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Bird Dispersal and Deterrent Techniques for Oil Spills in the Beaufort Sea

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BIRD DISPERSAL AND DETERRENT TECHNIQUES FOR OIL SPILLS IN THE BEAUFORT SEA

William R. Koski, Sherrene D. Kevan and W. John Richardson

LGL LIMITED, environmental research associates
22 Fisher Street, P.O. Box 280
King City, Ontario
L7B 1A6

with contributions by

Kirk Strom

The Delta Environmental Management Group Ltd.
555 Fourth Ave. S.W., Suite 907
Calgary, Alberta
T2P 3E7

Scientific Advisor: Lynne Dickson

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W. Jackson, Dep. Biol. Sci., Bowling Green State Univ., Bowling Green, OH

SUMMARY

This report describes the techniques that are most likely to be effective for dispersing and deterring birds in the event of an oil spill in the Canadian Beaufort Sea. Potential techniques were identified during a literature review that emphasized information published since 1976. An evaluation of their likely effectiveness in the Beaufort Sea region considered the species of birds present, the behaviour and mobility of the birds, logistics considerations, and the proven or likely effectiveness of the techniques based on the literature review. Few of the data on effectiveness of dispersal and deterrent methods have come from oil spill or related situations. Most relevant reports have involved attempts to keep birds away from airports, aquaculture facilities, orchards, or farm fields. Many of the published accounts are anecdotal; only a few involve controlled quantitative tests of deterrent effectiveness.

The major finding of this report is that no dispersal or deterrent method is likely to be very effective in protecting birds during a major oil spill in the Beaufort Sea. However, smaller spills are more common. In some of these situations, a significant reduction in mortality would be possible if bird dispersal and deterrent methods were applied promptly and diligently. Even in these cases, the bird deterrent/dispersal program may physically stress some birds and result in reduced breeding success in the year of the spill or (less likely) in later years. However, this may be acceptable if the alternative is prompt death of these birds by oiling.

In any given spill situation, judgements will be necessary as to the appropriateness of a bird dispersal/deterrent program. Use of dispersal and deterrent techniques may cause, or contribute to, the death of some birds, e.g. by displacing them from required habitat or into oiled areas. Therefore, a program should be chosen for maximum effectiveness and minimum likelihood of collateral losses of birds.

The techniques that are most likely to be effective will depend on the species of birds that will be encountered, the reason for their presence in the area, whether they can fly at the time of the spill, and the ability to deploy the technique. The most universally applicable method of bird dispersal is to haze birds with aircraft. The most universally applicable deterrent techniques include gas cannons, shotguns, shellcrackers, rockets and mortars. These devices would need to be stockpiled in the region prior to a spill in order to allow reasonably quick deployment.

In most spill situations, ***aircraft*** will have some value in dispersing birds from the spill area. Aircraft can fly quickly to spill locations and can be used to disperse birds from a large area with a minimum amount of manpower. Although helicopters tend to have more limited range and endurance than fixed-wing aircraft, the greater manoeuvrability of helicopters would be beneficial in "herding" birds away from the oil spill. Aircraft have limitations as dispersal and deterrent methods. They cannot be kept aloft in a spill area continuously for the days or weeks when the oil might be hazardous to birds. Also, during a major spill, aircraft will be in heavy demand, and may not be available for bird dispersal

Gas cannons, pyrotechnics and human effigies ("scarecrows") can be deployed in wetland areas, along shorelines, and on barrier islands adjacent to spills, or from rafts or boats in oiled water. Pyrotechnics are especially effective, both for bird dispersal and for bird deterrence, but are labour intensive. Cannons and effigies are easy to deploy, require minimum maintenance, and operate for several weeks without being replaced. However, they should be moved frequently to prevent or reduce habituation.

In some situations ***boats*** may be useful to herd birds, e.g. moulting waterfowl. Boats could also be used as platforms to deploy other techniques in sheltered waters or if winds are calm.

Several ***other methods*** might be useful and practical in certain situations, but are limited in applicability and/or probable effectiveness. Flashing lights, flares, trapping, hazing by model aircraft, playbacks of distress or alarm calls, displays of dead birds (or models of birds in "distressed" postures), and "Av-Alarm" may be useful in specific situations.

A few techniques could not be fully evaluated due to lack of data. The ***Phoenix Wailer*** and the Marine Wailer produce a variety of synthetic sounds, and may be useful in dispersing and deterring birds in various spill scenarios. In theory, ***dyes or foam*** could be used to colour or camouflage oil, and reduce the number of birds that mistake pools of oil for water. However, the practicality and effectiveness of dyes and foam are unknown.

This report also reviews the bird dispersal and deterrent methods that might be useful in each of five generic oil spill scenarios that could kill large numbers of birds:

Sedge lowlands could become oiled as a result of a storm surge in late summer or fall. Snow Geese, White-fronted Geese, Black Brant, and other species feed and rest in these areas prior to their southward migration. Aircraft are recommended for initial dispersal of birds from the oiled area. Gas cannons, human effigies, shotguns and shell-crackers should then be used to prevent birds from returning to oiled wetlands, and aircraft should haze any birds that land in oiled wetlands until they leave.

An oil spill near a seabird colony is potentially one of the most intractable scenarios from a bird dispersal/deterrence viewpoint. Small seabird colonies are present at Cape Parry (Thick-billed Murres) and Herschel Island (Black Guillemots). Although small, these colonies are unique in the Canadian Beaufort Sea. Any attempt to keep birds away from a colony and the surrounding waters would—at best—be only partially successful, and could lead to greater mortality than might occur if no dispersal/deterrent action were taken.

Oil in bays and lagoons could kill large numbers of sea ducks that moult there during summer. Other coastal species, including phalaropes, Sabine's Gulls, Glaucous Gulls and brood-rearing Brant, could also be at risk. Aircraft and/or boats, in combination with shotguns, shellcrackers, and rockets or mortars, should be used to disperse birds from bays and lagoons that are threatened by oil. Insofar as possible, the direction of movement of the birds should be controlled to move them to safer areas. These methods, plus gas cannons, the Phoenix/Marine Wailer (if effective), and human effigies, should be used to deter birds from returning to the oiled areas.

Oil on ice or in leads during spring could threaten some of the many sea ducks and other waterbirds that migrate along offshore leads to breeding areas in the Canadian Arctic. These birds are strongly attracted to open water and might land in pools of oil that form on the ice. Potential dispersal and deterrent techniques include hazing by aircraft and various surface-based methods: gas cannons, shotguns, shellcrackers, rockets, mortars and (probably) the Phoenix/Marine Wailer. Due to the remote locations of leads, hazing by aircraft may be the only practical technique. Unfortunately, the effectiveness of aircraft would be variable because some birds may dive into the water when disturbed by aircraft.

An oil spill in an offshore area during the open-water season would pose largely-intractable problems with respect to bird dispersal and deterrence. Birds are generally widely dispersed in offshore areas. However, small concentrations of birds may occur along oceanographic features, and significant numbers of birds (e.g. eiders, murres) may migrate across a given area over a period of days. Even if densities in any one area were low, total numbers of birds within the area affected by a major spill could be large. There are no effective dispersal and deterrent systems for large offshore areas. Aircraft, shotguns, shellcrackers, rockets and mortars could be used in an attempt to disperse and deter birds in some localized situations, particularly if the oil were contained.

Most dispersal and deterrent techniques reviewed have been evaluated to some degree in situations that are relevant to the Beaufort Sea. However, few tests are available for the Phoenix and Marine Wailers, which appear to have potential for dispersing and deterring water-associated birds. The Wailer should be tested in a bay/lagoon system where the reactions of several species of water-associated birds can be documented quantitatively, with appropriate controls. It should be tested with and without complementary devices, such as human effigies. A limited investigation should also be done to determine whether any dyes have the chemical characteristics necessary to be useful in colouring pools of oil some bright colour that might be unattractive to waterbirds. If so, tests of the reactions of sea ducks to coloured water or oil might be designed as a subsequent step.

SOMMAIRE

Ce rapport contient une description des techniques les plus susceptibles d'être efficaces pour disperser et dissuader les oiseaux en cas de déversement accidentel de pétrole dans la partie canadienne de la mer de Beaufort. Des techniques potentielles ont été identifiées pendant un examen de la documentation qui portait surtout sur les renseignements publiés depuis 1976. L'évaluation de leur efficacité possible dans la région de la mer de Beaufort tenait compte des oiseaux présents (espèces, comportement et mobilité), de questions de logistique et du degré d'efficacité possible ou réel indiqué dans la documentation examinée. Peu de données sur l'efficacité des méthodes de dispersion et de dissuasion proviennent de déversements de pétrole ou de situations connexes. Les rapports les plus pertinents décrivent les méthodes utilisées pour tenir les oiseaux éloignés des aéroports, des installations d'aquaculture, de vergers ou de champs de fermes. Un grand nombre de descriptions publiées sont anecdotiques. Seules quelques-unes comportent des essais quantitatifs dirigés sur l'efficacité des méthodes de dissuasion.

Essentiellement, ce rapport expose la constatation suivante : il est probable qu'aucune méthode de dispersion ou de dissuasion ne réussisse à protéger les oiseaux s'il se produit un important déversement de pétrole dans la mer de Beaufort. Les déversements moyens, toutefois, sont plus courants. Dans certaines situations, il serait possible de sauver un plus grand nombre d'oiseaux, si les méthodes de dispersion et de dissuasion sont utilisées rapidement et assidûment. Même alors, le programme de dispersion et de dissuasion risque de stresser certains oiseaux et de nuire à la reproduction l'année du déversement ou (ce qui est moins probable) les années subséquentes. Il vaut toutefois mieux prendre ce risque que de laisser les oiseaux mourir par mazoutage.

Dans toutes les situations de déversements accidentels, il faudra faire preuve de jugement dans le choix d'un programme de dispersion et de dissuasion des oiseaux. Le recours à des techniques de dispersion et de dissuasion peut entraîner, de façon directe ou non, la mort de certains oiseaux, par exemple en les éloignant d'un habitat essentiel ou en les repoussant vers une région mazoutée. Par conséquent, il faut choisir un programme qui offre une efficacité maximale et entraîne des risques minimes pour les oiseaux.

L'efficacité des techniques variera selon les espèces d'oiseaux présentes, leur raison d'être dans la région, leur capacité de voler au moment où se produit le déversement et les possibilités d'application des mesures choisies. La méthode de dispersion la plus universelle consiste à enfumer les oiseaux à l'aide d'un aéronef. Les méthodes de dissuasion les plus universelles incluent les détonateurs à gaz, les fusils de chasse, les cartouches à projectile détonant, les fusées à baguette et les mortiers. Toutefois, la dernière méthode ne peut être mise en oeuvre rapidement que si les engins énumérés sont stockés dans une région avant qu'un déversement accidentel s'y produise.

Dans la plupart des cas, des *aéronefs* seront utiles pour disperser les oiseaux de la région d'un déversement. Un aéronef peut se rendre rapidement à l'emplacement du déversement et peut

disperser les oiseaux d'une grande région en requérant un minimum de personnes. Même si les hélicoptères ont souvent une portée et une endurance plus faibles qu'un aéronef à voilure fixe, sa plus grande manoeuvrabilité peut aider à «grouper» les oiseaux loin du déversement. Les aéronefs sont limités comme méthodes de dispersion et de dissuasion. Le pétrole peut présenter un danger pour les oiseaux pendant des jours ou des semaines, et un aéronef ne peut rester en l'air pendant tout ce temps au-dessus de la région du déversement. De plus, les aéronefs sont très en demande lorsqu'il se produit un déversement important, et il est possible qu'ils ne soient pas libres pour participer à la dispersion des oiseaux.

Des détonateurs à gaz, des pièces pyrotechniques et des mannequins («épouvantails») peuvent être installés dans des régions de terres humides, le long des rivages et sur les cordons d'îles près du déversement. On peut également les installer dans les eaux mazoutées à l'aide d'un canot pneumatique ou d'une embarcation. Les pièces pyrotechniques sont très efficaces pour la dispersion et la dissuasion des oiseaux, mais leur installation requiert une main-d'oeuvre importante. Les détonateurs et les mannequins sont faciles à installer, nécessitent un entretien minimal et peuvent être utilisés pendant plusieurs semaines sans avoir à être remplacés. Toutefois, ils devraient être déplacés fréquemment pour éviter que les oiseaux s'habituent à leur présence.

Dans certains cas, des ***embarcations*** peuvent être utiles pour grouper les oiseaux, par exemple, des oiseaux aquatiques en mue. Les embarcations peuvent également être utilisées comme plate-forme pour l'installation d'autres techniques dans des eaux protégées ou si le vent est faible.

Plusieurs ***autres méthodes*** peuvent être utiles et pratiques dans certaines situations, mais leur utilisation et leur efficacité probable sont limitées. Parmi les méthodes qui pourraient être utiles dans des situations précises, on trouve les suivantes : feux à éclats, fusées éclairantes, trappage, enfumage par des avions miniatures, diffusion de cris de détresse ou d'alarme, montage d'oiseaux morts (ou modèles d'oiseaux en difficulté) et appareils «Av-Alarm».

Quelques techniques n'ont pu être évaluées à fond, faute de données. Les sirènes ***Phoenix et Marine*** produisent divers sons artificiels et peuvent aider à disperser et à dissuader les oiseaux dans certains cas. En théorie, ***des colorants ou de la mousse*** pourraient être utilisés pour colorer ou camoufler le pétrole. Ainsi, un nombre moins élevé d'oiseaux prendrait des mares de pétrole pour de l'eau. Toutefois, on ignore à quel point les colorants et la mousse sont pratiques et efficaces.

Dans ce rapport, on a également examiné les méthodes de dispersion et de dissuasion qui pourraient être utiles dans cinq situations types de déversement accidentel pouvant entraîner la mort d'un grand nombre d'oiseaux.

Les basses-terres de laiches pourraient être recouvertes de pétrole à la suite d'une onde de tempête à la fin de l'été ou à l'automne. L'oie des neiges, l'oie rieuse, la bernache noire et d'autres espèces se nourrissent dans ces régions et s'y reposent avant d'entreprendre leur migration vers le sud. Il est recommandé de disperser les oiseaux de la région du déversement tout d'abord à l'aide d'aéronefs. Les détonateurs à gaz, les mannequins, les fusils de chasse et les cartouches à projectile détonant devraient ensuite être utilisés pour empêcher les oiseaux de retourner aux terres humides mazoutées. Enfin, les aéronefs devraient enfumer les oiseaux qui se posent dans la région du déversement jusqu'à ce qu'ils partent.

Un déversement accidentel de pétrole près d'une colonie d'oiseaux marins est l'une des pires situations qui peut se produire du point de vue de la dispersion et de la dissuasion des oiseaux. On trouve de petites colonies d'oiseaux marins au cap Parry (marmette de Brünnich) et à l'île Herschel (guillemot à miroir). Malgré leur petite taille, ces colonies sont uniques dans la partie canadienne de la mer de Beaufort. Toute tentative de garder les oiseaux à distance d'une colonie et des eaux qui l'entourent risque de ne pas remporter beaucoup de succès et peut entraîner la mort d'un plus grand nombre d'oiseaux que si aucun moyen de dispersion ou de dissuasion n'avait été utilisé.

La présence de pétrole dans des baies ou des lagunes pourrait tuer un grand nombre de canards de mer qui y muent pendant l'été. D'autres espèces côtières, dont le phalarope, la mouette de Sabine, le goéland bourgmestre et la bernache cravant, pourraient également être menacées. La dispersion des oiseaux menacés par le pétrole devrait se faire à l'aide d'aéronefs et d'embarcations, de même qu'avec des fusils de chasse, des cartouches à projectile détonant, des fusées à baguette ou des mortiers. Autant que possible, il faudrait contrôler la direction du déplacement des oiseaux pour les diriger vers des régions plus sûres. Les méthodes énumérées plus haut devraient être utilisées conjointement avec des détonateurs à gaz, des sirènes Phoenix ou Marine (si elles sont efficaces) et des mannequins pour empêcher les oiseaux de retourner aux régions mazoutées.

La présence de pétrole sur la glace ou dans des chenaux au printemps pourrait menacer un grand nombre de canards de mer et d'autres oiseaux aquatiques qui migrent le long des chenaux extracôtiers pour se rendre aux aires de reproduction de l'Arctique canadien. Ces oiseaux sont fortement attirés par les aires de mer libre, et ils risquent d'atterrir dans des mares de pétrole qui se forment sur la glace. Dans ce cas, les techniques de dispersion et de dissuasion qui peuvent être utilisées, du haut des airs ou à la surface, sont les suivantes : enfumage par aéronefs, détonateurs à gaz, fusils de chasse, cartouches à projectile détonant, fusées à baguette, mortiers et (probablement) sirènes Phoenix et Marine. Étant donné l'emplacement éloigné des chenaux, il est possible que l'enfumage par aéronefs soit la seule technique pratique. Malheureusement, l'efficacité de cette technique est variable, car certains oiseaux risquent de plonger dans l'eau à l'approche des aéronefs.

Un déversement accidentel de pétrole dans une région extracôtière pendant la saison des eaux libres causerait des problèmes presque insurmontables par rapport à la dispersion et à la dissuasion des oiseaux. Habituellement, les oiseaux sont largement dispersés dans les régions extracôtières. Toutefois, il est possible que de petits groupes d'oiseaux se trouvent le long des reliefs océanographiques et qu'un nombre important d'oiseaux (eider, marmette) migre au-dessus d'une certaine région pendant quelques jours. Même si la densité d'une région était faible, le nombre total d'oiseaux touchés par un important déversement de pétrole dans cette région pourrait être élevé. Aucune méthode de dispersion ou de dissuasion n'est efficace pour les grandes régions extracôtières. On pourrait utiliser des aéronefs, des fusils de chasse, des cartouches à projectile détonant, des fusées à baguette et des mortiers pour tenter de disperser et de dissuader les oiseaux dans les cas où le déversement aurait eu lieu à un endroit précis, surtout si le pétrole ne s'était pas étendu.

La plupart des techniques de dispersion et de dissuasion étudiées ont été évaluées jusqu'à un certain point dans des situations pertinentes à la mer de Beaufort. Toutefois, peu d'essais ont été effectués avec les sirènes Phoenix et Marine, lesquelles semblent pouvoir être efficaces pour la dispersion et la dissuasion des oiseaux aquatiques. La sirène devrait être mise à l'essai dans un réseau de baies et de lagunes, où les réactions de plusieurs espèces d'oiseaux aquatiques pourraient être documentées quantitativement, de façon appropriée. Elle devrait être mise à l'essai avec et sans la présence d'autres méthodes, comme des mannequins. Il faudrait également procéder à une enquête restreinte pour déterminer si au moins un colorant a les caractéristiques chimiques nécessaires pour donner une couleur vive aux mares de pétrole, de façon à les rendre repoussantes pour les oiseaux aquatiques. Si c'est le cas, on pourrait procéder ensuite à l'examen des réactions des canards de mer face à l'eau ou au pétrole coloré.

INTRODUCTION

Public concern about the effects of oil spills has increased greatly since the recent *Exxon Valdez* and *Nestucca* oil spills. These spills again demonstrated that sea-associated birds are the component of the environment that is most vulnerable to the effects of spilled oil. Exposure to even very small amounts of oil can be fatal to birds (e.g. Clark 1978, 1984; Leighton 1983, 1990; Fry 1990; Piatt et al. 1990). The principal concern is destruction of the insulative capabilities of feathers leading to hypothermia and death. This problem is likely to be particularly severe in the generally cold waters and climate of the Beaufort Sea.

In many previous spills, there have been substantial efforts to clean oiled birds and, after rehabilitation, release them. This is a very expensive, and usually relatively unsuccessful, operation even in areas with a much better logistics infrastructure and warmer climate than are present in the Beaufort Sea. In a report to the Beaufort Sea Steering Committee, LGL Limited reviewed possible wildlife restoration options in the event of an oil spill in the Beaufort Sea. Based on data from the *Exxon Valdez*, it was found that much less than one per cent of the oiled birds were saved by cleaning, and the average cost per successfully rehabilitated bird was about $30,000 (Cross et al. 1991). A similar 1% success rate was found in the recent Kuwait oil spill (Preen 1991). Clearly, cleaning of oiled birds is not a practical mitigation measure in the event of an oil spill in the Beaufort Sea. Therefore, it makes sense to focus research on techniques that could be used to prevent birds from becoming oiled.

This preventative approach was recognized in the *Kulluk* Drilling application by Gulf Canada Resources Ltd. to the Environmental Impact Review Board (EIRB). A component of Gulf's spill response plan called for the use of deterrent techniques to prevent birds from reaching oiled waters. However, there was little discussion of the techniques available, and of their logistic feasibility and probable effectiveness in the Beaufort Sea environment at a time when a full scale well-control operation would also be occurring. The present study provides the technical review necessary to evaluate the utility of deterrent measures to protect birds from an oil spill in the Beaufort Sea region.

Koski & Richardson (1976) reviewed waterbird deterrent and dispersal systems for use at oil spills and evaluated the probable effectiveness of various techniques and methodologies in situations that were similar to those that might be encountered in the Canadian Beaufort Sea. However, during the 17 years since their study, new techniques have been developed and new information has become available for assessing the effectiveness of old techniques. Thus, there is a need to update the Koski & Richardson (1976) report in order to develop contingency plans to minimize the impacts of an oil spill on birds in the Canadian Beaufort Sea, and to identify any techniques deserving of field tests.

The current study updates the Koski & Richardson (1976) report by reviewing world-wide literature on bird deterrent technology and by summarizing what is known about each technique that could deter birds in the Canadian Beaufort Sea or a similar situation. The potential effectiveness of each of these techniques is then evaluated for five oil spill scenarios, taking into account the species of birds and logistic situation that would be present in each scenario. The final products of this evaluation are a description of recommended techniques or combinations of techniques to disperse birds in each of the five situations, and a list of deterrent systems that should be tested in the Beaufort Sea.

The five scenarios identified for evaluation were as follows:

1. Oil in sedge lowlands and the adjacent shoreline during late summer or autumn as the result of a storm surge depositing spilled oil there. The main birds of concern would be autumn-migrating waterfowl (Koski 1977a,b; Alexander et al. 1988a).

2. Oil near a seabird colony. The small colony of Thick-billed Murres at Cape Parry is the most notable seabird colony in the region (Johnson & Ward 1985; C.W.S. 1989).

3. Oil in bays or lagoons during mid-to-late summer, when large numbers of sea ducks moult in some bays and lagoons. Phalaropes staging along shorelines might also be affected (Vermeer & Anweiler 1975; Alexander et al. 1988a; Ealey et al. 1988).

4. Oil or in leads or on sea ice during spring, when many spring-migrating waterfowl and other waterbirds travel along and land in leads (Richardson et al. 1975; Searing et al. 1975; Alexander et al. 1988b).

5. Oil in offshore waters during the open-water period.

A large number of references report on the deployment and effectiveness of deterrent devices. However, the great majority of these references evaluate effectiveness of deterrents based on only a few observations (often only one). These observations are often subjectively evaluated. When quantitative data are obtained, there usually are few or no appropriate control data and no statistical evaluation of effectiveness. Thus, available data are inadequate for a quantitative evaluation of the effectiveness of most deterrent techniques. Even when results from all related studies are pooled, the evaluations often still must be subjective. A further limitation is that almost all tests or observations of bird deterrent devices have been done in habitats and situations different from the Beaufort Sea scenarios listed above. In most cases, the species of birds present during tests and observations differed from those occurring in the Beaufort Sea.

In this report, evaluations of the likely value of various deterrent devices and techniques in the Beaufort are based on the available data insofar as possible. However, they also take account of the experience and judgement of the contributors to this report and of other bird deterrent specialists with whom we have consulted.

DISPERSAL AND DETERRENT TECHNIQUES

Aircraft

Use of fixed-wing aircraft and helicopters has shown potential for dispersing birds. In the case of fixed-wing aircraft, radio-controlled model aircraft as well as full-sized piloted aircraft have been used to disperse birds. It is not entirely clear why birds react to aircraft to the extent that they do. However, the physical appearance of an aircraft is similar to the silhouette of a bird of prey. Aircraft noise probably attracts the attention of birds, and in many cases may startle or alarm them.

Full-Sized Fixed-wing Aircraft and Helicopters

Observed Reactions to Fixed-Wing Aircraft.—Fixed-wing aircraft are often used to conduct surveys of wildlife. Much information has been obtained during these surveys about the responses of waterbirds to the noise and physical presence of aircraft. Many survey biologists have practical experience concerning the reactions of birds in the Beaufort Sea area to aircraft overflights. Most of this experience was obtained incidental to the main purposes of various wildlife survey projects. As a result, relatively little of this information about bird reactions was collected in a systematic manner, and little of it has been reported formally. The few specific studies and observations of the reactions of Beaufort Sea birds to aircraft are emphasized in the following review.

Davis & Wiseley (1974) gathered systematic data on the reactions of flocks of Snow Geese to fixed-wing aircraft and helicopters during the autumn staging period on the North Slope of the Yukon Territory and Alaska. Geese were subjected to straight-line overflights by a Cessna 185 at ½-h and 2-h intervals. They found that 48% of flocks flushed when overflights were ½-h apart and that 97% flushed when flight spacing was 2 h; this difference was statistically significant ($\chi^2 = 19.62$; df = 1; $P < 0.005$). For the overflights at 2-h intervals, there was no significant difference in the number of geese flushing during the morning (91%) compared to the number observed in the afternoon (100%) ($P = 0.37$; Fisher's Exact Test). However, the overflights at ½-h intervals indicated that flocks were more likely to flush in the morning (76%) than in the afternoon (24%); $\chi^2 = 12.46$; df = 1; $P < 0.005$). The Davis & Wisely (1974) study suggested that Snow Geese may quickly habituate to frequent aircraft overflights, but not to less frequent flights. Similar proportions of Snow Geese flocks reacted to fixed-wing aircraft and helicopters. However, specific reactions varied with the aircraft type. Snow Geese flushed by helicopters flushed earlier (2.7 km away) than those flushed by fixed-wing aircraft (1.6 km), but geese flushed by fixed-wing aircraft flew longer (3.0 min) than those flushed by helicopters (1.7 min). Also, the interruption in normal behaviour lasted longer when geese were overflown by fixed-wing aircraft (10.3 vs. 3.8 min, respectively).

