PLAN D'URGENCE

Service canadien de la faune

Environnement Canada

ATELIER SUR LE PLAN D'INTERVENTION D'URGENCE

Lieu de la rencontre

Réserve nationale de faune du cap Tourmente (La Petite Ferme)

Date

Le 15 septembre 1987

Activités

09:00	Mot de bienvenue du directeur du Service canadien de la faune
09:10	Présentation du contenu du plan d'intervention d'urgence et rôle des intervenants
10:30	Pause-café
10:45	Explication des méthodes d'effarouchement
11:00	Expérimentation des méthodes d'effarouchement
12:00 *	Déjeuner
13:30	Diaporama sur les soins à apporter aux oiseaux contaminés par des hydrocarbures
15:00	Pause-café
15:15	Expérimentation des techniques apprises avec des oiseaux vivants
17:00	Clôture de l'atelier

* NOTE: Un buffet sera servi sur place

N/Réf.: 508-E (HM-87-128 / 0544y)

Plan d'intervention lors d'un déversement d'hydrocarbures en fonction des oiseaux migrateurs

Le Service canadien de la faune est à mettre sur pied un plan d'intervention d'urgence visant à s'occuper des oiseaux lors d'un déversement d'hydrocarbures le long du Saint-Laurent. Ce plan est rendu nécessaire par le fait que le couloir du Saint-Laurent constitue un lieu de rassemblement privilégié pour plusieurs dizaines de milliers d'oiseaux aquatiques et par le fait que près de 4,000 navires, dont certains pétroliers jaugeant quelque 100,000 tonnes, y transitent annuellement.

Notre expérience passée nous prouve que des déversements accidentels impliquant des produits pétroliers surviennent en moyenne au rythme de un accident par année. Dans certains cas, ces déversements s'avèrent mortels pour les oiseaux comme cela fut noté aux Iles de la Madeleine durant l'hiver de 1981 où un minimum de 12,000 oiseaux ont trouvé la mort suite au déversement de 12 tonnes de mazout.

Afin de minimiser la mortalité des oiseaux confrontés avec une nappe d'hydrocarbures, le Service canadien de la faune élabore présentement une stratégie d'intervention qui permettra, à l'aide d'un équipement approprié, d'effaroucher les oiseaux d'un secteur pollué et de prendre en charge ceux qui auraient été contaminés.

Dans le but de rendre l'opération la plus efficace possible, le Service canadien de la faune s'est déjà assuré la collaboration des services fédéraux et provinciaux pour la protection de l'environnement, du Ministère du Loisir, de la Chasse et de la Pêche, du Service des Parcs d'Environnement Canada, du Jardin zoologique de Québec, de cliniques vétérinaires de même qu'une vingtaine d'organismes non-gouvernementaux impliqués dans le domaine de l'environnement et répartis un peut partout le long du Saint-Laurent.

Au terme de l'opération, soit d'ici deux ans, le Service canadien de la faune espère pouvoir compter sur sept centres de nettoyage et d'effarouchement d'oiseaux répartis entre Montréal et Mingan et pris en charge par Environnement Canada, le Ministère du Loisir, de la Chasse et de la Pêche et Parcs Canada, tout en disposant d'une banque d'environ 150 personnes-ressources prêtes à intervenir lors d'un accident affectant des oiseaux.

Denis Lehoux

Denis Lehoux, biologiste
Service canadien de la faune
Conservation et Protection
Région du Québec

Le 4 septembre 1987

N/Réf.: 508-E (HM-87-133 / 0548y)

INFORMATION SUR LE TRI BIRD RESCUE CENTER DU DELAWARE

Le Tri Bird Rescue Center est un organisme américain à but non lucratif qui a vu le jour en 1976. Il fut formé suite à divers déversements majeurs d'hydrocarbures survenus le long de la côte du Delaware et impliquant plusieurs milliers d'oiseaux aquatiques. L'organisme regroupe trois personnes travaillant sur une base permanente et peut compter sur quelque 120 personnes-ressources. Le support financier est assuré par l'État du Delaware, par des dons en provenance de compagnies ou de fondations ainsi que par la vente de cartes de membres. Le Tri Bird Rescue Center traite environ 1,500 oiseaux annuellement. Le succès assez impressionant que connaît ce centre pour le traitement d'oiseaux contaminés par des hydrocarbures (jusqu'à 90% de réussite) résulte, pour une grande part, sur une approche multidisciplinaire impliquant à la fois des biologistes, des vétérinaires, des chimistes et des nutritionistes. Notons en terminant que le Centre encourage aussi plusieurs programmes de recherche sur les oiseaux.

Denis Lehoux

Denis Lehoux, biologiste
Service canadien de la faune
Conservation et Protection
Région du Québec

Le 8 septembre 1987

N/Réf.: 508-E (HM-87-129 / 0545y)

PLAN D'INTERVENTION D'URGENCE POUR S'OCCUPER DES OISEAUX AQUATIQUES LORS DE DÉVERSEMENTS D'HYDROCARBURES:

Problématique et mise en application

Denis Lehoux

Biologiste

Service canadien de la faune

Environnement Canada

Septembre 1987

JUSTIFICATION D'UN PLAN D'URGENCE

Un plan d'intervention d'urgence pour s'occuper des oiseaux migrateurs lors d'un déversement d'hydrocarbures ... pourquoi ?

Plusieurs raisons peuvent justifier la mise sur pied d'une telle opération. La toute première est celle de la présence d'oiseaux.

1) L'abondance des oiseaux

Saviez-vous qu'au sommet des migrations le couloir du Saint-Laurent (fleuve-estuaire-golfe) totalise des effectifs de sauvagine approchant les 3/4 de million d'individus. En été, les oiseaux aquatiques demeurent encore abondants dans la région puiqu'on en dénombre près de 1/2 million. En période hivernale, quelque 1/4 de million de canards se rassemblent dans les habitats côtiers où les courants et les marées empêchent la formation d'une couverture de glace.

2) La distribution des oiseaux

Si les oiseaux aquatiques se trouvaient uniformément distribués le long des rives du Saint-Laurent, leur concentration s'avèrerait relativement peu élevée. En effet, sachant que le Saint-Laurent compte approximativement 4,300 km de rives, une distribution régulière des oiseaux ferait qu'on en dénombrerait environ 1,500 pour chaque 10 km de rivage. Une telle concentration pourrait probablement être considérée comme peu problématique. Malheureusement, la situation qui prévaut est toute autre. De fait, durant les migrations, on enregistre 15 zones qui regroupent un minimum de 15,000 oiseaux par 10 km de rivage; une d'entre-elles en compte même jusqu'à 60,000. En hiver, même si les oiseaux sont moins abondants, huit sites supportent des densités élevées de sauvagine avec des effectifs minimum de l'ordre de 4,000 individus par 10 km. Élément important à considérer, ces sites s'échelonnent un peu partout le long du Saint-Laurent, autant dans le fleuve que dans l'estuaire et le golfe.

