency of sheens at offshore oil and gas platforms on the Grand Banks are not available to the public.

Data required to estimate relevant seabird parameters

To develop *a priori* models to assess the impact of oil sheens on various seabird populations, the following seabird data are required:

- Data on the at-sea density and distribution of marine birds by species in sufficient detail to capture spatial and temporal variation in the distributions and to estimate the portion of a population that would be present in the Environmental Assessment Study Area at a given time of year
- Species-specific information on attraction to platforms
- Species-specific breeding population estimates
- The degree of vulnerability to contact with oil pollution for each seabird species.

Seabird abundance, distribution, and spatial and temporal variability

Marine birds are not randomly distributed at sea. They often congregate near areas of high productivity such as continental shelf edges or artificial reefs such as oil and gas platforms (e.g. Piatt *et al.* 1990, Wiese *et al.* 2001). Current offshore oil production platforms on the Grand Banks are 60–110 km from the shelf's edge (300–350 km east of the coast of Newfoundland and Labrador). For the Grand Banks, information on species-specific at-sea distribution and abundance of marine birds is limited. In general, seabird densities on the Grand Banks are considered to be high, particularly with influxes of migratory birds in spring and fall (Montevecchi & Tuck 1987, Lock *et al.* 1994). Lock *et al.* (1994: 6) describes the Hibernia region as an area with "a dense pelagic bird population at all times of year."

Two datasets on at-sea distribution and abundance are available for use in modeling efforts. The PIROP (Programme Intégré de Recherches sur les Oiseaux Pélagiques) database project is managed by the Canadian Wildlife Service (Lock *et al.* 1994). These data span several decades of opportunistic at-sea marine bird observations (1966–1992). All observations in the database were made before the installation of offshore production platforms on the Grand Banks. The other data source is a more recent survey, conducted primarily from offshore oil support vessels during 1999–2003 (Burke *et al.* 2005). A third dataset, collected internally by offshore oil operators, is disregarded because of sampling problems identified by the authors (Baillie *et al.* 2005).

Lock *et al.* (1994) estimated at-sea seabird densities in areas proximate to the location of, but prior to the presence of, current offshore oil production as ranging from 1 to 9.99 birds per kilometre from October to June and 10–99.9 birds per kilometre from July to September. Burke *et al.* (2005) report a range of 1–500 birds in five square kilometres [mean ± standard deviation (SD): winter (2 surveys) = 1.8 ± 3.5 birds/5 km^2, spring (4 surveys) = 1.83 ± 1.7 birds/5 km^2, summer (8 surveys) = 23.8 ± 22.7 birds/5 km^2, fall (7 surveys) = 1.7 ± 1.20 birds/5 km^2). Alcids dominated the species observed (61%; Burke *et al.* 2005). Burke *et al.* (2005) observed, in the vicinity of the platforms, Northern Fulmars *Fulmarus glacialis,* Greater Shearwaters *Puffinus gravis,* Sooty Shearwaters *Puffinus griseus,* Leach's Storm-Petrels *Oceanodroma leucorhoa,* Herring Gulls *Larus argentatus,* Great Black-backed Gulls *Larus marinus,* Black-legged Kittiwakes *Rissa tridactyla* and auks (Common and Thick-billed Murres, Dovekies). Baillie *et al.* (2005) also noted Atlantic Puffins, Great Skuas *Catharacta skua,* Pomarine Jaegers *Stercorarius pomarinus,* Parasitic Jaegers *Stercorarius parasiticus,* Wilson's Storm-Petrels *Oceanites oceanicus* and Ivory Gulls *Pagophila eburnea* (currently listed as Endangered under the Species at Risk Act; Government of Canada 2002; see also Alder Institute 2005).

Seabird attraction to platforms

Marine birds are attracted to offshore structures (Tasker *et al.* 1986, Baird 1990, Wiese *et al.* 2001). Localized enrichment from sewage disposal and artificial reefs created by underwater structures act as attractants (Tasker *et al.* 1986, Baird 1990, Wiese *et al.* 2001). Attraction to offshore oil platforms increases the likelihood of exposure to oil pollution. An additional attractant for some species (e.g. storm-petrels, Dovekies; Wiese *et al.* 2001) is the presence of lights from the platform itself and from nighttime flaring of gas. Of particular concern are migratory Dovekies, because they appear to be attracted to nighttime lights, are highly vulnerable to oil pollution, occur in very high densities in the winter and are under-detected in surveys (Burke *et al.* 2005). Both Wiese *et al.* (2001) and Burke *et al.* (2005) note higher seabird densities near oil and gas platforms than in surrounding waters on the Grand Banks, but further work is required to document the extent of attraction on a species-specific basis. Montevecchi *et al.* (1999) reviewed the attraction issue in Newfoundland and Labrador and provided recommendations on how it may be quantified (see also Baillie *et al.* 2005).