Reactions by spring-migrating waterfowl appear to be similar to those observed during the autumn, although no systematic studies have been conducted in spring. Davie & Webb (1980) found that 7 of 12 flights by single and small twin-engine fixed-wing aircraft caused geese to flush. These flights were conducted near Norman Wells, N.W.T., and passed within 1-5 km of staging Snow Geese. Sikstrom & Boothroyd (1985) conducted aerial surveys near Norman Wells, N.W.T., during the spring migration period during 1983-85. Over the 3-yr period, they conducted 22 survey flights in a Cessna 185 or 207 aircraft, and found that Snow Geese were the first species to flush from among a mixed-species group of waterfowl. Staging Snow Geese and other waterfowl flushed when aircraft approached within 0.5 to 1.0 km. In response to aircraft flying at altitudes of 150-500 m above ground level (AGL), geese flew for up to 3 minutes before returning to their initial locations. This same flush-and-return response by Snow Geese to fixed-wing aircraft was also noted by Boothroyd (1986). T. Barry (pers. comm. to Boothroyd 1987) reported that planes flying at altitudes of 30 to 50 m AGL generally flushed Snow Geese at a distance of 0.2 to 1.2 km from the aircraft. Snow Geese may be somewhat less sensitive to aircraft disturbance at spring staging sites on the Mackenzie River than at fall staging sites on the North Slope and Mackenzie Delta.

Although fixed-wing aircraft may cause birds to flush, other factors such as their life history stage (nesting and brooding) could determine whether or not birds will react. Jacobson (1974 in Fletcher 1980) found that nesting female Canada Geese remained on their nests when overflown by fixed-wing aircraft at altitudes of 15-30 m. However, prenesting geese flushed from the noise of similar aircraft flying at altitudes of 60-150 m. Brooding and incubation activities of nesting seabirds (e.g. Herring Gulls, cormorants, puffins, razorbills and guillemots) were not interrupted by aircraft flying 100 m above the colony (Dunnet 1977). Nesting herons and egrets did not respond to repeated disturbances by F-16 jet fighters flying 150 m above them (Black et al. 1984). Fixed-wing aircraft flying 20-200 m from incubating or brooding eagles did not flush them from their nests (Fraser et al. 1985). Cessna 185 aircraft flying at altitudes of 150 m over incubating and non-incubating Arctic Terns in the Yukon Territory flushed all birds (Gollop et al. 1974). Most of them returned to the ground approximately 1 min after flushing.

The amount of noise from aircraft can also influence whether or not birds will be dispersed. An especially noisy transport aircraft flying over nesting gulls[1] caused more of them to fly from their nests than did other low-flying transport aircraft (Burger 1981a). Likewise, birds reacted less to noise created by Boeing 747 aircraft than to Boeing 707s, which are louder than 747s (Burger 1983b). Low-level flights by military jet aircraft (F-4, A-10, A-7) occasionally caused nesting Peregrine Falcons and 7 other species of raptors to fly when aircraft passed within 500 m of the eyrie (Ellis et al. 1991). Recordings of a DeHavilland Beaver (DHC-2) overflight were broadcast to nesting Crested Terns (Brown 1990). Background ambient noise levels ranged from 55 to 75 dB. The received levels of the broadcast sounds by the birds were carefully measured prior to the conduct of the experiments and ranged from 65 dB to 95 dB. Changes in behaviour included head turning, alert posture, startle reactions and flushing. Reactions were more severe as the aircraft sound level increased. Although over 85% of the birds turned their heads (lowest response level) in response to the lowest levels of

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[1] Concorde supersonic transport flying slowly while on approach to or departure from an airport.

aircraft sounds (65 dB), which were barely audible above the background noise, less than 10% of the birds flushed even at the highest sound levels (95 dB). Preliminary tests using balloons in conjunction with playbacks of aircraft sound suggested that visual stimuli may be more important than sound in causing a high level of response.

Most observations of aircraft disturbance to birds have been obtained in situations when the aircraft was not being flown with the objective of dispersing or harassing birds. However, the intentional use of aircraft to harass or *haze* birds from an area is increasing, especially in agricultural situations. A study by Handegard (1988) found that hazing using fixed-wing aircraft, plus shooting from the ground with a 12-gauge shotgun, helped to reduce blackbird predation on sunflowers. One Piper Super Cub (PA-18) was used per district (7000-10,000 square miles) in each of 6 districts. Effectiveness was variable. Three flights a day were necessary in some districts where feeding by birds was heaviest. The relevance of these results on a passerine species to the types of waterbirds of concern in the Beaufort Sea is questionable.

Bradford et al. (1991) recommended hazing as a method of deterring birds from evaporation ponds in agricultural drainage waters in California. A major consideration in their study was that large flocks of birds had to be dispersed from hundreds of hectares of evaporation ponds. Hazing was most effective when other aquatic habitat was present nearby, forming a potential destination for dispersed birds.

Sugden (1976) noted that some experimental aircraft-hazing tests on ducks and Sandhill Cranes in agricultural areas on the Canadian prairies had produced poor results, but that other tests had been more successful. A study by Salter & Davis (1974) on the Yukon North Slope showed that a Cessna 185 fixed-wing aircraft could disperse autumn-staging Snow Geese from a 50 mi^2 area in 15 min by hazing them. This situation is similar to one of the scenarios that we consider later in this report (p. 51).

Observed Reactions to Helicopters.—Birds often react to helicopters. The high noise output from some helicopters may assist in dispersing birds, and the extreme manoeuvrability of helicopters may be helpful when using a helicopter to haze birds. It has also been suggested that the physical appearance of a helicopter could be one of the features that makes it useful to disperse birds. Gunston (1959) speculated that helicopters moving slowly, with a "forward-peering" outline, may give the illusion of a predator ready to attack.

Bird reactions to helicopters depend on the species involved (Madsen 1984; Boothroyd 1987). Barnacle Geese did not flush when helicopters were flying 4 km away, but Pink-footed Geese "panicked" when approached at the same distance. Helicopters caused widespread panic in flocks of Brant (Owens 1977). Helicopters flying as low as 60 m over nesting colonial wading birds seemed to cause only minor disturbance, but some birds flushed. Birds that flushed from the nest returned within 5 minutes (Kushlan 1979). Frequent helicopter flights to oil pipeline and exploration sites in the N.W.T. flushed Snow Geese, but most geese returned to their original locations shortly after being flushed (Boothroyd 1985, 1986; Sikstrom & Boothroyd 1985).

A controlled study on helicopter disturbance to moulting sea ducks, primarily Oldsquaws and Surf Scoters, was carried out near the south shore of Herschel Island, Yukon (Ward & Sharp 1974). Hourly flights by a Bell 206 helicopter were conducted along the same route on three consecutive days. Flights were conducted at a speed of 145 km/h at altitude 100 m above sea level (ASL). Although the helicopter displaced birds, reactions were short term. There was no lasting effect on bird behaviour and birds did not leave the area. Flock size, flock type and feeding behaviour were not affected. These observations are directly relevant to one of the oil-spill scenarios discussed later (p. 58).

Sharp (1978) used a helicopter to haze moulting sea ducks in order to test the effectiveness of this technique for dispersing birds from the area of an oil spill along the coast of the Beaufort Sea. This study was done in a 1.5 x 5 km area on the west side of McKinley Bay along the Tuktoyaktuk Peninsula. It was difficult to herd ducks (mainly Oldsquaws) under conditions of clear skies, rough seas, and SE winds at 16 km/h. When approached by the helicopter, birds flew from the shore into high winds and high waves. When the aircraft approached within 50 m of the birds, they scattered in various directions or dove. Three hazing flights were conducted. Before the first flight 124 birds were present within an area of approximately 7.5 km^2. Only 30 birds were present immediately after the first flight which lasted for 85 min. However, during the 70 min interval between the first and second flight, 71 birds returned. When hazed a second time for 135 min, only 23 birds remained. None returned during the 55 min interval between flights two and three. However, this may have been partly related to the fact that other potentially disturbing activities occurred during this interval. The third flight, which lasted 35 min, dispersed all but 6 birds. The best success was obtained when the helicopter hovered slowly at 0-10 m ASL about 70-100 m behind the ducks. They reacted by flying short distances or swimming away and then diving. Some birds did not fly away and it was speculated that they were moulting birds. During Sharp's first two flights to disperse birds, 11-18 minutes were required per km^2. This level of effort would not be logistically possible during a large-scale oil spill.

Hazing by helicopter has also been used in an attempt to keep birds away from a fish-farm operation. A two-seat piston-engine Hughes 300C was used to haze cormorants at aquaculture ponds in the Netherlands (Moerbeek et al. 1987). Hazing had no long term effectiveness. Cormorants eventually habituated to the disturbance.

Application.—Full-sized fixed-wing aircraft and helicopters can be useful in dispersing and herding birds from an oil spill on land or water. Birds appear to react sooner to helicopters than to fixed-wing aircraft. Also, the direction in which birds flush and disperse can be better controlled by a helicopter than a fixed-wing aircraft. A helicopter has the ability to travel very slowly and has better manoeuvrability. Inclement weather conditions, such as strong winds and heavy rain or snow, may reduce the effectiveness and feasibility of using this technique. Bird-aircraft collisions are a potential hazard. At least one aircraft has crashed during a bird-hazing flight, apparently when manoeuvring to avoid a bird flock (U.S. National Transportation Safety Board, File No. 1612).

Because of their mobility and (for some birds) large radius of influence, both fixed-wing aircraft and helicopters have the ability to disperse birds from larger areas and in a shorter period of time than any other technique that has been used.

Although aircraft usually are readily available for charter in the Beaufort Sea area, they will be in great demand during any significant oil spill. Aircraft that are usually available locally on short notice will likely not be available in the event of a spill. Aircraft from a distant location are likely to be needed.

Advantages

1. A large area can be covered by aircraft in a short period of time.

2. Many species of birds can be dispersed.

3. Hazing with aircraft requires very limited manpower.

4. The direction in which birds are dispersed can be controlled, especially when a helicopter is used.

Disadvantages

1. An aircraft will be effective only when over the spill area, and a single aircraft cannot remain airborne continuously. Unless the spill area is small and more than one aircraft is available, birds may land in the spill area when the aircraft is absent.

2. Birds may return shortly after being flushed by the aircraft, and birds flushed from an unoiled area may move into an oiled location.

3. Some species of waterbirds are not easily frightened by aircraft.

4. Nesting or moulting water birds may not disperse.

5. Aircraft are not effective at night.

6. The cost of charter aircraft in remote locations can be high.

7. Bird-aircraft collisions are a potential hazard.

Literature Reviewed.—Bélanger & Bédard 1989, 1990; Black et al. 1984; Boothroyd 1985,1986,1987; Bradford et al. 1991; Brown 1990; Bunnell et al. 1981; Burger 1981a,b; 1983a,b; Burger & Galli 1987; Busnel & Briot 1980; Coniff 1991; Conomy 1993; Davie & Webb 1980; Davis & Wiseley 1974; Dunnet 1977; Ellis et al. 1991; Fletcher 1980; Fraser et al. 1985; Fyfe & Olendorff 1976; Geist 1975; Gilbert & Harrison 1979; Gollop et al. 1974; Grubb 1979; Gunston 1959; Handegard 1988; Henson & Grant 1991; Johnson et al. 1987; Koski & Richardson 1976; Kushlan 1979; Madsen 1984; Moerbeek et al. 1987; Norriss and Wilson 1988; Owens 1977; Salter & Davis 1974; Sharp 1978; Sikstrom & Boothroyd 1985; Solman 1981; Taylor & Kirby 1990; USDA 1991; Ward & Sharp 1974; White & Sherrod 1973.

Radio-Controlled Model Aircraft

Observed Reactions.—Radio-controlled (RC) model aircraft have shown some promise in scaring birds away from airports, agricultural areas, aquaculture operations and landfill sites (e.g. Saul 1967; Ward 1975a; DeFusco & Nagy 1983; Parsons et al. 1990). RC model aircraft require skilled operators (Littauer 1990a). For that and other reasons, they have not been widely adopted in dispersing birds at airports (B.S.C.E. 1988).

Model aircraft have been used to deter fish-eating birds, such as cormorants and herons, from aquaculture operations (Parsons et al. 1990; Coniff 1991). Flying one model plane for every 200-300 acres has been recommended for larger land-based fish farms (Littauer 1990a). Model aircraft have proven to be useful in reducing numbers of gulls visiting a landfill site in the southeastern United States (R. Davis, LGL, unpubl. obs.). A model aircraft with a supplementary noisemaking device on the aircraft has been used to disperse birds in Israel (Maj. R. Merritt, USAF/BASH, pers. comm.).

An experimental falcon-shaped aircraft was successful at deterring starlings and Killdeer at Vancouver Airport and ducks and geese at Westham Island, Vancouver, B.C. (Ward 1975a; Solman 1981). Most birds exhibited avoidance behaviours similar to those caused by a real falcon. However, a falcon-shaped model aircraft is difficult to fly, requires a highly-skilled operator. Another effective approach is to paint a raptor design onto a more conventionally-shaped model aircraft (Saul 1967).

Application.—Model aircraft would have a limited use for deterring birds from oil spills. Model aircraft could be used to disperse birds from small wetlands, lakes and lagoons. However, they would be effective only over small areas, and would have other limitations as noted below.

Advantages

1. Birds may habituate only slowly to a model aircraft that actively hazes them, especially if it is falcon-shaped.

2. This technique is likely to be less species specific than are many others.

Disadvantages

1. Skilled operators are necessary, and the technique is labour-intensive.

2. Nearby landing and refuelling areas are needed.

3. Model aircraft cannot be used in heavy winds, rain or snow.

4. Some birds may land on the water and become oiled when attempting to escape from the aircraft.

5. Model aircraft may be damaged or destroyed by collisions with birds or other accidents. More seriously, there could also be a risk of collisions between model aircraft and low-flying aircraft or helicopters.

Literature Reviewed.—Coniff 1991; B.S.C.E. 1978; DeFusco & Nagy 1983; Inglis 1980; Littauer 1990a; Parsons et al. 1990; Saul 1967; Solman 1976, 1981; Ward 1975a.

Boats

Observed Reactions.—Boats can be used to disperse birds on water by rapidly approaching the birds. The noise from the motor and the physical presence of the boat probably frighten them. Boats can also be used as platforms to deploy other dispersal and deterrent techniques.

Harassment of birds by powerboat has been carried out at offshore aquaculture facilities and at wildlife refuges surrounded by agricultural areas. In Nova Scotia, harassment by boat helped to deter sea ducks from cultured mussel beds at locations where access was otherwise difficult (Parsons et al. 1990). Sea ducks flushed at distances of 75 m to more than 300 m, depending upon their previous exposure to the boats. Early in the season, sea ducks were easily flushed, while later in the season they became habituated to boats and were less likely to fly away.

Havera et al. (1992) studied the effects of human disturbance on waterfowl on Keokuk Pool, Mississippi River. They concluded that boat traffic was the most common source of disturbance and that various types of boating activities during the autumn caused more than half of the disturbed birds to fly out of sight. Disturbances caused by barges and shore based activities did not cause birds to fly as far as those caused by the various types of boat activities. Havera et al. (1992) speculated that boat disturbance contributed to the decline in diving duck use of their study area from 1971-80 to 1981-1990.

Canada Geese were harassed by airboats at night in a wildlife refuge in Wisconsin. Geese were effectively dispersed at the beginning of the control program. However, geese learned to avoid areas patrolled by boats and rested on mudflats where boats could not travel (Gilbert & Harrison 1977). Flushing distance of the geese from the boat was not determined.

In response to a hovercraft operating in the Stikine River delta (between Alaska and British Columbia), mergansers flushed readily (95% flushed at a mean distance of 84 ± s.d. 37 m from the boat), and flew an average of 258 ± s.d. 383 m (Wiggins 1991). Adult Bald Eagles flushed at a mean distance of 60 m (s.d. 32) from the boat, and subadult eagles flushed when 33 m (s.d. 12) from the boat and flew 72 m (s.d. 32) before landing. There may be variation in the distances that Bald Eagles flush depending on their previous experience with boats. On Chesapeake Bay, Bald Eagles flushed from boats at distances of 40-475 m (Buehler et al. 1991). A study by Knight & Knight (1984) in northwestern Washington suggested that tolerance of Bald Eagles to approaching canoes was related to food availability and the frequency of encounters with canoes. The latter may have been related to degree of habituation. They did not find a difference in the flushing distance of eagles standing on the ground versus those perched in trees, nor did they find an age effect on flushing distance.

Diving ducks are sensitive to powerboat disturbances. Although Kahl (1991) did not measure flushing distances of Canvasbacks that reacted to boat disturbances, he believed that there was a direct relationship between the speed of a boat and the distance that birds flushed from that boat. Powerboats that approached within 550 m of Common Goldeneyes at high speeds flushed them even though strong winds reduced the sound from the boats (Hume 1976). Goldeneyes did not become habituated to repeated visits by the boats (Hume 1976). During a different study, Canvasbacks were observed to flush at distances up to 1 km from power boats. The reaction to disturbance increased as the number of birds in the flock increased (Korschgen et al. 1985). Larger flocks of waterbirds may be more sensitive to boat disturbance than are smaller flocks (Batten 1977).

Racing of model powerboats on an Australian lake resulted in waterfowl moving to other parts of the lake or to sheltered areas, or leaving the lake completely (Bamford et al. 1990). However, the swans, ducks, and gulls returned once the model boats left the area.

In some situations, even wary birds will tolerate approaches by boats. Whooping Cranes tolerated a direct airboat approach within 440 m, even though this species is reported to be wary of humans (Mabie et al. 1989).

There is little information as to whether presence of boats will prevent waterbirds from landing nearby. It is more important to prevent birds from landing in oil than to move them away after they have become oiled.

Application.—A boat could be used to flush birds from an oil spill in an aquatic situation, especially where access by land is difficult. It would be most useful in combination with other techniques such as pyrotechnics, and it could be used as a platform to deploy deterrents such as a playback system for distress calls or for underwater sounds of predators. However, it may be difficult or impossible to deploy boats at some locations because oil might clog the cooling systems of motors or because volatile oil fractions might be harmful to operators. Boats may also be difficult or impossible to deploy during the adverse weather or ice conditions that might be encountered in coastal and offshore areas.

Advantages

1. Boats could be used to facilitate access to hard-to-get-to areas.

2. This technique is not species specific.

3. Dispersal operations could be carried out at night or in fog if GPS navigation systems were available on the boat.

4. The direction of movement of birds could be controlled in the case of moulting birds that swim away from the boat.

5. Flightless birds could be herded with boats.

Disadvantages

1. Deployment is highly weather dependent.

2. May not be deployable because of oil hazards to operators or motors.

3. Some species rapidly habituate to boats.

4. Although boats may be able to disperse waterbirds, it is uncertain how effective boats are in preventing birds from landing on oiled waters.

Literature Reviewed.—Bamford et al. 1990; Batten 1977; Buehler et al. 1991; Doughty 1976; Gilbert & Harrison 1977; Havera et al. 1992; Hume 1976; Kahl 1991; Knight & Knight 1984; Korschgen et al. 1985; Lister 1984; Mabie et al. 1989; Taylor & Kirby 1990; Parsons et al. 1990; Wiggins 1991

Shooting and Pyrotechnics

Pyrotechnics include a wide variety of devices that emit loud, banging noises, produce flashes of light, or both. Pyrotechnics are widely used to scare birds, for example at airports. The banging noise from some pyrotechnics resembles that from a shotgun. That resemblance no doubt enhances the effectiveness of these devices in scaring birds that are hunted. However, birds gradually habituate to pyrotechnic devices. Other supplementary scaring techniques, including the occasional shooting of a bird with live ammunition, are often used to reduce the rate of habituation to pyrotechnics.

Shotguns and Rifles with Live Ammunition

Shotguns and rifles, when fired into the air, produce a loud banging or "whirring" noise that may disperse birds whether or not some birds are hit and killed. (A rifle should not be used in this manner, given the potential hazard to people at distances of 2-3 km or greater.) Shooting has been used to frighten or kill birds at fisheries operations

(Lagler 1939; Davidson 1968; Anderson 1986; NCC 1989), in agricultural fields (Nomsen 1989), and at airports (DeFusco & Nagy 1983; B.S.C.E. 1988). In these situations, birds are commonly killed. In most cases, this is done mainly to reinforce the effectiveness of non-lethal bird scaring devices that are also in use, not in an attempt to kill a significant proportion of the birds present. In an oil spill situation, it will not be desirable to kill birds by shooting. It would only be justifiable to shoot a few birds if that was the only way to scare many other birds away from the oil spill. However, killing of the species of concern in the Beaufort Sea is unlikely to reinforce the value of pyrotechnic deterrents. Other pyrotechnic devices would probably be at least as effective as "shooting to miss" with live shot. Hence, it is doubtful that live shot should be used to scare birds from an oil spill unless it is the only technique readily available.

Birds habituate to shots, especially in the case of species that are not widely hunted. For example, shooting at cormorants and herons, and killing some of them, only temporarily repelled the survivors from fish farms (EIFAC 1988; Coniff 1991). Shooting was not effective in dispersing egrets from airports; most egrets returned shortly after being shot at, even if some birds were killed (Burger 1983a; Fellow & Paton 1988). Shooting also was not effective in dispersing roosting geese (Taylor & Kirby 1990).

It would be best to shoot while birds are approaching an oil-contaminated area, not after they have landed. After they land, some birds will dive in response to a shot. Although shooting at birds may not be acceptable in some public places (Mattingly 1976; Amling 1980), this would not be a concern in the Beaufort Sea region.

Ammunition for a 12-gauge shotgun can be expensive (Feare 1974) in comparison to the operating costs of gas cannons ("exploders"), which are discussed below. However, a shotgun is more easily deployed, and the cost of ammunition is likely to be insignificant in comparison to other logistics costs associated with an oil spill in the Beaufort Sea region. Furthermore, shotguns and shells are more readily available than alternative methods. There would be a safety concern in using live shotgun ammunition in an area where oil cleanup activities were underway. However, the maximum distance that shotshells could injure people or birds is 60-90 m, depending on the size of the shot being used. Thus shotguns (unlike rifles) do not have the potential to injure at long range.

Shellcrackers

Scare or Bird Frite cartridges, commonly referred to as shellcrackers, are usually deployed from 12-gauge shotguns. A single shot or double-barrel gun with short barrel and no choke should be used for safety reasons. Shellcrackers contain a firecracker that is projected approximately 45-90 m (50-100 yd) and then explodes (Mott 1980; Salmon & Conte 1981; Littauer 1990a). The noise from the explosion causes birds to flush.

Exploding shells have proven useful in repelling and dispersing birds at airports (Burger 1983a; DeFusco & Nagy 1983; B.S.C.E. 1988), at landfill sites (Southern & Southern 1984), in fruit orchards (Nelson 1990b), and on cereal crops (Booth 1983).

Shellcrackers have longer range than do smaller cartridges launched from starter's pistol (see below). This can have the advantage that less manpower is required to cover an area (Mott 1980). When fish-eating birds are dispersed from aquaculture ponds by shell-crackers, the effect is relatively short-term: most birds are deterred from returning for a few hours to a few days (Draulans 1987). In a few rare situations, birds have been prevented from returning for longer periods (up to four weeks) before habituation took effect.

Shellcrackers can be expensive to use, depending upon the sizes of the flocks that need to be moved. However, the cost is likely to be inconsequential in relation to other costs associated with an oil spill. At some times in the past, shellcrackers have been difficult or impossible to obtain at short notice. Thus, if this method is to be applied, an adequate supply of shellcrackers should be kept in stock as a contingency measure. Hussain (1990) recommended caution in using shellcrackers in areas of dry vegetation where fires can start. In certain very limited circumstances, this might also be a concern around oil spills, e.g. if volatile fractions are present.

Screamer shells, which are a type of shellcracker, were found to be 100% effective at dispersing Canada Geese from urban parks even though broadcasts of alarm/distress calls were not (Aguilera et al. 1991). The use of screamer shells had some long-term effects on the goose distribution. After five days of using screamer shells, Aguilera et al. (1991) found an 88% reduction in the number of geese using a site during the following five days.

Flares

Flares are modified shotgun shells fired from a pistol or shotgun or brightly burning firecracker-like devices that can be deployed from hand-held launch units or placed on the ground to burn. When fired, the flare leaves a trail of smoke that may frighten birds (Koski & Richardson 1976). Flares are not as effective as shellcrackers. However, when used in conjunction with other deterrent methods, flares might be useful in influencing the direction in which birds disperse.

Firecrackers

Several kinds of firecrackers are available for use as bird deterrents. Some of them are "fixed location" devices; others can be fired as far as 25 m into the air from a 15 mm flare pistol or a 6 mm blank pistol. Firecrackers are commonly called noise, bird, whistle, or crow bombs (Mott 1980; Salmon & Conte 1981; Salmon et al. 1986). Firecrackers have a shorter range than shellcrackers when used to disperse birds.

Small cracker-shells launched from pistols, often referred to by the names "bangers", "whistlers", "screamers" or "cracklers", are widely used in deterring birds from agricultural areas and other locations, such landfill sites (e.g. Miller & Davis 1990a,b). Because these devices can be fired into the air toward birds, they are the most useful of the firecracker-type deterrents. However, they have shorter range than do 12-gauge shellcrackers.

The rope-firecracker is a pyrotechnic device made of cotton rope with waterproof firecrackers attached (Littauer 1990a). The rope is lit at one end. It burns slowly from one end to the other, and intermittently ignites the next firecracker along the rope; each firecracker makes a loud noise when it detonates. Rope-firecrackers have been suggested for use in deterring birds from landfill sites, fish-farms and agricultural areas (Salmon & Conte 1981; Booth 1983; DeFusco & Nagy 1983). Firecrackers are useful for deterring birds from a small area for a short time.

Store-bought firecrackers (normally used for holiday celebrations), attached to a piece of wood and ignited, were reported to scare thousands of roosting blackbirds from a residential area. The firecrackers were deployed for three consecutive nights (Bliese 1959). This approach is unlikely to be effective in most situations in the Beaufort Sea because it would not be effective over a large area, and it would be manpower intensive.

Rockets and Mortars

Rockets (e.g. marine signal rockets, skyrockets and star shells) are normally projected from a launching rod and make a hissing sound as they travel (Hussain 1990). Some rockets may explode (e.g. jupiter shell), producing a display of fireworks and a loud noise at the same time. Mortars would be used in the same way as other pyrotechnic devices to disperse birds (Koski & Richardson 1976). Rockets would be useful at night, but would not be useful during the day unless they also produced a loud bang. Mortars, on the other hand, would be useful during both day and night. The noise produced by a mortar is louder than that from gas cannon or shotgun, and thus, would probably disperse birds from a larger area. Skilled operators may be required. However, this method could be useful in many situations in the Beaufort Sea region, primarily because the radius of effectiveness around a single "launch" location would be larger than for other types of pyrotechnics.