3) La vulnérabilité des oiseaux

Existe-t-il des espèces qui peuvent être considérées comme étant plus exposées lorsque survient un accident pétrolier ? Une étude réalisée aux États-Unis en 1979 par King et Sanger, a tenté de répondre à cette question. Vingt facteurs ont ainsi été analysés dont la distribution des espèces, l'importance de leur population, leur comportement, leur taux de mortalité, l'historique des déversements,... L'étude conclue qu'effectivement certaines espèces sont plus sensibles à un déversement d'huile que d'autres, et que parmi ces dernières on retrouve: la Bernache cravant, le Canard kakawi, l'Eider à duvet, les macreuses et les marmettes, soit toutes des espèces qui se retrouvent en très grand nombre dans nos eaux côtières.

4) Les effets sur les oiseaux

Une autre question qu'on peut se poser avant de mettre en oeuvre un plan d'urgence est la suivante: quels sont les effets que peut engendrer la présence d'une nappe d'huile en un endroit fréquenté par des oiseaux aquatiques ? Doit-on parler d'effets bénins ou tout au contraire d'effets pouvant être qualifiés de sérieux ?

Un oiseau qui vient en contact avec un produit pétrolier voit son plumage se colmater sur le corps lui faisant, d'une part, perdre ses propriétés hydrofuges et, d'autre part, modifier de façon importante son métabolisme. Dans ce cas, l'oiseau devient une véritable éponge. Son poids corporel peut augmenter de 25% d'où la difficulté à flotter et même un risque de noyade. De plus, la couche d'air qui se trouve habituellement trappée entre le plumage et le corps de l'oiseau ayant tendance à disparaître, celui-ci peut se trouver rapidement en situation d'hypothermie. On estime qu'un oiseau dont l'abdomen se voit souillé par de l'huile subit, à une température de 15°C, le même stress qu'un oiseau normal placé à une température de -20°C. On comprend dès lors que la situation soit beaucoup plus périlleuse en hiver qu'en toute autre saison. Par ailleurs, sachant que l'oiseau n'ingère que peu ou pas de nourriture lorsqu'il est contaminé de façon importante, les risques de mortalité deviennent alors très élevées. La littérature rapporte à ce sujet que, pour la période comprise entre 1955 et 1972, un million d'oiseaux ont trouvé la mort suite aux divers déversements survenus à travers le monde. Le cas le plus dramatique est survenu en 1955 en Allemagne alors qu'on a estimé à 275,000 le nombre d'oiseaux (des macreuses surtout) ayant péri suite au déversement de 8,000 tonnes d'huile brute.

Si l'oiseau ne meurt pas des suites de la contamination, il peut se rendre malade lors de l'ingestion d'une certaine quantité d'hydrocarbure. Cette ingestion résulte du fait que l'oiseau, dont le plumage est souillé, tente constamment d'enlever le produit indésirable avec son bec. On estime alors que, dans un délai de deux semaines, certains parviendront ainsi à leurs fins. Malheureusement en agissant de la sorte, l'oiseau s'expose à des problèmes notamment à l'irritation de son système digestif, à des diarrhées, à des dommages au pancréas et au foie, à de l'anémie sans compter un manque de coordination généralisé imputable aux phosphates présents dans les hydrocarbures et qui inhibent le bon fonctionnement de son système nerveux.

De plus, si le déversement d'huile survient tard au printemps, on pourra noter aussi des effets sur la reproduction. Un oiseau qui avale de l'huile peut retarder sa ponte de plusieurs jours (6 à 8) et même diminuer jusqu'à 50% le nombre d'oeufs pondus. Si des traces d'huile apparaissent sur ses pattes et son abdomen, il pourra transférer sur ses oeufs une quantité d'huile suffisante pour entraîner une mortalité embryonnaire pouvant affecter la presque totalité de la couvée. Notons que l'embryon s'avère beaucoup plus sensible à la toxicité du produit pétrolier durant les 2 premières semaines de son développement. Si l'embryon ne meurt pas, il pourra présenter à la naissance des malformations notamment au niveau du bec et du foie.

Bref, on peut conclure que certaines espèces d'oiseaux peuvent effectivement se retrouver dans des situations très périlleuses lorsque mises en contact avec une nappe d'huile.

5) Les probabilités de déversements

Si la présence d'oiseaux est une raison fondamentale pour inciter à la mise en place d'un plan d'urgence, la possibilité qu'un déversement majeur ait lieu le long du Saint-Laurent, s'avère être un motif complémentaire dans la justification de ce plan.

Le Saint-Laurent constitue une voie maritime de première importance. À chaque année, environ 4,000 navires y circulent. Parmi eux, on note la présence de pétroliers à fort tonnage principalement dans la région de Québec. Par exemple, à Saint-Romuald, au-delà de 50 pétroliers jaugeant environ 100,000 tonnes viennent annuellement remplir les réservoirs de la compagnie ULTRAMAR!

6) Historique des déversements

Un plan d'urgence ne serait probablement pas justifié si le trafic maritime était à ce point sécuritaire qu'on ne notait jamais de déversements d'hydrocarbures dans notre région à l'étude. Ce n'est malheureusement pas le cas puisque durant la période s'échelonnant de 1972 à 1986, on n'y rapportait 16 déversements majeurs soit l'équivalent d'un déversement par année.

7) L'impact des déversements

Ces déversements n'auraient rien de problématique s'ils survenaient toujours en des endroits où on ne retrouve jamais d'oiseaux ou en des lieux utilisés par des espèces qui ne sont pas reconnues comme étant vulnérables à la présence d'hydrocarbures. Encore là, ce n'est pas la situation qui prévaut. Pour la même période, soit celle comprise entre 1972 et 1986, des oiseaux ont été contaminés à trois reprises.

Ainsi, aux Iles de la Madeleine en décembre 1981, près de 12,000 oiseaux (en majorité des Mergules nains) ont trouvé la mort suite au déversement de 12 tonnes de "bunker". Ce chiffre de 12,000 oiseaux ne donne qu'un faible aperçu des impacts réels. Plusieurs études démontrent en effet qu'il faut multiplier au moins par cinq le nombre d'oiseaux qu'on trouve morts pour obtenir une image qui se rapproche sensiblement de la réalité.

