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Seabird Attraction to Offshore Platforms and Seabird Monitoring from Offshore Support Vessels and other Ships Literature Review and Monitoring Design

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Seabird Attraction to Offshore Platforms and Seabird Monitoring from Offshore Support Vessels and Other Ships

Literature Review and Monitoring Designs

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Forward

The evolution of offshore oil and gas production on Canada's East Coast has been accompanied by public concern for the effects of these activities on seabirds and seabird populations. Canada's East Coast hosts large and globally significant resident and migratory populations of these birds.

The environmental assessment of the Terra Nova project drew attention to some potential risks to seabirds from the operation of offshore platforms. In response to the review panel's recommendations the Canada-Newfoundland Offshore Petroleum Board (C-NOPB) brought forward the two issues addressed by this report – the state of understanding and the potential significance of seabird attraction to offshore platforms and the feasibility of monitoring seabird populations from vessels of opportunity – to the Environmental Studies Research Funds Management Board. As a result the oil and gas industry on the East Coast, offered to directly fund research on these two issues, under the oversight of the Management Board. This study is the result.

The study was undertaken by regional experts in seabirds and their population ecology from Memorial University of Newfoundland and the University of New Brunswick. Carried out in consultation with a steering committee comprised of representatives of the oil and gas industry and government, including the Canadian Wildlife Service and the C-NOPB, the study also benefited from a technical workshop attended by these parties, the Canadian Coast Guard, Fisheries and Oceans Canada and invited experts from the North Sea and the United States.

The industry funders of this study believe it most appropriate that its results be published under the auspices of the ESRF. The East Coast oil and gas industry has taken the study and its recommendations under advisement and has started to develop policies and programs to address those findings and recommendations which are safe and feasible to do.

The Canadian Association of Petroleum Producers on behalf of the industry has asked that its thanks be conveyed to all those who participated in the study for their work and contributions.

Executive Summary

This report involved comprehensive literature reviews of seabird attraction to offshore platforms and of the scientific feasibility of monitoring fluctuations in the spatial and temporal distributions and abundances of seabirds from support vessels. A web site was constructed to provide access to the bibliography resulting from our literature search (http://dogsbody.psych.mun.ca/seabirdsandoil, password: birds) and to a copy of this final report. In this document, we synthesize this information and propose a research design to systematically address these two issues. A draft report of the present document was distributed and fully discussed at a 2-day workshop with oil industry and seabird ecology experts. This final report incorporates the comments and suggestions of reviewers made at the workshop and in subsequent communication with reviewers,

We propose a multi-agency, cooperative research program which will simultaneously provide baseline data on seabirds and help generate public confidence in offshore hydrocarbon developments in eastern Canada. This research will benefit seabird ecology and conservation by documenting bird responses to lighted offshore platforms and by documenting long-term variability in the spatial and temporal distributions and abundances of birds on the Grand Banks and Scotian Shelf. This will provide the oil industry with information necessary to manage their operations and minimize impacts on seabirds.

Seabirds, the most conspicuous marine organisms, are attracted to large offshore structures such as oil drilling platforms. Possible causes for this attraction include the physical structure itself, increased concentrations of food around the structure, night lighting and flaring. Although concerns about this attraction have been referred to frequently in environmental assessments of offshore oil and gas exploration, these impacts have not been documented systematically, nor quantified. Concerns in the Northwest Atlantic are unique in that huge concentrations of seabirds move through the region in autumn (storm-petrels), winter (dovekies, murres), spring and summer (shearwaters). Birds attracted to offshore platforms are consequently at increased risk of oiling should hydrocarbons escape from the drilling platform. Most of the birds that occur at sea in the study area throughout the year are migrants and do not breed in Canada. As a result, regional hydrocarbon development could affect both local and global breeding populations of seabirds.

This report first recommends a monitoring system that will measure the degree of association of birds with offshore platforms and would quantify and determine the nature, timing and extent of any bird mortality caused by these structures. Second, this report recommends a research design to quantify baseline information on seabird occurrence, distribution, abundance and density in the study area from supply vessels. Additional data collected during vessel-based surveys (e.g. physical and biological oceanography) are needed to allow managers to better interpret changes in seabird densities or distributions. Integration of oceanographic data is needed to place seabird distribution and abundance into the larger context of the marine environment. Recommended survey designs emphasize the necessity of having skilled and specifically trained and dedicated bird observers on offshore platforms and supply vessels. A rigorous year-round survey scheme is outlined. Monthly surveys and more intense efforts during migration periods from the platform are recommended in conjunction with experimental studies before and after flares are turned off

for operational purposes. Weekly surveys aboard supply vessels should be conducted throughout the year. Such survey effort will reduce both the intrinsic variation in seabird densities due to their clumped distributions at sea and extrinsic variation in seabird densities due to errors inherent in counting methods. Exploratory research will be particularly important during the nonbreeding season when seabirds are more vulnerable to oil spills, and in periods of high bird flux due to major migration movements. This research program would be greatly facilitated and enhanced by the use of fisheries and coast guard vessels as well as those of the petroleum industry.

The proposed platform-based and vessel-based approach will allow the identification of critical periods when seabirds are at greatest risk from mortality associated with both the platform and oil pollution events. The recommended research program also will quantify seabird mortality and permit the development of comprehensive and effective forms of mitigation. Overall, this will ensure a conservative monitoring scheme for seabird populations in the Northwest Atlantic and help researchers to better identify and understand factors affecting population change. Such a rigorous research commitment would reflect a high level of corporate responsibility and would help instill public confidence in the safe-guarding and protection of a clean marine ecosystem in eastern Canada.

Résumé

Ce rapport rend compte de plusieurs analyses des publications portant sur l'attraction des oiseaux de mer pour les plates-formes de forage en mer et sur la faisabilité technique de surveiller les fluctuations spatiales et temporelles des distributions et des abondances de ces oiseaux à partir de bateaux de soutien. Un site Web a été construit pour donner accès à la bibliographie résultant de notre analyse http://dogsbody.psych.mun.ca/seabirdsandoil, mot de passe : birds) et à une copie du présent rapport final. Nous synthétisons ici ces informations et nous proposons un protocole de recherche permettant de surveiller systématiquement ces deux aspects. Une ébauche du présent document a été distribuée et discutée lors d'un atelier de deux jours auquel ont participé des experts de l'industrie pétrolière et de l'écologie des oiseaux de mer. Le présent rapport final incorpore les suggestions et les commentaires formulés par les spécialistes pendant cet atelier et au cours des communications avec les examinateurs.

Nous proposons la mise en place d'un programme de recherche coopératif à financement partagé qui permettra d'obtenir des données de base sur les oiseaux de mer et de renforcer la confiance du public à l'égard des développements pétroliers extra-côtiers dans l'Est du Canada. Ces travaux de recherche enrichiront nos connaissances dans le domaine de l'écologie et de la conservation des oiseaux de mer puisqu'ils consisteront entre autres à analyser la réponse des oiseaux aux plates-formes éclairées et la variabilité à long terme des distributions et des abondances spatiales et temporelles des oiseaux sur les Grands bancs et sur la plate-forme néo-écossaise. L'industrie pétrolière pourra utiliser ces informations pour gérer ses exploitations de manière à minimiser ses impacts sur les oiseaux de mer.

Les oiseaux de mer sont sans nul doute les créatures marines les plus aisément observables. Curieusement, ils sont attirés par les grandes structures extra-côtières telles que les plates-formes de forage. On a émis plusieurs hypothèses concernant les raisons de cette attraction : un attrait pour la structure elle-même, un intérêt pour la densité relativement élevée de nourriture autour de la structure ou une attirance par les lumières nocturnes (éclairage de la plate-forme et torchage). Bien que des inquiétudes au sujet de cette attraction aient été fréquemment formulées dans des évaluations environnementales de projets d'exploration pétrolière et gazière en mer, les impacts éventuels sur les populations d'oiseaux concernées n'ont jamais été ni quantifiés, ni analysés de manière systématique. Dans le nord-ouest de l'Atlantique, le problème prend une dimension particulière puisque de grandes concentrations d'oiseaux de mer traversent cette région en automne (pétrels de Castro), en hiver (mergules nains et guillemots), au printemps et en été (puffins). Les oiseaux attirés vers les plates-formes courent un risque accru d'être imprégnés de pétrole en cas de fuite sur la plate-forme de forage. La plupart des oiseaux de mer que l'on rencontre en mer tout au long de l'année dans les secteurs étudiés sont des migrateurs qui ne nichent pas au Canada. Les développements pétroliers régionaux peuvent par conséquent affecter des populations nicheuses provenant d'autres parties du globe et non pas seulement des populations locales.

Le présent rapport recommande tout d'abord de mettre en place un système de surveillance qui permettra de mesurer le degré d'association des oiseaux de mer avec les plates-formes extra-côtières ainsi que de déterminer et de quantifier la nature, le moment et le nombre des accidents mortels affectant les oiseaux au voisinage de ces structures. Les auteurs recommandent ensuite

de concevoir un projet de recherche visant à recueillir, à partir d'un bateau, des données quantitatives de base sur la présence, la distribution et la densité des oiseaux de mer dans les secteurs étudiés. Plusieurs données supplémentaires recueillies lors des relevés en bateau (p. ex. données océanographiques physiques ou biologiques) permettront d'autre part aux gestionnaires de mieux interpréter les changements de densités ou de distribution chez les oiseaux de mer. Il est nécessaire d'intégrer les données océanographiques de façon à placer la distribution et l'abondance des oiseaux de mer dans le contexte plus large de l'environnement marin. On recommande que des relevés soient effectués à partir des plates-formes et des navires de soutien par des observateurs d'oiseaux compétents, enthousiastes, et formés spécifiquement à cette tâche. Le présent rapport donne l'aperçu d'un plan de relevés rigoureux sur toute une année. Pendant les périodes migratoires, des relevés mensuels et des efforts plus intenses à partir des plates-formes sont recommandés, conjointement à des études expérimentales avant et après l'allumage des torches lors du fonctionnement normal de la plate-forme. Des relevés hebdomadaires à bord des bateaux de soutien devraient être effectués toute l'année. De tels efforts de surveillance permettront de réduire l'imprécision des estimations d'effectifs due d'une part à la variation intrinsèque des densités d'oiseaux provenant de leur distribution hétérogène en mer, et d'autre part à la variation extrinsèque de cette densité à cause des erreurs de comptage. La recherche exploratoire sera particulièrement importante en dehors de la période de nidification, lorsque les oiseaux sont plus vulnérables aux déversements d'hydrocarbures, et pendant les périodes de flux migratoires intenses. La logistique de ce programme de recherche serait grandement facilitée par l'utilisation des navires ministériels affectés aux pêches et à la Garde côtière ainsi que ceux appartenant à l'industrie pétrolière.

L'approche proposée, axée sur les relevés à partir des plates-formes et des navires de soutien, permettra d'identifier les périodes critiques pendant lesquelles les oiseaux de mer courent le plus grand risque de se faire tuer au contact des plates-formes ou des nappes de pollution par hydrocarbures. Le programme de recherche recommandé permettra également de quantifier la mortalité affectant les oiseaux de mer et contribuera au développement de techniques globales efficaces pour l'atténuation des impacts. Dans l'ensemble, une telle approche permettra d'assurer la mise en place d'un cadre de surveillance conservateur des populations d'oiseaux de mer du nord-ouest de l'Atlantique et d'aider les chercheurs à mieux identifier et à mieux connaître les facteurs qui induisent les changements observés au sein de ces populations. Un tel effort de recherche serait la preuve d'un haut niveau de responsabilité de la part des industriels et contribuerait à faire sentir au public que tout est fait pour conserver et protéger un écosystème marin sain dans l'Est du Canada.