General Considerations re Shooting and Pyrotechnics

Application.—Shotguns and pyrotechnic devices could be useful in deterring birds from small lakes, coastal waters or shoreline areas where fire may not be a problem. They could also be applied from the ice. A mortar launched from shore or (if practical) a boat could be effective over an extensive area. Rockets could be deployed from shore or ice. They probably could not be deployed from boats for safety reasons, and they probably would be less effective than mortars during the day. Shotguns with live ammunition or shellcrackers, along with flares, could be effective in relatively small areas, provided that there are other uncontaminated areas of land or water nearby. Pistol-launched cracker shells, which are short-range devices, probably would be useful only in very localized areas. Pyrotechnic devices are most useful for short-term dispersal and deterrence, particularly when used in combination with other techniques (Bomford & O'Brien 1990). Use of any of these pyrotechnic devices could be hazardous if the operators are untrained or careless. Direct injury to personnel or ignition of the oil could occur, particularly if high concentrations of volatile oil fractions were present.

Advantages

1. Pyrotechnics can be used to prevent approaching birds from landing in an oiled area.

2. Rockets and mortars are potentially effective over large areas.

3. Pyrotechnics are effective both during the day and at night.

4. Direction and intensity of firing could be controlled.

5. They can be used as complementary devices with deterrents such as the Marine Wailer, exploders and effigies (see below).

Disadvantages

1. Pyrotechnics cannot be used in situations where fire would be a hazard, e.g. near dry vegetation or volatile components of oil.

2. Use of pyrotechnics would be labour-intensive.

3. Birds habituate to pyrotechnics eventually.

4. Pyrotechnics may be difficult or impossible to deploy in some offshore situations.

5. Pyrotechnics can pose hazards to operators and bystanders if not used carefully.

Literature Reviewed.—Aguilera et al. 1991; Anderson 1986; Bartelt 1987; Beck 1968; Bliese 1959; Bomford and O'Brien 1990; Booth 1983; B.S.C.E. 1988; Burger 1983a; Coniff 1991; Cummings et al. 1986; DeFusco & Nagy 1983; Davidson 1968; DeHaven 1971; U.S. Dep. Inter. 1978; Draulans 1987; EIFAC 1988; Elgy 1972; Faulkner 1963; Feare 1974; Fellows & Paton 1988; Fitzwater 1978; Geist 1975; Green 1973; Grun 1978; Handegard 1988; Kevan 1992; Koski & Richardson 1976; Kress 1983; LGL Ltd. 1987; Littauer 1990a,b; Lucid & Slack 1980; Mattingly 1976; Miller & Davis 1990a,b; Mott 1980; NCC 1989; Nelson 1970; Nelson 1990b; Nomsen 1989; Norriss & Wilson 1988; Parsons et al. 1990; Radford 1987; Salmon & Conte 1981; Salmon et al. 1986; Southern & Southern 1984; Taylor & Kirby 1990; USDA 1991.

Gas Cannons and "Exploders"

Gas cannons or "exploders" are mechanical devices that produce loud, banging noises to frighten birds. Gas cannons produce "bang" noises by igniting gas (acetylene or propane). The noise of the explosion resembles or is louder than that of a 12-gauge shotgun (Feare 1974; Nelson 1990b). Blasts are emitted at adjustable time intervals, typically every 15 to 30 min (Salmon & Conte 1981; Salmon et al. 1986) but sometimes closer together, controlled by an automatic timing device. A photo cell can be included to turn the system off at night. Some gas cannons can be set to fire at random intervals and to rotate after each explosion so that subsequent shots are aimed in different directions.

Observed Reactions.—Gas cannons can be effective at dispersing birds if the frequency of the explosions is varied and if the cannons are moved every second or third day of use to a different area. Sometimes it is necessary to elevate the cannons if foliage or equipment interfere with the sound of the blast (U.S. Dep. Inter. 1978; Hussain 1990). Birds habituate to the sound of the explosions, particularly if no other techniques are used to reinforce the threat of the cannon (DeFusco & Nagy 1983; B.S.C.E. 1988). Rotary mounts, variable firing intervals, and use of other complementary deterrent methods are helpful in delaying habituation. Gas cannons, in combination with other dispersal methods such as pyrotechnics, have been found to reduce numbers of gulls visiting landfills (e.g. Risley & Blokpoel 1984; Miller & Davis 1990a,b).

For dispersing gulls at airports, one cannon for every 50 m of runway has been reported to be effective (DeFusco & Nagy 1983). However, cannons have also been found ineffective for long-term bird dispersal programs at many airports because of habituation (B.S.C.E. 1988). Sugden (1976) indicated that cannons are among the most useful methods for reducing waterfowl damage to grain crops. Propane cannons were very successful at frightening cormorants at shipyards (Martin & Martin 1984) and can be valuable in reducing blackbird damage on cornfields (Dolbeer et al. 1979). For dispersing blackbirds, one cannon for every 4-10 ha works well (LGL Ltd. 1987). Setting cannons to fire at 30-s intervals can disperse blackbirds and starlings from roosting areas (U.S. Dep. Inter. 1978).

Although most studies of the efficacy of gas cannons have been conducted in airport, agricultural, or landfill settings, some studies have dealt with the use of cannons to deter and disperse birds in the event of an oil spill. The effectiveness of a propane cannon to deter moulting sea ducks was tested near Atkinson Point along the Beaufort Sea coast (Sharp 1978). A cannon was mounted on a raft and anchored several kilometres from the shore. Blasts were emitted at a rate of 13/h and at maximum volume (reported to be 118 dB at 1 m). During the first two days of operation, the density and number of birds were reduced considerably. The scaring radius was 1000 m during the first day. However, by the third day of operation, the number of birds in the general area actually increased, indicating that the effectiveness of the cannon was waning; the birds had apparently started to habituate to the noise. The scaring radius decreased to 600 m. The average distance of flocks closely approaching the cannon was 381 ± 164 m (n=29).

Another study attempted to evaluate the effectiveness of the "Syncrude bird-scaring raft" for deterring waterfowl and other waterbirds from the Mildred Lake tailings pond in Alberta (Ward 1978). This raft contained a cannon set to fire at 1 min intervals, a scarecrow (bright orange), and two dim constantly-on lights. The raft was effective at excluding birds from portions of the tailings pond, but not the entire waterbody. Waterbirds tended to congregate along the shorelines, the most distant part of the pond from the raft. Lesser Scaup were the most sensitive to the raft. The scaring radius for this species was approximately 400 m; a 95% reduction in numbers of scaup was observed within 400 m of the device. Ducks responded much more readily than coots and grebes. The American Coot was the least sensitive species. It was suggested that a high density of rafts would be necessary to exclude coots from the pond.

Application.—Gas cannons could be useful in many oil spill situations. Cannons could be placed around the banks of a river or lake, or mounted to a raft for use in larger water bodies. Insofar as possible, cannons should be deployed before birds arrive at the contaminated area or after other techniques have been used to disperse birds. Gas cannons have proven to be effective deterrents for areas up to 4 ha in the cases of non-game species (Salmon et. al 1986), 18-24 ha for dabbling ducks in grain fields (Stephen 1960, 1961), and 50 ha for scaup on small lakes (Ward 1978). In the study by Ward (1978), the cannons were used in combination with scarecrows and lights.

Caution must be applied in using gas cannons (and especially older units) because they may catch fire. Cannons must not be deployed in areas with high concentrations of volatile oil fractions because the igniter for the cannon could ignite the vapour.

Advantages

1. Direction, timing and volume of the blasts can be controlled.

2. Gas cannons are relatively mobile.

3. They are automatically operated and require checking only once a day.

4. They are effective both during day and night.

Disadvantages

1. Birds rapidly habituate to the sound of the blasts.

2. Cannons must be supplemented with other deterrent devices.

3. Compared to the probable size of an oil spill, the effective area is relatively small.

Literature Reviewed.—Booth 1983; Bomford & O'Brien 1990; Bradley 1981; B.S.C.E. 1988; Conover 1984; DeFusco & Nagy 1983; U.S. Dep. Inter. 1978; Devenport

1990; Dolbeer et al. 1979; Feare 1974; Hussain 1990; LGL Ltd. 1987; Littauer 1990a; Martin & Martin 1984; Miller & Davis 1990a,b; Mott 1978; Naggiar 1974; Nelson 1990b; Payson & Vance 1984; Risley & Blokpoel 1984; Salmon & Conte 1981; Salmon et al. 1986; Sharp 1978; Stephen 1960, 1961; Stickley & Andrews 1989; Sugden 1976; Truman 1961; Ward 1978.

Other Sound-based Deterrents

The pyrotechnics and gas cannons discussed above produce sharp impulses of sound, sometimes associated with visual stimuli. Several other sound-based deterrent devices broadcast other types of sounds that are intended to alarm or stress the target birds. These include broadcasts of recorded distress or alarm calls from the target species, or abstract sounds that suggest danger or produce stress. Birds that hear these sounds may leave the area.

Distress or Alarm Calls

Observed Reactions.—Some birds produce distress or alarm calls when they encounter situations of great danger, such as being captured by a predator. Captured or stressed individuals may produce special types of calls that warn other members of the species to disperse. In some cases, distress calls of one species are recognized by another species. Thus distress or alarm calls may be effective at dispersing more than one species (Aubin & Brémond 1989; Aubin 1991). Distress calls are sometimes effective over long distances (Aubin & Brémond 1989).

The optimum hearing range of most birds is at frequencies from about 1000 Hz to 4000 Hz (Hamershock 1992), and most species can detect stronger sounds at frequencies as low as 100 Hz and as high as 8000-10,000 Hz. Some species, particularly pigeons, can detect strong sounds at frequencies as low as 0.05 Hz (Kreithen & Quine 1979). Many species of birds detect strong sounds at frequencies as high as 20,000 Hz and a few can do so up to 30,000 Hz. Hearing has not been measured for the species of concern in the Beaufort Sea (Fay 1988), but Mallard hearing has a lower limit of 300 Hz and an upper limit of 8000 Hz. For comparison, the range of human hearing is often said to be 20-20,000 Hz, although the effective range for most adults is considerably narrower than that.

Playbacks of recorded distress or alarm calls are commonly used in attempts to disperse birds from airports, agricultural and residential areas, aquaculture facilities, and some other locations. Tapes of distress and/or alarm calls are played on a portable tape recorder and broadcast through a loudspeaker. Loudspeakers are generally mounted on the roof, hood or bumper of a vehicle (Elgy 1972; Currie & Tee 1978), and could be mounted on the cabin of a boat. It is important to broadcast the sound at the most effective location and time so as to have the greatest possible deterrent effect. Thus, a mobile vehicle is desirable. In order to maximize effectiveness and minimize habituation, it is important that the sound be played sparingly and at times when the birds are likely to be most responsive (e.g. Transport Canada 1986). This requires a human operator rather than an automatic timer. The effectiveness of this method also depends on the quality of sound that is broadcast; therefore, high quality equipment should be used (Brémond et al. 1968).

Playbacks of distress or alarm calls are widely used in dispersing gulls from airports, and occasionally from landfills and reservoirs (e.g. DeFusco & Nagy 1983; Payson & Vance 1984; Transport Canada 1986; B.S.C.E. 1988; Howard 1992). Playbacks have also been very successful in dispersing large flocks (up to 10,000) of starlings from roosting sites (Frings & Jumber 1954; Block 1966; Pearson et al. 1967; Feare 1974). Keidar et al. (1975) found that distress calls deterred flocks of Skylarks and Calandra Larks from feeding on agricultural crops. Smith (1986) reported that birds were dispersed from airports by repeated broadcasts of distress calls. Spanier (1980) reported that juvenile and adult Black-crowned Night Herons could be deterred from commercial fish ponds by playing recordings of their distress calls. Playbacks of distress/alarm calls are most effective if they are begun before birds have established a routine or normal activity pattern in an area. They should also be applied before or as birds are entering an area rather than after they have arrived and settled there to feed or roost (Elgy 1972).

Gulls emit an alarm or distress call when they have been captured or sense danger (Frings et al. 1955). When they hear an alarm call, gulls do not react in the same way as starlings. Many gulls initially fly toward the source of the alarm call, apparently to investigate, but then may slowly fly away. Playback of distress or alarm calls is often most effective if used in conjunction with another deterrent method, e.g. firing of shellcrackers (Transport Canada 1986). Some species of birds such as the Oystercatcher and Wood Pigeon are reported not to emit distress calls (Bridgman 1976). Insofar as we are aware, sea ducks like the Oldsquaws and eiders that occur in the Beaufort Sea are not known to emit distress or alarm calls. These species often react to visual cues, and it is possible that distress or alarm calls do not exist for these species.

Mott and Timbrook (1988) found that distress or alarm calls are effective at dispersing Canada Geese from nuisance situations at campgrounds. Their call combination did not include a typical distress call; it included an alarm call of a lone goose and the calls made by a flock of geese as they flew away after being harassed. The calls alone resulted in a 71% reduction in the number of geese using the campgrounds after five days of broadcasting calls. When supplemented with racket bombs, 96% of geese left. However, Aguilera et al. (1991) found that Canada Geese in parks reacted to the same alarm/distress calls by becoming alert and sometimes moving up to 100 m away from the source of the call, but the birds did not leave the area.

Proper deployment of distress or alarm calls will increase their efficacy and reduce habituation. Habituation may occur if the call is played continuously (Langowski 1969; de Jong 1970; Burger 1983a). For example, starlings habituated to distress calls played continuously but not to those played intermittently for intervals of 2-95 s. The Department of Interior (1978) recommended playing calls for 10-15 s each minute when starlings and blackbirds are entering a roosting area. Block (1966) reported that broadcasting distress calls for 10 s per minute for 50 min successfully dispersed starlings. To minimize the rate of habituation, the broadcast of distress/alarm calls should be repeated as soon as birds attempt to return after being dispersed (Slater 1980). This does not allow birds time to recover from the stimulus. Mott & Timbrook (1988) reported that Canada Geese did not habituate to playbacks of distress/alarm calls, but they mentioned that birds recognised the vehicle that broadcast the sounds and retreated before it began broadcasting. Thus the true stimulus for dispersal is ambiguous.

Other factors may influence the effectiveness of distress/alarm calls. Species found in open habitats, such as prairie, field, tundra and marine habitats, may depend on visual cues, while species found in forested areas may rely on distress calls that they can hear (Boudreau 1972).

Application.—Alarm and distress calls have been known for over 20 years to be effective at dispersing some species of birds. Because broadcast systems are mobile and versatile, distress/alarm calls could be useful in oil spill situations whether the spill occurs on land or in water. However, distress/alarm calls are apparently not available for any of the major species occurring in the Beaufort Sea scenarios that we consider in this report, and many of these species may not emit such calls. Distress or alarm calls may be effective and obtainable for Glaucous and Sabine's Gulls. Alarm and distress calls could be useful for dispersing or deterring species such as Red-necked Phalaropes in some coastal areas during summer. Distress calls have been obtained and proven effective for Lapwings (B.S.C.E 1988). However, distress calls are difficult to obtain for some species of shorebirds (Gunn 1973) and have not been proven to be effective for many other species of shorebird (B.S.C.E. 1988). If distress or alarm calls were determined to be effective on sea ducks, portable broadcasting units could be put up around small and large lakes, lagoons, and leads in the ice. Rafts with broadcasting units could be attached to containment booms.

Advantages

1. Habituation to distress or alarm calls may be relatively slow if the calls are used sparingly and in conjunction with other complementary deterrent methods. Therefore, this method could be effective during a prolonged clean-up effort.

Disadvantages

1. Many species of birds do not emit distress or alarm calls. It is not known whether the major species that are susceptible to an oil spill in the Beaufort Sea region have distress or alarm calls.

2. Distress and alarm calls have not been recorded for many arctic species, whether or not these species emit such calls. Recordings of these calls would need to be obtained prior to a spill in order to be available for timely use.

3. Most distress/alarm calls are at least partially species specific. Broadcasting the call of one species may not disperse other birds.

4. Weather conditions may affect transmission of sound.

Literature Reviewed.—Aguilera et al. 1991; Aubin 1991; Aubin & Brémond 1989; Beklova et al. 1981, 1982; Block 1966; Boudreau 1968, 1972; Brémond 1980; Brémond & Aubin 1989, 1990, 1992; Brémond et al. 1968; Bridgman 1976; B.S.C.E. 1988; Burger 1983a; Currie & Tee 1978; DeFusco & Nagy 1983; U.S. Dep. Inter. 1978; de Jong 1970; Elgy 1972; Fay 1988; Feare 1974; Fitzwater 1970; Frings & Frings 1967; Frings et al. 1955, 1958; Frings & Jumber 1954; Grun & Gunn 1973; Mattner 1978; Howard 1992; Inglis et al. 1982; Keidar et al. 1975; Kreithen & Quine 1979; Kress 1983; Langowski 1969; Littauer 1990a; Morgan & Howse 1974; Mott and Timbrook 1988; Naef-Daenzer 1983; Payson & Vance 1984; Pearson et al. 1967; Rohwer 1976; Salmon & Conte 1981; Schmidt & Johnson 1983; Slater 1980; Smith 1986; Spanier 1980; Transport Canada 1986.

Predator Sounds

Observed Reactions.—Predator sounds might have a deterrent effect similar to that of distress and alarm calls. Predators of birds include other birds (such as hawks or falcons), certain mammals, and humans (Gunn 1973; Thompson et al. 1968). Sounds of aerial or terrestrial predators could be broadcast using the same equipment as distress or alarm calls. However, most predators are silent when they hunt, and emit sounds mainly when they are engaged in other activities. Therefore, reactions of potential prey species to predator calls could be less pronounced than one might initially suspect. Also, one reaction of flying birds to the calls of a hawk might be to dive into the water. That could be counterproductive in an oil spill situation.

The killer whale is one marine predator that certain birds occurring in the Beaufort Sea might be familiar with from their winter range. Jackass Penguins responded to an underwater loudspeaker broadcasting killer whale vocalizations by grouping together and swimming away from the source of the sounds (Frost et al. 1975). However, it is unlikely that underwater broadcasts of killer whale sounds would be very useful in the Beaufort Sea: killer whales rarely occur there; only diving birds would be likely to hear the sounds; and birds would only hear the sounds when they were underwater, by which time they might already be oiled.

In-air playbacks of predator sounds have somewhat greater potential applicability. Broadcasts of the protest calls of the Sparrow Hawk successfully repelled House Sparrows, and habituation was not observed after 6 days of exposure to the sounds (Frings & Frings 1967). The playback of a Peregrine Falcon call was effective at dispersing gulls from Vancouver International Airport (Gunn 1973; LGL Ltd. 1987).

Although predator sounds can have a startling effect on birds, they can also attract birds in some situations. For example, crows and blackbirds will mob or attack Great Horned Owls, particularly when the owls are near newly-fledged young. This reaction also occurs around nests or rookeries of gulls and terns.

Application.—Predator sounds might be useful in oil spill situations where many species of bird need to be dispersed. Their effect is likely to be less species-specific than is that of distress or alarm calls. One concern is that playbacks of raptor sounds might cause flying water birds to dive into the water. If this occurred, it might increase, not decrease, the incidence of oiling.

Advantages

1. Predator sounds may disperse several species of birds.

2. Killer whale sounds projected into the water or near the surface may be useful in dispersing some waterbirds that are in the water under certain circumstances.

3. Predator sounds can be played at any time of the day.

4. Because of the efficiency of underwater sound transmission, sounds projected into the water could be received within a large area if the source level was high enough.

Disadvantages

1. More research needs to be conducted on many aspects of predator sounds and responses by birds. The basic premise that waterbirds respond to predator calls needs to be demonstrated, and the nature of the response needs to be determined.

Av-Alarm

An Av-Alarm is a commercially-available electronic sound-producing device that broadcasts synthetic sounds in the 1500 to 5000 Hz frequency range at sound levels of 118 dB at one metre. To be effective, Av-Alarm sounds should be selected to match natural frequencies of alarm and distress calls of the species of concern, or to match the frequencies of intra-flock communications. Sounds are projected through speakers that each cover an angle of 120°. The timing and frequency of broadcasts can be controlled by interval timers and photocells. The unit can be powered either by a 12-volt battery or by 110/220-volt 50-60 Hz A.C.

Observed Reactions.—Av-Alarm has been used primarily in the agricultural industry to deter birds from food crops. Most evaluations of its success have been subjective. However, Av-Alarm has been tested as a method of deterring waterfowl from agricultural and coastal areas, and at airports.

Av-Alarms appear to have been used successfully to reduce numbers of small birds feeding on various crops (see Koski & Richardson 1976 and DeFusco & Nagy 1983 for reviews). Preliminary tests from a more recent study suggest that Av-Alarm was an effective method of reducing passerine-caused damage to grapes (Jarvis 1985). Although most tests of Av-Alarm have been on landbirds in agricultural areas, some reports suggest that Av-Alarm can also be useful in reducing numbers of gulls and plovers at airports (B.S.C.E. 1988).

Av-Alarm units appear to have some deterrent effect by themselves, but may be more useful in combination with other scaring methods. For example, Av-Alarm had some deterrent effect on starlings feeding on blueberries, but the addition of shotguns, gas cannons or decoy traps sometimes appeared to result in less depredation (Nelson 1970). Martin (1980) used an integrated system consisting of Av-Alarm, a propane cannon and other manually deployed devices to reduce numbers of birds that used a waste-water holding pond, but he did not attempt to isolate the value of the deterrent devices separately. Likewise, Potvin et al. (1978) found that an Av-Alarm and propane cannon in combination were more effective in deterring landbirds from corn fields in Quebec than was either of these devices by itself.

Negative evaluations of Av-Alarms were provided by Booth (1983), who reported that Av-Alarms were not as effective as distress calls in repelling birds. Various reviews have noted that birds habituate to the noise. Thompson et al. (1979) noted that the heart rate of starlings increased only slightly when they were exposed to Av-alarm whereas marked increases in heart rates occurred when birds were subjected to broadcasts of distress and alarm calls of starlings from both North America and Europe.

We are aware of only one rigorous study of the effectiveness of Av-Alarm as a deterrent device for waterfowl in agricultural situations. Canada Geese were successfully deterred from agricultural fields surrounding a wildlife refuge in Wisconsin (Heinrich & Craven 1990). During these experiments, control and experimental fields were interspersed and it is not known whether the device would have been as effective if there had not been nearby areas of suitable habitat without the deterrent device.

Wiseley (1974) studied the effect of a gas-compressor simulator on the distribution and behaviour of Snow Geese on the Yukon North Slope. This study provides an indication of how Snow Geese might react to noises that do not have a biological significance to them. The simulator caused geese to break from their normal flight formations, to flare, to call, to increase or decrease their speed of flight and to land. They avoided an area within 800 m of the simulator where the most intense sound was broadcast. Thus, noise from an Av-alarm or Phoenix or Marine Wailer (see below) is likely to cause similar reactions by Snow Geese.

Two studies that are directly relevant to oil spill situations in the Beaufort Sea have been conducted.

1. Crummet (no date, approx. 1973) conducted two experiments suggesting that Av-Alarm might be an effective method of dispersing water-associated birds in aquatic situations. He did not, however, provide sufficient details to permit evaluation of changes in numbers of birds with respect to distance from the deterrent device before and during the experiment, or to assess the possibility

that factors other than the Av-Alarm may have contributed to the observed changes in numbers.

2. Sharp (1978) tested the ability of an Av-Alarm deployed on a raft to deter moulting sea ducks (primarily Oldsquaw) in Louth Bay (part of McKinley Bay) along the Tuktoyaktuk Peninsula, N.W.T. Sharp (1978) had sufficient control data to evaluate the effect of changing wind conditions on the distribution of birds. During the first day of operation of the Av-Alarm, densities of ducks were reduced to 10% or less of control densities out to 600 m from the deterrent. However, by the second day, densities 0-400 m from the device were approximately 50% of those during control periods, indicating that some birds very quickly habituated to the Av-Alarm. The effectiveness of Av-Alarm may have been underestimated because the birds had habituated to a gas cannon that was deployed in the same fashion during an experiment that ended five days earlier.

<u>Application</u>.—Av-Alarm units could be set up around the perimeters of lakes, rivers, lagoons and seabird colonies, or perhaps around the perimeter of an oil spill in a coastal or off-shore area. Av-Alarm systems could also be placed on boats or rafts for use in offshore situations but they might not be deployable during periods of high winds. Av-Alarm may be more effective when used in combination with other devices such as pyrotechnics and gas cannons.

<u>Advantages</u>

1. Can be used to disperse birds in many types of habitats.

2. Av-Alarms may be effective at night.

3. Av-Alarm is not as species specific as some deterrent systems.

4. Av-Alarm does not require constant human attention, but changes in location and adjustments in the characteristics of the sounds will reduce the rate of habituation.

<u>Disadvantages</u>

1. Birds appear to quickly habituate to the sounds if Av-Alarm is used by itself.

2. Other devices may have to be used to make the Av-Alarms effective.

3. Personnel working near Av-Alarms should wear hearing protection devices.

<u>Literature Reviewed</u>.—Bomford & O'Brien 1990; Booth 1983; B.S.C.E. 1988; Crummet n.d. [1973]; DeFusco & Nagy 1983; Devenport 1990; Gunn 1973; Heinrich &

Craven 1990; Koski and Richardson 1976; LGL Ltd. 1987; Jarvis 1985; Martin 1980; Nelson 1970; Potvin et al. 1978; Sharp 1978; Thompson et al. 1979; Wiseley 1974.

Phoenix and Marine Wailer

The Phoenix Wailer, available from Phoenix Agritech (Canada) Ltd. in Nova Scotia, is a recently developed bird deterrent device that is currently being tested and marketed in Canada and the U.S.A. (McNeill 1992). The Marine Wailer is a waterproof version, apparently of the same device, that comes in a self-contained unit supported above the water by a quadrapod attached to floats. The Phoenix/Marine Wailer emits 64 different audio and ultrasonic sounds. The frequency range of sounds from a speaker is 450-4000 Hz and the frequency range of sounds produced by a horn tweeter is 3500-30,000 Hz. The sounds are broadcast in a randomly selected order and the source level is adjustable. The time between broadcasts is adjustable from 5 to 40 min. The duration of the blast is adjustable from 5 to 40 s. Sounds are projected through speakers that rotate in a 360° arc.

Observed Reactions.—One Phoenix Wailer unit has been reported to effectively deter birds from an area of 2-5 ha [presumably passerines in agricultural situations], and one Marine Wailer is reported to be able to "protect" 4.1 ha. The Marine Wailer is reported to be "90% effective" against eiders, cormorants and gulls during preliminary tests conducted by the manufacturer. A Phoenix/Marine Wailer unit can also be programmed to turn on at dawn and off at specific times. Power is supplied to the units by a 12-volt battery.