OBJECTIFS D'UN PLAN D'URGENCE

Nous disposons de suffisamment d'éléments pour affirmer que le couloir du Saint-Laurent représente un endroit à risques élevés pour les oiseaux lors d'éventuels accidents impliquant des hydrocarbures. Pour être en mesure dès lors de faire face efficacement et rapidement à toutes les situations d'urgence, nous nous devons de mettre sur pied un plan d'intervention permettant de rencontrer les trois objectifs suivants:

1) Informer les responsables des urgences à Environnement Canada et à Environnement Québec de la gravité de la situation pour les oiseaux aquatiques

   Lorsqu'une nappe de pétrole est rapportée aux services de protection de l'environnement, ces derniers s'empressent habituellement de contacter les responsables de la faune pour savoir s'il existe des risques qu'un grand nombre d'oiseaux puissent être contaminés. Cette information doit donc être rapidement acheminée afin qu'on puisse déterminer, de concert avec eux, des mesures à prendre afin de minimiser les dégâts.

2) Effaroucher les oiseaux présents dans le secteur

   S'il appert que le déversement d'huile se produit sur un site de rassemblement privilégié par les oiseaux, il sera peut-être opportun de mettre en place des équipements d'effarouchement de façon à éloigner immédiatement les oiseaux non contaminés.

3) Prendre en charge les oiseaux contaminés

Même si des mesures visant à tenir les oiseaux aquatiques hors du site contaminé sont rapidement déployées, il peut arriver que certains de ces oiseaux entrent en contact avec l'hydrocarbure et se retrouvent ainsi dans une situation fâcheuse. Des dispositions doivent donc être prises afin de récupérer ces oiseaux et les soigner adéquatement.

APPLICATION DU PLAN

1) Les collaborateurs

Pour être en mesure de rencontrer les objectifs du plan d'urgence en n'importe quel endroit le long du Saint-Laurent, le Service canadien de la faune espère compter sur la collaboration d'autres organismes. Pour ce faire, nous avons initialement divisé le Saint-Laurent en cinq zones comparables à celles déjà utilisées par le Ministère du Loisir, de la Chasse et de la Pêche: Montréal, Trois-Rivières, Québec, la péninsule de la Gaspésie et la Côte-Nord.

Pour chacune de ces régions, nous avons ensuite identifié les partenaire susceptibles de participer au plan. La structure mise en place tente autant que possible de regrouper dans chacune des régions des représentants des organismes suivants: Ministère du Loisir, de la Chasse et de la Pêche du Québec, le Service des Parcs d'Environnement Canada, un groupe d'ornithologues, une association locale de chasse et pêche ou une société impliquée dans le domaine de l'environnement ainsi qu'une clinique vétérinaire ou un jardin zoologique (annexe). Pour les régions englobant de vastes territoires, nous avons fait appel à plusieurs associations ou sociétés.

2) Matériel et infrastructures

À l'intérieur de chacune des cinq régions déjà identifiées, nous escomptons pouvoir disposer d'un minimum de matériel d'effarouchement sous la forme de canons, balles explosives, épouvantails ainsi que de matériel pour soigner et nettoyer les oiseaux souillés. Les coûts inhérents à l'achat de cet équipement se situent entre $5,000 et $10,000. De plus, un local doit être disponible pour accueillir entre 100 et 150 oiseaux pendant une période de près de 10 jours.

Il n'est nullement nécessaire que ce local soit disponible sur une base permanente; cependant, on devrait être en mesure de l'aménager et de l'utiliser à quelques heures d'avis. Ce local devrait également être chauffé et éclairé et approvisionné en eau chaude.

3) Rôle des intervenants

a) Urgences environnementales

Lorsque survient un déversement d'huile, les premiers organismes qui en sont avertis sont ceux travaillant aux urgences d'Environnement Canada et d'Environnement Québec. Leur rôle consiste, entre-autres, à avertir les organismes travaillant dans le domaine de l'environnement de l'importance de l'accident (types de produits pétroliers répandus, quantité, emplacement et superficies impliqués). Nous espérons que les groupes d'urgences environnementales joueront aussi un rôle de liaison entre le pollueur (s'il est connu) et les services environnementaux (Service canadien de la faune, Ministère du Loisir, de la Chasse et de la Pêche, Service des Parcs d'Environnement Canada) au niveau logistique.

b) Service canadien de la faune, Ministère du Loisir, de la Chasse et de la Pêche et le Service des Parcs d'Environnement Canada

Deux rôles incombent à ces trois organismes. Le premier vise à coordonner les activités d'inventaires, d'effarouchement et de nettoyage d'oiseaux. Le second concerne l'acquisition du matériel d'effarouchement et de nettoyage d'oiseaux tout en s'assurant de la disponibilité d'un local pouvant accueillir des oiseaux souillés. Ces locaux seraient idéalement situés à des endroits stratégiques comme Montréal, Trois-Rivières, Québec, Rimouski, Forillon, Sept-Iles et Mingan.

c) Clubs d'ornithologie

Les clubs d'ornithologie seront très utiles pour aider aux recensements et pour indiquer précisément les sites de rassemblements privilégiés d'oiseaux aquatiques. Ces informations s'avèreront profitables pour déterminer les endroits à protéger ou à nettoyer prioritairement. Les membres des clubs pourront aussi servir de personnes-ressources lors de captures d'oiseaux souillés afin de les regrouper par espèces. Nous espérons que chaque responsable des différents clubs participant au plan d'urgence dressera une liste de personnes-ressources qui pourront être rapidement contactées si le besoin s'en fait sentir.

d) Autres organismes non-gouvernementaux

Les autres organismes non-gouvernementaux oeuvrant dans le domaine de l'environnement et qui désirent prendre part à cet exercice, s'occuperont de fournir, le cas échéant, la main d'oeuvre nécessaire aux différentes activités que sont la capture, l'effarouchement et le nettoyage d'oiseaux. Ici aussi, les responsables de ces associations devraient tenir à jour une liste de personnes disposées à participer aux opérations mentionnées.

e) Vétérinaires

Le succès de l'opération dite "nettoyage d'oiseaux" pourra en grande partie dépendre des soins vétérinaires qui seront administrés aux oiseaux. Les vétérinaires auront donc pour tâche de dresser un bilan de santé des différents oiseaux qui seront capturés, de déterminer les traitements nécessaires et même de juger s'il est à propos de tenter de sauver un oiseau si sa condition physiologique laisse trop à désirer.

CONCLUSION

Que peut-on conclure sinon que la réussite de cette vaste opération dépend de chacun d'entre nous. Le Service canadien de la faune ne peut assumer seul cette tâche. Il assurera la coordonnination des activités et de la mise sur pied d'un centre de nettoyage pleinement opérationnel au cap Tourmente. Pour les autres activités, nous comptons sur votre participation active. Si chacun met la main à la pâte, nous croyons que ce plan d'urgence pourra fonctionner avec un minimum d'effort tout le long du Saint-Laurent, et ce d'ici deux ans, grâce à la mise sur pied de sept centres de nettoyage et d'effarouchement et à quelque 150 personnes-ressources. C'est là l'objectif que s'est fixé le Service canadien de la faune.