I Introduction

This study arises from the C-NOPB (Canada-Newfoundland Offshore Petroleum Board)/ Government response to the Terra Nova Public Review. The Panel Report recommended (1) studies of the attraction of seabirds to platforms; (2) observer placement on offshore supply vessels, tankers and other boats to document fluctuations in seabird distributions and numbers, and mortality; and (3) the promotion of collaborative research among industry, university and government researchers.

This report involved a comprehensive literature review of seabird attraction to offshore platforms and of the scientific feasibility of monitoring fluctuations in the spatial and temporal distributions and abundances of seabirds from support vessels. A web site was constructed to provide access to the bibliography resulting from our literature search (http://dogsbody.psych.mun.ca/seabirdsandoil, password: birds) and to a copy of the final document. Both studies are constrained by the lack of current field data from offshore platforms and vessels in the study area. We developed research designs to systematically address these two issues. We propose a multi-agency cooperative research program to simultaneously provide baseline data on seabirds and to help generate public confidence in offshore hydrocarbon developments in eastern Canada. Support of this research by the petroleum industry will benefit seabird ecology and conservation by documenting bird responses to lighted offshore platforms and long-term variability in the spatial and temporal distributions and abundances of birds on the Grand Banks.

Seabirds are the most conspicuous marine organisms and relatively easy to survey. Their distributions and abundances are influenced by natural abiotic and biotic processes such as oceanographic variation, weather, season, food availability, and by human activities such as fishing, vessel traffic, pollution, artificial lighting, and large offshore structures. As a result, seabirds have been frequently used as monitors of the marine environment (e.g. Furness and Greenwood 1993).

As part of a contract with the Canadian Association of Petroleum Producers (CAPP), scientists from Memorial University of Newfoundland and the University of New Brunswick formed a research team to review and design for the study area (Figure 1) scientific studies that relate to:

- Bird Attraction to Offshore Platforms
- Bird Monitoring from Offshore Support Vessels and Other Ships.

Our objectives for the first part of this study are to review the literature relating to seabird attraction to offshore platforms, to recommend research designs to monitor and quantify seabird attraction and associated mortality, and to propose ways to mitigate possible detrimental effects. Our objectives for the second part of this study are to review the literature on seabird counting methods and to recommend a research design to systematically survey seabird occurrences throughout the year appropriate to the conditions prevailing around CAPP's oil platforms and oil transportation lines. These data can then be used as a baseline for future studies and comparisons.

This report benefited from its circulation and feedback from both oil industry and international seabird experts at a workshop sponsored by CAPP and held in St. John's on 17 – 18 October 1999. A list of workshop participants is given in Appendix 1.

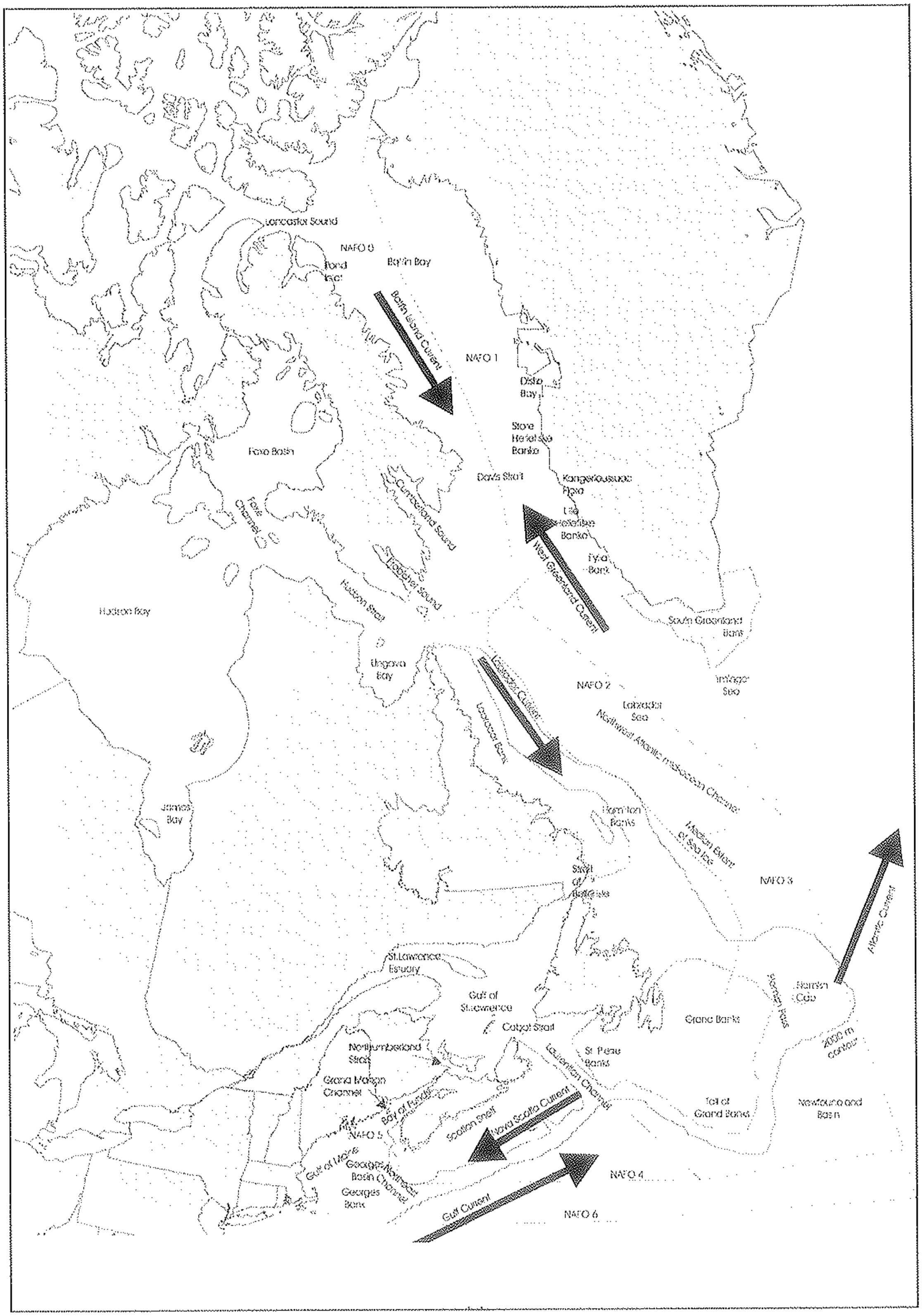

Figure 1. A map of the study area showing major oceanographic and bathymetric features.

II Seabird Distribution in the Northwest Atlantic

1 Seabird Distribution

There are large seasonal fluxes of seabird species and populations in the Northwest Atlantic throughout the year. Interestingly, for most of the year the majority of seabirds in the study area do not breed in Canada but rather travel very substantial distances from the Southern Hemisphere, the Arctic and northern Europe to the offshore banks and coastal waters of Atlantic Canada. Owing to colder water regimes in the Newfoundland region, there are substantial differences in the seabird communities in the offshore and coastal waters of Newfoundland and Nova Scotia.

The major seabird species that move into the region in large numbers for substantial periods, primarily during summer, but do not breed in the study area, are the transequatorial migrants: Greater Shearwater *Puffinus gravis*, Sooty Shearwater *P. griseus* and Wilson's Storm-Petrel *Oceanites oceanicus* that breed around the southern tip of South America (Brown 1986, Diamond et al. 1993, Lock et al. 1994, Montevecchi 1999). Species that breed in the Arctic and Northeast Atlantic and move into the region in large numbers during winter are Northern Fulmar *Fulmarus glacialis*, Iceland Gull *Larus glaucoides*, Glaucous Gull *L. hyperboreus*, Black-legged Kittiwake *Rissa tridactyla*, Dovekie *Alle alle* and Thick-billed Murre *Uria lomvia* (Brown 1986, Diamond et al. 1993, Lock et al. 1994, Montevecchi 1999). The populations of all these nonbreeding seasonal residents are globally significant. Important populations of seaducks reside in the area in winter, including Common Eider *Somateria mollissima*, the endangered Harlequin Duck *Histrionicus histrionicus*, Oldsquaw *Clangula hyemalis* and the scoters *Melanitta* spp. (Montevecchi and Tuck 1987, Lock et al. 1994, Montevecchi et al. 1995, Montevecchi 1999).

The major seabird species that breed in the Newfoundland and Labrador region are Leach's Storm-Petrel *Oceanodroma leucorhoa*, Northern Gannet *Morus bassanus*, Ring-billed Gull *L. delawarensis*, Herring Gull *L. argentatus*, Great Black-backed Gull *L. marinus*, Black-legged Kittiwake, Common Tern *Sterna hirundo*, Arctic Tern *S. paradisaea*, Common Murre *U. aalge*, Thick-billed Murre, Razorbill *Alca torda*, Atlantic Puffin *Fratercula arctica* (Brown 1986, Montevecchi and Tuck 1987, Cairns et al. 1989, Lock et al. 1994, Montevecchi 1999). Other species that breed in the Newfoundland and Labrador region in small numbers are Common Eider, Northern Fulmar (Stenhouse and Montevecchi 1999), Manx Shearwater *Puffinus puffinus* (Storey and Lien 1985), Great Cormorant *Phalacrocorax carbo*, Double-crested Cormorant *P. auritus* (Cairns et al. 1989), Common Black-headed Gull *L. ridibundus* (Montevecchi et al. 1987), Caspian Tern *S. caspia*, and Black Guillemot *Cepphus grylle* (Cairns et al. 1989, Montevecchi 1999). Abundant breeding seabird species in the Nova Scotia region include Herring Gull, Great Black-backed Gull, Black-legged Kittiwake, Common Tern, Black Guillemot and Common Eider, Double-crested and Great Cormorants (Lock et al. 1994).

Some of the globally and regionally significant breeding sites in the area include the world's largest colonies of Leach's Storm-Petrels (Sklepkovych and Montevecchi 1989), the only North American colonies of Manx Shearwaters (Storey and Lien 1985) and Common Black-headed Gulls (Montevecchi et al. 1987), three of the six North American gannet colonies including the world's southernmost colony at Cape St. Mary's (Montevecchi and Tuck 1987, Nettleship and

Chapdelaine 1988), North America's largest colonies of Atlantic Puffins (Rodway et al. 1996), the largest colonies of Northern Fulmars, Caspian and Roseate Terns in eastern Canada, the major colonies of Common Murres on Funk and Green Islands (Newfoundland) and the world's southernmost breeding sites for Thick-billed Murres (Cairns et al. 1989, Lock et al. 1994).

2 Species Information

We queried PIROP (Programme Intégré des Recherches sur les Oiseaux Pélagiques) data for an area of latitude 43° to 50° N and longitude 67° to 42° W which contains the only published vessel-based data available for seabird distribution in the Northwest Atlantic (Brown et al. 1975, Brown 1986, Lock et al. 1994, Huettman and Lock 1997). Unpublished data are also available for the study area (Davoren unpubl. data, Wiese unpubl. data, Huettman and Diamond unpubl. data). We will briefly discuss the species observed in the survey area, which are categorized into appropriate subgroups.

Fulmars and Shearwaters

Northern Fulmar (local name-Noddy): A pelagic bird that can be found in the study area throughout the year (Huettman and Diamond In press). Colour morphs occur. This bird is known to be attracted by fishing vessels in large numbers (e.g. Garthe and Hüppop 1999). Many recently established and growing colonies occur in the region (Montevecchi & Tuck 1987, Stenhouse and Montevecchi 1999).