This device has shown some promise when tested at a grape research station in Ontario, Canada. A Phoenix Wailer was set up in a 0.6 ha section of vinifera grape cultivars. Subjective observations indicated that damage to grapes was minimal and the number of birds seen was less that would have been seen without the device. Controlled experiments are needed to substantiate these claims. No independent scientific evaluations of these devices have been conducted, insofar as we know. However, results with a different type of synthesized sound (Wiseley 1974) suggest that Snow Geese and perhaps other species of geese are likely to react to sounds produced by the Wailer units.

Application.—The Phoenix and Marine Wailers may be useful for small spills or for deterring birds from restricted areas such as lagoons or small lakes. The area of effectiveness seems small, indicating that this device would not be of practical value in offshore areas or for large spills. This device should be tested on sea ducks in coastal, bay and lagoon situations. If its radius of effectiveness in those situations proves to be larger than suggested by the preliminary evidence now available, the Wailer might be useful in some offshore open water situations. The Phoenix and Marine Wailers have the potential to be more effective than some other devices such as Av-Alarm because of the wider range of sounds that can be produced. Thus, it has the potential to disperse a larger number of species at the same time. The Phoenix Wailer could be deployed along beaches or barrier islands, or on sea ice. The Marine Wailer could be deployed in offshore area anywhere where it could be anchored or moored. The waterproof enclosure and built-in flotation are attractive features of the Marine Wailer. The efficacy of either unit would probably be increase by using complementary devices such as shotguns, shell-crackers, effigies, cannons, rockets and mortars.

Advantages

1. The Phoenix and Marine Wailers produce a wide variety of sounds that may be able to deter many species of birds at once.

2. The Marine Wailer is the only deterrent system designed specifically for deployment in marine situations.

Disadvantages

1. This device is newly introduced; very little information about its effectiveness is available. Independent tests are needed to determine its efficiency at deterring birds from oil spills, and to document the rate of habituation of various types of birds.

Ultrasonics

Ultrasound is normally defined as sound at frequencies too high to be detected by humans. The upper limit of human hearing is generally taken to be 20,000 Hz, although few adults have effective hearing at frequencies that high. The obvious advantage of ultrasound as a dispersal or deterrent technique, if it were effective, would be that it would not be audible to humans. In many situations, other types of noise-based deterrents are annoying to humans. Suppliers of ultrasound-emitting devices have for many years claimed that their devices can deter birds. However, most species of birds do not hear ultrasound (Fay 1988; Hamershock 1992). Therefore, ultrasound is not likely to be an effective deterrent.

Observed Reactions.—Even though some birds can detect sounds up to or slightly above 20,000 Hz, they do not appear to be affected by broadcasts of ultrasound, probably because they do not use ultrasonic communication. Woronecki (1988) found that pigeons did not exhibit a fright response when exposed to ultrasound. Also, there was no evidence of a reduction in the number of pigeons nest-building or egg-laying when the nesting area was ensonified with ultrasound. Beuter & Weiss (1986) found no evidence that gulls either heard or reacted to ultrasounds. Griffiths (1988) reported that a combined sonic-ultrasonic bird repelling device did not affect several species of birds (e.g. chickadees and jays). Based on the known frequency ranges for hearing by the above species, it is unlikely that any of them could hear ultrasound.

Previous reviewers have concluded that ultrasonic methods are ineffective in scaring birds (e.g. Koski & Richardson 1976; DeFusco & Nagy 1983; Bomford & O'Brien 1990). Likewise Hamershock (1992), based on an extensive review, found that ultrasound did not reduce bird numbers by more than 5 %, if at all. Ultrasound has also been found ineffective in repelling rodents (Lund 1984; Bomford & O'Brien 1990), but showed some promise in repelling bats, many of which have good hearing at ultrasonic frequencies (Martin 1980; Fay 1988).

Application.—Ultrasound is not effective as a bird deterrent device.

Literature Reviewed.—Beuter & Weiss 1988; Bomford & O'Brien 1990; B.S.C.E. 1988; DeFusco & Nagy 1983; Fay 1988; Frings & Frings 1967; Griffiths 1988; Hamershock 1992; Koski and Richardson 1976; Lund 1984; Martin 1980; Truman 1961; Woronecki 1988.

High Intensity Sound

High intensity sound would presumably produce distress, pain or discomfort, and therefore cause birds to leave the areas where they were broadcast in an attempt to avoid the stimulus.

Observed Reactions.—High intensity sounds can be produced by sonic booms, blasting using explosives, horns, and air-raid sirens. Thiessen et al. (1957) conducted preliminary tests using an air-raid siren to disperse ducks from ponds. They found that repeated broadcasts of intense sound caused some birds to vacate the pond after two or three days. Their methods and sound level measurements were not clearly explained. Holthuijzen et al. (1990) reported that a number of Prairie Falcons flew away from their nests after blasting occurred. The sound levels of the blasts, measured at the entrances of two aeries, averaged 136 and 139 dB, respectively. However, the falcons returned to their nests within minutes. Bell (1971) reported that the reactions of birds to sonic booms varied considerably. Most species reacted by flying, running or crowding together.

Although not a sophisticated a device, a bicycle horn that was inserted into an agitator of a washing machine produced an "ear-splitting" noise that dispersed roosting blackbirds from a residential area (Bliese 1959).

Application.—High intensity sounds produce variable responses when birds are exposed to them. Most high intensity sounds cannot be reproduced easily, nor are they immediately effective in repelling birds. A horn attached to a boat or vehicle may be useful as a supplementary device in lagoons and marshes, and smaller water bodies. However, to produce sound levels high enough to repel birds at a practical distance would require extremely high intensities near the sound source. Because high intensity sounds can cause hearing damage and other health effects (Fuller et al. 1950; Fringes 1964; Wright 1970; Kryter 1985), the hazards to man and other animals make this technique impractical.

Literature Reviewed.—Bell 1971; Bliese 1959; Davis 1967; Ellis et al. 1991; Fringes 1964; Fuller et al. 1950; Holthuijzen et al. 1990; Kryter 1985; Thiessen et al. 1957; Wright 1970.

Vision-based Deterrents

Vision-based deterrents present a visual stimulus that is startling or that the birds associate with danger. The danger can be a predator, a simulated predator, the results of a predator attack (dead bird or model thereof), or some unusual object that birds fear because it is unfamiliar. Lights, scarecrows, dyes, reflecting tape, predator decoys, kites, balloons, smoke, and dead or live birds are visual stimuli that may disperse birds.

Many birds discriminate the colour of light at wavelengths between 400 and 700 nm, comparable to humans (Pearson 1972; Martin 1985). In addition, some species, including pigeons, hummingbirds, Mallards, Belted Kingfishers, boobies and some passerines (Martin 1985; Meyer 1986; Reed 1987; Maier 1992), also perceive ultraviolet light (<390 nm). Humans do not detect ultraviolet light. Pigeons and some songbirds have also exhibited sensitivity to the plane of polarization of light (Martin 1985), to which humans have very limited sensitivity. Since birds can apparently detect colour, it could be an important consideration during the construction and development of devices that are used to deter and disperse birds.

Lights[2]

Attempts to use lights to disperse or repel birds have involved flashing, rotating, strobe and search lights (Krzysik 1987).

Observed Reactions.—Searchlights have been used to deter ducks from landing and feeding in grain fields, and tests have shown that some nocturnal migrants illuminated by light beams take evasive action (see Koski and Richardson 1976 for review). Although searchlights are effective deterrents in some situations, they sometimes attract birds at night, especially when it is cloudy or foggy.

Most information on the use of strobe lights in deterring birds has involved aircraft and airfields where birds pose serious safety hazards. Recent information on the use of strobe lights in airfield situations indicates mixed levels of success. Lawrence et al. (1975) reviewed various types of evidence—anecdotal, statistical and experimental—, and concluded that strobe lights have some deterrent effect. A study in the UK in 1976 revealed that the use of aircraft landing lights during the daytime produced a decrease in bird strikes. The simultaneous use of strobe anticollision lights, produced a further decrease in bird strikes. Strobe lights appeared to be more effective at deterring lapwings than gulls. However, Zur (1982) found no significant reduction in the number of bird strikes on DC-9 aircraft with strobe lights versus those without strobe lights.

Briot (1986) observed the reactions of crows, magpies and jays that were tethered to the ground to overflights by low-flying aircraft with and without white 100,000

[2] This section is based in part on text supplied by K. Strom, Delta Environmental Management Group Ltd., Calgary, Alberta.

candela strobe lights flashing at 4 Hz. The distance between the bird and aircraft when a bird attempted to fly was recorded. No significant difference was observed in the flushing distance between overflights with and without strobe lights. However, a slight increase in scare distance with an increase in flash frequency was recorded. However, the experimental procedure may have affected the results. The tethered birds may have been reluctant to fly as the aircraft approached.

In a study of the effects of strobe lights on Laughing Gulls and American Kestrels, Bahr et al. (1992) found that strobe light frequencies of 50 Hz elicited faster responses in heart rates than frequencies of 5, 9 and 15 Hz. However, the lower strobe frequencies appeared to produce the greatest overall increases in heart rates. A study by Briot (1986) hinted that scare distance increased with an increase in strobe frequency. Laty (1976) suggested that frequencies not exceed 100 Hz. Gauthreaux (1988) used a frequency of 1.3-2 Hz in laboratory studies with migratory sparrows. Other studies have shown that frequencies from 8-12 Hz produce stress in gulls, pigeons, and starlings (Belton 1976; Solman 1976). Belton (1976) found that gulls delayed approaching a feeding area by 30 to 45 min when it was illuminated by a white or magenta strobe at 2 Hz. No repellant effect was observed when the strobe light flashed at higher frequencies to 60 Hz.

A few studies using strobe lights, amber barricade lights, and revolving lights on aquaculture facilities (Salmon et al. 1986; Nomsen 1989; Littauer 1990a) indicate that these lights are effective in deterring night-feeding birds (e.g. herons). The lights probably produce a blinding effect so that birds become confused and cannot easily catch fish. In some cases, birds became habituated to the lights, and even learned to avoid the lights by landing with their backs to them.

Mossler (1979) experimented with the use of flashing lights at a refuse dump. A "light board" was constructed with car lamps flashing (0.75 Hz) in sequence from the centre of the board outwards. This pattern was thought to mimic the flapping of wings. The flight board was carried by a person walking toward a flock of gulls, and flight responses were monitored. The strongest responses noted were to red and blue lights. However, the use of the flashing light board provided no significant change in flight responses compared to that elicited by a person approaching the gulls without the light board. Use of the light board mounted on a car elicited a lesser flight response by gulls than had been observed to a car without the light board.

Lefebvre and Mott (1983, *in* Krzysik 1987) found that flashing amber lights, in combination with movable owl decoys, were successful in dispersing a starling roost. Gauthreaux (1988) observed that Savannah Sparrows maintained in outdoor cages with a view of the horizon oriented themselves directly away from a red strobe light. However, they did not show any significant response to white strobe light or constant red or white light.

Lights have had limited success at deterring birds from oil spills. Blinking lights were found to be 50-60% effective at dispersing all birds from oil spills (U.S. Dep. Inter. 1977, in DeFusco and Nagy 1983). Some tests have shown lights to be effective in dispersing waterfowl, waders, sparrows, gulls, and other species (DeFusco and Nagy 1983). Other tests, however, have shown lights to be ineffective against waterfowl (Boag and Lewin 1980), gulls, blackbirds and starlings (DeFusco and Nagy 1983).

During the 1970s, Syncrude Canada experimented with weather-proof lights in combination with human effigies to deter migratory waterfowl from tailings ponds near the Athabasca River. Functional problems and high costs led to the eventual abandonment of this system in the late 1970s (T. Van Meer, pers. comm.). SUNCOR Inc. also experimented with flashing lights in an attempt to deter migratory waterfowl from similar, smaller tailings ponds. Beacons were added to an existing deterrent system consisting of effigies and propane cannons. Their subjective evaluation was that lights did not increase the success of the system, and the use of the beacon lights was subsequently discontinued (J. Gulley, pers. comm.).

Application.—Flashing and strobe lights could be useful in deterring birds from an oil spill at night and during twilight periods. A steady light, such as a searchlight, is not as effective as flashing and revolving lights and may attract birds during some weather conditions.

Flashing or strobe lights could be set up around an oil spill or along the shoreline of a river, lake or lagoon. They are most likely to be useful in combination with other deterrent devices such as cannons, Marine Wailers and effigies. Flashing lights might increase the effectiveness of these other techniques at night.

Advantages

1. Lights are easy to deploy and require very little maintenance.

2. Lights could be effective for deterring certain birds at night.

3. Lights are portable and could be set up on booms around an oil spill, or placed on boats or rafts for greater mobility and accessibility.

Disadvantages

1. Lights may not be effective for some species during daylight hours.

2. Lights may attract birds on foggy, misty nights.

3. Effectiveness on large water bodies has not been tested.

Literature Reviewed.—Bahr et al. 1992; Belton 1976; Boag & Lewin 1980; Briot 1986; Gauthreaux 1988; Koski & Richardson 1976; Laty 1976; Lawrence et al. 1975; Littauer 1990a; Lefebvre & Mott 1983; Mossler 1979; Nomsen 1989; Salmon et al. 1986; Solman 1976; Thorpe 1977; Zur 1982.

Scarecrows

Scarecrows are one of the oldest devices that have been used to control birds (Frings and Frings 1967; Hussain 1990). Most scarecrows are human-shaped effigies that are constructed of a wide variety of inexpensive materials such as grain sacks or old clothes stuffed with straw. The more realistic the facial features and the human shape, the more effective scarecrows are likely to be. Painting scarecrows a bright colour can increase their detectability (Littauer 1990a).

Observed Reactions.—Scarecrows are more effective if they are moved every 2-3 days (DeFusco & Nagy 1983; LGL Ltd. 1987; Hussain 1990). Scarecrows that move in the wind and that are used with other deterrent devices (e.g. gas cannons) are more effective than immobile scarecrows that are not used with complementary devices. Littauer (1990b) suggested that periodically driving a vehicle near the scarecrow, or placing the scarecrow on a stationary vehicle, could increase its effectiveness.

More recently, several types of mechanical pop-up scarecrows have been created. Nomsen (1989) reported that a human-like scarecrow that popped up from a double propane cannon when it fired was very successful in keeping blackbirds from feeding over 4-6 acres of sunflowers. Ducks and geese were observed to be much easier to frighten off than blackbirds.

Another model of scarecrow consists of an inflatable, human-shaped bag that is mounted on a battery-powered compressor or electric fan. It inflates every five minutes. Timers could also be connected to a photo cell switch which would allow the scarecrow-inflation sequence to begin at dusk or dawn. Once inflated, the scarecrow stands up and then emits a screeching, siren-like noise before it deflates (Littauer 1990a; Coniff 1991). Coniff (1991) reported that this kind of scarecrow set up near a catfish pond effectively frightened cormorants.

Littauer (1990b) described another mechanical scarecrow model with a mannequin head attached to a steel rod. A propane cannon projects the head approximately 30 inches into the air. No information was available on the effectiveness of this kind of scarecrow.

Some species of birds become habituated to scarecrows whether or not they move. Naggiar (1974) reported that scarecrows (stationary) and shooting were not effective in deterring wading birds from fish ponds. After two hours, birds became accustomed to the scarecrow.

Cummings et al. (1986) used a propane cannon and a CO_2 pop-up scarecrow to deter blackbirds from sunflowers. They found that most birds were frightened away by the scarecrows; fewer birds returned during the treatment period than were observed during the control period. Cummings et al. speculated that the birds that returned had become habituated to the scarecrow in some cases, and in other cases, that feeding patterns were too well established in others to effectively deter birds.

Scarecrows have been tested for use in deterring birds from landing on oil-contaminated tailings ponds in Alberta. Ward (1978) tested a "bird-scaring raft" with a large fluorescent orange scarecrow, two continually-burning lights, and a gas cannon. Two studies were carried out on seven lakes near Rich Lake, Alberta. In the first study, 12 experiments were conducted with single rafts at a time when ducks were moulting, and therefore flightless. The cannon, when fired at intervals of 1 min, would cause the scarecrow to move in either a back-and-forth or swivelling motion. The second study evaluated the effectiveness of the rafts, at densities of 2 to 9 rafts/km^2, in excluding all species of waterbirds from the lakes.

Single rafts deterred birds within 100 m. During both studies (single and multiple rafts), the deterrent rafts were not able to exclude all birds. Ducks, in particular Lesser Scaup, were the most sensitive to the rafts. American Coots and grebes were the least affected. Increasing the number of rafts was effective in excluding some species but not others. Bad weather, the stage of moult of birds, and habituation, could have decreased the effectiveness of the rafts to deter birds.

Boag and Lewin (1980) found that a human effigy was effective in deterring dabbling and diving ducks from small natural ponds. When the effigy was present, the total number of ducks on the ponds declined by 95%. Over the same interval there was only a 20% decline on adjacent control ponds, indicating that the effigy was quite effective.

Boag and Lewin (1980) also attempted to evaluate the efficacy of 27 effigies placed around a 150 ha tailings pond. Counts of dead birds found in the pond were compared to counts from the previous year when effigies were not deployed. Although numbers of dead waterfowl were slightly higher in the year with effigies (104 vs. 98), the effigies were still considered effective. More waterfowl and shorebirds were believed to be present in the area during the year when effigies were deployed, and retrieval efforts were more intensive in that year.

Application.—Scarecrows are a flexible deterrent technique. They can be deployed on land or water. Scarecrows could be placed on a raft with a propane cannon and/or light and placed on large or small waterbodies. They can also be deployed by shoving an upright pole into the ground or into cracks or holes in ice.

Scarecrows should be deployed before birds arrive (Nomsen 1989) and they should be used with other deterrent devices (Booth 1983). They should be moved frequently to reduce the rate of habituation.

Advantages

1. Scarecrows are easy to make, and materials are readily available.

2. Scarecrows are relatively mobile.

Disadvantages

1. Birds habituate to scarecrows.

2. Scarecrows must be used in combination with other deterrent devices to make them more effective.

3. Scarecrows are not likely to be useful at night unless lights are used with them.

Literature Reviewed.—Boag & Lewin 1980; Coniff 1991; Cummings et al. 1986; DeFusco & Nagy 1983; Devenport 1990; EIFAC 1988; Frings & Frings 1967; Kevan 1992; LGL Ltd. 1987; Littauer 1990a,b; Naggiar 1974; Nelson 1990b; Nomsen 1989.

Dyes

Observed Reactions.—The literature contains many observations on the use of coloured objects, such as scarecrows, flags and balloons, to frighten and repel birds from agricultural crops and aquaculture operations. However, there is little research on the use of coloured dyes as a method to deter birds.

Coloured runways had no deterring effects on birds (ACBHA 1963), but a pond dyed greenish-yellow was reported to have temporarily deterred waterfowl as long as "dye-free" ponds were present nearby (Richey 1964). When all the ponds were dyed, the colour had no repelling effect and ducks landed in the dyed water. Salter (1979) reviewed the use of dyes for deterring birds from oiled leads and polynyas in the Beaufort Sea. He concluded that dyes may be effective in reducing the number of birds entering oil spills. However, he noted that more research was needed on behavioural responses by birds to the dyes (i.e. habituation and species-specificity) and the technical feasibility of applying dye to oil or areas around spills.

Lipcius et al. (1980) tested young Mallards' responses to coloured water. The ducks were deprived of food for 24- and 48-h periods, and then placed in a pen adjacent to a pool. Across from the pool was a feeding tray. The Mallards were exposed to clear and coloured water (dyes were water-soluble); the colours tested included red, yellow, orange, green, blue, indigo, violet and black. Orange was the most effective and consistent colour in delaying Mallards from entering water. Other colours were generally less effective and showed less consistency in Mallard responses. Among colours, black was one of the least effective in deterring or delaying Mallards from entering water. The results suggested that black water may even attract Mallards. Lipcius (1980) suggested that it would be worthwhile to conduct further related research, including tests of orange dyes or coloured objects as a method of deterring seabirds from oiled waters.

Future research on the potential for use of coloured dyes for deterring birds from entering oiled waters needs to consider the possibility of species-specific responses to colour, and the chemical and physical properties of dyes. Dye that would adhere to or dissolve in the oil would presumably be desirable. Water soluble dyes would be rapidly diluted in the water surrounding the oil. However, in areas with small patches of oil it might be necessary to dye the water as well. To be practical, it would be necessary for a small quantity of dye to colour a large area. Weather conditions, wave action, and the movement of oil on the water would presumably affect the life of the dye.

Application.—Greenish-yellow and bright orange coloured dyes, when added to water, have shown some potential in deterring birds. Adding dye directly to oil, and possibly the water surrounding it, may help to keep birds from entering the area. Another possible use for dyes could involve "colouring" an area that extends beyond the oil spill in order to repel and deter birds before they enter the spill. However, this method may be impractical because of the large area of water that might need to be dyed, and the likely rapid dilution of the dye by the surrounding water.

Advantages

1. Application of dyes to spilled oil may deter birds from landing in the oil.

2. Aircraft might be able to apply dyes to oil quickly and effectively even in offshore areas.

3. An oil-soluble dye would be more likely to remain with the oil as it drifted than would most other types of deterrents.

Disadvantages

1. The effectiveness of dye as a practical bird deterrent is unknown and would require confirmation prior to operational use (see "Recommended Studies", p. 78).

2. Water-soluble dyes could not be used effectively, at least for a large spill, because of the large quantity of dye that would be required.

3. Application of dyes may be difficult because of weather conditions, and wave action would probably limit their duration of effectiveness.

4. Dyes would not be effective at night.

5. Dyes may break down quickly, depending upon the type of oil spilled and the type of dye.

Literature Reviewed.—ACBHA 1963; Koski & Richardson 1976; Lipcius et al. 1980; Maier 1992; Martin 1985; Meyer 1986; Pearson 1972; Richey 1964; Reed 1987; Salter 1979.

Reflectors, Kites and Balloons

Reflectors and Reflecting Tape.—Several early studies suggested that reflectors could be used to deter birds from crops and airports. These studies have been summarized by Koski and Richardson (1976). More recent studies have concentrated on the use of reflecting tape rather that just bright flashy objects. Reflecting tape produces noise when it flaps in the wind, and the auditory stimulus is believed to make reflecting tape more effective than other reflectors.

Reflecting tape is an elastic, 3-layered tape that has a silver metal layer coated on one side and a coloured (usually red) synthetic resin on the other side (Bruggers et al. 1986). This type of tape flashes when it reflects sunlight, and produces a humming or crackling noise when it stretches or flaps in the wind. Because of its noise and reflective features, reflecting tape has been used to deter birds in agricultural settings.

Bruggers et al. (1986) used reflecting tape (0.025 mm thick and 11 mm wide) to deter birds from cornfields, sunflowers and sorghum. The tape was successful in deterring birds when it was suspended above the ripening crops in parallel rows, and when the entry point into the fields was also protected. High winds may have also increased the effectiveness of the tape by increasing the noise it makes. Dolbeer et al. (1986) used reflecting tape to repel blackbirds from crops by stringing tape at intervals of 3, 5 and 7 m. The tape was suspended from poles spaced 3 m apart and the tape sagged 0.5-1.0 m at its low point between poles. The 3 m spacing was more effective at repelling birds than were the 5 and 7 m spacings. Reflecting tape did not deter all species of birds and it was not effective when it became twisted such that the reflecting side was no longer visible.

Summers and Hillman (1990) tested a red fluorescent tape (20 mm wide) in fields of winter wheat in the U.K. to deter Brant. One half of a 20.2-ha field was the control area and the other half was the treatment. A second control field (7.5 ha) was set up in another area that had one gas cannon and two scarecrows. Lines were strung at 40-60 m intervals across the rows of wheat in the experimental field. The tape proved more successful than the cannon and scarecrows in repelling Brant. Geese caused a 1% reduction in grain yield in the taped field, but a 6% reduction in the untaped field. Geese apparently grazed within 2 m of the edges of the fields with tape.

Reflecting tape was ineffective in deterring birds from ripening blueberries (Tobin et al. 1988). Tape was set up in the fields 10 to 12 days before the first bird and berry counts were taken. During this time, the birds could have become habituated to the tape. Also, only 7-10 strands were set up per plot, which may have not been enough to deter birds.

Raptor-Kites and Balloons.—Kites that mimic hawks and other raptors have been used to frighten birds from corn and sunflower crops (Harris 1980; Conover 1983) and from grapes (Hothem et al. 1981; Hothem & DeHaven 1982). Usually these kites are suspended from helium-filled balloons or hung from poles in order to keep them aloft with or without wind.

Conover (1983) conducted experiments with four different designs of hawk-kites (Mausebussard, Falke, Steinalder and Habicht). These varied in the species represented, size, wing-span and coloration. Each kite was attached to the middle of a braided nylon line that was strung between two bamboo poles set 3 m apart. The kites did not effectively deter birds from feeding on corn. Because the kites were not attached to balloons, they were less mobile (40 m range of movement for kites with balloons vs. 2 m range for kites only), and therefore, probably less effective at scaring birds.

Hothem et al. (1981) used four kites, with balloons, to repel birds from vineyards: 1 eagle kite with a 1.35 m wingspan, 1 eagle kite with four circular holes in the leading edge of the wings, 1 kite with a falcon image on the lower side, and 1 eagle kite made of cloth (1.65 m wingspan). All kites were attached to helium balloons (diameter 1.2 m). The balloons were tethered with 23-kg test nylon line; each day the length of the tether was adjusted to be between 8 and 52 m. One kite-balloon was set up per 1.0-1.1 ha of vines for a 7-day evaluation period (treatment), and then removed for another 7-day period (control). To reduce the likelihood of habituation, kites and the colour of balloons (5 different colours) were changed every 1-2 days. Although results suggested that bird damage was reduced during the 7-day period with the kite-balloons, the decrease in damage was not significant. The sample size may have been too small for a meaningful test.

Hothem and DeHaven (1982) tested a "kite-hawk" to reduce bird damage in vineyards. The kite had a 1.3 m wingspan and was coloured to resemble an immature Golden Eagle. The kite was suspended from a blue helium-filled balloon with diameter 1.7 m. Based on six 7-day-on/7-day-off treatment periods, no difference was found in the percent loss of grapes (2.8% for treatment vs. 2.9% for control). However, damage levels were found to have increased with increased distance from the kite-balloon, suggesting that the deterrent may have been effective over a very small area. Kites were damaged when winds exceeded 8 km/h, but generally lasted up to 14 days.

Brant were reportedly repelled from a large area (5 km in radius) when a helium-filled diamond-shaped kite was tethered to a line on the ground and moved along that line in an erratic pattern (DeFusco & Nagy 1983). The Brant apparently did not habituate to this device.