ANNEXE

Liste préliminaire des organismes contactés

Région de Montréal

- Urgences Environnement Canada
- Ministère du Loisir, de la Chasse et de la Pêche
- Club d'observation d'oiseaux Marie-Victorin
- Société québécoise pour la protection des oiseaux
- Clinique vétérinaire Jean Gauvin

Région de Trois-Rivières

- Ministère du Loisir, de la Chasse et de la Pêche
- Association sportive de Batiscan
- Association des chasseurs et des pêcheurs du comté de Maskinongé
- Club d'ornithologie Sorel-Tracy
- Clinique vétérinaire Michèle Chartier

Région de Québec

- Ministère du Loisir, de la Chasse et de la Pêche
- Urgences Environnement Québec
- Fondation les Oiseleurs du Québec inc.
- Société Duvetnor
- Jardin zoologique de Québec

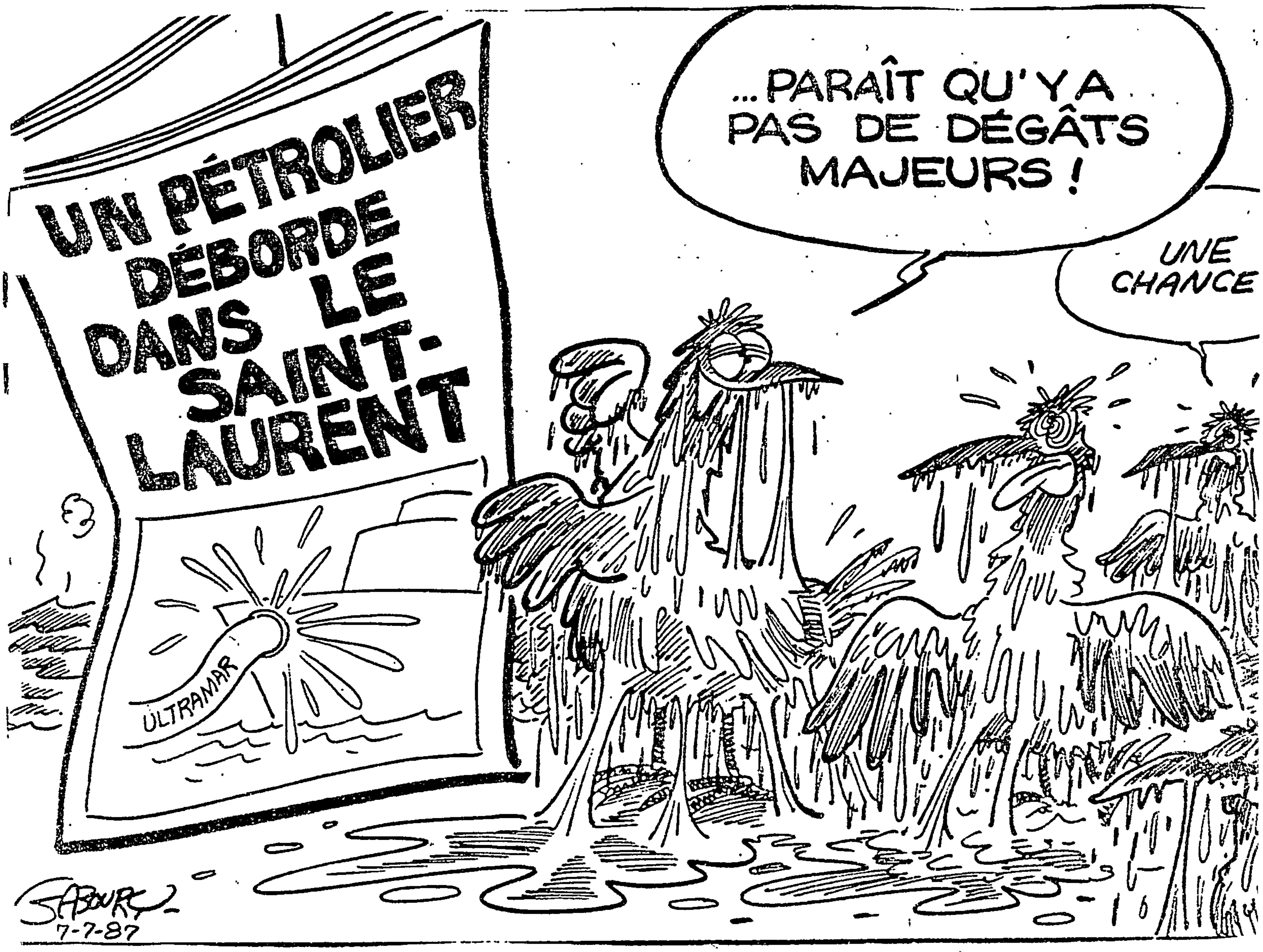
Péninsule de la Gaspésie et Iles de la Madeleine

- Ministère du Loisir, de la Chasse et de la Pêche
- Parcs Canada

- Urgences Environnement Québec
- Club d'ornithologie du bas Saint-Laurent
- Club d'ornithologie de la Gaspésie
- Club d'ornithologie des Iles de la Madeleine
- A.Q.T.A.C.H.
- Société de conservation de la baie de L'Isle-Verte
- Musée de la Mer
- Clinique vétérinaire Suzanne Lecompte
- Clinique vétérinaire Lynda Plourde
- Clinique vétérinaire André Banville

<u>Côte-Nord</u>

- Ministère du Loisir, de la Chasse et de la Pêche
- Parcs Canada
- Club d'ornithologie de la Manicouagan
- Corporation du parc d'interprétation naturelle de Pointe-aux-Outardes
- Corporation et promotion industrielle et touristique de Sept-Iles
- Association de Chasse et Pêche de Havre Saint-Pierre
- Clinique vétérinaire Elizabeth Chenail


UN PÉTROLIER DÉBORDE DANS LE SAINT-LAURENT
ULTRAMAR
...PARAÎT QU'Y A PAS DE DÉGÂTS MAJEURS !
UNE CHANCE
SABOURIN
7-7-87

Effects of Petroleum on Arctic and Subarctic Marine Environments and Organisms

VOLUME II

BIOLOGICAL EFFECTS

EDITED BY

Donald C. Malins

Environmental Conservation Division
Northwest and Alaska Fisheries Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
U.S. Department of Commerce
Seattle, Washington

ACADEMIC PRESS, INC. New York San Francisco London 1977

A Subsidiary of Harcourt Brace Jovanovich, Publishers

Chapter 7

BIOLOGICAL EFFECTS OF PETROLEUM ON MARINE BIRDS

W. N. HOLMES and J. CRONSHAW

Department of Biological Sciences
University of California
Santa Barbara, California 93106

INTRODUCTION

Seepage of petroleum through parts of the ocean floor is an ancient geological phenomenon and for many centuries man has made use of this oil. For example, the coastal Indians of Southern California used weathered crude oil to waterproof their rude coracles and Christopher Columbus and Sir Francis Drake in the 15th and 16th centuries used tar from oil seeps in the Caribbean Sea and the Santa Barbara Channel to caulk the decks and planks of their ocean ships.