Greater Shearwater (Hagdown, Bawk): A seasonal trans-equatorial migrant from the southern hemisphere that occur in the area from May to December (Huettman and Diamond In press). Can be found in larger flocks sitting on the water or gliding close to the surface. Moulting birds are observed from May to August.

Sooty Shearwater (Black Bawk, Black Hagdown): Similar to the Greater Shearwater, this species is a seasonal, trans-equatorial migrant. Sooty Shearwaters are found in lower numbers than Greater Shearwaters (ca. 1:7 - 1:1).

Manx Shearwater (Skerwink): This North Atlantic shearwater is smaller and much more rare than the Greater and Sooty Shearwater. Manx Shearwater occur regularly in the area and breed at a few sites in Newfoundland (Storey and Lien 1985, Montevecchi and Tuck 1987).

Jaegers and Skuas

Three species of jaegers (Pomarine, Parasitic and Long-tailed) and two species of skuas (Great and South Polar) occur in the area.

Gannets

Northern Gannet: Breed in the area and are absent from December to March (Huettman and Diamond In press).

Storm-Petrels

Leach's Storm-Petrel (Carey Chicks, Careys): Most abundant and smallest breeding seabird in the Northwest Atlantic. Its world distribution is concentrated in eastern Newfoundland (Montevecchi and Tuck 1987). Occur from spring until end of fall. These pelagic seabirds feed nocturnally and diurnally. They congregate in small flocks and can at times be found in association with floating matter (e.g. seaweed).

Wilson's Storm-Petrel: Among the most numerous seabird species in the world. Breed in the southern South Atlantic.

Gulls and Kittiwakes

Herring Gull: A coastal bird that was the most abundant sighting in the PIROP data. Although birds migrate south in winter, they are abundant all year in the area (Huettman and Diamond In press). Can be found in large flocks behind fishing vessels in coastal areas.

Great Black-backed Gull (Saddle-backed Gull): Mostly a coastal bird but also occurs farther offshore than Herring Gulls. Occur year round in the area but move southward in winter (Huettman and Diamond In press). This bird is attracted to fishing vessels and is rarely encountered in large flocks.

Iceland Gull (Slob Gull): Migrate through the area in fall and spring and normally winter in coastal waters of Newfoundland (Huettman and Diamond In press). Observations of individual birds in summer.

Black-legged Kittiwake (Tickle-ace): Offshore distribution in winter but more coastal during the breeding season. Some birds undergo a trans-Atlantic migration and are found year-round in the Northwest Atlantic, normally in groups.

Alcids (Auks)

Common Murre (Murre): Breed in the area. Owing to the considerable time that they spend sitting of the water, this species and the next are highly vulnerable to oil pollution at sea (Montevecchi and Tuck 1987, Wiese and Ryan 1999).

Thick-billed Murre (Turr): At the southern limit of breeding range with low numbers of breeders in the area. Birds from the Canadian Arctic and Greenland occur in the millions in the region in winter (Huettman and Diamond In press). This species and the previous one are hunted in Newfoundland during winter (Montevecchi and Tuck 1987).

Razorbill (Tinker): Breed and occur in small numbers in the area. They are much less common than murres (Chapdelaine et al. 1999).

Dovekie (Bullbird): Smallest auk in the area and often occur in larger flocks during fall or spring migration and in winter. Summer observations are rare and normally of a few individuals. Often occur close to shore.

Atlantic Puffin: Breed in the Northwest Atlantic, and can be found offshore especially in winter.

Black Guillemot (Pigeon): Coastal breeders and foragers that occur throughout the year.

III Seabird Attraction to Offshore Platforms

1 Influences

Seabirds have long been known to be attracted to large offshore structures such as oil drilling platforms. The causes that have been postulated for this attraction include the structure itself (Tasker et al. 1986, Baird 1990), concentrations of food around the structure (Carlisle et al. 1964, Klima and Wickman 1971, Shinn 1974, Duffy1975, Sonnier et al. 1976, Ortego 1978, Wolfson et al. 1979, Tasker et al. 1986), oceanographic processes around the structure (Fedoryako 1982), and light (Terres 1956, Imber 1975, Bourne 1979, Sage 1979, Hope Jones 1980, Crawford 1981, Verheijen 1981, Wallis 1981, Reed et al. 1985, Reed 1986).

The association of seabirds with offshore installations is readily observable. Bird observers, boat and platform personnel, as well as researchers have noted and commented on this association, though few have attempted to quantify it. Tasker et al. (1986) noted that birds were seven times more dense within a 500 m radius of a platform than birds in the surrounding waters. Baird (1990) found similar results in the Bering Sea, where bird densities (birds/km^2) around a rig were six to seven times higher after "spudding" (i.e. commencement of drilling) than before.

The platform as a structure may act to concentrate both seabirds and their prey. The availability of a roosting refuge at sea and increased availability of food may be the most important reasons why birds persist at offshore oil platforms following initial attraction. Oil platforms also create artificial reefs and increase levels of benthic flora and fauna, zooplankton and fish (Carlisle et al. 1964, Klima and Wickman 1971, Shinn 1974, Duffy 1975, Sonnier et al. 1976, Ortego 1978, Wolfson et al. 1979, Baird 1990, de Groot 1996). This fact is so well documented that "fishing the rigs" has become a colloquial expression in Louisiana (Duffy 1975). The discharge of human wastes at offshore platforms may 'fertilize' artificial reefs and may also attract birds directly in much the same way as sewer outlets. Rigs are considered a "useful resource for the study of patterns and interactions among marine plant and animal populations" (Wolfson et al. 1979). Consequently, for some seabirds, offshore oil platforms may have become sites where otherwise patchy or scarce prey (food) is concentrated and predictable. Observed increases in seabird concentrations near offshore oil platforms are therefore not surprising.

Seabirds are for the most part visually oriented organisms. A large vertical structure and a brilliant source of light in an environment which is otherwise relatively flat and very dark at night presents a conspicuous visual cue for seabirds and a roost for wayward landbirds. Flares might be especially attractive because of the sharp contrast that they impose against nocturnal darkness. Bourne (1979) pointed out that the flares in the Sahara and Middle East were much brighter than lights in Europe. Muirhead and Cracknell (1984) were able to identify individual gas flares in the North Sea using satellite data. Petrels and other procellariforms forage at night on vertically migrating bioluminescent prey and are, therefore, naturally attracted to light of any kind due to this association (Imber 1975). Other authors have recorded large attractions and mortalities of birds around tall lighted man-made structures (lighthouses, ceilometers, communication towers, navigational lights, oil platforms) mostly during overcast nights with drizzle and fog (Weir 1976). The attractive effect of lights on cloudy nights is enhanced by fog, haze or drizzle because the moisture droplets in the air refract the light and can greatly increase an illuminated area. Mortality was also higher during migration periods, when large numbers of birds were forced down to a lower flight path or to the ground by inclement weather (Terres 1956, Weir 1976, Sage 1979, Hope Jones 1980, Crawford 1981, Verheijen 1981). Birds that migrate at night climb to their migrating altitude almost immediately after takeoff and begin a gradual descent shortly after midnight (Weir 1976). This pattern might help explain the much higher numbers of birds at tall, illuminated, man-made structures in the latter part of the night. The numbers of Leach's Storm-Petrels visiting colonies near lighthouses also peak after midnight (Bryant 1985).

Regardless of the processes that attract and hence concentrate marine organisms at offshore oil platforms, their mere presence near the structure may lead to immediate or long-term detrimental impacts on their lives. An obvious negative influence around oil platforms is the intermittent presence of oil in the water. Hibernia, for example, reported 60 spills at the rig since 1997, averaging 10 litres per spill (D. Burley pers. comm.). A dime size oil spot can kill a bird (Wiese 1999, W. Montevecchi, P. Ryan, T. Power, F. Wiese, pers. obs.) and that the level of seabird mortality is not directly related to spill volume (Burger 1993). Rather, timing and location of a spill and birds determine avian mortality. In light of seabird association with offshore platforms, spills are always unfavorable. Oil at sea is a threat to seabirds because it forms a thin layer on the ocean's surface where seabirds spend much of their time. The hydrophobic nature of oil causes plumage to lose insulation, waterproofing and buoyancy. This results in death due to hypothermia, exhaustion and starvation. Oil can also be ingested or inhaled while preening of even slightly oiled feathers (Birkhead et al. 1973, Stout 1993) or by ingesting contaminated prey (e.g. fish around oil platforms, Davies and Bell 1984). This can lead to debilitating and/or fatal effects that can further reduce survival rates and lifetime reproductive success (Leighton 1990, Khan and Ryan 1991, Frink and Miller 1995, Hartung 1995).

Other potentially negative influences of platforms on birds include the effects of lights and flares. As indicated above, many seabirds in the offshore environment, especially storm-petrels and shearwaters, are strongly attracted to light. Whether by instinct or by a learned capacity to associate light and smell with food, these birds often circle platforms and the flare for days and eventually die of starvation (Bourne 1979). They also were often observed to fly directly into lights (Terres 1956, Weir 1976, Crawford 1981, Verheijen 1981, Reed et al. 1985) and too close to flares (Bourne 1979, Sage 1979, Avery et al. 1980, Wood 1999). This resulted in death or injury by impact or burning (Sage 1979, Hope Jones 1980, De Groot 1996, Wood 1999).

Production licenses stipulate that surplus gas may be burned at sea only with the consent of the regulating authorities. For economic reasons alone, gas should be re-injected into the bottom or stored in reservoirs for later transport ashore (De Groot 1996). Unfortunately, this has not been the case in Canadian offshore waters since production began in 1997. Since "steady state" operations have not yet been reached, flaring is still a common practice. If estimates are correct, about 0.44 million m^3 of gas are burned daily on an oil field (De Groot 1996). More critical for the birds than the amount of gas burned, is perhaps the height of flares, their numbers and the consistency of flaring. The number of flares in the Northwest Atlantic will increase in the coming years and periods of high flaring at the onset of production are undetermined, potentially making bird mortality at flares (Wood 1999) more than just a short-term localized problem.

Despite the attention these negative impacts of oil platforms on birds have received and their mention in past environmental assessment reports, the extent of these problems has not been quantified for this region nor have any baseline data on seabirds at sea for the study area been collected. The only bird mortalities at oil platforms documented and published come from the North Sea, focus on flares, and date back 20 years. Results from these studies vary and it is worthwhile to point out that even mortalities in large numbers can be very hard to detect at sea. Both Hope Jones (1980) and Wallis (1981) did not observe any fatalities directly due to the flare, whereas Sage (1979) witnessed, reported and compiled information of several occasions where hundreds and sometimes tens of thousands of birds were killed by flying into the flare. This difference might have come about by the reduction of flare sizes after the first study but no information on this is available. Again, it is necessary to collect such data in the Northwest Atlantic. Avian species impacted in these earlier studies were mainly songbirds during spring and fall migration but also included storm-petrels. Locally, reports from boat and platform personnel indicate the regular occurrence of storm-petrels flying into the lights of boats and the platform (F. Wiese and W. Montevecchi unpubl. data). Despite the existing skepticism towards early reports on large bird kills coming from the North Sea, the critical difference between the predominance of songbirds in the North Sea, versus storm-petrels and other seabirds off eastern Canada needs to be emphasized. Storm-petrels are known to be attracted to light and have been reported killed there, while alcids occur seasonally around platforms in large numbers and are considered the most vulnerable group of birds to oil (Wiese 1999, Wiese and Ryan 1999). Alcids and storm-petrels occur in the Northwest Atlantic in massive numbers, and the potential threat offshore oil platforms represent given the current knowledge cannot be ignored. Although birds may not be killed at oil platforms every day, platforms can be a daily threat to birds and birds die from the described impacts. There is a clear association of birds with Canadian offshore oil platforms but the degree, nature, timing and extent of the described bird mortality associated with these platforms is unknown and needs to be assessed. The objective of our recommended monitoring system is to determine, quantify and document the timing of association of different bird species with offshore oil platforms and to determine avian mortality associated with the platform. The goal is to minimize avian mortality.