Seabird population estimates

The White Rose EA did not provide any population-specific data for the environmental effects assessment (Husky Oil 2000). From a biologic perspective, it is important to determine how the loss of a portion of a given population affects the overall population growth of a species (e.g., Wiese *et al.* 2004). Life-history parameters and population sizes differ sufficiently among species of marine birds that the EA approach should be species-specific.

In general, all of the seabirds using this part of the northwest Atlantic follow life-history strategies built on high annual adult survival (>70%), low reproductive success, and delayed recruitment. Small changes in adult mortality for such species can cause population declines (e.g. Weimerskirch 2002). However, the large variance typically associated with population estimates impedes timely detection of such changes. There is a mismatch between the small scale of change in adult survival that may be predicted to have significant effects on a population and the ability of current population estimates to detect such small-scale change in a timely manner (see Piatt *et al.* 1990).

Although the posing of testable hypotheses should be encouraged, preventive action should not await the practical testing of such hypotheses. Rather, the need for a precautionary approach may be argued from basic knowledge such as the known theoretical relationship between small changes in adult survival and population change for long-lived species that are slow to mature. The Precautionary Principle holds that when threats of serious or irreversible damage exist, lack of full scientific certainty must not be used as a reason for postponing cost-effective measures to prevent environmental degradation (Principle 16 of the Rio Declaration on Environment and Development). In such instances, modeling efforts should include a precautionary approach in assessing these issues.

Degree of sensitivity to oil pollution

In cold-water regions, such as the Grand Banks, exposure to very small amounts of oil can compromise thermoregulatory capabilities and kill a diving bird (Jenssen *et al.* 1985, Culik *et al.* 1991, Doerffer 1992, Wiese & Ryan 2003). Seabird susceptibility to petroleum hydrocarbons released into the marine environment depends upon species-specific behaviours that influence exposure, combined with the ambient water temperature. Observations from beached bird surveys demonstrate that diving bird species operating at the air–sea interface, such as auks, are significantly more sensitive to oil pollution than are non-diving bird species such as gulls (e.g. Peakall *et al.* 1987, Lock *et al.* 1994, Camphuysen 1998, Wiese & Ryan 2003). Greater Shearwaters moult when in the North Atlantic, which increases their time spent on the water and hence increases their susceptibility to oil pollution (Brown *et al.* 1981, Huettmann & Diamond 2000, Burke *et al.* 2005; see also Stephenson 1997).

Montevecchi and Burke (2004) conducted observations around offshore oil platforms (in addition to transects from the coast to the platforms). During four different surveys (three in February 2002 and 2003, one in April 2003) at the Hibernia platform, they observed nine oiled auks (Thick-billed Murres and Dovekies) out of a total of 87 auks observed; two Dovekies were dead. Montevecchi and Burke (2004) also note personal communications from employees working on the offshore ships or platforms observing oiled murres near the Hibernia platform. Oiled non-auk species observed around the platforms included Great Black-backed Gulls and Black-legged Kittiwakes (Burke *et al.* 2005).

A data gap in the assessment of the environmental effects of oil at sea on marine birds is an understanding of the relationship between the oil concentration encountered and subsequent feather structure modification. Currently, the assumption in offshore oil and gas environmental assessments in Atlantic Canada is that oil sheens do not harm seabirds (e.g. Husky Oil 2000, LGL Limited 2005a). No data are available on the relationship between oil sheen thickness and its lethality for marine birds; some specialists believe that any contact of a bird with oil or oily water will be lethal (e.g. Peakall *et al.* 1987, Stephenson 1997), but field evidence is inadequate (Hartung 1995).