In regions of natural seepage, crude oil has been present in the local seawater for many thousands of years and organisms living in these areas have evolved with petroleum as an integral part of their environment. The prolonged presence of petroleum in these regions has been construed to suggest that petroleum has little adverse effect on the flora and fauna in these areas. Since we know nothing about the abundances of organisms in these environments prior to the onset of natural seepage, this argument is misleading. Nevertheless, this reasoning has been extended by some to suggest that periodic accidental spillages of petroleum into coastal waters have little permanent effect on the local flora and fauna. The amounts and concentrations of petroleum pollutants that are now present in some of our estuarine and coastal waters, however, far exceed those in areas of natural seepage and the comparison is not justified. Indeed, the amount of petroleum entering the marine environment by natural seepage through the ocean floor may account for less than 10% of the total worldwide petroleum pollution.

EFFECTS OF SPILLAGE ON MORTALITY

The effects of heavy petroleum pollution on marine bird populations are probably more rapid and more conspicuous than they are on other forms of wildlife. Accidental spillage of crude oil often leads to high mortality of birds in the vicinity of the spill and one of the earliest accounts of such an accident was published by Jenny Mothersole [1]. She reported that in 1907 the seven-masted schooner, *Thomas W. Ralston*, released 2 million gallons of crude oil into the waters around the Isles of Scilly. One of these isles, Annet, had a seabird colony that was reputed to include more than 100,000 puffins and "vast numbers" of these birds were reported to have died as a result of this spillage. Since then several more incidents have occurred in the area and today only about 100 puffins are left on Annet. Other colonies of puffins in the Western Approaches have also been reduced proportionately during the past 50 yr [2,3] and there is little doubt among ornithologists that persistent spills of petroleum have been a major factor contributing to their decline [4].

Numerous other reports on the effects of oil spills were published during the period between World War I and World War II but estimates of the number of birds affected in these incidents were poorly documented. Since 1945, however, the worldwide consumption and transportation of petroleum has increased dramatically and concomitantly the accidental spillage at sea has become more frequent and more extensive. Occasional catastrophic spillages caused by leakage from shipwrecked tankers and blowout accidents on offshore drilling rigs have focussed public attention on the seriousness of the problem. Although ornithologists had long realized that large numbers of seabirds perish as a result of these spills, it was not until oil pollution reached a serious level that a general public awareness of the problem developed and there was publication of more complete records of mortalities among bird populations. These reports fall roughly into four categories. The most abundant records deal with the effects of spillage in terms of total seabird mortality. A few reports examine the mortalities of individual species within the resident population. Other reports deal mainly with the implied effects of mortality sustained during periods of acute and chronic spillage on the size and growth of surviving colonies and finally there are one or two reports dealing with the differential mortality rates observed among different species exposed to similar degrees of contamination.

TOTAL MORTALITY

Although the very high levels of contamination which occur immediately after a catastrophic spillage may be short-lived, the effects of the petroleum on birds may persist long after the environment has returned to a relatively pristine state. For instance, the estimates of mortality recorded during the first few days after a spill will be derived mainly by counting beached carcasses. No estimate can be made of the number of carcasses that sank or were devoured. During subsequent weeks birds that have been collected into cleansing centers will die and this number must be added to the initial estimates. Since some of the cleansed birds may survive several weeks, data from all sources may not be collected and included in the final estimate. Thus, quite apart from the fact that not all casualties are found, serious inaccuracies may occur during the collection of mortality data from these sources.

In contrast to the acute contamination resulting from major accidents, the petroleum pollution occurring in the industrialized areas of the world is often continuous and more persistent; this type of chronic pollution results from minor spillage from tankers and offshore rigs, leakage from transmission lines, jettisoning of bilge washings, etc. The total effect of this chronic petroleum pollution on bird populations, which may be monitored more reliably and certainly less hurriedly than the effects resulting from catastrophic spillage, may exceed the effects of major spillages. However, casualties counted by observers following both acute contamination and during chronic low-level leakage may represent only a small fraction of the actual mortality.

In 1967, the tanker *Torrey Canyon* became grounded off the Cornish Coast of England and more than 100,000 tons of Kuwait crude oil were released. The total number of birds killed during the 3-week period following the accident may have exceeded the estimated 20,000-30,000 (Table 1). Less than 2 yr later, on 28 January 1969, a blowout occurred on an offshore drilling operation in the Santa Barbara Channel, California and during the next 10 days approximately 18,000 tons of crude oil were released into the surrounding water; seabird carcasses collected on the beaches and deaths reported by cleansing centers during the next 6 weeks indicated that approximately 3,600 birds died.

TABLE 1

The estimated mortalities sustained by seabird populations following some of the major oil spills that have occurred since 1937

Incident	Spillage	Mortality	Species	Reference
March 1937 San Francisco Bay USA	Crude oil 9,000 tons	10,000 (1.1 birds/ton)	Murre, grebe, scoter	5
Jan. 1953 Howacht Bay Baltic Sea	Oil residues 500 tons	10,000 (20 birds/ton)	Eider, merganser, scoter	6
Jan. 1955 Gerd Maersk Elbe River, Germany	Crude oil 8,000 tons	275,000 (34.4 birds/ton)	Scoter	6
Sept. 1956 Seagate, Washington, USA	Bunker C fuel oil	6,000	Scoter, guillemot	7
1962 Gotland, Sweden	No record	30,000	Long-tail duck	8
March 1967 Torrey Canyon, SW England	Crude oil 117,000 tons	30,000 (0.26 birds/ton)	Guillemot, razorbill	9
Feb. 1969 N. Zeeland, Denmark	No record	10,000	Eider, common scoter	10
Feb. 1969 Terschelling, Holland	Crude oil	30-35,000	Eider, common scoter	11
March 1969 Santa Barbara, Calif., USA	Crude oil 11,000 tons	3,600 (0.3 birds/ton)	Western grebe, loon, scoter, cormorant	12,13
April 1969 Hamilton Trader, Irish Sea	Heavy fuel oil 600-700 tons	6,000 (9.2 birds/ton)	Guillemot, razorbill	14
May 1969 Palva, Kökar, Finland	Crude oil 150 tons	3,000-3,500 (21.7 birds/ton)	Eider, long-tail duck	15
Jan. 1970 NE Britain	Fuel oil 1,000 tons	50,000 (50 birds/ton)	Sea duck, auk	16
Feb. 1970 East Jutland, Denmark	No record	12,000	Eider, common scoter, velvet scoter	10
Feb. 1970 Delian Apollon Tampa, Florida, USA	Bunker C fuel oil 80-100 tons	9,000 (90 birds/ton)	No record	17
Feb.-April 1970 Arrow & Irving Whale Newfoundland & Nova Scotia	Bunker C fuel oil 10,000 tons	12,800 (0.8 birds/ton)	Sea duck, auk, alcid, eider, ducks	18
Feb.-March 1970 Kodiak Oil Spill Alaska	Tanker ballast	10,000	Alcid, sea duck, gull, kittiwakes	19
Dec. 1970-Jan. 1971 South Kattegat	No record	15,000	Eider, scoter	19
Jan. 1971 San Francisco Bay, Calif. USA	Bunker C fuel oil 300-350 tons	7,000 (21.5 birds/ton)	Grebe, guillemot, scoter	20
March 1972 Jutland	No record	30,000	Eider, scoter	21
Dec. 1972 Danish Waddenzee	No record	30,000	Eider, common scoter	21