High winds can decrease the effectiveness of kites. Harris (1980) reported that kite-balloons could not withstand high winds on the Manitoba prairies. The rate of habituation is not clear; some workers have reported slow or no habituation (DeFusco & Nagy 1983), whereas others have reported more rapid loss of effectiveness. Inglis (1980) reported that Wood Pigeons habituated to a kite-balloon after only 4 hours.

Smoke.—Smoke has been used to disperse birds from nesting and roosting sites (see Koski & Richardson 1976 for review). However, smoke has not been tested for use near oil spills.

Application.—Reflectors, kites, balloons, and perhaps smoke could be useful as bird deterrents at small oil spills on land. Reflectors, kites and balloons could also be placed around the edges of small lakes or lagoons. It would be necessary to use other complementary scaring devices (e.g. cannons, scarecrows) to make them effective.

Advantages

1. Reflecting tape and kite-balloons are easy to set up and could be moved to other locations.

Disadvantages

1. Balloons may be difficult to keep inflated.

2. High winds and rain destroy their effectiveness.

3. Habituation is likely to occur, although the rate is uncertain.

Literature Reviewed.—Bruggers et al. 1986; Conover 1979, 1983, 1984; DeFusco & Nagy 1983; Dolbeer et al. 1986; Harris 1980; Hothem et al. 1981; Hothem and DeHaven 1982; Inglis 1980; Koski & Richardson 1976; LGL Ltd. 1987; Summers & Hillman 1990; Tobin et al. 1988.

Dead Birds, Bird Models and Predator Decoys

Observed Reactions.—Dead birds, either actual or models, serve as a warning that some form of danger is, or recently has been, present in the area. Initially birds often approach a dead bird to look at it, but they usually leave the area after discovering the unnatural position of the bird. Bird bodies have been used to repel and scare birds from agricultural areas (Naef-Daenzer 1983) and from airports (see Koski & Richardson 1976, Inglis 1980, and DeFusco & Nagy 1983 for reviews). Models of dead birds have also been useful in scaring birds in certain circumstances. For example, models of dead gulls, or actual dead gulls displayed prominently, have been useful in scaring gulls away from some airports and landfills (Saul 1967; Stout and Schwab 1979; Howard 1992). However, in most countries these methods have not been found to be sufficiently effective to be adopted operationally (B.S.C.E. 1988).

Predator decoys are imitations of bird predators. They are used to invoke fear in birds. Decoys or models have usually been used to scare birds from agricultural crops (Conover 1979, 1983, 1984, 1985b; DeFusco & Nagy 1983; Crocker 1984). Conover (1979, 1983) found that stationary mounted hawks and hawk-kites deterred birds from feeding stations and corn fields but that their effectiveness was short-term. When movement was incorporated into the deterrent (kites suspended from balloons), the kites became effective at deterring birds from feeding in corn fields (Conover 1984). Hothem and DeHaven (1982) also found hawk-kites suspended by balloons to be effective at reducing damage to vineyards, but birds habituated to the kites unless the location and deployment techniques were frequently changed.

Models of predators sometimes attract rather than repel birds (Conover 1983; LGL Ltd. 1987). For example, blackbirds and crows often mob owls or owl models. However, Conover (1982, 1985b) found that a moving plastic owl model with a plastic crow model in its talons repelled crows from gardens and small fields. A stationary version of the same models was not effective at deterring birds.

Predator decoys and dead birds have not been used for deterring birds from oil spills and probably would not be useful for most species of concern in the Beaufort Sea. Predator decoys might have the undesirable effect of causing sea ducks to dive into the water. Predator decoys might be effective in deterring shorebirds.

Application.—Dead birds and decoys could be placed around small lakes and lagoons and in wetland habitats to deter shorebirds. Models could be mounted on posts or on rafts, and placed in areas where birds congregate or might land if they were stopping during migration.

Advantages

1. Models are inexpensive and easy to deploy.

Disadvantages

1. As the condition of dead birds deteriorates, they lose their effectiveness in scaring other birds.
2. Models or dead birds need to be moved frequently to reduce habituation.
3. Predator models may cause some birds to dive into the water and become oiled.
4. The effectiveness of these techniques has not been determined for sea ducks and most other species that may encounter oil in the Beaufort Sea.

Literature Reviewed.—B.S.C.E. 1988; Conover 1979, 1982, 1983, 1984, 1985b; Crocker 1984; DeFusco & Nagy 1983; Frings and Frings 1967; Hothem and DeHaven 1982; Inglis 1980; Koski & Richardson 1976; LGL Ltd. 1987; Naef-Daenzer 1983; Saul 1967; Stout & Schwab 1979

Hawks and Falcons

Observed Reactions.—Raptors have been used to disperse birds from a number of airports, including some in Canada (for reviews, see Koski & Richardson 1976; DeFusco & Nagy 1983; Hild 1984; B.S.C.E. 1988; Erickson et al. 1990). More recently, raptors, along with other deterrent methods, have been used to control the size of a Ring-billed Gull colony on Toronto's Eastern Headland (Intercept 1991). Various species of raptors are tethered on perches as part of this multi-year operational program. The raptors are only occasionally allowed to fly free. The raptors plus other techniques have been successful in restricting the size of the gull colony, but some other species, such as Canada Geese, have not been affected.

In a study by Kenward (1978, *in* Inglis 1980), Goshawks were unsuccessful in deterring Wood Pigeons from *Brassica* fields. After repeated attacks by the Goshawk, the pigeons usually resettled and continued to feed.

Application.—Raptors could be useful in dispersing birds from oil spills on land and from smaller water bodies. Raptors may not deter all birds, but it is unlikely that deterrence would be species-specific. Although a number of airports use raptors in controlling birds on airfields, finding falconers would be difficult on short notice, the supply of trained raptors is limited, and establishment of an operating falconry facility near an oil spill would take considerable time. There are legal restrictions on the possession and transport of raptors. If the raptors were allowed to fly freely and thus to kill an occasional wild bird, there would be some risk that the raptors would become oiled by contact with oiled prey.

Advantages

1. Birds do not habituate to raptors.

Disadvantages

1. Experienced handlers and trained raptors are required; neither may be available on short notice.

2. Falconry would not be a practical method for deterring birds from landing in large bodies of water.

3. Raptors could not be used at night, or during periods of high winds or heavy rains.

4. Raptors may cause some birds to dive into the water.

5. Free-flying raptors would be at risk of becoming oiled themselves.

Literature Reviewed.—Blokpoel & Tessier 1987; B.S.C.E. 1988; Burger 1983a; DeFusco & Nagy 1983; de Jong 1970; Doughty 1976; Erickson et al. 1990; Hild 1884; Inglis 1980; Intercept 1979; Kenward 1978; Koski & Richardson 1976; Lucid & Slack 1980; R. Neth. A.F. 1969; Solman 1976; Ward 1975b.

Physical Barriers

Foam, nets, fences, wires, lines and water spray can be used to provide an apparent or actual barrier to prevent birds from entering areas with spilled oil, or to disguise the presence of the oil.

Foam

It has been suggested that, in the arctic, a pool of oil on the ice or snow might attract waterbirds, which might mistake the oil for water (T.W. Barry *in* Koski and Richardson 1976). If the oil could be disguised, it might not attract birds. Koski and Richardson (1976) suggested that some type of foam might be used to cover oil-contaminated snow or ice. We are not aware that any type of foam has been applied for that purpose. However, at some sanitary landfill sites, foam is now used as an alternative to earth for the daily cover material. Although quantitative data are not available, gulls that were attracted in large numbers to one landfill site seemed reluctant to enter foam manufactured by Rusmar Foam Technology and sometimes used as daily cover material at that site (R. Harris, LGL Ltd., unpubl. obs.).

It is unlikely that it would be logistically feasible to create and apply foam in an arctic field situation. It is unlikely that foam could be used to cover a large spill, or that it could be maintained for a prolonged period over a spill in water. It is also not known how foam would interact with the oil. Even if those considerations did not pose severe problems, its effectiveness would also depend upon weather conditions. Foam is not an effective cover material at landfills in rainy weather, and it might not be useful on windy days.

If oil occurs in pools on the ice, efforts to burn the oil are likely to be more effective at reducing bird problems than would application of foam. Application of foam might hinder or prevent subsequent burning.

Nets

Netting is sometimes used to prevent songbirds from feeding on high-value crops such as cherries, blueberries and grapes (Grun 1978; Twedt 1980; Biber & Meylan 1984; Cocchi 1986). Netting is also occasionally used in attempts to keep birds out of airport facilities, buildings or other locations (LGL Ltd. 1987; Skira & Wapstra 1990). Netting is widely used to deter fish-eating birds from aquaculture facilities on land and offshore (EIFAC 1988; Kevan 1992).

Bird-exclusion netting is made out of polyethylene, other synthetic materials, or cotton, and is available in a variety of mesh sizes. It would not be practical in most spill situations because spill areas would be too large to cover. Netting might be useful in special situations where the oil was confined, or for deterring birds from landing at specific sites such as nest sites. Other deterrent devices, such as pyrotechnics, may enhance deterrent efforts when netting is being used (EIFAC 1988).

Fences

Fences made out of poultry wire (or cable), plastic (Vexar Fencing), netting, and electrical wire, have all been used to deter birds from fish culturing facilities (Mott 1978; Meyer 1981; Ueckermann et al. 1981). Fencing has also been used to keep pigeons from roosting on ledges of buildings, and electrified fences have been effective in some situations for deterring both birds and mammals where regular fences were ineffective (see Koski & Richardson 1976).

Fences would generally not be practical in oil spill situations because the areas involved would be too large to fence, and because many birds would be able to fly over them. Constructing fences may be effective for deterring birds from oil spills if birds are flightless (i.e. moulting or brood rearing) and if the area of concern was relatively small.

Wires, Lines

As early as 1936, overhead wires or lines were recommended as a method of deterring waterbirds from reservoirs and fishponds (McAtee & Piper 1936). In the past two decades, widely-spaced overhead wires have been used to reduce the numbers of gulls attracted to various landfill sites, reservoirs, pools, picnic areas and beaches in the U.S.A. and Canada. Wire spacing has varied widely, from less than 1 m to as much as 25 m. Even wires that are very widely spaced relative to the wingspan of gulls seem to have some deterrent effect on gulls. The gulls are reluctant to fly down between the wires. In a few cases, systematic counts of gulls and other birds have been made in the presence and absence of the wires. These studies have shown that the deterrent effect on gulls is quite pronounced (e.g. Blokpoel & Tessier 1983, 1984; Forsythe & Austin 1984; McLaren et al. 1984). Areas as large as 220 acres have been covered by wires in order to deter gulls from landfill sites (Dolbeer et al. 1988).

Other types of sites where overhead lines or wires have been applied include fish rearing facilities (Ostergaard 1981; Salmon & Conte 1981; Barlow & Bock 1984; Salmon et al. 1986; Moerbeek et al. 1987), airports (Blokpoel & Tessier 1987), fruitcrops (Steinegger et al. 1991; Knight 1988) and backyard feeding stations (Agüero et al. 1991; Kessler et al. 1991). The effectiveness of overhead wires or lines varies widely among species and circumstances. However, some deterrent effect has been shown for a variety of waterbirds, including various gulls, ducks, geese and cormorants (Pochop et al. 1990).

The reason or reasons for the repelling effect of lines or wires are not well understood. Wires that are closely spaced, e.g. 1 m or less, may come close to forming a physical barrier. However, birds are sometimes deterred by wires whose spacing is much greater than the dimensions of the bird.

The required line spacing is highly variable, depending on the species of bird being deterred, the activity of the birds, and the structure or crop that needs protection. To repel gulls from a fish hatchery or nesting colony, the lines must be close together, whereas at a landfill site they can be 3-12 m apart, or even more in some situations (McLaren et al. 1984; Pochop et al. 1990).

Although overhead lines and wires have recently attracted considerable attention as a deterrent measure for landfills, reservoirs, fish hatcheries and aquaculture facilities, this method would not be practical for large oil spills. Deployment would be impossible in offshore areas. Other methods would be more practical and effective. Also, if wires were deployed, some birds might not see the wires. If they collided with a wire, it could be injured and/or oiled.

Water Spray

Water cannon and sprinkler systems using water or water with wetting agents (surfactants) are sometimes employed to control "pest" birds (Harke 1968; Smith 1970; Lustick 1976; Glahn et al. 1991). Water spray has been used as a lethal control method to prevent birds from roosting in urban and agricultural areas; surfactants are sometimes added in order to penetrate feathers. Once they are wet, the body temperature of birds drops and, if the weather is cold, they may die.

Spear (1966) suggests that a sprinkler or water spray system is useful as a method of keeping birds away from water systems. However this method would be impractical for present purposes. Aside from the logistical difficulty of establishing a water spray over a spill in a remote area, it would be counterproductive if any birds entered the water spray. Also, during an oil spill, the sprinkler system might become clogged by oil. The spray system would promote the mixing of oil with water, and it could make cleanup more difficult.

General Considerations re Physical Barriers

Application.—Fences, wires, lines, netting and sprinkler systems would not be practical unless the oil spill were restricted to a small area. Even in the case of a small spill, fencing would only be useful if birds were flightless. Fences and nets might be useful in keeping moulting waterfowl or broods from small spills, or in combination with trapping (see below) to move flightless birds from the area of the spill.

A non-toxic foam may have some potential. If logistically feasible, it could be applied to oil spills on ice, snow or (less likely) in a lead to disguise the oil so that birds would not land. However, the feasibility of using foam in these situations is unknown, and it is unlikely that large areas could be covered. It would probably be more effective to burn any pools of oil on the ice.

Advantages

1. Netting, wires and lines are readily available.

2. Foam may disguise a small oil spill and keep birds from landing in it.

Disadvantages

1. None of these techniques is practical for large spills in coastal areas or for any spill in an offshore situation.

2. Foam has not been tested for use on oil spills.

Literature Reviewed.—Agüero et al. 1991; Amling 1980; Barlow & Bock 1984; Biber & Meylan 1984; Blokpoel & Tessier 1983, 1984, 1987; Cocchi 1986; Devenport 1990; Dolbeer et al. 1988; EIFAC 1988; Forsythe & Austin 1984; Galbraith 1992; Glahn et al. 1991; Grun 1978; Harke 1968; Kessler et al. 1991; Kevan 1992; Knight 1988; Koski & Richardson 1976; Littauer 1990b; Lucid & Slack 1980; Lustick 1976; McAtee & Piper 1936; McLaren et al. 1984; Meyer 1981; Moerbeek et al. 1987; Mott 1978; Pochop et al. 1990; Ostergaard 1981; NCC 1989; Salmon & Conte 1981; Salmon et al. 1986; Skira & Wapstra 1990; Smith 1970; Spear 1966; Steinegger et al. 1991; Twedt 1980; Ueckermann et al. 1981; Whittington 1988.

Lure Areas

Lure areas can be established as a means of attracting and holding birds so that they will not move elsewhere where their presence is undesirable (Sugden 1976). In the case of an oil spill, lure areas would attempt to keep birds from moving into the oiled area until it had been cleaned up. The most efficient attractant would be food, but open water would also be an attractant for sea ducks during the spring period.

Most lure areas in agricultural settings are set up near roosting areas and intercept birds that would otherwise feed in surrounding agricultural fields. The lure crops are generally the preferred food of the species involved. The main objective of establishing the lure area is to attempt to concentrate waterfowl feeding activities inside the lure areas rather than having the birds dispersed among the surrounding fields where they would cause more damage obtaining the same amount of food. Lure areas established because of an oil spill should incorporate the same principles.

Lure areas that satisfy needs other than food have also been established successfully. High-water roosts for shorebirds were constructed and successfully attracted wading birds away from an airfield (Saul 1967; Caithness 1970). In one case, a water-filled gravel pit along a river provided a resting place for waterbirds during an oil spill (Ummels 1983, *in* Hooper et al. 1987). An oil boom was placed across the entrance to prevent oil from contaminating the pit.

Application.—Attracting birds to a lure area requires careful consideration. The lure area must be far enough from the spill to ensure that birds will not encounter oil. Otherwise, the lure area, by attracting more birds into the area, might result in higher rather than lower numbers of birds being oiled. If the birds of concern are threatened by the spill, they must first be moved from the spill area using dispersal techniques that control the direction of movement of the birds. If the birds of concern are elsewhere and are suspected to be moving toward the spill, the lure area should ideally intercept and "short-stop" the birds at the lure area. The latter situation may be the most practical one. Once the birds arrive at the designated area, adequate supplies of the attractant, such as food, must be maintained. Lure areas must also be positioned so that other disturbances (e.g. clean-up operations) will not affect them.

Advantages

1. Provides an alternative area for birds to go.

2. If birds are "short-stopped", they can be kept away from the spill without exposing them to the hazards of the spill.

Disadvantages

1. Another suitable area may not be available when an oil spill occurs.

2. Must be well supplied with food to keep birds in the area.

3. Many of the most vulnerable species, such as eiders, Oldsquaws and loons, are not known to be attracted by artificial food supplies.

Literature Reviewed.—Caithness 1970; Fitzwater 1978; Hooper et al. 1987; Koski & Richardson 1976; Nomsen 1989; Saul 1967; Sugden 1976; Ummels 1983.

Trapping

Trapping is one of the oldest methods used to control birds (Shake 1968). Birds can be live-trapped using mist-nets, cage traps, cannon-nets (Hardman 1974; Draulans 1987; Beg 1990) or large funnel shaped lead-in traps. Pole-traps were once used on fish and game farms (Randall 1975). However, pole-traps are non-selective in catching and killing birds. They are useless as a method of saving birds lives and are illegal in many countries.

Successful deployment of traps depends on many factors such as the total number of birds, availability of food outside of the trap, and the birds' behaviour (i.e. wariness of traps, Nelson 1990a). Shake (1968) found that attempts to trap Red-winged Blackbirds near corn fields were ineffective because the population of birds was high in comparison to the number of birds that physically could be trapped. However, Mott (1978) reported that a small population of Green-backed Herons was captured by mist nets at a fish farm and released 40 km from the capture site. The birds did not return. Trapping was effective at controlling pigeons that roosted on the roofs of buildings and in city parks (Truman 1961). Birds that are hazardous to aircraft, such as hawks and owls, are sometimes trapped at airports and released in areas of suitable habitat distant from the airport (e.g. Hughes 1967; Wernaart & McIlveen 1989). It is important to release the birds far enough away and in suitable habitat; otherwise, many of them are likely to return to the trapping area. Moving traps to new locations every two days will increase the number of birds caught. In agricultural situations it is recommended to place traps in an area before birds arrive but this would not be possible in an oil spill situation.

Catching and moving birds could be time consuming, depending on the species and situation. Building traps can be expensive, especially if large numbers are needed. Complex traps may require considerable manpower and time to set up and maintain. Also, if large numbers (e.g. thousands) of ducks or geese were captured in an area threatened by oil, considerable manpower and logistics support would be required to transport them to a safe area.

Application.—Trapping is not recommended for most oil spill situations, given the logistical difficulties and the possibility that some birds would be driven into oil-contaminated areas by intensive trapping activities nearby. However, trapping may be useful in special circumstances. In particular, it might be the only way to save flightless and/or moulting birds that become trapped in a lagoon or bay by extensive oil moving from offshore to the coast. In such a situation, it might not be possible to disperse the birds by scaring methods, since all potential escape routes via water might be contaminated or threatened by encroaching oil. Creches of sea ducks or geese could also be trapped and moved in situations where extensive areas of coastal wetlands became oiled and similar habitat was not available nearby.

The best method of trapping birds would probably be to set up banding nets and traps, and to use a helicopter to herd the birds into the traps. This would be an efficient way to trap and move several thousand sea ducks, or smaller numbers of moulting or young Brant and White-fronted Geese. This work would need to be done under the supervision of wildlife biologists with experience in the use of such trapping techniques.

Literature Reviewed.—Beg 1990; Clark 1976; Davidson 1968; Draulans 1987; Fitzwater 1978; Hardman 1974; Hussain 1990; Jarvis 1985; LGL Ltd. 1987; Lucid and Slack 1980; Mott 1978; Nelson 1970, 1990a; Randall 1975; Shake 1968; Truman 1961; Wernaar & McIlveen 1989.

Chemical Aversion Agents

Observed Reactions.—Chemical "aversion" agents are used to control birds around commercial and residential areas (Fitzwater 1988; Woronecki et al. 1990), in agricultural situations (Clark 1976; Conover 1984; Knittle et al. 1988), and occasionally at airports (DeFusco & Nagy 1983; B.S.C.E. 1988) and at sanitary landfill sites (Caldara 1970; White & Weintraub 1983; Woronecki et al. 1989). These agents have been used primarily on starlings, blackbirds and other passerine birds. However, Avitrol has also proven useful in dispersing gulls (e.g. Caldara 1970; Wooten et al. 1973; DeFusco & Nagy 1983; White & Weintraub 1983). Methiocarb was effective at reducing grazing by Canada Geese on turf plots (Conover 1985a) and by captive Canada Geese feeding on winter rye (Conover 1989). However, a single treatment of methiocarb was not effective in dispersing free-ranging geese from grain fields (Conover 1989).

Avitrol (4-aminopyridine) and Methiocarb (3,5-Dimethyl-4-(methylthio)phenyl methylcarbamate) are poisons that, in sublethal doses, may cause disorientation and erratic behaviour. They are usually added to bait. When the bait is ingested, a distress response occurs (DeFusco & Nagy 1983; White & Weintraub 1983; Brooks & Hussain 1990). Distress calls from affected birds can start 15 min after ingestion, and can last up to 30 min after ingestion. Besides emitting distress calls, affected birds may become disoriented and exhibit erratic behaviour, often flopping about on the ground. This behaviour often alarms other birds, and causes them to fly away. If too high a dose is ingested, the bird will die. Tremors and convulsions occur before death if birds receive an overdose, and these may induce other birds to leave the area.

The aversive agent methyl anthranilate, known commercially as ReJeX-iT, is presently being tested for effectiveness in dispersing birds (e.g. Crocker & Perry 1990; Cummings et al. 1992; Dolbeer et al. 1992). This compound, unlike Avitrol and Methiocarb, is non-toxic. It can be mixed in bait or in water. Its taste is apparently unpleasant to birds, including Mallards and Canada Geese (Cummings et al. 1992). If its effectiveness and non-toxicity are substantiated through ongoing and future testing, methyl anthranilate may be more widely applicable than previously-available chemicals, which are difficult to use because of their toxicity. Ortho-aminoacetophenone, a non-toxic chemical similar to methyl anthranilate, also appears to have potential for repelling or dispersing birds (Mason et al. 1991).

<u>Application</u>.—Aversion agents may be applicable as a last resort in oil spill situations where flocks of birds, especially feeding birds, need to be dispersed immediately. Effectiveness of baiting could be influenced by environmental conditions, number of birds and bait preference. Birds have been shown to develop a conditioned aversion to some agents. Considerable care would be necessary in the use of potentially harmful agents like Avitrol and Methiocarb, and some mortality should be expected. Methyl anthranilate may prove to be a better choice because of its non-toxic nature, but as yet its effectiveness is not well documented.

Chemical aversion agents might be used if large numbers of birds are present in feeding congregations in an area that is imminently threatened by oil. Feeding birds are particularly difficult to disperse from an abundant food source, and aversion agents may be useful in breaking the attraction to the food source. Supplementary dispersal methods would be needed, along with the aversion agent, in order to obtain maximum effectiveness.

Advantages

1. Chemical aversion agents could be effective at dispersing large flocks of birds from large areas rapidly, assuming that a method of distributing the chemical-laden bait is available.

Disadvantages

1. It would be difficult if not impossible to apply these types of chemicals to the types of food eaten by the most vulnerable species of waterbirds and shorebirds.

2. If Avitrol or Methiocarb is used, some of the birds that ingest the bait will likely die.

3. Avitrol and Methiocarb must be applied by licensed pest control personnel.

4. Other supplementary deterrent techniques must be used with baiting.

5. The direction of movement of the birds is not controlled.

Literature Reviewed.—Brooks & Hussain 1990; B.S.C.E. 1988; Caithness 1968; Caldara 1970; Clark 1976; Conover 1984, 1985a; 1989; Crocker & Perry 1990; Cummings et al. 1992; DeFusco & Nagy 1983; Devenport 1990; Dolbeer et al. 1992; Fitzwater 1978, 1988; Green 1973; Knittle et al. 1988; Koski & Richardson 1976; Mason et al. 1991; Rodgers 1978; Skira & Wapstra 1990; Truman 1961; Wakeley & Mitchell 1981; White & Weintraub 1983; Wooten et al. 1973; Woronecki et al. 1989, 1990.

High Energy Electro-Magnetic Waves

Microwaves and lasers produce high energy electro-magnetic waves. The energy can cause a stress, discomfort and behavioral effects in both birds and mammals (including humans). If the energy is powerful enough, heating and physical damage can occur. For these reasons, microwaves and lasers have not been adopted as practical deterrent methods for birds.

Microwaves

Humans and other mammals can detect microwave energy at average power densities below 1 mW/cm^2 and at peak power densities below 100 mW/cm^2 (King et al. 1971; Frey and Messenger 1973). At higher power levels, thermal effects occur. In birds, thermal effects may occur at levels as low as 50 mW/cm^2 (Byman et al. 1985); in rats thermal effects have been noted at levels as low as 5-10 mW/cm^2 (Stern et al. 1979). Evidence reviewed by King et al. (1971) indicates that microwave radiation can produce a wide variety of physiological effects in humans, and that microwaves at densities below the "safety limit" of 10 mW/cm^2 accepted in North America can affect nervous activity. This human safety limit has been controversial, in part because of evidence that significant effects can occur at levels well below 10 mW/cm^2 (Steneck et al. 1980). In some countries, considerably lower safety limits have been established (Assenheim et al. 1979).

Evidence concerning the effects of microwaves on birds is conflicting, but it is clear that overt effects can be produced if power densities are sufficiently high. Tanner and his collaborators (1965-1970) have shown that intense microwave fields (average power 10-50 mW/cm^2) can cause temporary muscular and neurophysiological disturbances in chickens, pigeons, gulls and budgerigars. Responses to these fields included extension of legs and wings, unsteadiness of gait, and collapse. Of particular relevance to the deterrent potential of were the experiments of Tanner et al. (1970) that showed that the feeding behaviour of caged Leghorns could be changed by radiating at an intensity of 40 mW/cm^2 one of two feeding containers. The chickens chose to feed at the non-irradiated food source. After 12 days of irradiation, the hens did not return to the pre-radiation patterns of feeding until four days after the radiation ceased. Furthermore, they immediately avoided the radiated area when radiation commenced again. These levels of radiation, however, are considerably higher than levels that are safe for humans.