APPLICATION OF CRITERIA TO AUKS

We used a simple model applied to a generic population of auks to examine the conclusion of the White Rose EA (Husky Oil 2000) that the environmental effects on seabirds from produced water discharges are *nonsignificant.* Specifically, we examined the validity of a "negligible" magnitude rating. Based on the literature reviewed in the preceding subsections, the presumed geographic extent of 1 km^2 for produced water discharges appears to be based on a substantive body of knowledge; thus, we did not question the dilution models in the EA. The frequency of produced water discharges was continuous and for a duration greater than 72 months (Husky Oil 2000). No data were cited in support of the predicted frequency surficial sheens occurring 1% of the time. In the absence of data, our model assumes the occurrence of daily surficial oil sheens.

Because the PIROP database contained only four surveys in the area of the Hibernia platform, with these PIROP observations made before the existence of oil platforms (D. Fifield, Canadian Wildlife Service, pers. comm.), and given that birds are attracted to oil platforms, we used data from Burke *et al.* (2005) for our estimates. These recent data more likely reflect the current density of birds around oil platforms. Burke *et al.* (2005) report auk numbers (not species-specific) from 360-degree scans out to 500 m from a platform. Most of the auks appear to be present chiefly in the winter months (see Lock *et al.* 1994, Burke *et al.* 2005). Based on these data, we estimated that "auks" could be present within 1 km^2 of the platform on 210 days annually. Burke *et al.* (2005) report 0–23 auks present by the platforms in eight sampling periods from October to April over three different years (Table 3). We calculated the mean (± SD) of the minimum (0.25 ± 0.71 birds/5 km^2) and maximum (6.9 ± 7.6 birds/5 km^2) counts for the range of auks observed from the eight sampling periods (Table 3). The mean of the maximum counts also represents the number of individuals in the affected area daily (White Rose EA criterion).

Because oil sheen data are not available, we consider a worst-case scenario of sheens occurring daily (i.e. 210 days). We assume that any contact between marine birds and sheens eventually results in bird mortality from hypothermia (Jenssen *et al.* 1985, Culik *et al.* 1991, Doerffer 1992, Wiese & Ryan 2003).

A single platform discharging produced water which causes a sheen 210 days from October to April could oil between 52 (0.25 birds × 210 days) and 1444 (6.9 birds × 210 days) auks. The percentage of birds oiled from a single platform ranges from 3.6% to 100% (minimum and maximum scenario, respectively) of the total auk population (1444 individuals) in the 1 km^2 range over a 210-day period. Thus, the estimated magnitude of the impact, based on the White Rose EA criteria (Husky Oil 2000), ranges from low to high as opposed to the predicted "negligible."

CONCLUSIONS AND RECOMMENDATIONS

Our review of the methods and data used to assess the potential environmental effects on seabirds of produced water discharged from offshore oil platforms into the sea revealed several basic problems with the approach. First, the definition of a significant environmental effect used in the White Rose EA ("having a high magnitude or medium magnitude for a duration of greater than one year *and* over a geographic extent greater than 100 km^2"; Husky Oil 2000) makes it virtually impossible that any rating of significance

TABLE 3
Mean ± standard deviation and range of the number of auks observed by offshore platforms on the Grand Banks[a]

	October	November	February	April
Auks	0 (no range)	7.9±6.9 (0–23)	4.1±3.8 (0–12)	3.0±1.4 (2–5)
	1.1±2.6 (0–7)		0.8±0.1 (0–2)	0.8±0.1 (0–6)
	0 (no range)			

[a]Burke *et al.* (2005).

will occur. For example, the geographic extent of produced water will be only approximately 1 km^2; therefore, even with a medium- or high-magnitude rating, the overall impact on marine birds will always be considered nonsignificant.

Second, the null hypothesis that oil sheens do not kill seabirds needs to be tested. Null hypotheses are tools for applying the scientific method. If no data relevant to the testing of a null hypothesis are being collected, it is a subversion of science to accept and apply a null hypothesis as a management tool (i.e. in this case, an EA tool). The Precautionary Principle must be applied in this context (see Alder Institute 2001a, ERIN Consulting Ltd. & OCL Services Ltd. 2003). There are compelling legal precedents for applying the Precautionary Principle. The Principle has appeared in more than 20 international treaties, protocols and declarations (e.g. McIntyre & Mosedale 1997). Canada is a party to many of these. For example, the Oceans Act (Government of Canada 1996) provides a framework for the development of a national oceans management strategy based on, among other principles, the precautionary approach.

Third, the EA methodology is not species-specific. Species-specific models should be considered, because the mortality for each species is likely different. The mortality for some species may be avoided through mitigation strategies (Montevecchi *et al.* 1999). The employment of mitigation in this case has strong potential, but a review of the options is beyond the scope of this paper.