The *Torrey Canyon* and Santa Barbara Channel accidents were typical of the two major types of catastrophic spills that may occur somewhere in the world several times in every decade. Other major spills have had equally devastating effects on local seabird populations and between 1955 and 1972 more than 1 million deaths have been recorded following these incidents. However, data on the quantities of oil spilled, the number of birds killed, and the species involved in these accidents are almost always incomplete and they are frequently recorded in obscure publications and reports. In Table 1 we have attempted to assemble a representative listing of total bird mortalities recorded after some of the major accidents which have occurred since 1937; we emphasize, however, that this list is incomplete and the data are only estimates of the true values.

It is of interest to note that accidents involving partially purified petroleum products, such as fuel oil and Bunker C, seem to have caused more deaths per unit mass of oil spilled than comparable accidents involving unrefined crude oil (Table 1). Several other factors, however, may also have contributed to the high mortalities recorded following spills of refined product. For example, irrespective of the material spilled, contamination of the water in a confined bay that sustains a high seabird population may be expected to cause more deaths than a similar accident occurring in an open coastal channel at a time when the density of marine birds on a migratory flyway is low. These two factors alone may have accounted for the difference in mortality rates observed following the 1971 spillage of Bunker C fuel oil in the San Francisco Bay and the 1969 leakage of crude oil into the Santa Barbara Channel (Table 1). In contrast, however, the *Torrey Canyon* spill occurred when the seasonal migration of birds was in full swing and yet in spite of a high seabird population, the records indicate that less than one bird was killed per ton of crude oil released. The possibility exists, therefore, that under similar circumstances, refined products may be more hazardous to birds than crude oil and this topic is worthy of detailed examination.

In addition to these major accidents, either the continuous or the frequent intermittent leakage of lesser amounts of petroleum products into the marine environment may account for many more seabird deaths than those recorded following the major incidents recorded in Table 1. Spilling incidents of this type are quite frequent, as indicated by the records of the Liverpool Underwriters Association who reported 91 tanker groundings (17 spillages) and 238 tanker collisions (22 spillages) between June 1964 and April 1967; although this number of accidents is extremely small compared to the total number of sailings, the number of spills is clearly much larger than the number of major oil spills reported during the same period (Table 1).

In Great Britain, the Royal Society for the Protection of Birds, and in Europe, the International Beached Bird Surveys have attempted to monitor annually the effects of these minor spillages along beaches. In an attempt to standardize these surveys, measured lengths of beach have been monitored regularly and mortalities have been expressed as recorded deaths per unit length of coastline (Tables 2 and 3). The serious effects of persistent minor spillage are further emphasized by the personal records of Mr. W. E. Williams (reported in 4) who, from 1952 to 1963, counted the total number of contaminated birds that were washed ashore and estimated the amount of spilled oil appearing along 160 yd of beach in St. Agnes in Cornwall, England (Table 4). It is interesting to note that these records do not show any correlation between the estimated annual bird mortality and the quantities of oil washed ashore. However, on the basis of these data, Mr. Williams estimated that the annual mortality rates were equivalent to a total mortality between 1952 and 1963 of 100,000 birds along the shoreline of Cornwall. Indeed, it has been suggested that the effects of this low-level pollution around the world may greatly exceed the effects of the less frequent but larger accidental spillages [27].

VULNERABILITY OF SPECIES

There are several published reports regarding the comparative vulnerability of different species to petroleum contamination [4,22-26,28-33]. Most of these surveys have estimated this vulnerability in terms of the incidence of beached carcasses in areas where active regular surveys have been conducted. Some results of this type of study are summarized in Tables 2 and 3.

The effect of chronic persistent spillage may vary from year to year and the total number of recorded deaths will be roughly correlated to the amount of oil spilled. Records of the South African National Foundation for the Conservation of Coastal Birds (SANCCOB) show quite clearly that the mortality and incidence of oil contamination among colonies of jackass penguins is closely correlated with the incidence of oil spillage. Before 1967 there were only two recorded instances, one in 1948 and another in 1952, when petroleum spillage had affected colonies of these species. But, following closure of the Suez Canal in 1967, large numbers of fully-laden westbound tankers became susceptible to accident while rounding the Cape and the threat of persistent oil pollution became apparent for the first time. These shipping accidents that occurred between

TABLE 2

Annual total of oil-contaminated birds found on British beaches

	1951-52	1952-53	1966-67	1968-69	1969-70	1970-71	1971-72	1972-73	1973-74
Divers/Grebes	253	161	71	89	78	60	66	78	25
Gannet	-	-	60	9	46	29	40	53	47
Cormorant/Shag	-	-	59	21	72	24	58	72	133
Wildfowl (primarily ducks)	-	-	229	80	772	105	99	104	271
Waders	-	-	73	16	194	18	18	14	249
Gulls/Terns	4,700	331	1,141	353	290	303	462	311	529
Auk	1,065	402	1,417	1,878	2,646	620	1,315	837	1,559
Other	101	105	30	43	60	29	42	62	144
Total	6,722	1,408	3,080	2,511	4,158	1,188	2,100	1,489	2,957
Beach surveyed (km)	ca 220	ca 175	ca 600	2,839	4,009	4,605	9,826	11,942	12,517
Oiled birds/km	ca 30.6	ca 8.1	ca 5.1	0.89	1.04	0.26	0.21	0.13	0.24

From Bourne [4] and Bourne and Devlin [22,23].