2 Recommended Monitoring System

Two different monitoring systems are recommended:

1. Measuring the degree of association of birds with offshore platforms;
2. Quantifying and determining the nature and timing of bird mortality caused by offshore platforms.

2.1 Avian Associations with Offshore Platforms

The are essentially two ways to measure association of birds with offshore platforms:

1. Vessel-based bird surveys along transects that end at a platform. Test the hypothesis that birds occur in above-average abundance in the vicinity of the platform;
2. Observations taken from platforms at set intervals in a defined radius.

Tasker et al. (1986) quantified the number of birds associated with oil platforms by counting birds within a 500 m radius that were sitting on the water and that were not obviously flying rapidly past. Counts were made every 2 hours for several days and each species was assessed according to the maximum number of birds of each species seen per day (DMAX). From this evaluation, they determined mean abundance (MA) and relative abundance (RA) of each species during each season, as:

$$MA = \frac{\text{sum DMAX for each day spent at the platform}}{\text{MA for all species}} \qquad RA = \frac{\text{species MA * 100}}{\text{number of days recording at platform}}$$

The resulting numbers can be qualitatively compared to abundance estimates determined via transects in the region and can also stand alone as a description of the number and types of birds commonly found around platforms at different times of the year. In addition, density estimates (birds/km^2) can be derived from these numbers and then compared to densities outside the specified radius. Identification of species compositions as well as quantification of total numbers is essential for the determination of species specific vulnerability to different types of disturbances.

2.1.1 Recommended Survey Design

In order to systematically and comprehensively assess bird attraction to offshore platforms, we recommend a combination of simultaneous platform-based and boat-based surveys. Boat surveys provide comparisons within the transect route, among different surveys on the same route and with the rest of the area. However, these surveys provide only a restricted view around the platform, as boats stay outside the 500 m zone when not unloading or back-loading at the platform (usually a few kilometers away). Also, when supply boats come into the 500 m zone, they often travel at speeds below 4 knots/hour (unsuitable for seabird surveys) and allow the examination of only one side of the platform. These limitations can be eliminated by conducting surveys from the platform, which in addition also allow necessary night observations (see mortality section below).

We propose that trained dedicated observers conduct systematic survey scans with binoculars, spotting scopes, and night vision goggles during 30 minutes of every daylight hour and for 30 minutes of every hour throughout the night on different days. Given the frequent fog and often harsh weather conditions around platforms on the Grand Banks, we suggest that the radius for observations around the platform should not be fixed, observations should be carried out whenever possible and distance estimates be recorded for every observation. The problem of using DMAX is that it is likely to underestimate bird numbers due to the turnover rate of the birds at specific sites. Continuous daylight observations should permit estimation of turnover rates of birds in the survey area. Correction factors could then be incorporated in calculations of bird abundance and thereby minimize bird underestimation. In addition, it will likely not be possible to survey the entire radius around the platforms, unless a high enough position can be found which allows a clear 360° view. In this case, observation height should be considered in the analysis. We require platform visits to better define and refine the designs of platform surveys. If a 360° view is not possible, we propose to carry out observations consistently on the down-current side of the platform, where most bird aggregations are commonly found (F. Wiese unpubl. data). During the surveys, efforts will be made to record the behaviour of the birds (e.g. flying, resting, preening, feeding). Special attention to bird behaviour should be given during the time period when helicopters are present at the platform. Past studies on the influence of low level flying (below 100 – 150 m) of helicopters and aircraft on wildlife showed that birds are often disturbed and flushed from resting places especially by helicopters (e.g. Gladwin et al. 1988). Relevant information to this effect should be recorded, as distribution of birds may change as a result. Counts of birds will not be made during times when helicopters are present. The recording of the behaviour of birds at all times should give some insight into the mechanisms of bird associations with platforms, possibly provide species specific patterns, and potentially aid in long-term mitigation plans. Additionally, large-scale habitat information around the rig (such as chlorophyll concentrations and the location of oceanographic fronts) could be obtained using satellite images which could also aid in understanding bird association with platforms.

Timing is a critical aspect of every monitoring system. With respect to the associations of seabirds with platforms, it is essential in the first instance that the seasonal occurrences of different species of seabirds be delineated. In this respect, we propose that platform observers stay on the rig for 1 week per visit, and that surveys be carried out from the platform during each month of the year (resulting in at least 2 day and 2 night observations per month). Delineation of seasonal occurrences will not only indicate the times of highest risk should anything happen at the platform (see below) but also help clarify periods of major bird movements through the area and allow observations during a variety of seasonal and environmental conditions. Clearly, seasonal waves of migratory seabirds move over the Grand Banks, namely shearwaters in spring, storm-petrels in autumn and Dovekies and Thick-billed Murres in winter. Hence, we also propose, in addition to the above year-round surveys, to have an observer on the platform continuously for 2 months during September/October and during January/February. Air and water temperatures, salinity, wind speed and direction, visibility, sea state, lunar phase (see below), and if available speed and direction of ocean currents should be recorded during all surveys. Over the long-term, this survey design will allow interannual variation in the timing of seabird species occurrences and abundances to be documented.

It is important to stress that 'observers' should be people specifically trained for this task (Tasker et al. 1984, Webb and Durinck 1992). Given the intense work loads of platform personnel, the rigorous design of the proposed study and the necessity for consistency in the observations, it is possible to carry out an effective monitoring program **ONLY** if it is done by skilled observers who are dedicated to this purpose on the platform.

2.2 Quantifying Seabird Mortality Due to Offshore Platforms

Mortalities associated with platforms are outlined above and those related to light occur mainly at night. In the case of oil pollution, however, observations will be made during the day and can easily form part of the monitoring scheme outlined above. If a pollution event occurs, its impact will be monitored and quantified. The observer should carefully record species-specific information on: (a) behaviour relative to the oil (attraction, repulsion, indifference, escape techniques after contact, etc.), (b) number and percentage of oiled individuals, (c) number of individuals and time spent preening oiled feathers, and (d) number, percentage and timing (elapsed time after spill) of dead individuals, which should be collected and autopsied if possible.

Other mortalities such as those caused by collision with the structure and incineration by the flare are believed to occur mainly at night. Weir (1976) pointed out that "nocturnal kills are virtually certain wherever a lit obstacle extends into air space where birds are flying... . The time of the year, siting, height, light and cross sectional areas of the obstacle and weather conditions will determine the magnitude of the kill." Evidence also suggests an association between lunar phases and mortalities at lighted structures. Verheijen (1981), Crawford (1981) and Reed et al. (1985) all presented evidence and offered explanations for the influence of lunar periodicity. Lunar phase, visibility of the moon, sky conditions and ambient light need to be recorded and surveys need to be conducted during different lunar phases. Weather patterns greatly influence avian mortality. Specifically, periods before or after cold weather fronts, storms and fog, have been identified as critical times for increased avian mortality. With respect to time of day, Sage (1979) recorded the highest number of birds flying into a flare between 2300 and 2400 h, while Wallis (1981) noted the greatest number of birds circling lights between 0100 and dawn.

2.2.1 Recommended Survey Design

As indicated above, surveys should be carried out during each month and more intensely during migration periods. Ideally night surveys should begin at the onset of darkness (i.e. 30 minutes after sunset), last for 30 minutes and be repeated every hour until dawn. The number and behaviour of birds near the lights of the structure and the flare should be noted for each species. Care should be taken not to look continuously (and never with binoculars) into the flare due to possible irreparable damage to the eyes from the infra-red radiation. It is recommended that dark glasses be worn (Hope Jones 1980).

Surveys carried out in this manner will quantify species- and time-specific mortality due to the lighting and flaring at platforms. However, such studies will not allow investigation of effective means of minimizing these problems. The following manipulations are based on experiments elsewhere that have proven effective in reducing bird mortalities. In one case, experiments using red filters were found to reduce bird casualties by 80 % (LGL Limited 1972). Elsewhere ceilometer beams were outfitted with filters that only let UV-light through, greatly reducing the number of large kills. In addition, airports at the time were alerted of large migrating flocks in the area and shut off the ceilometer completely, reducing bird mortality at these sites to a minimum (Terres 1956, Weir 1976). An experiment conducted by Reed et al. (1985) also showed that the upward shielding of lights reduced the attraction of two petrel species by 40 %. Finally, many of the birds that are found around platforms (e.g. fulmars, shearwaters, storm-petrels) feed on small plankton. The current practice of discarding macerated gray water provides a direct food source and could easily be avoided.

We recommend the following experimental and mitigative manipulations:

1. Schedule flare shutdowns for maintenance during critical periods of migration (September/October, January/February);
2. Possibly add a non-noxious chemical to the flare which will change its colour towards the blue and/or red end of the spectrum;
3. Close the blinds of all windows of the living quarters after dark;
4. Turn off all outside lights not needed after 2200;
5. Shield safety and all outside lights towards the sky;
6. Consider making outside lights red or blue (or at least in one section of the platform for immediate comparison);
7. Do not discard any waste into surrounding waters for one month and compare the number of birds associated with platform to periods where waste was discarded.

Experiments of this kind have been carried out at platforms elsewhere and are essential, as birds are attracted primarily to light sources rather than the areas they illuminate (Reed et al. 1985). Together, surveys and experimentation will make it possible to identify critical times of the year (e.g. migration from September to November) and times of night and allow for development of effective forms of mitigation.

3 Conclusions

Despite the attention that negative impacts of offshore oil platforms on birds have received, the degree of association of birds around eastern Canadian offshore platforms and the nature and timing of the described bird mortality around them is unknown. Knowledge from elsewhere in the world suggests that there could be a potentially large problem. Risks associated with offshore oil exploration an production is unique in the Northwest Atlantic, not only because is occurs in deeper water much further form shore than any platform in the North Sea, but also because of the much larger numbers of vulnerable seabirds present. Inferences from other places to this area are, therefore, difficult and the need for baseline information for this area can not be overstated.

We recommend a monitoring and mitigation system that will measure and reduce both avian association and mortality around offshore platforms and in the long-term will lead to effective forms of mitigation. Specifically, we recommend:

1. Minimizing anthropogenic disturbance by light and the elimination of sewage discard;
2. Schedule flare shutdowns for maintenance during critical periods of migration (September/October, January/February);
3. Simultaneous platform-based and boat-based surveys to systematically quantify the degree of avian association with platforms in comparison to bird abundance in surrounding waters;
4. Weekly boat and monthly platform surveys, with more intense platform surveys during periods of migration;

5. Surveys in a radius around platforms with binoculars, spotting scopes and night vision goggles during 30 minutes of every hour during daylight and for 30 minutes of every hour at night on different days;
6. Experimental and mitigative manipulations, such as closing blinds of living quarters after dark, shielding outside lights toward the sky, and manipulating the light spectrum of outside lights;
7. Using trained observers who should be independent of the vessel and platform personnel due to the need for dedication to the task and the rigor of the surveys.

Together, surveys and experimentation will make it possible to identify critical times of the year (e.g. migration from September to November) and of the night, to quantify the extent of the problem and different impacts on various seabird species, and to recommend effective forms of mitigation.