A few studies have reported that radars have caused behavioral changes in flying birds (Poor 1946; Drost 1949; Knorr 1954; Hild 1971; Wagner 1972). However, numerous other investigators using both similar radars (Eastwood and Rider 1964; Gehring 1967; Houghton et al. 1967; Bruderer 1971; Able 1974 and many others) and higher-powered tracking radars (e.g. Williams et al. 1972; Emlen 1974) have not noticed strange behaviours in the birds that they were tracking, even at close distances.

Available evidence suggests that microwave radiation does not deter birds unless power levels are high enough to pose a potential hazard to humans and perhaps the birds themselves. Microwaves have not been adopted as a practical or safe bird deterrent technique (Hunt 1973; B.S.C.E. 1988).

Lasers

Lasers have been suggested as a technique for dispersing birds (Lustick 1972, 1973; Lawrence et al. 1975). Although Lustick's experiments suggested that starlings, Mallards and Herring Gulls were disturbed by either pulsed or continuous laser light, the light had to be directed at sensitive areas on the birds. When aimed at the feathers birds did not react even though the laser was capable of igniting their feathers.

Seubert (1965) described experiments in which caged gulls were exposed to pulsing lasers. Pulsed light at low powers (1-2 joules) produced some flinching but no distress or alarm calls. Light pulses of 100-200 joules directed at the birds singed feathers and caused bleeding in the bird's eyes. However, the gulls reacted no more to the stronger light than to the 1-2 joule light. A continuous laser was also tested (power not stated) but the gulls looked directly into the beam of intense red light with no appearance of discomfort.

More recently, Mossler (1980) tested whether the beam from a helium-neon laser would deter gulls at a landfill from feeding on highly-attractive food. The gulls showed some limited behavioural reactions to the laser beam, but it did not deter them from feeding.

Although lasers may in some situations be able to disperse birds, the required power levels would be hazardous to humans. Therefore, lasers are not practical as bird deterrents.

Literature Reviewed (Microwaves and Lasers).—Able 1974; Assenheim et al. 1979; Bruderer 1971; Burger 1983a; Byman et al. 1985; Drost 1949; Eastwood and Rider 1964; Emlen 1974; Frey and Messinger 1973; Gehring 1967; Hild 1971; Houghton et al. 1967; Hunt 1973; King et al. 1971; Knorr 1954; Koski & Richardson 1976; Lawrence et al. 1975; Lustick 1972, 1973; Mossler 1980; Poor 1946; Seubert 1965; Steneck et al. 1980; Stern et al. 1979; Tanner 1965, 1966; Tanner et al. 1967, 1970; Wagner 1972; Williams et al. 1972.

EVALUATION OF EFFECTIVENESS IN DIFFERENT HABITATS

As shown in the previous section, a large number of devices and procedures are available that might be useful for dispersing or deterring birds of certain types and in certain situations. However, few of these devices have been tested in situations similar to those that might be encountered in the Beaufort Sea, or on species of birds that occur there. The effectiveness and logistical practicality of various methods are likely to differ depending on the species, age and sex of bird; weather conditions; season; time of day or night; habitat; reasons for the birds' presence in the habitat; and proximity to other suitable habitat. Furthermore, the most effective methods will vary depending on whether one is attempting to disperse birds already in an area or to deter birds from entering the area, and on whether the area is already oiled vs. threatened by oil. Several otherwise-effective dispersal techniques may cause birds to dive into the water, which could increase rather than decrease bird mortality if oil is present.

In some situations the speed of deployment of dispersal or deterrent techniques is critical and will outweigh its relative effectiveness. If oil were moving toward a large numbers of moulting sea ducks in a bay or lagoon, and if it were impractical to block the oil with booms or other devices, rapid dispersal of most birds to a nearby unthreatened area would take precedence over a slower method that might be more effective if more time were available. In other situations (e.g. in autumn staging areas used by geese), long-term effectiveness of the deterrent is also important. Initial dispersal techniques may need to be followed up with different deterrent methods. Thus, different deterrent techniques may be necessary for similar species, or even the same species, in different habitats or situations.

Many deterrent techniques are likely to be most effective if used in combination with other complementary techniques. Complementary techniques may provide stimuli that reinforce one another. For example, an effigy or scarecrow and a propane cannon are complementary techniques. A scarecrow provides the visual stimulus of a hunter, and this is reinforced by the bang produced by the cannon. In this example the complementary techniques stimulate different senses (auditory and visual), and their simultaneous use will increase effectiveness and reduce habituation. Other complementary techniques might include

- falcons, distress calls, and models of hawks, falcons or dead birds;
- boats, flashing lights, and shell crackers;
- intermittent firing of rockets and mortars interspersed with shellcrackers, gas cannons and flares;
- foam in combination with dyes (white for camouflage or fluorescent orange as a deterrent); and
- herding of waterfowl in combination with lure areas or trapping.

It should be noted that this study only addresses deterrent and dispersal techniques to protect birds. It does not deal with integrated oil spill response methods. For example, this report mentions possible methods to disperse vulnerable birds if part of an oil slick were drifting toward flocks of flightless waterfowl in a lagoon behind a barrier island. A complementary and perhaps better approach would be to place oil containment booms across the entrance to the lagoon to prevent oil from reaching the waterfowl. It is also likely that activities associated with clean-up of the oil will contribute to dispersal and deterrent efforts. However, these complementary activities and approaches are beyond the scope of the present review.

In the following sections we integrate what is known about the effectiveness of various dispersal and deterrent techniques, bird distribution and behaviour in the Beaufort Sea area, and logistics considerations to obtain a short list of the dispersal and deterrent techniques that are most likely to be practical and effective in each of the five potential oil spill situations. We emphasize that ***few or none of these techniques (or combinations of techniques) have been tested in situations that might be encountered in the Beaufort Sea***. In some cases, field trials are advisable to test the effectiveness of the most promising techniques (p. 77).

Sedge Lowlands in the Mackenzie Delta During Autumn

Large areas of lowland near the coast of the Beaufort Sea are periodically inundated by storm surges (Henry & Heaps 1976; Reimnitz & Maurer 1979; Harper et al. 1988). These generally occur during late summer and autumn storms with strong west or northwest winds. Marine water can move over areas as much as 2 m or (very rarely) 3 m above sea level (Harper et al. 1988). The 2-m contour is several kilometres inland in some areas along the mainland coast of the Beaufort Sea. If a major oil spill occurred prior to or during a storm surge, patches of oil could be deposited over a large area of coastal lowland. Some of these lowland areas support very large numbers of waterfowl during parts of the late summer and autumn seasons.

Major Species of Concern

The sedge lowlands along the Beaufort Sea coast, particularly the outer Mackenzie Delta, are important late summer and autumn staging areas for ducks, geese and swans. Snow Geese and White-fronted Geese stage on the Yukon and Alaskan North Slope and in the Mackenzie Delta lowlands for about three weeks each year from late August to mid- or late September (Koski 1977b; Alexander et al. 1988a). In addition, large numbers of Black Brant (spring estimate=26,000, Richardson & Johnson 1981) migrate along the Beaufort Sea coast in late August and some stop to feed for a few days in sedge lowlands. The areas most heavily used by Brant are in the outer Mackenzie Delta and the Blow River Delta, at Phillips Bay, and on the Malcolm/Firth river deltas. All Black Brant nesting in the western Canadian Arctic migrate along the Beaufort Sea coast during this period, and would be vulnerable to oiling should oil be present in the bays, lagoons or sedge lowlands during late August. During years when the Yukon and Alaska North Slopes freeze in early September, the sedge lowlands in the Mackenzie Delta can be used by 300,000 Snow Geese and 25,000 White-fronted Geese at a single time. Total numbers using the area at some time during the season are much higher after allowance for day-to-day turnover of the individuals present (Koski 1977a).

Oiling of the sedge lowlands of the outer Mackenzie Delta could have a serious effect on the White-fronted Goose population and, during years of early freeze-up on the Yukon North Slope, the Snow Goose population as well. Use of these areas is traditional for Snow Geese and White-fronted Geese. Birds that are heavily oiled would die as a result of the loss of the insulation capabilities of their feathers or other problems. Although it would certainly be desirable for birds to be deterred from entering heavily oiled areas, some unoiled birds might also die or be severely stressed if they cannot build up the energy reserves that they normally accumulate on the autumn staging areas before migrating south (Patterson 1974; Wypkema & Ankney 1979). If geese are excluded from their normal staging areas, it is possible that no equally suitable alternate staging areas may be available. Ducks and Tundra Swans that stage in the sedge lowlands may move inland to alternate staging areas more readily than would Snow and White-fronted Geese. Ducks and swans traditionally use staging areas in the central and southern Mackenzie Delta in addition to those in coastal areas.

Other species of water and land birds occurring within or along the outer edge of the coastal lowlands area could also be affected if a spill coincided with a storm surge. The species and numbers would depend on the location and date. These species could include loons, jaegers, phalaropes, other shorebirds, gulls and terns. Some of the largest concentrations, e.g. of autumn-staging phalaropes and loons, occur along the coast. These coastal concentrations are considered in a later section dealing with an oil spill in a bay or lagoon.

General Considerations

The probable usefulness of each deterrent technique for dispersing and deterring waterfowl (particularly geese) from sedge lowlands is summarized in Table 1. The potential for habituation, the possibility that the method might attract birds, and the logistical practicality are also summarized for each technique. In the case of a large spill affecting a large area of lowland, few techniques are likely to be very useful, mainly because of the remoteness of much of the region and the associated logistical complications in deploying and maintaining sufficient equipment and personnel. However, if the area affected is not too large, several techniques could be useful deterrents for waterfowl. Some of the most useful methods are likely to be those that indicate or simulate the presence of hunters. The Phoenix Wailer, which has not been tested, may be useful for many species of birds that are not hunted. However, it is likely to be less effective for waterfowl than deterrents that suggest the presence of hunters. Deterrents that include or mimic avian predators should be avoided because they may cause waterfowl to land in or dive into the water, and hence increase their chances of becoming oiled.

The following sections discuss the techniques that are likely to be useful in dispersing and deterring birds. There is some overlap between the methods useful in ***dispersing***

Table 1. Probable usefulness of various bird dispersal and deterrent methods for oil spills in sedge lowlands in late summer and autumn. The methods that are most likely to be useful are highlighted in boldface and italics.

	Effectiveness			Attractant			
	Day	Night	Habituation	Day	Night	Logistical practicality	Complementary methods
1. ***Fixed-wing aircraft***	***Good***	Unsafe	Slow	No	-	Competing demands in spill situation	5-12, 20
2. ***Helicopter***	***Very good***	Unsafe	Slow	No	-	Competing demands in spill situation	5-12, 20
3. Model aircraft	Unlikely	No	Slow	No	-	Requires trained operator	-
4. Boats	No	No	-	-	-	Access limited to water; may chase birds into oil	-
5. ***Shotguns, shellcrackers and firecrackers***	***Good***	***Good?***	Slow	No	No	Good; purchase in advance; limited shelf life	6-12, 19
6. Verey flares and tracer shells	Fair	Good?	Possible	No	No	Good; must be purchased in advance	5, 7-12, 20
7. Rockets and mortars	Good	Good?	Doubtful	No	No	Good; training and permits needed; safety concerns	5, 6, 8-12, 20
8. ***Gas Cannons***	***Good***	***Good***	Slow	No	No	Good	5-7, 9-12, 20
9. Distress and alarm calls	Fair	Fair	Slow	Unlikely	Unlikely	Taped calls needed in advance	5-8, 10-12, 20
10. Sounds of predators	Unlikely	Unlikely	-	-	-	Fair but likely ineffective	-
11. Av-alarm	Fair	Fair	Rapid	No	No	Good	5-10, 19-21
12. Phoenix Wailer	Probable?	Probable?	Slow?	No	No	Good	5-10, 19-21
13. Ultrasonics	No	No	-	-	-	Few birds can detect ultrasounds	-
14. High intensity sounds	Doubtful	Possible	Probable	No	No	Hazard to humans	-
15. Dyes (oil soluble)	Unlikely	No	-	-	-	Deployment difficult due to vegetation	-
16. Searchlights and expanded lasers	Doubtful	Possible	Possible	Possible	Variable	Good	5-8, 11, 12
17. Flashing lights	Doubtful	Good?	Possible	Possible	Doubtful	Good	5-8, 11, 12
18. Flags, balloons, smoke	Doubtful	No	Rapid	Possible	-	Good but effectiveness doubtful	-
19. Models of dead birds/predators	Fair	No	Variable	Variable	-	Good; repositioning advisable	5-12, 17, 20, 21
20. ***Effigies***	***Fair***	No	Possible	No	-	Good	5-12
21. Hawks, falcons and dogs	Variable	No	Variable	Doubtful	-	Unlikely	9-12, 20
22. Foam	Impractical	No	-	-	-	Deployment impossible with vegetation present	-
23. Nets & Fences	Impractical	No	-	-	-	Good but areas potentially too large	-
24. Wires	Impractical	No	-	-	-	Good but areas potentially too large	-
25. Water spray	Impractical	No	-	-	-	Good but areas potentially too large	-
26. Lure areas	Unlikely	Unlikely	-	Possible	Possible	Low and potential hazards	-
27. Trapping	Impractical	No	-	-	-	Difficult to deploy	-
28. Chemicals	Unlikely	Unlikely	-	Doubtful	Doubtful	Possibly useful as a last resort	1, 2
29. Microwaves and lasers	Impractical	Impractical	-	-	-	Hazard to humans; heavy equipment for µ waves	-

birds within an oiled or oil-threatened area vs. those useful in ***deterring*** birds from landing in such an area. However, the dispersal and deterrent tasks are sufficiently different to warrant separate discussion.

Dispersal Methods

An initial task in the event of an oil spill would be to disperse as-yet-unoiled birds from the area of the spill and from areas where oil is soon expected to encroach. The optimal dispersal technique will depend on the size of the spill. Ideally, the selected technique or combination of techniques should allow some control over the direction of the bird movement. Random movements may result in increased numbers of birds encountering oil. In the case of a "small" spill (a few km^2 or less) in the sedge lowlands, pyrotechnic devices such as shotguns and shellcrackers should be deployed to disperse and deter birds from the oiled lowland. The procedures should be implemented to disperse birds from the spill area but to minimize disturbance in surrounding areas. This would be important for two reasons: to provide a nearby location for the dispersed birds to move into, and to minimize the chances that frightened birds from surrounding areas would move into the spill area.

In the case of a spill affecting large areas of the sedge lowlands, hazing by aircraft would provide the only practical method of dispersing waterfowl. Aircraft can be readily deployed and can disperse birds from a large area in a relatively short time. There is a danger that birds chased by aircraft will, while trying to avoid the aircraft, land in areas that have been oiled. However, total numbers oiled would probably be less than if no aircraft hazing were attempted. It would be important to chase all waterfowl away from the area of the oil even if some birds became oiled in the process. Birds remaining in the area would be at risk of oiling, and would also attract (decoy) other waterbirds flying over the area. Helicopters are preferable to fixed-wing aircraft for hazing operations because of their better manoeuvrability, which permits better control of bird movements.

If oil is present in the sedge lowlands during the Brant migration, a low-flying helicopter should be used to disperse them. Brant are much more tolerant of aircraft than are Snow Geese or White-fronted Geese. The escape reaction of Brant is frequently to flush from terrestrial locations and land in the water. The aircraft needs to remain low to the ground and behind the birds; if it overtakes them or is high in the air, Brant may land in the water and become oiled.

Deterrent Methods

Hazing by aircraft and use of pyrotechnics would also be important methods for deterring waterbirds from landing on the oiled lowlands. However, it is not likely to be possible to operate these methods continuously over a period of many days or weeks. Hence, additional deterrent measures that can operate on a semi-autonomous basis are needed. These should include gas cannons ("exploders") supplemented by human effigies and flashing lights where practical. Rockets, mortars, shotguns and shellcrackers can also be used when practical and necessary. Aircraft should be used to monitor the vicinity of the spill for birds that have habituated to the deterrent system. If birds are seen, they should be hazed by aircraft until they leave the area.

To minimize the rate of habituation, gas cannons should fire at random intervals so that firing is not steady or predictable. The cannons should also be of the type that rotate so they do not fire in the same direction each time. If possible, human effigies should be set up so that they move or turn in the wind. Birds that are chased with aircraft should be pursued until they leave the area.

Seabird Colony

Major Species of Concern

There are many seabird colonies in the Beaufort Sea and Amundsen Gulf, but two small colonies are of special significance: the Thick-billed Murre colony at Cape Parry (Johnson & Ward 1985; C.W.S. 1989; Johnson & Herter 1989) and the Black Guillemot colony at Herschel Island (Kuyt et al. 1976; Ward & Mossop 1986; Alexander et al. 1988a). Although neither colony is large, they are unique in the western Canadian Arctic. Small colonies of Glaucous Gulls, Sabine's Gulls and Arctic Terns are scattered in coastal areas of the Beaufort Sea and Amundsen Gulf. The largest of these is 50-300 pairs of Glaucous Gulls on Escape Reef near Shingle Point, Y.T. (Alexander et al. 1988a).

General Considerations

The primary goal of bird dispersal and deterrent efforts around a seabird colony should be to minimize the number of adults that are oiled even if it means loss of that year's production of young at the colony. Thus, in the case of a significant oil spill near Cape Parry or Herschel Island, it would be desirable to move birds away from the spill area for the remainder of that breeding season, ***if feasible***. Most seabirds, including murres, are long lived. Loss of young during one season will have less impact on the long-term health of the population than loss of breeding adults.

However, it is very questionable whether dispersal of adult murres from their colony would be feasible. The success of dispersal efforts would probably depend on the stage of the nesting cycle. Adults will be difficult or impossible to disperse if they have eggs or young on the cliffs. If it were possible to remove the eggs or young, this might increase the probability that adults could be induced, through application of dispersal and deterrent methods, to leave the colony and its environs. At least initially, the reaction of the adults to dispersal attempts would probably be to land in the water near the colony. This could increase rather than decrease adult mortality. If this approach were attempted, it would be necessary to apply intensive and continuous dispersal and deterrent effort to prevent birds from returning to the surrounding contaminated waters. A further consideration is that sea birds such as murres and guillemots tend to dive into the water to avoid predators. Thus, deterrents that are deployed on cliffs above birds or that mimic natural predators are likely to cause birds to dive into the water, which will increase their probability of becoming oiled.

In general, any significant spill that affects waters near a seabird colony, e.g. the murre colony at Cape Parry, will kill a significant proportion of the birds present. No known combination of bird dispersal and deterrent systems can prevent this mortality. ***Dispersal and deterrent activities near a colony should be done only with the approval of the agency responsible for protection of migratory birds in Canada: the Canadian Wildlife Service (offices in Yellowknife and Edmonton).***

Dispersal and Deterrent Methods

The methods that might be used to disperse birds from a seabird colony, if this is deemed appropriate, would depend on whether oil was present in the water at the colony when the initial dispersal was attempted. If oil is already present, it would be essential to set up an effective system of deterrents to prevent birds from landing on the water before attempting to disperse them from the colony (Table 2). Otherwise, birds dispersed from the colony would likely land in the oil-contaminated water and die.

If oil is not present initially, but a substantial spill moving toward the colony is highly likely to reach the colony, the first objective should be to disperse adults from the colony as part of an attempt to break their ties with territories or young. In some situations it might be possible to physically block access to nesting sites, e.g. with large nets. However, we suspect that this would be counterproductive even if it were feasible. Birds prevented from landing on the cliffs would try to land in the water near the colony. It might be safer (for the adults) to

- remove the eggs and young, thereby encouraging abandonment of the colony for the year,
- allow the adults to continue visiting the now-bare nest ledges, where they would be safe from oiling, until such time as they abandon the colony area for the year, and
- use water-based deterrent methods in an attempt to keep adults from landing on the contaminated water.

Water-based deterrent efforts using boats in combination with shotguns, shell-crackers, mortars and rockets are likely to be more effective than aircraft for dispersing murres and guillemots. An aircraft would cause these birds to dive rather than leave the area (Table 2). If waters around the colony are contaminated, complementary deterrent devices such as gas cannons, flashing lights and the Phoenix/Marine Wailer (if tests confirm its efficacy) might also be placed on rafts or booms, depending on weather conditions.

The drastic action discussed here needs to be weighed against the probability that significant amounts of oil will be present around the colony. These deterrent actions will, at best, reduce (rather than prevent) mortality of adult seabirds. It is also possible, although unlikely, that these deterrent actions may cause some or all adults to abandon

Table 2. Probable usefulness of various bird dispersal and deterrent methods for oil spills in the vicinity of a seabird colony. The methods that are most likely to be useful are highlighted in boldface and italics.

	Effectiveness			Attractant			
	Day	Night	Habituation	Day	Night	Logistical practicality	Complementary methods
1. Fixed-wing aircraft	Unlikely	Unsafe	-	-	-	Competing demands; unlikely to be effective	-
2. Helicopter	Unlikely	Unsafe	-	-	-	Competing demands; unlikely to be effective	-
3. Model aircraft	Variable	No	Slow	No	-	Requires trained operator	9-12, 19-21
4. ***Boats***	***Variable***	***c. lights***	Probable	No	No	Deployment depends on weather	5-10, 17-20
5. Shotguns, shellcrackers and firecrackers	Fair	Fair?	Slow	No	No	Good; shell crackers must be purchased in advance, others readily available	6-12, 19
6. Verey flares and tracer shells	Variable	Fair?	Possible	No	No	Good; must be purchased in advance	5, 7-12, 20
7. ***Rockets and mortars***	***Fair***	***Fair?***	Doubtful	No	No	Good; training and permits needed	5, 6, 8-12, 20
8. ***Gas Cannons***	***Good***	***Good***	Slow	No	No	Good	5-7, 9-12, 20
9. Distress and alarm calls	Untried	Untried	Slow	No	No	Good	3, 5-8, 10-12, 19
10. Sounds of predators	Unlikely	Unlikely	Possible	No	No	Good but likely ineffective	3, 5-9, 11, 12, 19, 20
11. Av-alarm	Variable	Variable	Rapid	No	No	Good	3, 5-10, 19-21
12. ***Phoenix Wailer***	***Possible?***	***Possible?***	Slow?	No	No	Good	3, 5-10, 19-21
13. Ultrasonics	No	No	-	-	-	Few birds can detect ultrasonics	-
14. High intensity sounds	Unlikely	Possible	Probable	No	No	Hazard to humans	-
15. Dyes (oil soluble)	Unproven	c. lights	Possible	Possible	No	Unproven. Aircraft required for application	16, 17
16. Searchlights and expanded lasers	Doubtful	Possible	Possible	Possible	Variable	Good	5, 7, 8, 11, 12
17. ***Flashing lights***	Doubtful	***Good?***	Possible	Possible	Doubtful	Good	5, 7, 8, 11, 12
18. Flags, balloons, smoke	Doubtful	No	Rapid	Possible	-	Good but doubtful effectiveness	-
19. Models of dead birds/predators	Fair	No	Rapid	Possible	-	Good	5-12, 17, 20, 21
20. Effigies	Fair	No	Rapid	Possible	-	Good	5-12
21. Hawks, falcons and dogs	Variable	No	Variable	Doubtful	-	Manpower intensive; limited availability of animals	9-12
22. Foam	Unlikely	No	Doubtful	Doubtful	-	Untested; variable; depending on weather	15
23. Nets and Fences	Doubtful	No	No	No	-	At a small colony site	17, 20
24. Wires	Doubtful	No	-	-	-	Good but doubtful effectiveness	-
25. ***Water spray***	***Possible***	No	Possible	No	-	Fair at colony site	-
26. Lure areas	No	No	-	-	-	Would increase hazard to birds	-
27. Trapping	Variable	Variable	No	No	No	Impractical on large cliff	-
28. Chemicals	Unlikely	Unlikely	-	Doubtful	Doubtful	Possibly useful as last resort	1, 2, 4
29. Microwaves and lasers	Impractical	Impractical	-	-	-	Hazard to humans; heavy equipment for μ waves	-

the colony permanently. That could be just as bad for the long-term viability of the colony as is the oil. As already noted, any deterrent efforts around a seabird colony need to be planned in consultation with appropriate people at the Canadian Wildlife Service in Edmonton and Yellowknife.

Bays and Lagoons During Summer

Major Species of Concern

Bays and lagoons along the coasts of the Beaufort Sea and Amundsen Gulf are potentially exposed to oil moving ashore from an offshore spill. These bays and lagoons include important feeding and moulting areas for sea ducks (primarily Surf and White-winged Scoter, Oldsquaw and scaup), autumn staging areas for Red-necked Phalaropes, and brood-rearing areas for Black Brant, Common Eiders, and Glaucous and Sabine's Gulls. The most heavily utilized areas tend to be the low, marsh flats and lagoons that are protected by barrier islands (Barry & Barry 1982; Alexander et al. 1988a).

General Considerations

The selection of methods for dispersing and deterring birds from bays and lagoons during the summer period needs to consider that many of the birds present will not be able to fly. This magnifies the importance of rapidly dispersing the birds from the area of the spill. Although initial dispersal is likely to be difficult, once birds are dispersed from the area of the spill, they are less likely to return.

Sea ducks are not as heavily hunted as are most other groups of waterfowl. Consequently, they are not as easy to disperse or deter as species such as Snow and White-fronted Geese. Young waterfowl and gulls are naive and are also likely to be difficult to disperse or deter. Dispersal will be particularly difficult if the spill is large and birds have to move a long distance to avoid oil.

Moulting waterfowl often concentrate in protected bays or lagoons behind barrier islands. In some of these situations, an oil containment boom of practical length might be able to prevent oil from entering the bay or lagoon. When practical, this approach would be preferable to any attempt to move the flightless birds.

Dispersal Methods

The recommended method of dispersal depends on whether birds are being dispersed before or after oil arrives in the area, and on the extent of the spill. If oil is spilled offshore and is moving toward a bay or lagoon, it will be important to disperse birds from the threatened area before oil arrives. This will greatly reduce the possibility of birds becoming oiled. Moulting birds cannot fly and will need to be herded to areas that are secure from encroachment by oil. In a spill, oil trajectories will be poorly known and variable, depending on changing wind conditions. Thus, in only a few situations is it likely that particular areas will be identifiable as target areas and others as safe areas.

Two dispersal techniques are possible for birds that cannot fly. One is to use a helicopter to herd the birds. The second is to herd them using boats in combination with some combination of shotguns, shell crackers, rockets and mortars (Table 3).

Helicopters are likely to be the only practical dispersal technique for birds in bays and lagoons in the Beaufort Sea during most oil spill situations, particularly if the area contaminated or threatened by oil is large. Provided that bird dispersal receives priority when helicopter support is being assigned during a spill situation, helicopters can be deployed rapidly to most coastal locations. However, helicopters have short ranges and require fuel caches to operate for extended periods in areas remote from bases. This could be a serious limitation in some areas.