TABLE 3

Annual total of oil-contaminated birds found on British (UK) and European (EU) beaches

	UK 1969	UK 1970	UK 1971	UK 1972	EU 1972	UK 1973	EU 1973
Divers/Grebes	16	33	27	13	123	19	102
Gannet	9	11	6	5	16	6	43
Cormorant/Shag	2	50	14	11	3	18	1
Wildfowl (primarily ducks)	30	283	55	47	329	15	923
Waders	3	43	9	5	77	3	20
Gulls/Terns	160	162	96	122	351	69	352
Auk	345	1,398	169	402	205	167	264
Other	9	55	12	9	5	2	26
Total	574	2,035	388	614	1,109	299	1,731
Beach surveyed (km)	753	1,529	1,489	1,964	1,181	2,336	1,769
Oiled birds/km	0.76	1.33	0.26	0.31	0.94	0.13	0.98

From Bourne and Devlin [22,23] and Bibby and Bourne [24,25,26].

TABLE 4

An estimate of the amount of oil and the number of birds washed ashore each year along 160 yards of beach at St. Agnes, Cornwall, England

Year	Estimated oil waste (kg)	Number of dead birds collected	Number of deaths per 100 kg of oil waste
1952	4,325	ca 80	1.8
1953	3,655	ca 80	2.2
1954	535	318	59
1955	235	74	32
1956	190	36	19
1957	185	56	30
1958	145	66	46
1959	1,240	33	2.7
1960	?	?	?
1961	50	27	54
1962	150	37	21
1963	150	37	25

From private records of W. E. Williams cited in 4.

1967 and 1974 and affected the colonies of jackass penguins along the South African Coast are recorded in Table 5.

The mortality sustained by individuals of a particular species, however, may be also correlated with their behavior. The relative abundance of some species in an area varies according to their seasonal migrations. In areas where their appearance and disappearance is abrupt, the changing effect of chronic petroleum spillage will be most pronounced. But, for a variety of reasons, the recorded mortality rates of some migratory species may not always show clear seasonal cyclicity. Species characteristics such as short migrations, prolonged periods during which individuals arrive and depart from an area, and the existence of sub-species and races with ill-defined and perhaps different patterns of migration are only a few of the factors that may tend to obscure true differences in seasonal mortality rates. Also, annual variations in climatic conditions may influence the frequency of marine accidents and the distribution of spilled petroleum; these physical factors may tend to further obscure seasonal differences in mortality.

Data purporting to show seasonal changes in the mortality of common guillemot exposed to chronic petroleum contamination are illustrated in Figure 1. These data were derived from weekly surveys of selected beaches in Great Britain by members of the Royal Society for the Protection of Birds [28]. During 1970-71 when 942 km of beach were surveyed and 260 oil-contaminated carcasses were found, the monthly mortality rate showed an apparent seasonal cyclicity; the mortality being highest during the autumn and winter months when the birds spend long periods on the water and lowest during the summer breeding period. However, when a similar census was conducted in 1973-74, a clear seasonal difference in mortality was not apparent, in spite of the fact that more beach was surveyed (12,465 km) and four times the previous number of dead birds were collected. At best, therefore, these data may be interpreted to indicate nothing more than the combined effect of seasonal differences in the location of the birds, climatic conditions, and incidence of oil spillage (Fig. 1).

The feeding behavior and defense postures assumed by some marine birds may also tend to increase their vulnerability to contamination by oil slicks. Breeding penguins are particularly vulnerable to contamination when oil slicks surround the coastal islands they inhabit [34]. The birds, being flightless, must swim through the oil when leaving and returning to the islands at feeding time.

Field observations suggest that although thin films of oil on seawater evoke little or no response, thicker patches of oil cause some species to dive below the surface [4]. The pattern of diving seems to be random and the birds do not

TABLE 5

Oil pollution incidents along the cape coast, South Africa, affecting jackass penguins, and the numbers of oiled penguins recovered, cleaned and released by SANCCOB 1968-1974

Origin (*name of ship*) or location of spill	Date	Spillage (tons)	Number of contaminated birds (minimum)	Number treated	% released
Esso Essen	April 1968	15,000	1,700	1,300	73
Cape Point slick	August 1969	-	52	52	94
Simonstown slick	August 1970	-	51	51	71
Kazimah	November 1970	200	599	414	64
Wafra	February 1971	25,000	1,216	1,139	64
Dassen Island slick	March 1972	-	> 2,100	1,706	60
Oswego Guardian	September 1972	?	400	400	63
Oriental Pioneer	July 1974	?	488	488	65
TOTAL	1968-1974	-	6,606	5,550	65

From Frost, Siegfried, and Cooper [34], Westphal and Rowan [35], and Percy, Westphal, and Westphal [36].

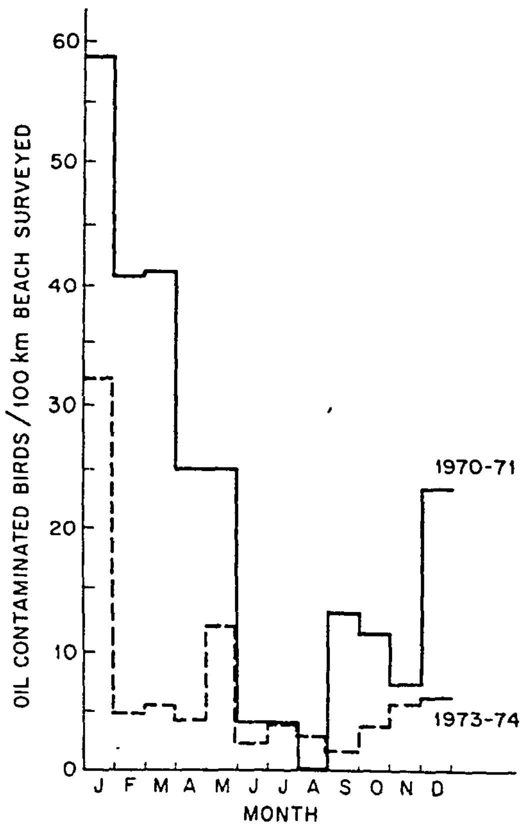


Fig. 1. The numbers of oil-contaminated common guillemot found along measured beaches in Great Britain during 1970-71 and 1973-74. These data are derived from the results of surveys conducted by the Royal Society for the Protection of Birds (Redrawn from IMCO [28]).

appear to select oil-free areas in which to surface. Thus, in regions of extensive spillage the probability of birds surfacing through the slick will increase and this is believed to be a serious cause for the selective contamination of diving seabirds [4]. Diving is also a primary means of foraging among many seabirds and of course this activity will be equally hazardous in areas of oil spillage. However, there seems to be no substantial evidence that birds actively seek oil slicks and suggestions that their vulnerability is increased because oil slicks either render the surface of the water smooth (and therefore attractive) or resemble shoaling fish and rip tides, etc., seem to be based on conjecture.