IV Seabird Monitoring from Offshore Support Vessels and Other Ships

The distribution of birds at sea has been studied for many years (e.g. Jespersen 1924, Wynne-Edwards 1935). Biological and physical factors influencing seabird distributions at sea and those ultimately regulating seabird populations are the subjects of long-existing debates in marine ornithology. Seabird biologists have recently made great advances in understanding short-term variability in densities and distributions of seabirds and relating these to dynamic processes in the ocean (e.g. Decker and Hunt 1996, Logerwell et al. 1998, O'Driscoll 1998). Most researchers counting birds at sea also record physical oceanographic features (e.g. sea surface temperature, salinity) and/or prey variables. Studies involved in counting birds at sea have also been used to estimate baseline densities in specific areas and to compare seasonal and interannual fluctuations (e.g. Veit et al. 1996). Ultimately, seabirds appear to reflect ocean climate change and shifts in trophic interactions within marine communities. Consequently, seabird distribution and abundance data, along with dietary data, collected over many years provide a tool for managers to predict or detect ecosystem change. Such baseline data are also important in quantifying changes in seabird population size with regard to offshore hydrocarbon developments that may influence seabird populations through spills, environmental contamination, attraction to platforms and supply vessels and general disturbance.

Counts of birds at sea can also contribute to population estimates, which can be used in conjunction with other data (e.g. population estimates at breeding colonies) to show long-term population change. High quality counting methods integrated with other aspects of biological and physical oceanography lay the groundwork for quantitative environmental impact studies of seabirds. Unless accurate methods are used consistently, such impact studies are of little value. This is particularly true for seabirds at sea, where animal detection and density estimate errors occur.

1 Goals and Objectives

The goals of this contract are to provide a comprehensive framework with which to assess the seasonal vulnerability of seabird species to hydrocarbon extraction activities and the long-term impacts of hydrocarbon industrial development on seabird populations on the Grand Banks and Scotian Shelf. The objectives of this report are to:

- review relevant methods of counting birds at sea
- recommend a research design to systematically survey seabird and marine mammal species occurrences, distributions and abundances throughout the year in the Northwest Atlantic study area

The research proposed in this report will provide baseline data on seabird and marine mammal species occurrences, abundances and densities in various areas and their associations with biological and physical oceanographic features. This baseline information will enable managers to assess the vulnerability of seabirds and marine mammals to oil pollution in certain areas and during certain times of year. In addition, risk analyses and quantitative impact studies of pollution events can be conducted. Overall, the integration of baseline data into future oil development decisions will help shift management orientation more from reactive contingencies toward proactive conservation strategies for the marine environment. All objectives will be set in a context appropriate to the conditions prevailing around the CAPP oil platforms and oil transportation lines off Newfoundland and Labrador.

2 Review of Seabird Counting Methods

Systematic transects present standardized methodologies with which to investigate wildlife populations (Yapp 1956, Emlen 1971, Krebs 1989, Bibby et al. 1992). Transects allow estimation of seabird abundance in survey areas. They can consist of several small units, during which seabirds are counted for 10 minute intervals or a continuous recording of seabirds while a ship is moving between two points (Gould and Forsell 1989). Suggestions for carrying out seabird counts with confidence limits are given by Ford and Qualis (1984).

Obtaining comparable density estimates for seabirds in different oceanic regions was the main motivation for standardizing counting methods of seabirds at sea. We carried out an intensive literature review of seabird counting schemes worldwide. Table 1 summarizes counting protocols used in various oceanographic regions. The locations of these studies are presented in Figure 2,and Table 2 lists the relevant seabird counting methods available at present. We conclude from this review that the most relevant seabird counting techniques are the following:

- **Strip transects**. Transect with a set width, also called zone count, band transect including instantaneous or 'snapshot' accounts (Griffith 1981, Heinemann 1981, Tasker et al. 1984, Van Franeker 1994).
- **Line transects**. Counts with unlimited width (Bailey 1966, Shuntov 1972, Brown et al. 1975).
- **Bar counts** (Griffith 1981). Birds flying over an imaginary perpendicular line from the vessel.
- **Vector method** (Spear et al. 1992a, 1992b).

There are few empirical comparisons of these counting methods (e.g. Powers 1982, Duffy and Schneider 1984, Van Franeker 1994, Van der Meer and Camphuysen 1996, see Briggs et al. 1985 for ship vs. aerial surveys). The primary counting methods used currently are modifications of the strip transect method. The method detailed in Tasker et al. (1984) is the most widely accepted strip transect method among seabird surveyors in the North Atlantic (see Spear et al.

1992a, 1992b for the Pacific). Potential criticisms of this method are related to the difficulty of estimating distances of birds from the ship and to the time-demanding and difficult nature of instantaneous counts of flying birds ('snapshots') in areas of high bird abundance (Haney 1985, Gaston et al. 1987a; but see Tasker et al. 1985). Despite these problems, the 'Tasker Method', or European Method, allows a very solid estimation of bird densities (birds per unit area) which is essential when using vessel-based surveys to monitor seabird population fluctuations. The vector method (Spear et al. 1992a, 1992b) is potentially even more reliable because it takes movements of birds directly into account. In areas of high bird abundance, however, a single observer would become overwhelmed and the enhanced precision of this method would be quickly swamped by the inherent variability in bird numbers along a transect. The vector method has not been applied in the North Atlantic due to the high abundance of birds in this area and because it requires a minimum of two observers. For the remainder of this review, we primarily consider strip transect methods, with a particular focus on the 'Tasker Method'.

A major component of density estimations from seabird counts involves measuring the distance of birds from the ship, which can be difficult due to the lack of spatial references at sea. Determining whether birds are inside or outside of the transect has been identified as one of the major sources of imprecision among observers (Ryan and Cooper 1989). Heinemann (1981) advanced the use of a range finder that allows accurate distance estimations. This technique, however, requires the ship to be stable and a clear view of the horizon, which rarely exist in combination (Gould and Forsell 1989). The accuracy of the range finder also is reduced at observer heights less than 8 m. Another method of distance estimation is triangulation of an object using calipers combined with ship speed measurements (Dixon 1977, Heinemann 1981, Gould and Forsell 1989). This technique, however, can be severely biased if ship movement is considerable and works only for stationary objects, such as sitting birds, when ship speed is known and constant. Other methods of distance measurement include using distance bands, where the distance can be evaluated on radar or in a harbour prior to the survey using objects at known distances.

Conversion factors for seabird counts are available to correct density estimates for species that are detected at only moderate distances from the ship (Emlen 1971, Griffith 1981, Diamond et al. 1986). These factors are normally based on a detection curve for each species and require seabird observations to be accompanied with distance information. Procedures for this are well described and evaluated and appropriate software is available (e.g. DISTANCE; Buckland et al. 1993). Seabird counts, however, can vary over 3-5 orders of magnitude along a single transect. Due to this inherent variability in seabird counts, conversion factors have little utility unless density estimates in an area are consistent.

The angle of view for seabird counts is another important consideration for density estimates. Tasker et al. (1984) outlined a 90o angle, covering 300 m off one side of the ship. This approach has the disadvantage that flocks of birds are excluded if they occur on the "wrong" side of the ship. Therefore, this approach is not recommended when birds are distributed in clumps or are rare. Other common counting approaches cover a 180o angle centred on the bow of the vessel. This involves a larger area of coverage and can result in bird densities being underestimated, owing to the larger area that observers have to scan. Counts made using a 360o angle might be useful for areas where very few birds are expected, though ship-following species have to be accounted for (see Griffith 1981).

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Table 1. Summary of seabird survey characteristics (observation period, viewing arc, ship speed, transect width and length, ship-following birds, seabird counts) as used and/or recommended by various researchers in various locations

Location	Method of survey[1]	Period of observation	Viewing arc[2]	Ship speed[3]	Transect width	Transect length	Seabird counts (behaviour)	Ship-following birds	Author(s)
Baltic Sea	Strip transect	10 min	90^0	n.a.	300 m (+ inner divisions)	10 min	all birds	n.a.	Durinck et al. 1994
North East Atlantic	Line transect	10 min	180^0	6-40 km/h	Unlimited	10 min	all birds (behaviour recorded)	recorded separately	Blake et al. 1984, Tasker et al. 1984, Webb and Durinck 1992, Camphuysen and Leopold 1994
	Strip transect	10 min	90^0	6-40 km/h	300 m (+ inner divisions)	10 min + end of visibility for snapshots	flying birds with snapshot counts	recorded separately	Blake et al. 1984, Tasker et al. 1984, Webb and Durinck 1992, Camphuysen and Leopold 1994
Atlantiic	Line transect	1 day	360^0	n.a.	Unlimited	1 day	all birds	counted once daily	Jespersen 1924
	Line transect	10 min	90^0	n.a.	Unlimited	10 min	all birds	n.a.	Bourne 1976
NW Atlantic	Line transect	10 min	360^0	4 km/h	Unlimited	10 min	all birds (behaviour recorded)	recorded each time when seen	Brown et al. 1975 Brown 1986 (PIROP)
NW Atlantic	Strip transect	15 min	90^0	4 km/h	300 m (+ inner divisions)	15 min	all birds (behaviour optional)	recorded separately	Miller et al. 1980 (Manomet Observatory Manual), Smith et al. 1990
Arctic	*Does not report any methods*								Hunt 1990, 1991

Location	Method of survey[1]	Period of observation	Viewing arc[2]	Ship speed[3]	Transect width	Transect length	Seabird counts (behaviour)	Ship-following birds	Author(s)
Alaska Continental Shelf)	Strip transect	continuous	90^0	n.a.	300 m (+ inner divisions)	n.a. (continuous)	Recorded all birds (behaviour recorded)	recorded once	Hunt et al. 1981
(Kodiak)	Strip transect	10 min	90^0	7-9 km/h	300 m	10 min + end of visibility for snapshots	flying birds with snapshot counts	recorded separately	Forsell and Gould 1981, Gould et al. 1978
	Strip transect	10 min	90^0	10 km/h	300 m	10 min + 300-500 m for snapshots	flying birds with snapshot counts	recorded separately	Gould and Forsell, 1989
Northern Pacific	Line transect	1 h (exact min)	270^0	10 km/h	Unlimited	1 h	all birds (behaviour recorded)	n.a.	Gould 1974
	Strip transect	10 min	90^0	15-22 km/h	300 m	10 min (max. 3000m)	all birds	recorded separately	Gould 1983
NE Pacific (Canada)	Strip transect	exact min	90^0	3-10 km/h	300 m	Depending on sampling design	all birds (behaviour recorded)	n.a.	Logerwell and Hargreaves 1996
California & California Current	Strip transect	exact min	90^0	18.5 km/h	200 m	3 km	all birds (behaviour recorded)	recorded separately	Croll 1990
	Strip transect	10-20 min	90^0	n.a.	400 m	4 Nm	all birds	n.a.	Briggs and Hunt 1981, Briggs et al. 1985 Spear et al. 1992
	Vector method								

Location	Method of survey[1]	Period of observation	Viewing arc[2]	Ship speed[3]	Transect width	Transect length	Seabird counts (behaviour)	Ship-following birds	Author(s)
New Zealand	Strip transect	continuous (summed every 2 min)	180^0	6 km/h	200 m (100 m each side)	6 and 21 km 400 m for snapshots	flying birds with snapshot counts	recorded separately	O'Discroll 1998
Indian Ocean	Line transect	1 h	360^0	n.a.	Unlimited	1 h	all birds	recorded each time when seen?	Bailey 1966
	Line transect	2-3 h (stationary vessel)	360^0	0 km/h	Unlimited		all birds	n.a.	Gill 1967
		1 h (moving vessel)	180^0	10-15 km/h	Unlimited		all birds	n.a.	
S Atlantic	Line transect	continuous (during day-time)	180^0	n.a	Unlimited?	1 day	all birds	n.a.	Tickell and Woods 1972
S Africa	Strip transect	exact min	90^0	n.a.	300 m	Continuous (300m)	all birds	n.a.	Schneider and Duffy 1985
Southern Ocean	Line transect with distance bands	10 min	130^0	26 km/h (14 knots)	Unlimited (but with distance bands)	1 h	all birds that crossed a line perpendicular to the transect	recorded separately	Griffith 1981

Location	Method of survey[1]	Period of observation	Viewing arc[2]	Ship speed[3]	Transect width	Transect length	Seabird counts (behaviour)	Ship-following birds	Author(s)
	FIBEX: Line transect with distance bands	10 min	90^0	n.a.	Unlimited (but with distance bands)	10 min	all birds	recorded separately 10-min stern counts every h	BIOMASS 1992
	SIBEX: Strip transect				300 m				

[1] Line transects are unlimited width transects, strip transects are limited width transects [2] Some reported by Tasker et al (1984) [3] Recommended or used sheep speed

Table 2. Detailed summary of major counting methods including evaluations (advantages, disadvantages, observer's skill, accuracy and feasibility of method).