We tested the public availability of data relevant to generating *a priori* impact assessment predictions for various seabird populations on the Grand Banks and found that these data are not available to the public. The process of follow-up and accountability in an EA is a critical step whereby predictions are verified. If predictions are not supported by empirical data, then the environmental effects impact needs to be revisited (Storey & Noble 2004). In the EA process, a continuous, transparent exchange of information involving all stakeholders must occur. With regard to the potential impacts of produced water on seabirds, this exchange is not happening.

Our modelling exercise found that approximately 3.6%–100% of the auk population within a geographic extent of 1 km^2 may be oiled annually (52–1444 birds in 210 days per platform). The accuracy of our mortality estimates could be improved if our understanding of species-specific distribution and abundance was more extensive and if the data on oil sheens were available for consideration. A critical assumption of this exercise is the occurrence of a daily sheen. Because our attempts to obtain oil sheen frequency data failed (see above), it is up to the operators to demonstrate that oil sheens occur on fewer than 1% of the days that auks are in the region if they are to achieve a "low-magnitude" rating (i.e. <10% of the individuals in the area affected).

Some may argue that even a cumulative scenario of three platforms discharging produced water would not have a significant ecologic impact on seabird populations. We suggest that our maximum estimates of mortality are likely underestimates of the actual mortality for the following reasons:

- Although the geographic extent of produced water may be only 1 km^2, the geographic extent of birds being attracted by light is likely much greater (Wiese *et al.* 2001).
- The result could be that birds are attracted to the 1 km^2 from a considerably larger area and that the platforms may act as population sinks over large distances.
- The estimates of bird density at platforms reported by Burke *et al.* (2005) are preliminary, and maximum densities may be higher. Our paper considers mortality related only to produced water discharges; it does not assess total seabird mortality associated with offshore platforms.
- Lastly, it is clear that offshore oil extraction activities in this region will undergo expansion (e.g. LGL Limited 2005a), although the extent and timing are uncertain. Engaging in further development activities requires predictive models to assess the impact on seabirds.

Environmental assessments—future focus

Our current understanding of the dynamics of seabird distribution and abundance across the seasons and of how particular species are attracted to platforms is very limited; thus, our ability to predict the potential interaction between marine birds and produced water oil sheens from offshore oil platforms is also limited (see also Fauchald *et al.* 2002). Montevecchi *et al.* (1999) provide recommendations on survey design to determine impacts on seabirds during oil pollution events for platforms in eastern Canada. In 2006, the Canadian Wildlife Service and C-NLOPB began to implement some of these recommendations (G. Robertson, pers. comm.). Data from these survey protocols will strengthen our ability to assess the impacts of oil sheens on seabird populations.

If the operational generation of oil sheens lethal to marine birds cannot be prevented, the potential for birds to encounter such sheens must be adequately assessed before earlier commitments or licensing are made to a project. At present, consideration by the Canadian Government of offshore oil and gas leasing excludes addressing the potential effects to marine birds frequenting Canadian waters. The government is not taking adequate measures to protect them, which is clearly a violation of the Precautionary Principle.

This paper considers only the effects of oil sheens from produced water. Other oil or oil-like substances (e.g. synthetic-based drilling fluids) that are discharged from drilling activities may have the same practical effect as oil on a bird's thermoregulatory performance because of compromised plumage. All such substances discharged into the ocean should to be considered in the impact assessment under cumulative impact scenarios (see Mines and Energy 2000, Alder Institute 2001b).

To improve the quality of assessment of the effect of offshore oil and gas activities on the marine environment, future EAs should

- provide detailed information on the oil sheen dynamics from produced water and other oily discharges
- consider the impact of oil sheens on each seabird species separately and provide detailed quantitative models of associated mortality estimates
- consider the issue of attraction when identifying geographic extent
- refine the criterion of 10% mortality on which nonsignificance is partly based by providing species-specific predictions
- be realistic in the scientific certainty used to determine the level of impact
- consider the implications of mortality in the context of international agreements such as the Migratory Bird Convention Act (Government of Canada 1994).

We conclude by emphasizing that the argument that methods used in earlier environmental assessments are established and are therefore valid is indefensible (LGL Limited 2005b). Methods of assessment that reach conclusions without reference to either data or biologic assumptions are not scientifically viable.

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