A helicopter has been shown to be effective in dispersing moulting sea ducks from a relatively small lagoon system. The ability to control bird movements over a much larger area has not been demonstrated. Dispersal using a helicopter is likely to be extremely stressful on the birds, particularly if they must be herded a long distance.

People on foot walking along barrier islands or the shoreline, in combination with boats, shotguns, shellcrackers, rockets and mortars, would also be an effective method of dispersing birds. Moulting birds would move ahead of the people and boats. Bird movements and destinations could be better controlled using this method than by helicopter. However, deployment would be slower and would require considerably greater logistical support. If oil were present in the area, this technique would be preferable to using a helicopter because of the greater ability to control the movements of birds. However, this method would be too slow, and hence impractical, if the area involved were large.

Deterrent Methods

Once birds are dispersed from coastal bays or lagoons, deterrent systems would need to be deployed to prevent birds from returning. Gas cannons and possibly the Phoenix Wailer could be set up on shore or on rafts along the shoreline (Table 3). The Marine Wailer could be deployed in offshore areas. Human effigies, boats, shotguns, shell crackers, rockets and mortars would complement the cannons and the Phoenix/Marine Wailer, and would help to reduce habituation. Aircraft, particularly helicopters, could be used to harass and chase away any birds that return. It is important to prevent birds from remaining in or returning to a spill area because these individuals might attract other flying birds.

If oil has moved up against a barrier island and many flightless birds are temporarily isolated from the oil in a lagoon behind the island, it might be possible to trap and relocate the flightless birds. This technique would be manpower intensive and expensive because of the need to transport birds from the spill location. However, for species that might attempt to flee to open-water (i.e. into the oil) during dispersal attempts—e.g.

Table 3. Probable usefulness of various bird dispersal and deterrent methods for oil spills in bays and lagoons during summer. The methods that are most likely to be useful are highlighted in boldface and italics.

	Effectiveness			Attractant			
	Day	Night*	Habituation	Day	Night	Logistical practicality	Complementary methods
1. ***Fixed-wing aircraft***	***Good***	Unsafe	Slow	No	-	Competing demands in spill situation	-
2. ***Helicopter***	***Very good***	Unsafe	Slow	No	-	Competing demands in spill situation	-
3. Model aircraft	Fair	No	Slow	No	-	Requires trained operator	9-12, 19-21
4. ***Boats***	***Variable***	*c.* lights	Probable	No	No	Deployment may depend on weather	5-10, 18-20
5. ***Shotguns, shellcrackers and firecrackers***	***Good***	***Good?***	Slow	No	No	Good; shell crackers must be purchased in advance, others readily available.	6, 7, 8, 20
6. Verey flares and tracer shells	Fair	Good?	Possible	No	No	Good; must be purchased in advance.	5, 7, 8, 20
7. ***Rockets and mortars***	***Good***	***Good?***	Doubtful	No	No	Good; training, permits and caution needed	5, 6, 8, 20
8. ***Gas Cannons***	***Good***	***Good***	Slow	No	No	Good	5, 6, 7, 20
9. Distress and alarm calls	Possible	Good	Slow	Possible	Possible	Calls needed for most species	10, 19, 21
10. Sounds of predators	Untried	Untried	-	-	-	Good but unknown effectiveness	-
11. Av-alarm	Fair	Fair	Rapid	No	No	Good	5-9, 18-21
12. ***Phoenix Wailer***	***Probable?***	***Probable?***	Slow?	No	No	Good	5-9, 18-21
13. Ultrasonics	No	No	-	-	-	Few birds can detect ultrasonics	-
14. High intensity sounds	Doubtful	Possible	Probable	No	No	Hazard to humans	-
15. Dyes (oil soluble)	Unproven	*c.* lights	Possible	Possible	No	Unproven; aircraft required for deployment	-
16. Searchlights and expanded lasers	Doubtful	Possible	Possible	Possible	Variable	Variable; perhaps good	4-8, 11, 12
17. Flashing lights	Doubtful	Good?	Possible	Possible	Doubtful	Good	4-8, 11, 12
18. Flags, balloons, smoke	Doubtful	No	Rapid	Possible	-	Good but effectiveness doubtful	-
19. Models of dead birds/predators	Fair	No	Variable	Possible	-	Good but repositioning advisable	5-12, 20
20. ***Effigies***	***Fair***	No	Rapid	Possible	-	Good	5-12
21. Hawks, falcons and dogs	Variable	No	Variable	Doubtful	-	Manpower intensive; limited availability of animals	9-12, 20
22. Foam	Unlikely	No	Doubtful	Doubtful	-	Untested; variable; depending on location and weather	15
23. Nets and Fences	Impractical	Impractical	-	-	-	Deployment impossible	-
24. Wires	Impractical	Impractical	-	-	-	Very difficult or impossible to deploy	-
25. Water spray	Impractical	Impractical	-	-	-	Difficult to deploy	-
26. Lure areas	Unlikely	Unlikely	-	-	-	Variable *c.* situation, species, season	1, 2
27. Trapping	Possible	No	No	No	No	Rarely practical	26
28. Chemicals	Unlikely	Unlikely	-	Possible	Possible	Possibly useful as last report	1, 2, 4
29. Microwaves and lasers	Impractical	Impractical	-	-	-	Hazard to humans; heavy equipment for μ waves	-

* There is 24-h light during most of the period considered here. We have included these columns for completeness even though they are not relevant to most situations covered by this evaluation.

Oldsquaw, scoters and mergansers—trapping might be the best method. This method would only be practical if the area were relatively small.

Sea Ice or Leads During Spring

Major Species of Concern

Extremely large numbers of King Eiders (800,000-1,000,000), Common Eiders (150,000) and Oldsquaws (240,000) migrate through offshore areas of the Beaufort Sea during their spring migration toward breeding areas (Alexander et al. 1988a; Johnson & Herter 1989). Smaller but regionally significant numbers of Glaucous Gulls; Pacific, Red-throated and Yellow-billed loons; White-winged Scoters and probably Thick-billed Murres also use this route. Open-water habitat used by these species for resting and feeding is restricted at this time of year, and migrating birds are strongly attracted to the available areas. Should a lead be oil-contaminated during the spring, extremely large numbers of birds could become oiled if they were not deterred from landing in the lead.

General Considerations

Offshore drilling technology does not now permit oil companies to drill during spring in offshore areas where leads develop in sea ice. Therefore, oil that is present on sea ice or in leads during spring will have been spilled earlier. The oil will be present before the birds arrive and may seep to the surface after being trapped under the ice during the winter. It probably will not be necessary to disperse birds from oil-free leads, but it will be important to deter birds from landing in leads that are oiled. The cold temperatures at this time of year will exacerbate the impacts of oil on birds and may result in the death of birds that are only lightly oiled.

Migration of eiders and Oldsquaws through offshore areas continues, at variable rates, for several weeks and throughout the day. There is no dark period in the Beaufort Sea during this migration period. For deterrent techniques to be effective, they must be able to operate unattended for long periods of time.

Areas of open water that are oiled, and pools of oil that look like open water, will be attractive to passing waterbirds. This will be particularly true if little or no open water is available nearby. If birds have flown a long distance since they last stopped to rest and feed, it will be very difficult to prevent them from landing in areas that they perceive to be open water.

Dispersal and deterrent efforts in offshore lead situations should avoid aerial deterrents, where possible, because one of the normal reactions of sea ducks and murres to avian predators is to dive into the water. Thus aircraft, model aircraft and predators may be less effective than some other methods. However, aircraft may be the only method that could be deployed practically in some remote offshore locations.

Dispersal Methods

Birds that land in partially oiled leads should be dispersed before they enter the oil both for their own benefit and to reduce their tendency to attract additional birds that are passing. Birds that are severely oiled will die and should be shot so that they do not attract other birds. A dead bird that is covered by oil will probably not be recognized as a bird, and hence would not attract passing birds; the movement of a live, oiled bird might attract them. If practical, dead birds should be retrieved so they are not consumed by predators or scavengers. Birds that are lightly oiled should be dispersed using shotguns, shellcrackers, rockets, mortars, or aircraft (Table 4).

Deterrent Methods

Deterrence of birds from leads in spring is likely to be extremely difficult because of the remoteness of the leads from any logistics base and because the sea ice around the leads will often be unstable. To deter birds from landing in oil on the ice surface or in an offshore lead, deterrent devices should be set up on the ice or in the water around the oiled area. These deterrents should consist of human effigies, gas cannons, and perhaps Phoenix/Marine Wailers, all of which can operate unattended for prolonged periods. Where possible, these devices should be supplemented with shotguns, shellcrackers, rockets and mortars.

Foam and dyes might be considered if their efficacy and logistical practicality can be proven by field tests. Foam might be aerially applied to oiled leads to disguise the oiled area. Ice-based equipment might be used in applying foam over pools of oil on the ice. However, it might be undesirable to apply foam if this would make it less likely that the oil could be ignited and burned. Biodegradable oil-based dyes (e.g. fluorescent orange) might also be applied to these areas in an attempt to make them unattractive to birds. However, if no uncontaminated areas are available nearby, birds may land in the dyed oil despite its colour unless other deterrents are also used. Also, if the slick is thick enough and fresh enough to allow bonding with an oil-soluble dye, it may be possible and more effective to ignite and burn the oil using helicopter-deployed igniters.

Offshore During the Open-Water Period

Major Species of Concern

Significant concentrations of birds are scarce offshore in the Beaufort Sea during the open-water period (Searing et al. 1975). However, birds that are present are often found concentrated along fronts between different water masses or in upwellings that, as viewed from the air, visually resemble oil slicks. Gulls are the major species group found along offshore oceanographic features. Loons, Arctic Terns and jaegers are found dispersed throughout offshore areas in smaller numbers, with occasional concentrations of some species in oceanographic features. Large numbers of male eiders fly westward over the offshore Beaufort Sea during late June to early August *en route* to moulting areas in Alaska, and female and young eiders fly over offshore areas in September and October

Table 4. Probable usefulness of various bird dispersal and deterrent methods for oil spills in leads and in sea ice during spring. The methods that are most likely to be useful are highlighted in boldface and italics.

	Effectiveness			Attractant			
	Day	Night[a]	Habituation	Day	Night	Logistical practicality	Complementary methods
1. *Fixed-wing aircraft*	*Variable*	Unsafe	Slow?	No	-	Competing demands; 2 engines desirable	-
2. *Helicopter*	*Variable*	Unsafe	Slow?	No	-	Competing demands; 2 engines desirable	-
3. Model aircraft	Possible	No	Variable	No	-	Difficult; requires trained operator	-
4. Boats	Possible	Unsafe	Probable	No	-	Deployment very difficult, possibly unsafe	5-8, 20
5. *Shotguns, shellcrackers and firecrackers*	*Good*	*Good?*	Slow	No	No	Variable; depends on situation	6-8, 20
6. Verey flares and tracer shells	Variable	Fair?	Possible	No	No	Variable; depends on situation	5, 7, 8, 20
7. *Rockets and mortars*	*Good*	*Good?*	Doubtful	No	No	Deployment may be difficult	5, 6, 8, 20
8. *Gas Cannons*	*Good*	*Good*	Slow?	No	No	Deployment may be difficult	5, 6, 7, 20
9. Distress and alarm calls	Untried	Untried	Slow	No	No	Calls needed; difficult to deploy	-
10. Sounds of predators	Untried	Untried	?	No	No	Difficult; underwater broadcasting required	-
11. Av-alarm	Fair	Fair	Rapid	No	No	Variable; depends on situation	5-10, 20
12. *Phoenix Wailer*	*Probable?*	*Probable?*	Slow	No	No	Variable; depends on situation	5-10, 20
13. Ultrasonics	No	No	-	-	-	Few birds can detect ultrasonics	-
14. High intensity sounds	Doubtful	Possible	Probable	No	No	Variable; hazardous to humans	-
15. Dyes (oil soluble)	Unproven	c. lights	Possible	Possible	Possible	Unproven; aircraft required for deployment	16, 17
16. Searchlights and expanded lasers	Doubtful	Possible	Possible	Possible	Variable	Variable	-
17. Flashing lights	Doubtful	Good?	Possible	Possible	Doubtful	Variable	-
18. Flags, balloons, smoke	Doubtful	No	Rapid	Possible	-	Variable; doubtful effectiveness	-
19. Models of dead birds/predators	Fair	No	Variable	Possible	-	Variable	5-12, 20, 21
20. *Effigies*	*Fair*	No	Rapid	Possible	-	Variable	5-12
21. Hawks, falcons and dogs	Variable	No	Variable	Doubtful	-	Manpower intensive; limited availability of animals	9-12, 20
22. Foam	Possible	No	Doubtful	Doubtful	-	Unproven; difficult to deploy; might hinder burning	-
23. Nets and Fences	Impractical	Impractical	-	-	-	Impossible to deploy	-
24. Wires	Impractical	Impractical	-	-	-	Impossible to deploy	-
25. Water spray	Impractical	Impractical	-	-	-	Difficult to deploy, area too large	-
26. Lure areas	Unlikely	Unlikely	-	-	-	Difficult or impossible (e.g., break thin ice elsewhere)	1, 2
27. Trapping	Doubtful	No	-	Possible	-	Not practical	2, 5
28. Chemicals	Unlikely	Unlikely	-	Possible	Possible	Possibly useful as last resort	1, 2, 4
29. Microwaves and lasers	Impractical	Impractical	-	-	-	Hazard to humans; heavy equipment for μ waves	-

[a] There is 24-h light during the period considered here. We have included these columns for completeness even though they are not relevant to this evaluation.

en route to wintering areas in Alaska (Johnson & Herter 1989). Smaller numbers of other species of sea ducks and waterbirds moult in open waters of the Canadian Beaufort Sea, but seldom far from coastlines.

General Considerations

An oil spill in offshore waters during the open-water period would provide one of the most difficult situation in which to deploy bird dispersal and deterrent measures. The extent of the spill is likely to be large because there are no physical barriers (i.e. beaches) to contain the spill. Unless the oil is contained by booms, there are no platforms on which to deploy deterrents (although the Marine Wailer has its own platform). Therefore, any deterrent technique considered for this area needs to incorporate a platform for deployment. Furthermore, no deterrents have been tested in offshore open-water situations. Hence, evaluations of the effectiveness of various techniques are difficult for this scenario.

In the event of an open-water spill, there will be numerous slicks and areas of sheen interspersed with oil-free water. The locations of slicks and sheens will be difficult to determine, and largely unpredictable from one time to another. If waterbirds are dispersed from one area, they will move into other areas. Without full knowledge of the present and future distribution of oil throughout the area, it will be difficult to predict whether bird mortality would be reduced, unchanged or increased if the birds are dispersed from any one location.

As mentioned in the "Sea Ice or Leads During Spring" section, aerial dispersal and deterrent techniques may cause many flying birds to dive into the oiled water. Some moulting waterbirds would be unable to fly.

Dispersal Methods

No dispersal technique is likely to be very effective at dispersing birds from a major oil spill in offshore waters during the open-water period. Hazing by aircraft is the only technique that may be feasible in some offshore areas. However, the effectiveness of aircraft will depend on the species being dispersed, and it will be difficult or impossible to control the directions of movements of the displaced birds. Aircraft need to have two engines for safety reasons, and long-range fuel tanks are desirable.

Underwater broadcasting of sounds of predators such as killer whales (Frost et al. 1975) or seals may disperse some species of birds. However, this method has not been tested, and could only be effective if birds were diving below the surface. Even if birds did leave the immediate area, there is no guarantee that they would not land in a nearby oiled area. Because underwater sounds attenuate slowly with increasing distance, this method might be effective over a large area if it is effective at all.

Boats could be used as platforms to deploy rockets, mortars, flares, shotguns and shellcrackers to disperse birds (Table 5). Rockets and mortars would be more useful than

Table 5. Probable usefulness of various bird dispersal and deterrent methods for oil spills in open-water offshore situations. The methods that are most likely to be useful are highlighted in boldface and italics.

	Effectiveness			Attractant			
	Day	Night	Habituation	Day	Night	Logistical practicality	Complementary methods
1. ***Fixed-wing aircraft***	*Variable*	Unsafe	Slow?	No	-	Competing demands; 2 engines required	-
2. ***Helicopter***	*Variable*	Unsafe	Slow	No	-	Competing demands; 2 engines required; nearby ship or land support	-
3. Model aircraft	Impractical	No	Slow	No	-	Difficult; requires trained operator	-
4. Boats	Variable	*c.* lights	Probable	No	No	Deployment depends on weather	5-10, 17-20
5. ***Shotguns, shellcrackers and firecrackers***	*Variable*	*Variable?*	Slow	No	No	Good if deployment is possible	6, 7, 10, 20
6. Verey flares and tracer shells	Doubtful	Fair?	Possible	No	No	Difficult to deploy	5, 7, 8
7. ***Rockets and mortars***	*Good*	*Good?*	Doubtful	No	No	Boats required	6, 7, 10, 20
8. Gas Cannons	Unlikely	Impractical	-	-	-	Difficult to keep with oil	-
9. Distress and alarm calls	Impractical	Untried	Slow	No	No	Calls needed; difficult to deploy	-
10. Sounds of predators	Untried	Untried	?	No	No	Fair if broadcast into water	4-8, 20
11. Av-alarm	Doubtful	Doubtful	Probable	No	No	Difficult to deploy; depends on area	-
12. Phoenix Wailer	Doubtful	Doubtful	Possible	No	No	Difficult to deploy	-
13. Ultrasonics	No	No	-	-	-	Few birds can detect ultrasonics	-
14. High intensity sounds	Doubtful	Possible	Probable	No	No	Hazard to humans	-
15. Dyes (oil soluble)	Unproven	*c.* lights	Possible	Possible	-	Unproven; aircraft required	16, 17
16. Searchlights and expanded lasers	Doubtful	Possible	Possible	Possible	Variable	Difficult; boats needed	5, 7, 8, 11, 12
17. Flashing lights	Doubtful	Possible	Possible	Possible	Doubtful	Difficult; boats needed	5, 7, 8, 11, 12
18. Flags, balloons, smoke	Impractical	Impractical	-	-	-	Difficult to deploy	-
19. Models of dead birds/predators	Impractical	Impractical	-	-	-	Difficult to deploy	-
20. Effigies	Possible	No	Rapid	Possible	-	Could be deployed from booms	8, 12
21. Hawks, falcons and dogs	Variable	No	Variable	Doubtful	-	Manpower intensive; limited availability of animals	9-12, 20
22. Foam	Impractical	No	Doubtful	Doubtful	-	Unproven; difficult to deploy	-
23. Nets and Fences	Impractical	Impractical	-	-	-	Deployment impossible	-
24. Wires	Impractical	Impractical	-	-	-	Impossible to deploy	-
25. Water spray	Impractical	Impractical	-	-	-	unproven, difficult to deploy	-
26. Lure areas	Unlikely	Unlikely	-	-	-	Variable with situation	1, 2, 4, 7, 8, 10
27. Trapping	Impractical	Impractical	-	-	-	Deployment impossible	
28. Chemicals	Unlikely	Unlikely	?	Possible	Possible	Possibly useful as last resort; see text	-
29. Microwaves and lasers	Impractical	Impractical	-	-	-	Hazard to humans; heavy equipment for µ waves	

flares and shellcrackers because of their larger area of coverage. However, even rockets and mortars would have limited utility in offshore situations because of the potentially large area involved and because they could not be deployed in areas where people were working.

Deterrent Methods

The principal deterrent techniques for offshore areas during the open-water period would be the same as those listed above for dispersing birds. In addition, if the oil were surrounded by booms, rafts with human effigies and cannons or Phoenix/Marine Wailers might be moored to the booms. The feasibility of deploying these deterrents will depend on weather. Biodegradable oil-soluble dyes might be applied to the oil by aircraft if this presently-unproven method can be shown to be useful. However, the area of the spill would probably be too large, and much of the oil either too thinly or too sparsely distributed, to permit effective coverage of the oil by dye.

RECOMMENDED DISPERSAL AND DETERRENT METHODS

The above section identifies the dispersal and deterrent methods that might be useful in each of five situations in which large numbers of birds might be affected by an oil spill in the Beaufort Sea region. Table 6 summarizes the information from that section and lists deterrent methods that might be useful. It must be emphasized that, in the event of a major oil spill, any practical combination of bird dispersal and deterrent methods would have serious limitations. This would be particularly so in the case of an open-water spill and a spill near a major seabird colony. At least in those cases, it is doubtful that any combination of bird dispersal and deterrent methods would be very effective in reducing waterbird mortality.

This section gives a description of the conditions that should exist to permit useful deployment of each technique. It also gives a description of the deployment, equipment and manpower requirements, logistics considerations, cost considerations, and suppliers of the equipment.

Aircraft

Aircraft are likely to be the most widely useful method of dispersing standing or swimming birds threatened by an oil spill in the Beaufort Sea region. Provided that bird dispersal efforts are given priority when aircraft are scheduled, aircraft can be deployed rapidly and can cover large areas in a short period of time. No additional equipment is required for aircraft to be effective, and they require minimum manpower. Although aircraft will be very useful in the initial dispersal effort, they are likely to be less effective in deterring birds from entering an oiled area over a prolonged period: aircraft (especially helicopters) must be refuelled frequently, they could not be used safely at night, and many flying birds would land in or dive into oiled water to avoid aircraft.

In most oil spill scenarios, aircraft could be useful in dispersing birds before oil had arrived in the area. However, hazing by aircraft probably would not be useful in the seabird colony scenario (p. 55). Aircraft would be especially valuable in the "sedge lowlands" and "bay/lagoon" scenarios (see p. 51 and p. 58). After oil is present, aircraft could be used to haze birds from upland areas that are oiled. Helicopters could be used to herd birds to oil-free areas in or adjacent to bays and lagoons. Aircraft probably would not be useful for herding or hazing in offshore areas:

- fuel constraints would limit aircraft endurance and range,
- unoiled areas would be hard to find,
- the direction of movement of birds would be difficult or impossible to control, and
- most species found offshore would probably dive in response to the aircraft.

Equipment and Manpower

Aircraft can be used to disperse birds without ancillary devices or manpower other than the pilot and an observer/biologist. The latter is needed to help observe the reac-

Table 6. Probable usefulness of various dispersal and deterrent methods for oil spills in different situations in the Beaufort Sea region (see Tables 1-5 for details). The methods that are most likely to be useful are highlighted in boldface and italics.

	Sedge Lowlands	Seabird Colony	Bays & Lagoons	Leads	Offshore
Fixed-wing aircraft	***Good***	Unlikely	***Good***	***Variable***	***Variable***
Helicopter	***Very Good***	Unlikely	***Very Good***	***Variable***	***Variable***
Model aircraft	Unlikely	Variable	Fair	Possible	Impractical
Boats	No	***Variable***	***Variable***	Possible	Variable
Shotguns, shellcrackers and firecrackers	***Good***	Fair	***Good***	***Good***	***Variable***
Verey flares and tracer shells	Fair	Fair	Fair	Variable	Fair
Rockets and mortars	Good	**Fair**	***Good***	***Good***	***Good***
Gas Cannons	***Good***	***Good***	***Good***	***Good***	Unlikely
Distress and alarm calls	Fair	Untried	Possible	Untried	Impractical
Sounds of predators	Unlikely	Unlikely	Untried	Untried	Untried
Av-alarm	Fair	Variable	Fair	Fair	Doubtful
Phoenix Wailer	Probable	***Possible?***	***Probable?***	***Probable?***	Possible
Dyes (oil soluble)	Unlikely	Unproven	Unproven	Unproven	Unproven
Searchlights and expanded lasers	Possible	Possible	Doubtful	Doubtful	Possible
Flashing lights	Possible	***Possible***	Doubtful	Doubtful	Possible
Models of dead birds/predators	Fair	Fair	Fair	Fair	Impractical
Effigies	***Fair***	Fair	***Fair***	***Fair***	Possible
Foam	Impractical	Unlikely	Unlikely	Possible	Impractical
Nets & Fences	Impractical	Doubtful	Impractical	Impractical	Impractical
Lure areas	Unlikely	No	Unlikely	Unlikely	Unlikely
Trapping	Impractical	Variable	Possible	Doubtful	Impractical

tions of the birds, plan the most effective dispersal strategy, and maintain a watch for collision hazards (other aircraft, ground obstructions, or birds).

In order to haze birds with an aircraft, it is necessary to fly close to the ground or water, and to engage in vigorous manoeuvres. This type of flying is inherently more hazardous than conventional flying. Furthermore, there would be an unusually high potential for bird-aircraft collisions, which can be hazardous. Hazing operations should be done only by pilots with much flying experience, preferably in the arctic, and the aircraft should be equipped with appropriate survival gear. During offshore hazing operations at low level, personnel aboard the aircraft should wear immersion suits.

Logistics

Without stopping to refuel, fixed-wing aircraft can generally fly farther and for longer periods of time (approx. 4 h) than helicopters (approx. 2 h). In many remote situations this is an overwhelming consideration in favour of using fixed-wing aircraft for dispersing birds. However, where either could be used, helicopters are recommended because they would be more efficient at controlling the movements of birds. If fuel is available near the spill, or if a fuel cache can be established, the shorter range of a helicopter might be counterbalanced by its greater flexibility in refuelling.

Sources of Supply

Various fixed-wing aircraft and helicopters are based in Inuvik, and in the case of an emergency may be seasonally available in Tuktoyaktuk through Polar Continental Shelf Project. If oil industry operations in the region increase, as is likely to have happened in advance of a major spill, several oil industry helicopters and perhaps some small fixed wing aircraft would probably be based in the region. However, it must be recognized that, in the event of a significant oil spill, there will be heavy demands on all suitable aircraft for many spill-related tasks. The bird-dispersal task will need to be assigned a high priority by responsible authorities in order to ensure that suitable aircraft will be available on a priority basis. In practice, it is likely to be necessary to bring aircraft in from other areas for bird deterrent work.

A Cessna 185 or 206 fixed-wing aircraft, or a Bell 206 or similar helicopter, would be suitable for bird dispersal work in upland, coastal and nearshore areas. A small twin-engine aircraft such as a Piper Aztec, Cessna 337, Britten-Norman Islander or DeHavilland Twin Otter would be suitable for offshore locations. These types of aircraft are usually available for charter in Inuvik. Additional aircraft, if required, could be chartered from Norman Wells, Yellowknife or other locations. Twin-engine helicopters, which would be required for offshore work, may not be available in Inuvik on short notice, but can be obtained within a few days from the south. Some or all of the oil-industry helicopters that might be based in the area would likely be twin-engined.