Author(s)	Method	Location	Characteristics	Advantage	Disadvantage	Observer's skill	Accuracy	Feasibility
Bailey 1966	birds/h	Indian Ocean (Arabian Coast)	Observation deck at 13 m. 360° viewing arc. width: unlimited. length: unlimited. ship's speed: n.a., counting periods: 1 h. counted all birds and species	easy to do in an undescribed avifauna (not preoccupied with estimating width). comparable abundance estimates within study area	temporal scale too coarse for examining seabird-environment interactions (environmental heterogeneity missed). behaviour not reported. ship-following species not specified	good bird identification skills		very feasible. but in areas of high concentration. a 90° or 180° viewing arc may be more practical.
Brown et al. 1975. Brown 1986	birds/10 min. birds/km	Western North Atlantic (Eastern Canada)	Observations made from various ships between 1969-1983. 360° viewing arc. width: unlimited. length: unlimited. ship's speed: min. 7.4 km/h. counting periods: 10 min. counted all birds and species within transect including ship-following species	10 min periods are sensitive to areas of rapid oceanographic change. long-term project	ship-following species are part of relative abundance likely leading to overestimations	good bird identification skills		very feasible. but in areas of high concentration. a 90° or 180° viewing arc may be more practical.
Gould 1983	birds/km^2	Northern Pacific (Alaska and Hawaii)	observation deck at 8 m. 90° viewing arc. width: 300 m. length: projected forward end of 10 min counting periods (max. 3000 m). ship's speed: 15-22 km/h. counted all birds and species within transect but ship-following birds recorded separately	estimates of density are produced. ship-following species not part of density estimate	behaviour not reported. density likely to be overestimated by flying bird fluxes. requires rangefinder as a tool. potential rare sightings outside transects are ignored	good bird identification skills. requires to be trained well to deal with limited width counting	level of accuracy decreases at the forward end of the 10-minute transect where the width of 300 m is difficult to estimate	feasible if observer is well trained in estimating width

Author(s)	Method	Location	Characteristics	Advantage	Disadvantage	Observer's skill	Accuracy	Feasibility
Miller et al. 1980 (Manomet manual)	birds/km^2	Western North Atlantic (New England, USA)	90° viewing arc. width: 300 m. length: projected forward end of 15 min counting periods. ship's speed: min. 7.4 km/h. counted all birds and species within transect area but ship-following birds recorded separately. rare sightings also recorded separately. behaviour, age, colour phase description optional	estimates of density are produced. ship-following species not part of density estimate. rare sightings not ignored	behaviour description not mandatory. density likely to be overestimated by flying bird fluxes. requires rangefinder as a tool	Good bird identification skills. requires to be trained well to deal with limited width counting		Feasible if observer is well trained in estimating width
Spear and Ainley 1992a, 1992b	Vector Method: Absolute densities of flying birds	California	Observation deck 4-11 m. 90° viewing arc. two observers minimum. width 300-600 m depending on height. unlimited 15-30 min segments. correction for ship followers	High detection rate (2 observers). unbiased density estimates. detection of migratory movements. estimates of density. narrow confidence limits possible. sensitive to rapid change	Trained observers necessary. two observers	Good birding identification skills. skills using range finder		Feasible if two observers are well trained
Tasker et al. 1984. Webb and Durinck 1992	1) birds/km^2 2) birds/10 min	North East Atlantic (but also elsewhere, e.g. Falkland Island, Antarctica)	Two methods exist which shall be used simultaneously <u>1) density estimates:</u> 90° viewing arc width: 300m with inner 100m divisions. length: projected forward end of 10 min counting periods. ship's speed: 6-40 km/h counted all sitting birds within transect area. counted flying birds via instantaneous counts. birds moving across the bow of the ship are counted in 1 min counts. ship-following species recorded separately. <u>2) index of abundance:</u> unlimited width counts. 90° viewing arc at high bird densities. 360° viewing arc at low bird densities	The simultaneous use of two methods provides absolute densities but also indices of abundance comparable with past studies: method 2 ensures that birds present at low densities are not entirely ignored: theoretically, instantaneous counts give an accurate representation of density of flying birds at a given place and time	The simultaneous use of two methods may take two observers. instantaneous counts may take too much time in areas of high activity and thus not be instantaneous anymore	Good bird identification skills. method 1 requires well trained and experienced observer. method 2 requires a casual observer only		Feasible for one observer (but we suggest a second observer) and at least one observer is very experienced

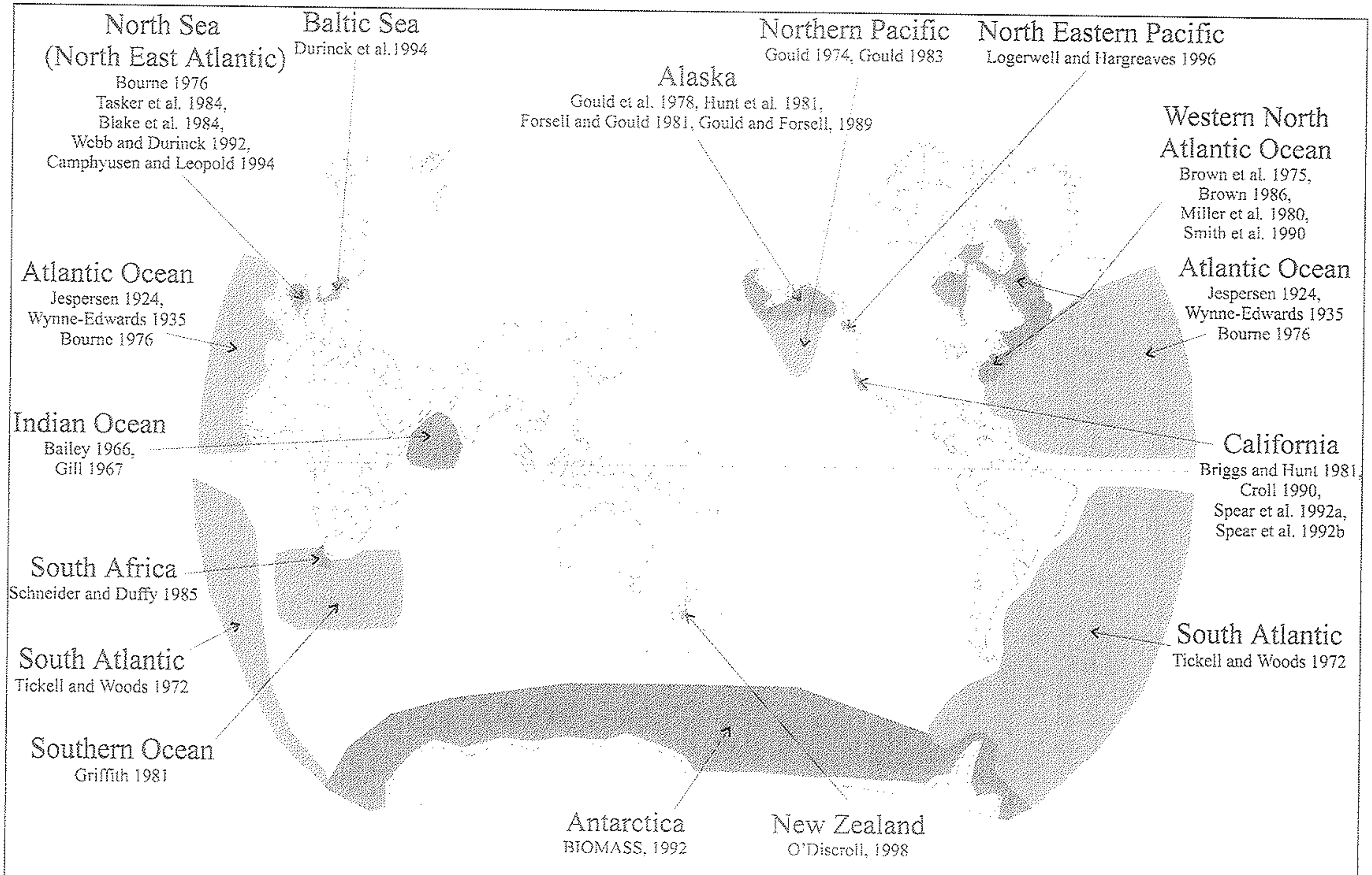

Figure 2. The locations of all seabird surveys investigated in this review along with associated references.

2.1 Research Design Considerations for Counting Birds at Sea

Seabird counts at sea can be inaccurate in two general ways. First, birds can be overlooked or not detected at sea, resulting in density underestimates. Second, bird densities can be overestimated at sea. These inaccuracies can be minimized by rigorous training of observers and must be considered when designing a research program to estimate bird densities via vessel-based strip transect methods.

2.2 Problems with Bird Detection (Underestimates of Densities)

Birds sitting on the water are less likely to be counted than flying birds because they are less conspicuous. A number of environmental characteristics, primarily wind and fog, can make sitting birds difficult to detect at sea. Bird characteristics also can lead to density underestimates of some species throughout the year and of some species at certain times of the year. Generally, dark coloured species that are more likely to sit on the water (e.g. auks) are more prone to density underestimates.

2.2.1 Environmental Characteristics

Weather can lead to a reduced ability to detect birds sitting on the water. Atmospheric conditions include wind speed, wind direction, sunlight, and precipitation (i.e. rain, snow, hail, mist, fog). These influence sea surface conditions, such as wave height and direction and white cap frequency, all of which limit bird detection. Other marine conditions, such as currents, tides, fronts, influenced by wind, atmospheric and Corriolis effects, global forcing and bathymetry, also affect bird distribution and hence detectability at sea. The following weather characteristics must be considered to reduce detection biases at sea (Webb and Durinck 1992).

Strong Wind: High wind and larger swells render birds on the water less visible. High wind can also affect bird behaviour and may cause birds to fly off the water earlier to escape an approaching ship, stay air-borne, or stay sitting. This forces the observer to look further ahead. Observers may find it more difficult to see and to hold equipment (e.g. clipboard, binoculars). Overall, observers should avoid counting in winds over 45 – 55 km/h (25-30 knots). A smaller area should be scanned (90° vs. 180° scan) and observers should move to a higher position on the vessel. Increasing observer height by 2.1 m (from 4.8 to 6.9 m) increased the mean maximum distance for detecting auks by 25% (Dixon 1977). At times, ship heading can be changed relative to the prevailing surface wind. The mean distance at which flying birds were seen increased by 23% when the angle of the wave fronts was less than 45° from the ships bow (Dixon 1977).

Wave/Swell Height: Heinemann (1981) and Duffy (1983) reported that wave height affects the time needed to detect each bird and hence the number of birds observed. In relation to observer height, fixed-width transects are relatively insensitive to swell height, whereas unlimited counts are not (Diamond et al. 1986).

Precipitation, Spray and Fog: These factors can obstruct vision and reduce the distance at which birds are detected. If visibility is less than 300 m, however, counts should not be stopped. In areas that are always foggy (e.g. southern Grand Banks), the width of the count zone can be reduced appropriately. Individual birds will be missed but major aggregations will be detected. The frequency of encounters with aggregations may be a useful indicator of population change due to the patchy distribution of seabirds at sea. Data can later be analyzed for occurrence of aggregations using appropriate statistical methods (e.g. spectral or spatial autocorrelation analyses). This precludes discarding large data sets and allows researchers to survey areas where fog is consistently a problem.

Sun Glare: Glare can increase the amount of contrast on the surface of the water and can obliterate part of the field of view. Cloud cover can darken the colour of the sea, also rendering birds sitting on the water less conspicuous (Dixon 1977). These factors can reduce the distance at which birds are first detected.

Ice: Some seabirds associate with breaks in ice flows and with the edges of ice sheets (e.g. Dovekies and Thick-billed Murres). Care should be taken not to overlook birds near ice.

Sea conditions can also bias seabird counts indirectly, through seasickness of observers (Webb and Durinck 1997). Sea conditions, namely wave height, can also influence ship speed. Reduced ship speed can attract birds and mammals and thereby affect the number of seabirds counted due to the "confusion" of ships with trawlers that concentrate and provide discarded food (Van Franeker 1994, Garthe and Hüppop 1999).

2.2.2 Bird Characteristics

The size, plumage, colour and behaviour of seabirds play important roles in determining the detectability and hence the precision and accuracy of counts for particular species (Dixon 1977, Drummer and McDonald 1987). The two most relevant factors appear to be the size of the bird and the contrast of the bird's plumage with the background (Dixon 1977, Ryan and Cooper 1989). Ryan and Cooper (1989) investigated bird conspicuousness in detail using indices of bird detectability at sea for strip transects. These factors can change throughout the year as a result of different plumage types (e.g. breeding vs. winter plumage) and behaviour (e.g. inability to fly during wing moult vs. ability to fly during non-moulting periods).

2.3 Problems with Density Estimates (Overestimates of Densities)

Surveys employing transect methods should comprise an instantaneous count of a subset of a population (Griffith 1981). This is difficult in practice when animal movement is high relative to the mobility of the vessel (e.g. Bailey and Bourne 1972). Flying birds are more likely to be counted than birds sitting on the water because they are more conspicuous and more likely to cross the count zone. Generally, species that are more likely to fly (e.g. shearwaters) are more prone to an overestimate of density because an individual may be recorded repeatedly during the transect (Powers 1982, Tasker et al. 1984).

Tasker et al. (1984) described a method to reduce the overestimation of densities of flying birds, relative to sitting birds (the 'snapshot' method). They specify that flying birds should be counted continuously during the counting unit (10 minutes) along with a number of instantaneous counts. Instantaneous counts allow a single picture of traveling birds within the count zone at any one time by putting together a series of smaller pictures. The number of instantaneous counts required during the count unit depends on the maximum distance at which all traveling birds can be detected ahead of the ship and on the ship's speed. Small birds, such as storm-petrels, may require more instantaneous counts. The standard instantaneous count zone is about 300-500 m in front of the ship. Gaston et al. (1987a) investigated whether the time taken to complete the "snapshot" would correct the bias caused by bird movements by creating a simulation model based on a simplified strip transect. It was concluded that counting flying birds continuously and conducting the instantaneous counts could reduce attention aimed at sitting birds (Gaston and Smith 1984). Field tests of the snapshot method, however, suggest that it is a reliable method to reduce overestimates of flying birds, without increasing underestimates of sitting birds (Garthe pers. comm.).

The 'contact time' of a bird within the count zone influences the number of birds counted. Therefore, the chance of a flying bird entering the count zone is dependent on its flight speed and direction relative to the ship (Duffy and Schneider 1984, Gaston et al. 1987b, Spear and Ainley 1992a, 1992b). The rate of contact with the count zone will increase with increasing bird speed but the detection rate will decrease with increasing ship speeds (Wiens et al. 1978, Duffy and Schneider 1984, Spear and Ainley 1992a, 1992b). Gaston et al. (1987b) suggested that the effective area covered for flying birds must take into account the bird's speed and direction relative to the ship. If the birds are flying with uniform headings and the ship is in motion, then the number of birds observed will be affected by the angle between the ship's heading and the bird's heading (Gaston et al. 1987b). Researchers have also explored the effects of headwinds and tailwinds in order to adjust seabird densities for errors caused by wind speed and direction (e.g. Broni et al. 1985, Spear and Ainley 1997). Researchers also emphasize that these factors can hardly be measured or corrected under field conditions (Duffy and Schneider 1984).

2.3.1 Vessel Attraction and Ship-following Counts

Some species of seabirds forage opportunistically and are attracted to vessels (e.g. Duffy and Schneider 1984, Garthe and Hüppop 1999). Vessel attraction can lead to overestimates of density because an individual can be counted repeatedly (Griffith 1981). Therefore, the presence of a vessel can result in clumped observations that represent an overestimate of the true number of birds in an area. This subject is rarely addressed in seabird counting schemes but deserves more attention (e.g. counting protocols that take "clustering" into consideration; Bailey and Bourne 1972, Burnham et al. 1980, Drummer and McDonald 1987, Buckland et al. 1993). It is also important to distinguish between species that regularly follow the ship, and those that largely ignore the ship, to identify which species may be overestimated (Frost 1976).

2.4 Feasibility of Vessel-based Surveys for Monitoring Seabirds

The interaction of these biases is complex and density estimates may be misleading if they are not controlled or corrected. Methods for correcting biases are available (e.g. detectability analysis; Beavers and Ramsey 1998) if relevant environmental information (e.g. wind speed and direction) is collected while conducting counts (see Buckland et al 1993 for covariate modeling).

Vessel-based surveys limit the ability to randomly sample the survey area due to their slow speed. Webb and Durinck (1992) outlined the limitations of ship surveys as opposed to other transport mechanisms (e.g. aerial surveys).

Limitations of ship surveys:

- Ships have a low horizon, thus it is difficult to conduct total counts of species which form large flocks, such as some of the sea ducks, for which sampling surveys result in highly variable density estimates. (Supply vessels that service offshore platforms have sufficient height and space outside of the bridge for observers.)
- Ships move slowly and require long periods to survey large areas. If a rapid survey is required, it may be necessary to employ several ships.
- Slow speeds make ships expensive to charter for each square kilometer surveyed.
- Cost efficient ships that are engaged in other activities have the drawback of little or no control over the ship's route and survey track.
- Some ship activities, such as trawling, can influence the distribution of some seabirds.

Advantages of ship surveys:

- Ships allow time to record details about birds, such as species, age, plumage, and behaviour.
- Generally a large scanning area is available, which improves the chances of recording rare, inconspicuous, and diving birds.
- There is generally sufficient time to record birds, so one observer is usually sufficient.
- Ship surveys are cost efficient if the ship is engaged in other activities and is not especially chartered for surveys
- Biological and hydrographic factors that may influence seabird distribution can be collected simultaneously.
- Ships are only moderately vulnerable to weather and surveys can be carried out in up to gale force winds and in moderate visibility.
- The variation in density estimates of birds at sea is consistently higher for aerial transects than ship transects. This increases the number of surveys required to detect a change in population size (see section 3.2 on Power Analysis).

Given the biases involved in seabird density estimation outlined above, any additional bias, such as that caused by the inter-observer differences, must be minimized. Count discrepancies between observers can be reduced through intensive observer training programs and corrected by using individual detection curves (Ryan and Cooper 1989, Buckland et al. 1993, Beavers and McDonald 1998). Observers must become familiar with the detailed counting protocol being used and must be aware of potential biases in the counting method (Bailey and Bourne 1972, Miller et al. 1980, Tasker et al. 1984, BIOMASS 1992, Webb and Durinck 1992).

A number of studies have focused on inter-observer biases and have provided suggestions for observer training programs (Kepler and Scott 1981, Erwin 1982, Ryan and Cooper 1989, Van der Meer and Camphuysen 1996, Evans and Raphael 1999). First, surveyors should have some knowledge of the life history of relevant birds and scientific literature. Surveyors should learn seabird identification in the laboratory through the use of study skins, pictures and slides and this should be followed up with identification tests in the field. Observers must also be taught how to estimate distances, how to scan and where to focus eyes during the survey (Evans and Raphael 1999). Approximately 60-100 distance estimates per observer during the training period is recommended and distance estimates can be verified with a Laser Rangefinder using buoys as targets, allowing for direct feedback and corrections (Evans and Raphael 1999). Overall, training significantly reduces the errors caused by inter-observer differences (Kepler and Scott 1981, Erwin 1982, Buckland et al. 1993). In addition, some physiological and psychological factors must also be considered. Visual acuity (i.e. tunnel vision) and audio acuity must be evaluated (Kepler and Scott 1981), as must psychological factors, such as motivation, attention span and willingness to make identifications.

3 Experimental Design

3.1 Systematic Vessel-based Surveys for Seabird Occurrence, Abundance, Density and Distribution

There are a number of considerations that need to be taken into account when designing a seabird-monitoring program for impact assessment of oil pollution. The precision and accuracy of density measurements must be identified to determine the number of surveys required to detect a change in abundance. This is determined through "power analysis", which will be discussed in detail in the next section.

3.2 Power Analysis

Statistical tests are used to determine whether there is a statistically significant difference in seabird abundance estimates or density between two time periods (e.g. before and after an oil pollution event). The "power" of such a test refers to the likelihood of detecting a difference in estimates when density has changed. This ability to detect a significant difference depends on the smallest change in density that researchers are interested in (**S**), variation within the study area (**s**), and the number of surveys conducted (**n**). The basic relationship of these three variables follows:

$$n = s^2/S^2.$$

As the variation in density estimates increases and/or the smallest change in density desired to be detected decreases, the number of surveys needed increases (Figure 3). Seabird distributions tend to be naturally patchy. Therefore, estimates in one section are not independent of those in neighbouring sections of transects (autocorrelation; Schneider 1990). This introduces natural variation in density estimates of seabird data. Both the extrinsic and intrinsic variation should be carefully considered when designing seabird-counting studies.

Based on seabird counts conducted in our survey area (Davoren unpubl. data), we applied the software TRENDS (Gerrodette 1987, 1993, Link and Hattfield 1990, Thomas and Krebs 1997) to assess the required sample size to detect a difference in seabird density estimates. We preferred to use TRENDS rather than MONITOR because we assume that seabird surveys will be carried out regularly and from the same survey line (Thomas and Krebs 1997). The results are shown in Figure 3 and are based on the t-distribution, linear model and on the assumption that variance remains constant.

A number of scenarios were run based on different levels of variation in density estimates, which is represented here by the coefficient of variation (CV). The CV is simply the variance, specifically standard deviation, in density estimates divided by the mean density estimate. The CV for recent seabird density estimates in our study area range 0.20 - 8.3 in different seasons using systematic strip transects, specifically the 'Tasker Method' (Davoren unpubl. data, Wiese unpubl. data, Huettman and Diamond unpubl. data). Different levels of statistical power are suitable for biological studies, ranging from a 80 - 99 % chance of detecting a change when a change has occurred, or alternately, a 1 - 20 % chance of not detecting a change when a change has occurred. A power of 0.50 is equivalent to flipping a coin to determine where a change in density estimates has occurred and is included for comparison only. The number of surveys required to detect the rate of change in population size at different levels of power is shown in Table 3.