Model Aircraft

Radio-controlled model aircraft could be useful as a dispersal and deterrent technique for a small spill or for dispersing birds from a specific area such as the vicinity of a seabird colony.

Equipment and Manpower

Several model aeroplanes and one or two people capable of flying them.

Logistics

A flat area (runway) is required for take-off and landing by conventional model aircraft. Some specialized model aircraft are designed for launch from a rail and/or for landing by flying into a net. Model helicopters exist, but they are less common than fixed-wing model aircraft.

Sources of Supply

National Assoc. of Model Airplanes
Burlington, Ont.
Phone: 416-632-9808

Local chapters are found in most major centres and contact numbers can be obtained from the above.

Boats

Boats may be useful to disperse birds from an area that is about to become oiled or as platforms on which to deploy other deterrent devices. A single boat is not likely to be very effective without use of supplementary scaring measures, but a number of boats paralleling each other could be effective at dispersing birds. Provided that winds are light, small boats may be deployed near a seabird colony, in bays and lagoons, and possibly in offshore leads. In good weather, small boats could be deployed from ships to work near the ship. However, large boats or ships would be required in offshore areas even during calm seas for safety reasons.

Equipment and Manpower

Each boat that is deployed requires two or more people and appropriate safety equipment (e.g. life jackets and/or immersion suits, compass, oars, signal flares, bailer, lights, emergency survival rations, radio, radio beacon) in addition to any deterrent gear that will be deployed.

Logistics

The ease of deploying boats would depend on the proximity to a community or runway. If the spill were near an existing runway, small boats and associated supplies could be transported to the runway via a small transport aircraft such as a Twin Otter. Movement to the specific spill location would then be restricted by weather conditions.

Sources of Supply

Boats and motors can be rented in Inuvik and are available for purchase at local stores. They are also abundant in all communities in the Beaufort Sea area and could probably be rented from local people. However, in the event of a major spill, many of the boats in the region may be used for other spill-related purposes.

Pyrotechnics

Pyrotechnic devices can be readily deployed from any location that can be reached by people. They will be useful as complementary or supplementary devices during most ground or water-based dispersal or deterrent efforts. In offshore areas, rockets and mortars will be more effective than other techniques because they can (presumably) disperse or deter birds over a large area. However, rockets and mortars cannot be used in areas where people or equipment are working.

Equipment, Manpower and Logistics

Personnel deploying rockets and mortars must be specially trained and special permits are required to use them. Other devices can be deployed by anyone after a brief training session. People using shotguns require a Firearms Acquisition Certificate, and they should take a firearms handling course for safety reasons. Persons who might need to use pyrotechnics should obtain the necessary permit and training in advance of a spill. Ear and eye protection is needed when using most pyrotechnic devices.

Pyrotechnic devices cannot be transported on vehicles that are transporting passengers. They need to be specially marked and shipped as DANGEROUS GOODS.

Once received at a logistics base in Inuvik or Tuktoyaktuk, pyrotechnic devices would be portable and easy to transport and deploy. The platform for deployment could be land or a boat. However, it might not be possible to launch the more powerful rockets and mortars safely from a small vessel.

Sources of Supply

Shotguns and shotshells are readily available at stores in all communities in the Beaufort Sea area. Shotguns need to have an open choke in order to deploy 12-gauge pyrotechnic devices. The open choke minimizes the chances of an explosive detonating in the barrel. When shellcrackers are used, the shotgun barrel must be checked for obstructions after every shot. Additional guns and ammunition can be ordered and received from Edmonton within a few days.

Small quantities of marine flares can be obtained locally in Inuvik but all other pyrotechnic devices must be ordered from suppliers in southern locations. Some pyrotechnic devices are frequently out-of-stock, and there is no assurance that they will be available for purchase on short notice. Thus, a supply of pyrotechnic devices should be maintained as part of an oil spill contingency plan. Two Canadian suppliers of pyrotechnics and various other bird scare supplies are as follows:

Margo Supplies Ltd.
Site 20, Box 11, R.R. #6, Calgary, Alberta T2M 4L5
Phone: 403-285-9731 Fax 403-280-1252
Contact: Jeff Marley

C. Frensch Ltd., Bird Scaring Systems
168 Main St. E, POB 67, Grimsby, Ont. L3M 4G1
Phone 416-945-3817 Fax 416-945-4128
Contact: Ian Frensch

In the event that appropriate pyrotechnics are not available on short notice within Canada, there are several U.S. suppliers.

Gas Cannons or "Exploders"

Gas cannons would be effective deterrents in most oil spill scenarios (Table 6), especially when used in combination with human effigies or other techniques designed to reduce habituation effects. Cannons would be relatively easy to deploy in many of the oil spill situations that might be encountered in the Beaufort Sea region. One situation in which cannons would be largely impractical and ineffective would be in the case of a large spill in an offshore area (p. 62). In that situation, cannons would be largely impractical because of the lack of a platform on which to deploy cannons, the potential for rough seas that would prevent deployment, and the large areal extent of the spill. However, cannons might be useful along shorelines toward which oil from an offshore spill is moving.

Equipment, Manpower and Logistics

Several types of gas cannons are commercially available, with different capabilities. We suggest using a propane cannon that produces 2 or 3 shots in rapid succession, with variable firing intervals and rotation after each shot. Thus, explosions are aimed in different directions. These characteristics reduce the rate at which birds will habituate to the cannons.

Once a cannon is set up, it will operate for about two weeks without refuelling. However, cannons should be visited more frequently to check that they are operating, and to change their locations. Moving cannons will reduce the rate at which resident birds will habituate to the noise blasts.

A single cannon has been reported to be effective over an area of 20-50 ha for waterfowl, depending on the situation, and over much smaller areas (4-10 ha) for other species of birds. Cannons could be deployed around the periphery of a spill on raised ground, beaches, islands, or rafts. (Rafts should be inside of and attached to oil booms when booms are used.) Cannons could be deployed from anchored boats and rafts in sheltered areas where waves would not splash the igniter.

Sources of Supply

Gas cannons are available from various suppliers, including those listed on page 72.

Recorded Distress or Alarm Calls

Playbacks of recorded distress or alarm calls have not been tested on the types of waterbirds that would be at risk from an oil spill in the Beaufort Sea. Furthermore, the use of these techniques is complicated by the fact that a significant amount of sound play-back equipment must be procured and transported. Also, playback of distress or alarm calls is not likely to be useful unless the timing of the playbacks is controlled by an on-site operator. Thus, the method is labour-intensive. Once oil is present in an area playbacks are likely to be ineffective because birds that reacted to the sound would likely land on the nearest land or water. These methods should not be relied upon as primary dispersal techniques unless their utility and practicality has first been demonstrated by appropriate field tests.

Despite their limitations, playbacks of recorded distress or alarm calls may prove useful as a dispersal method in selected situations. Distress or alarm calls of gulls and shorebirds may be useful to disperse these species from bays, lagoons and sedge lowlands during summer. Phalaropes, in particular, may be very difficult to disperse via other methods. We do not know whether phalaropes emit or react to distress or alarm calls. If they do, this technique could be valuable if deployed before oil encroached on one of the coastal staging areas utilized by large numbers of phalaropes in late summer.

Equipment, Manpower and Logistics

One or two people would be required full-time to project distress or alarm calls of birds. The required equipment would include recorded calls, portable tape recorder, amplifier, loudspeaker(s) and cables. Appropriate transportation, probably a small boat and motor, would be needed to be efficient.

Tapes of distress or alarm calls for Red-necked Phalarope, Glaucous Gull and Sabine's Gull are probably not available and would have to be recorded. It has proven difficult to obtain suitable recordings for many species. Therefore, this would need to be done in advance of the spill if there are plans to use distress calls as a dispersal or deterrent method.

Sources of Supply

A wide variety of sound broadcasting equipment is available from numerous retail outlets. A system suitable for field use could be assembled from commercially available components. This would need to be done in advance of a spill in order to have an operational system available on a timely basis. A system specifically designed for playback of distress and alarm calls from a vehicle is advertised by Reed-Joseph Co., Greeneville, Mississippi. The cost of tape players, amplifiers, and loudspeakers depends on the quality, desired source level, and frequency range of the sounds to be broadcast. A functional system for broadcasting distress and alarm calls in air could be bought for $1,000-2,000.

High-quality recordings of the calls (distress, alarm and otherwise) of many species of birds are available from

Cornell Laboratory of Ornithology
Library of Natural Sounds
159 Sapsucker Woods Rd., Ithaca, NY 14850
Phone: 607-254-2407
Contact: Andrea L. Priori

and also from

Borror Laboratory of Bioacoustics
Ohio State University, Dept. of Zoology
1735 Neil Ave., Columbus, OH 43210
Phone: 614-292-2176 Fax: 614-292-1538
Contact: Dr. Sandra L.L. Gaunt

Electronic Sounds

The Phoenix and Marine Wailer and the Av-alarm are commercially-available electronic sound generators that could be useful for deterring birds. The Marine and Phoenix Wailers are probably superior to Av-alarm; the latter is not discussed further. The Marine Wailer could be deployed in all situations encountered in the Beaufort Sea region except a spill in open offshore waters where the area of the spill would be too large to permit effective use of a stationary deterrent device.

Equipment, Manpower and Logistics

The Marine and Phoenix Wailers are powered by a 12-V lead acid battery that will operate the unit for up to several weeks, depending on the frequency and power level of broadcasts. It can be connected to a solar panel to charge the battery so the battery would not have to be changed. As in the case of gas cannons, however, the units should be visited periodically to ensure that they are operating. If possible, the units should be moved every 2-3 days to decrease the rate of habituation by birds.

The Marine Wailer is water-proof and floats on water. It is not available at the date of writing, but it is expected be available by early summer 1993. It could be deployed in wetland areas or on the water. A boat or aircraft on floats would likely be necessary to deploy the unit on the water. The size and weight of the Marine Wailer have not been determined yet, but the Phoenix Wailer unit (excluding power supply and support) is 2.75 kg. Even with floatation devices and a car battery, the units should be readily portable.

Source of Supply

Phoenix Agritech (Canada) Ltd.
P.O. Box 10, Truro, Nova Scotia, B2N 5B6
Phone: 902-897-2728

Dyes

The use of dyes to deter birds is a possible technique that has not been proven. However, dyes warrant study because they might be used in situations where few or no alternative techniques are available. If dyes are effective at deterring birds from landing in oil, dyes might be useful in marine areas where the oil is relatively thick and unweathered—perhaps in a spring lead situation, or when a pool of oil forms on the ice in spring (see p. 61). An oil soluble dye is most likely to be useful because it would attach to the oil and remain with it wherever the oil moved. Dye is most likely to be effective in situations where oil-free water is present near dyed oil-contaminated waters. In this situation, birds may avoid the oil-contaminated water that is dyed and land in the oil-free water that is not dyed. If no oil-free water is available, the birds might land in the dyed oil-contaminated water anyhow.

Dyes should not be relied upon as a primary deterrent method at this time, given the lack evidence that they would be effective. However, we recommend (p. 78) that it be determined whether a chemically-suitable dye exists. If so, its potential effectiveness in an oil-spill situation should be tested. No technique for applying dyes to oil has been tested, insofar as we know. It is probable that dyes can be aerially applied using equipment designed to apply chemical dispersants to spilled oil, pesticides to forests, or pesticides and fertilizers to agricultural areas.

Lights

Lights are not likely to be an effective deterrent technique in any situation during the day. Because there is 24-h daylight in the Beaufort Sea region during much of the spring and summer, lights are not likely to be very useful in this region during the scenarios considered by this report. They may, however, be useful deterrents when dark does occur, particularly when used in combination with other deterrents such as gas cannons, the Marine Wailer, and human effigies.

Battery powered flashing lights would be easy to set up and would operate for several days to several weeks, depending on the light intensity, before the battery would need to be changed. The lights should be orange coloured to have maximum deterrent value. Flashing light might be the only deterrent technique that could be easily deployed on offshore oil booms, given the potential for rough seas that might destroy other deterrents. Flashing lights are available from standard safety and marine supply outlets.

Human Effigies and Models of Predators

Models of predators include models of hawks, falcons, owls and man (effigies). All predators except man have the potential to cause some species of waterbirds to dive into the oiled water as an avoidance reaction. Thus, the only "predator" model that is considered here is the human effigy. Effigies could be useful deterrents, in combination with other methods, in all situations except offshore open water. Deployment of effigies would be extremely difficult or impossible during an offshore spill unless booms were placed around the oil. In that situation, effigies might be placed on the booms or on rafts moored to the booms, at least during relatively calm conditions.

Effigies can be purchased from numerous suppliers or made from scrap or inexpensive materials. They can be shoved into the ground in terrestrial situations or attached to rafts, booms or other structures in marine or aquatic situations. Movement enhances the deterrent value of human effigies. Hence, it is desirable to mount them on turrets, swivels or springs so they move in response to wind or wave action.

Foam

The most likely use of foam would be to disguise pools of oil on ice, or perhaps oil in leads, during spring (see p. 61*ff*). Foam is not likely to be an effective deterrent in other situations. However, the use of foam as a bird deterrent has not been tested, and it could be incompatible with attempts to burn the oil. Where practical, it would be preferable to remove oil via burning than to disguise it temporarily via foam.

RECOMMENDED STUDIES

Few tests or observations of bird scaring methods have been done in the Beaufort Sea, or anywhere in the arctic. Thus, the literature contains little specific information about the effectiveness of bird scaring measures on the predominant types of birds in the Beaufort Sea region. From that perspective, it could be argued that most of the potentially useful bird scaring methods that are mentioned above should be tested in the Beaufort region. However, we suggest a different approach. There is sufficient evidence, direct and indirect, to indicate that certain scaring measures will be useful in various oil spill scenarios. These techniques with known effectiveness include hazing by aircraft, pyrotechnics, and gas cannons. There is also sufficient information to show that some other methods can be ruled out as ineffective, too difficult to apply, or both. We recommend that tests of effectiveness and practicality be directed to other potential deterrent measures that are not in either of the above two categories.

Several potential scaring measures show promise for use in certain situations in the Beaufort Sea region, but their effectiveness and practicality are either totally unknown or are unknown in any situation related to the Beaufort Sea region. These untested techniques include

- Phoenix or Marine Wailers,
- dyes to make oil unattractive to birds,
- broadcasts of phalarope distress calls (if they exist) and
- foam to disguise oil on ice or in a restricted area such as a lead.

The Phoenix and Marine Wailers might be useful in many marine spill situations and on many species if proven to be effective deterrents for waterbirds. Field tests are recommended.

We recommend that some investigation be made as to whether any dyes have the chemical characteristics necessary to be useful for this application. If so, field tests might be done.

The last two of these techniques probably would have only limited applicability to oil spills in non-arctic regions. This, in part, accounts for the fact that their usefulness has not been tested elsewhere. To our knowledge, there are no recordings of phalarope distress calls. It is possible that phalaropes do not have a distress call. Even if they do, there is considerable doubt that they would be effective as a dispersal or deterrent technique; therefore we do not recommend field tests at this time. However, given that no other dispersal or deterrent method is likely to be effective for phalaropes, we recommend that an effort be made to determine if phalaropes have a distress call. If so, it should be recorded and a field test of the reactions of a few birds could be conducted to determine if further testing is warranted. At this time, we do not recommend field tests of foam. In the situations when foam might be useful as a deterrent, the foam could interfere with attempts to burn the oil, and burning is likely to be the more desirable approach.

Phoenix and Marine Wailers

The Phoenix and Marine Wailers are new deterrent devices that have recently become commercially available. Based on initial evaluations, they appear to have considerable potential for dispersing and deterring water-associated birds. They are likely to be more effective than a related device available for many years (Av-alarm) because Wailers produce a larger number of sounds in a wider frequency range. These sounds are also projected in random order, which should reduce the rate of habituation. The Wailer is said to have better capabilities for adjusting the frequency and duration of the broadcasts.

Although the Wailers seem promising, very few test data are available. This device should be tested in a bay/lagoon system where the reactions of several different species of water-associated birds can be documented quantitatively. A study design similar to that of Sharp (1978), with control and experimental periods, would be appropriate. The methods of data collection should permit an assessment of the size of the scaring radius. We recommend that the Wailer be tested with and without complementary devices, such as human effigies.

Dyes

Biodegradable oil-soluble dyes may be useful to prevent birds from landing in oil, particularly in offshore areas where other deterrent techniques are not easily deployed and where oil-free water may be available nearby. We recommend that a search be made for one or more dyes with suitable chemical properties. The dye should be oil-soluble or oil-adhering, and bright in colour. A small amount of dye must be able to dye a large quantity of oil. Ideally, the dye should be effective on both thick slicks and thin sheens of oil, and on both fresh and weathered oil. However, a dye with all of these properties is unlikely to exist.

If a dye with suitable properties is found, experiments should be conducted to determine

- whether Oldsquaws and eiders avoid dyed water if clear water is available nearby, and
- whether they avoid dyed water if clear water is not available nearby.

It would probably be most efficient to conduct an initial trial on captive sea ducks. If the results are promising, a field test should then be done. These tests should be done with non-toxic water-soluble dyes in the absence of oil, to ensure that the tests will have no negative effects on ducks or other organisms. However, an oil-soluble or oil-adhering dye would be needed for operational use in the event of a spill. Based the observations of Lipcius et al. (1980), bright orange is likely to be the most effective colour. However, fluorescent yellow, green or other colours should also be tested. Previous observations of colour avoidance have come from dabbling ducks (Mallards), which may have different colour discrimination abilities or different colour preference/avoidance characteristics than do sea ducks.

If dyes are found to have some promise, a study to develop a method of deployment and to evaluate its feasibility should also be conducted. A likely method of deployment is to use aerial spray equipment to spray dye concentrate onto spilled oil. The dye might have to be dissolved in a solvent that is attracted to oil.

CONCLUSIONS

No dispersal or deterrent technique, singly or in combination with other techniques, can eliminate bird mortality during a major oil spill in the Beaufort Sea. However, in some spill scenarios, a significant reduction in mortality would be possible if bird dispersal and deterrent methods were applied promptly and diligently. Even in these cases, the bird deterrent/dispersal program may physically stress some birds and result in reduced breeding success in the year of the spill or (less likely) in later years. However, this may be acceptable if the alternative is prompt death of these birds by oiling.

In any given spill situation, judgements will be necessary as to the appropriateness of a bird dispersal/deterrent program. Use of dispersal and deterrent techniques may cause, or contribute to, the death of some birds, e.g. by displacing them from required habitat or into oiled areas. Depending on the circumstances, the number of birds lost as a result of bird dispersal/deterrent efforts could be either less than or more than the number that would have been lost to oiling if the dispersal/deterrent effort had not been attempted. If such a program is to be done, the methods should also be chosen for maximum effectiveness and minimum likelihood of collateral losses of birds.

Recommended Dispersal and Deterrent Methods

Hazing by fixed-wing aircraft and/or helicopters, and use of gas cannons, pyrotechnics and human effigies ("scarecrows"), are likely to be the only practical and effective techniques in most oil spill situations in the Beaufort Sea area. Useful pyrotechnic methods could include shotguns, shellcrackers, mortars and rockets.

In most spill situations, ***aircraft*** will have some value in dispersing birds from the spill area. Aircraft can fly quickly to the locations where they are needed, and can be used to disperse (herd or frighten) birds from a large area with a minimum amount of manpower. Although helicopters tend to have more limited range and endurance than fixed-wing aircraft, the greater manoeuvrability of helicopters would be beneficial in "herding" birds away from the oil spill.

Aircraft have limitations as dispersal and especially as deterrent methods. Aircraft cannot, in practice, be kept aloft in a spill area continuously for the days or weeks when the oil might be hazardous to birds. Thus, aircraft must be supplemented or replaced by other deterrent methods in order to keep birds from entering an oil-contaminated area. Also, during a major spill, aircraft will be in heavy demand, and bird dispersal may not have sufficient priority to command the use of aircraft already in the Beaufort Sea region. It may be necessary to bring aircraft into the region from bases far to the south. One situation in which aircraft probably would not be useful would be in the event of a spill near a major seabird colony, e.g. at Cape Parry.

Gas cannons, pyrotechnics and human effigies ("scarecrows") can be deployed in wetland areas, along shorelines, and on barrier islands adjacent to spills, or from rafts or boats in oiled water. Pyrotechnics are especially effective, both for bird dispersal and for bird deterrence, but are labour intensive. Cannons and effigies are easy to deploy, require minimum maintenance, and operate for several weeks without being replaced. However, they should be moved frequently to prevent or reduce habituation (progressive decline in effectiveness).

Boats may be useful to herd birds, e.g. moulting waterfowl that are incapable of flight. Boats could also be used as platforms to deploy other techniques in sheltered waters or if winds are calm.

Several ***other methods*** might be useful and practical in certain situations, but are limited in applicability and/or probable effectiveness. Flashing lights could be useful at night in combination with other techniques. Trapping could be useful if flightless birds needed to be moved a long distance and were in a situation where they could be caught and transported. Other "limited value" dispersal and/or deterrent methods include hazing by model aircraft, flares, playback of distress or alarm calls, display of dead birds (or models of birds in "distressed" postures), and production of synthetic sounds via "Av-Alarm" devices.

The ***Phoenix Wailer*** and the Marine Wailer produce a variety of synthetic sounds, and may be useful in dispersing and deterring birds in various spill scenarios. However, the Wailer is a relatively new device, and its effectiveness is not well established.

It has been hypothesized that ***dyes or foam*** could be used to colour or camouflage oil, and reduce the number of birds that mistake pools of oil for water. These methods are unproven. Foam might have the disadvantage of hindering the burning of oil. Underwater broadcasts of predator (killer whale) sounds have also been suggested, but are unlikely to be effective.

Evaluation of Effectiveness in Five Habitats

Sedge lowlands could become oiled as a result of a storm surge in late summer or fall. Snow Geese, White-fronted Geese and Black Brant, among other species, could become oiled as they feed in these areas prior to their southward migration. Aircraft are recommended for initial dispersal of birds from the oiled area. During late summer and autumn, Snow Geese are relatively easy to disperse by aircraft hazing. Gas cannons, human effigies, shotguns and shellcrackers should then be used to prevent birds from returning to oiled wetlands, and aircraft should haze any birds that land in oiled wetlands until these birds leave the area.

An oil spill near a seabird colony is potentially one of the most intractable scenarios from a bird dispersal/deterrence viewpoint. Although there are no large seabird colonies along the coast of the southeastern Beaufort Sea, Cape Parry has a small Thick-billed Murre colony and Herschel Island has a Black Guillemot colony. Although small, these colonies are unique in the Canadian Beaufort Sea. Birds that use a seabird colony often land on water near the colony. Any attempt to keep birds away from a colony and the surrounding waters would—at best—be only partially successful, and could lead to greater mortality than would occur if no dispersal/deterrent action were taken.

Oil in bays and lagoons could kill large numbers of sea ducks that moult in bays and lagoons during summer. During part of the moult period, sea ducks cannot fly. In addition, large numbers of phalaropes gather in some coastal areas in late summer, e.g. along the barrier islands near Herschel Island. Other coastal species, including Sabine's Gulls, Glaucous Gulls and brood-rearing Brant, could also be at risk. Ideally, oil might be prevented from reaching the key areas by blocking lagoon entrances or similar constrictions with oil containment booms. If that is not possible, aircraft and/or boats, in combination with shotguns, shellcrackers, and rockets or mortars, should be used to disperse waterfowl and gulls from bays and lagoons. Insofar as possible, the direction of movement of the birds should be controlled to move them to safer areas. These methods, plus gas cannons, the Phoenix/Marine Wailer, and human effigies, should be used to deter birds from returning to the oiled areas. If a phalarope concentration area were threatened by oil, it is not certain that any method would be effective.

Oil on ice or in leads during spring could threaten some of the many sea ducks and other waterbirds that migrate along offshore leads to breeding areas in the Canadian Arctic. These birds are strongly attracted to open water. Especially at times when little open water is available, they might land in pools of oil that form on the ice. Birds that land in oil on ice or leads will probably die. If logistically practical, they should be dispersed or removed to reduce the attraction of other birds. Potential dispersal and deterrent techniques include various surface-based methods: gas cannons, shotguns, shellcrackers, rockets, mortars and (probably) the Phoenix/Marine Wailer. However, in the remote locations where most leads are found, hazing by aircraft may be the only practical technique. Unfortunately, aircraft cause many waterbirds to dive into the water, so the effectiveness of this method would be variable at best.

An oil spill in an offshore area during the open-water season would pose largely-intractable problems with respect to bird dispersal and deterrence. There are few major concentrations of birds in offshore areas during the open-water season. However, small concentrations of birds may occur along oceanographic features, and significant numbers of birds (e.g. eiders, murres) may migrate across a given area over a period of days. Even if densities in any one area are low, total numbers of birds within the large area that might be affected by a major spill could be large. Also, larger concentrations could be affected in bordering nearshore areas. There are no effective dispersal and deterrent systems for large offshore areas. Aircraft, shotguns, shellcrackers, rockets and mortars could be used in an attempt to disperse and deter birds in some localized situations, particularly if the oil were contained.

The major finding of this study is that no dispersal or deterrent method is likely to be very effective in protecting birds during a major oil spill in the Beaufort Sea. The large area of a major spill, along with the often-severe weather and ice conditions, would likely reduce the effectiveness of bird dispersal and deterrent systems. Logistics support for bird dispersal and deterrent efforts is likely to be scarce during a period when a major spill response and cleanup effort is underway. Thus, the most effective deterrent systems may not be deployable during some oil spills.

However, smaller spills are more common. In some of these situations a significant reduction in mortality would be possible if bird dispersal and deterrent methods were applied promptly and diligently. The methods that are most likely to be effective will depend on the species of birds that will be encountered, the reason for their presence in the area, whether they can fly at the time of the spill, and the ability to deploy the technique. The most universally applicable method of bird dispersal is to haze birds with aircraft. The most universally applicable deterrent techniques include gas cannons, shotguns, shellcrackers, rockets and mortars. These devices would need to be stockpiled in the region prior to a spill in order to allow reasonably quick deployment.

Recommended Studies

The Phoenix and Marine Wailers appear to have potential for dispersing and deterring water-associated birds, but few test data are available. The Wailer should be tested in a bay/lagoon system where the reactions of several different species of water-associated birds can be documented quantitatively, with appropriate controls. We recommend that the Wailer be tested with and without complementary devices, such as human effigies.

We recommend that a limited investigation be done to determine whether any dyes have the chemical characteristics necessary to be useful in colouring pools of oil some bright colour that might be unattractive to waterbirds. If so, tests of the reactions of sea ducks to coloured water or oil might be designed as a subsequent step.

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