Table 3. A hypothetical example of the relationship between rate of change in population size and the number of surveys required to detect a change in population size of Common Murres with a breeding population size of 1,000,000. This is based on a CV of variation of 0.60 in density estimates throughout the study area

Rate of change in population size	No. of Individuals	No. of surveys required (Power=0.95)	No. of surveys required (Power=0.80)
0.10	100,000	34	28
0.20	200,000	30	22
0.40	400,000	26	18
0.60	600,000	24	16

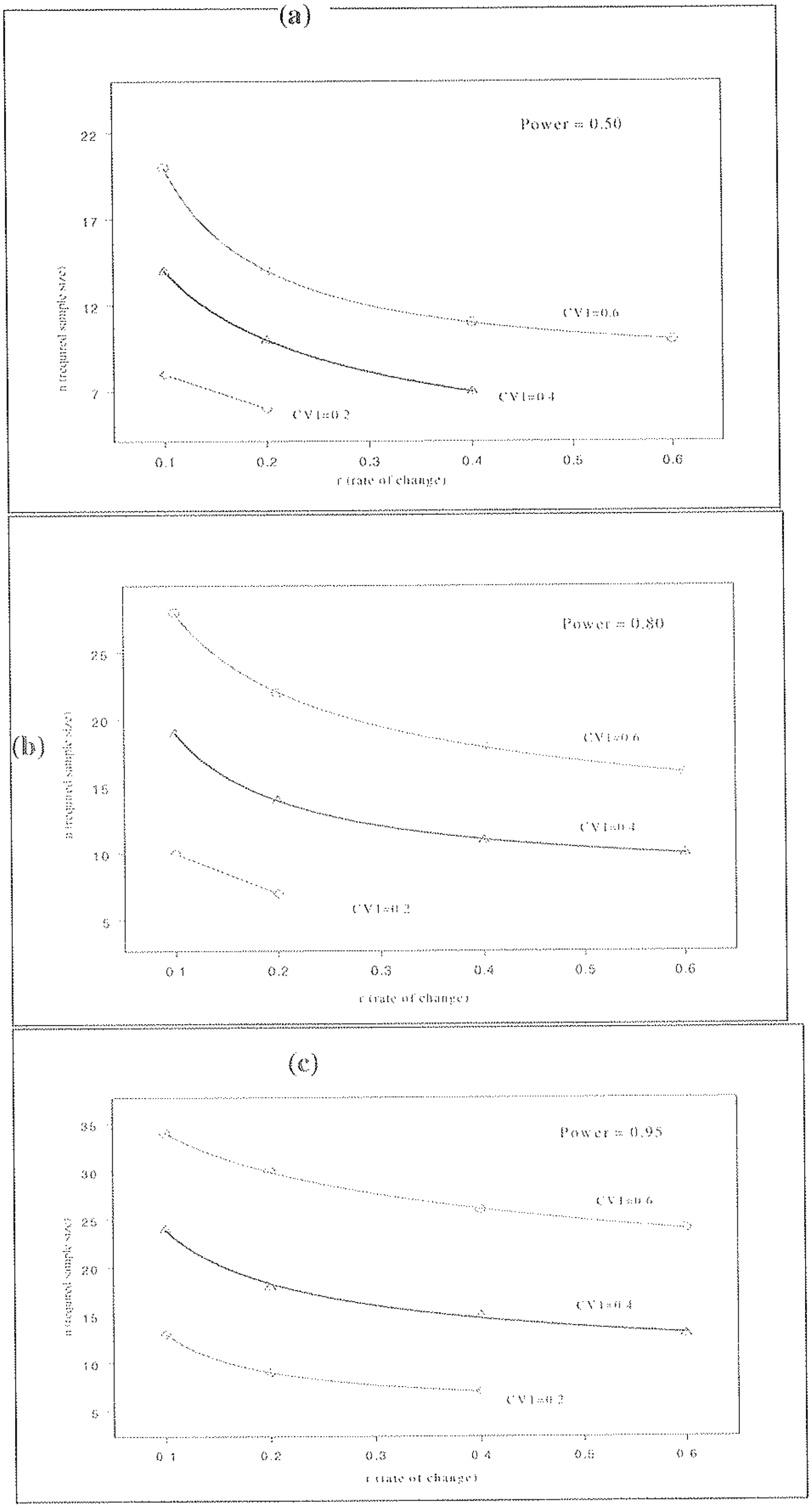

Figure 3. Calculated sample sizes for different coefficients of variation and power levels of 0.50 (a), 0.80 (b) and 0.95 (c).

4 Recommendations / Research Design

Bailey and Bourne (1972), Frost (1977), Drummer and McDonald (1987) and Buckland et al. (1993) indicated the importance of additional data (covariates) collected while counting seabirds, such as oceanographic or bird behaviour information. Basic physical oceanographic data that should be measured simultaneously with seabird counts are sea surface temperature and salinity. Biological oceanographic data that should be collected are the distribution and abundance of prey (i.e. fish and plankton) using hydroacoustic sampling equipment (e.g. EK 500 echosounder). In addition, marine mammal observations should be recorded similar to and simultaneously with seabirds counts (Gould and Forsell 1989, Buckland et al. 1993). Wind speed and direction should also be recorded via computer interfacing. During transects, Global Positioning System (GPS) should also be used to obtain accurate distribution data. These additional data will allow researchers to distinguish between shifts in seabird distribution and actual population declines.

An essential component of monitoring is training workshops for observers before, during and after survey seasons to assure quality control, correct use of equipment, assess bird counts, and accurate distance estimations. The counting method that we recommend is an unlimited-width line transect with distance estimation for bird observations. Birds will be counted continuously with instantaneous estimates of flying birds (Tasker et al. 1984) over a view angle of 90°. These counts can later be translated into fixed-width strip transect data with widths of various sizes. Well-trained and evaluated observers should conduct these surveys at least weekly (more often if possible) aboard supply vessels throughout each season. The resulting number of surveys (52 surveys/year, 13 surveys/season) will be sufficient to overcome both the intrinsic and extrinsic variation in seabird density estimates at sea and will ensure a conservative monitoring scheme for interannual and interseasonal comparisons (see Figure 3 for details). To further enhance the ability of distinguishing between shifts in seabird distribution and population declines, at least one survey covering the entire survey area (Grand Banks and Scotian Shelf) should be conducted in each season (minimum 4 surveys/year). Many vessels of opportunity occur in our study area including Canadian Coast Guard, Department of Fisheries and Oceans research surveys and oil tankers. Interpretations of population declines should be complemented with population estimates from breeding colonies conducted by the Canadian Wildlife Service. This approach is important in monitoring studies to specifically examine factors influencing biological processes and to place seabird distribution and abundance into the larger context of the marine ecosystem.

V Future Considerations: Assessment of Seabird Vulnerability to Oil Pollution

It is critical that we attempt to predict the risks associated with offshore oil development due to the adverse effects that oil pollution can have on marine systems (Wiens et al. 1984). Assessing the temporal and spatial vulnerability of each seabird species present in an area is important and involves evaluating a number of criteria.

1. The most important characteristic is the proportion of time a species spends on the water (i.e. primarily aquatic or aerial). This is mainly determined by the feeding ecology of the species and indicates the likelihood of contacting oil (Seip et al. 1991). All seabirds are vulnerable to oil pollution but those that spend most of

their time on the water's surface and dive (e.g. murres) are the most vulnerable (Camphuysen 1989, Wiese 1999).

2. Time spent along major shipping routes can increase the possible contact rate of seabirds with oil. 97% of all oil found on beaches and birds is heavy fuel oil which originates from large ships (T. Lock pers. comm.). Most Atlantic Canadian breeding and non-breeding aggregations of seabirds appear to be in proximity to major shipping lanes or offshore production sites.
3. Seasonal occurrence of different seabird species is crucial. Lock et al. (1994) suggested that the threat of oil pollution in the Atlantic region of Canada is highest during the nonbreeding season when populations are dominated by mainly aquatic species (auks), water temperatures are lowest and populations expand into oil development and shipping areas. This suggestion was recently corroborated by Wiese and Ryan (1999) who showed through beached bird surveys that the proportion of oiled birds found is significantly higher in winter (71%) than in summer (9%).
4. Seabird life histories are generally characterized by a long lifespan, delayed sexual maturity and production of a small number of offspring once each year. This life history strategy renders seabirds highly vulnerable to declines in survival rates of breeding individuals. Aggregative behaviour of seabirds (i.e. colonial breeding, flocking at prey concentrations) further increase the likelihood of high numbers of individuals contacting oil pollution events.

Overall, this suggests that the abundance of seabird species along major shipping routes and near offshore oil production sites is most important in the winter, though migratory passages during autumn and spring and high concentrations of birds around breeding colonies during summer are also of concern and need to studied (Huettman and Diamond in press).

Spear et al. (1995) emphasized that density estimates in areas where oil spills are likely are important in assessing the vulnerability of seabirds to oil contamination. They also emphasized the need to quantify qualitative attributes (i.e. behaviour, biology) and combine these with distribution and abundance data into indices that assess vulnerability in the context of potential exposure to oil (e.g. Bird Oil Index, Spear et al. 1995; Oil Vulnerability Index, King and Sanger 1979; see also Carter et al. 1993). Using a similar index (Area Vulnerability Index), European seabird researchers can provide risk assessments of different areas and times of year (Carter et al. 1993). They can attempt to assess the impact of establishing a drilling platform in specific areas, the impact of an oil pollution event and can recommend the scale of the response effort (e.g. response rate) for specific oil spills (M. Tasker pers. comm.). They can also determine population trends by comparing current density estimates with a long time series of baseline data. Our long-term goals are to conduct similar risk analyses and collect baseline data which will allow us to conduct quantitative impact studies of pollution events. We are presently limited by the lack of basic understanding of the behavioural ecology of marine birds at sea. More information is needed on populations at sea, spatial and temporal distributions, abundances and activities of marine birds, as well as on survival rates at sea, sizes and age structures of breeding populations and reproductive output of colonies.

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VII Appendices

Appendix 1. The names of people who were invited to the workshop and their place of business

Name	Company
Attended	
Terry Harvey	Canadian Coast Guard
Pierre Ryan	Canadian Wildlife Service
Paul Barnes	Canadian Association of Petroleum Producers
Kim Oxford	Canadian Association of Petroleum Producers
Dave Burley	Canada-Newfoundland Offshore Petroleum Board
Richard Veit	College of Staten Island
Mark Shrimpton	Community Resources Ltd.
John Anderson	Department of Fisheries and Oceans
Dave Taylor	Hibernia Management Development Company
Bill Montevecchi	Memorial University of Newfoundland
Francis Wiese	Memorial University of Newfoundland
Gail Davoren	Memorial University of Newfoundland
Len Zedel	Memorial University of Newfoundland
Stephen Full	PanCanadian Petroleum Ltd.
Urban Williams	Petro-Canada/Terra Nova
Mark Tasker	UK Joint Nature Conservation Committee
Tony Diamond	University of New Brunswick
Falk Huettmann	University of New Brunswick
Julia Linke	University of New Brunswick
Regrets	
Andre d'Entremont	Canada-Nova Scotia Offshore Petroleum Board
Don Sutherland	Husky Oil
Cal Ross	Sable Offshore Energy Inc.