EFFECT ON FUTURE POPULATIONS

The volume, the chemical composition, and the geographical location of a spill, together with the prevailing climatic conditions, are some of the physical factors that will determine the vulnerability of seabirds to a spillage of petroleum. The interactions between these factors and the biological characteristics of an affected species will influence the future recovery of a diminished population. For example, the frequency of breeding and the duration of postnatal care will either separately or in combination influence the rate of increase in population size. The alcids (guillemots, razorbills, other auks, and puffins), which have suffered steady severe losses in recent years, do not reach sexual maturity for 3 or more years and then during each breeding season they may lay only one egg. Furthermore, mature adults may not breed every year, and when they do, the period of postnatal care is often long and the chicks are vulnerable to attack by predators. It has been shown that within colonies of Brunich's and the common guillemot, the average annual population recruitment to the fledgling stage of development is only 0.2 individuals per breeding pair [37,38] and that even without any mortality due to oil pollution it might take about 50 yr for a guillemot colony to double in size [39]. Clearly, a serious mortality within colonies of these species will have a more serious effect on the rate of growth of the surviving population than a similar reduction in the population of mallard ducks; a species that lays 8 to 14 eggs in each clutch, does not engage in prolonged postnatal care of the rapidly maturing chicks, and where the size of a colony may double within a single breeding season.

However, annual estimates of seabird numbers do provide some convincing circumstantial evidence that crude oil and petroleum products have been implicated in the decline of many seabird colonies. The populations of puffins in the Scilly Isles [2,3,40], common guillemots on Ailsa Craig [41], razorbills on the Newfoundland Coast [42], and the long-tail ducks migrating across Finland [43] have all declined drastically in recent years. More specifically, population studies on seabird colonies on Sept Ile, Brittany, suggest that mortalities resulting from the *Torrey Canyon* accident may have reduced the breeding pairs of common guillemots by 81%, razorbills by 89% and puffins by 84% [44].

Frost and his coworkers, however, have suggested that the magnitude of the effect of petroleum contamination on the jackass penguin populations along the South African coast may be much less than is popularly believed [34]. The average annual rate of contamination of these birds is estimated to be about 0.7 to 0.9% of the total population. This figure is well below the probable annual mortality rate (8.5%) of adult birds. They have concluded, therefore, that petroleum contamination alone may be relatively unimportant, though in combination with others factors it may adversely affect future populations of penguins.

DIFFERENTIAL MORTALITIES OF SPECIES

The comparative mortalities of seabird species exposed to similar types of external contamination have been examined objectively in only one study [12]. In this instance the survivals of several species were compared following routine cleansing of contaminated individuals. We must emphasize, however, that these studies do not necessarily reflect differing systemic sensitivities of the various species to petroleum contamination. A more accurate assessment of their significance would be that they demonstrate different responses of the individuals from several species to the sequence of events and treatments following external contamination with petroleum.

During the 33-day period following the Santa Barbara oil spill, 652 contaminated birds representing 26 species were cleansed at a small local zoo in Santa Barbara, California. The proportion of survivors and the survival time of the individuals from each species were carefully recorded for groups consisting of 10 or more individuals of each species [12]. Although the degree of contamination in this sample ranged from light patches of oil that did not interfere with the bird's movements to a heavy coating that completely covered the bird, no correlation between survival and the amount of oil was apparent. However, even though 88% of the birds died during the 33-day period, the mortality rate and survival time of some species were much lower than others. In Figure 2 the survival records are illustrated for the groups of each species. It is clear that the gulls, mergansers, and scoters survived the effects of oil and cleansing much better than did other species such as the grebes, ruddy ducks, and loons. Furthermore, under these conditions of cleansing and maintenance, the mean survival time or mean time to death of a species was positively and significantly correlated ($r = 0.9$, $P < 0.01$) with the survival rate observed for that species. Thus, there was no evidence to suggest that acute toxicity occurred among those individuals that succumbed.

Survival records maintained by Mr. David C. Smith at the International Bird Rescue Research Center in Berkeley, California, show that a total of 502 contaminated seabirds consisting of 11 or more individuals of 11 species were cleansed at the Center during 1973. The overall survival rate of these cleansed birds was 41.6% which is considerably higher

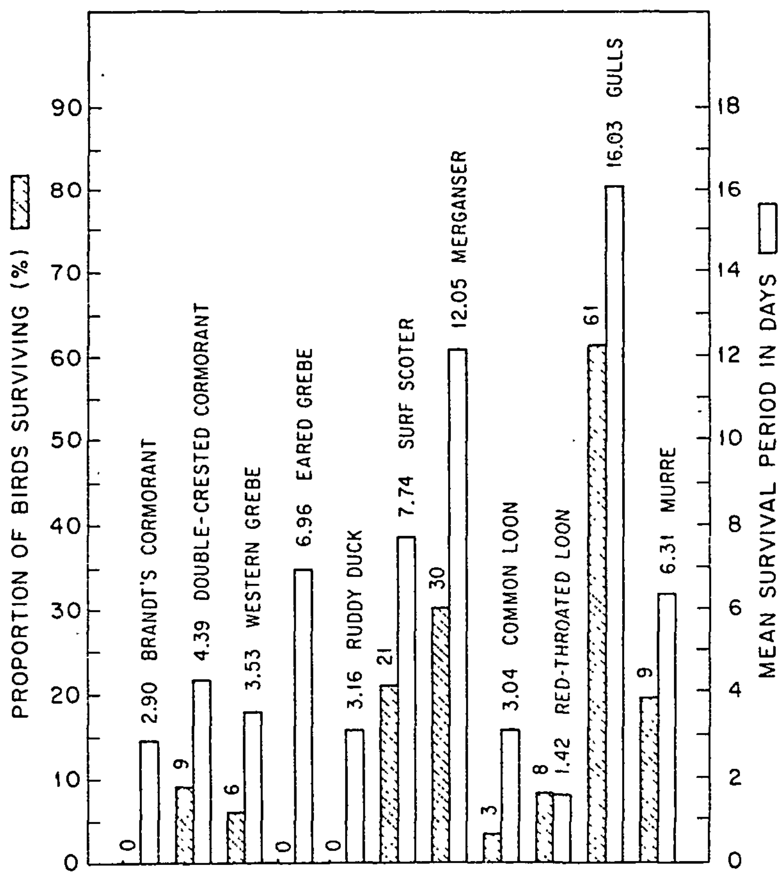


Fig. 2. The survival records among groups of 10 or more individuals of various species cleansed following contamination with crude oil during March 1969 in Santa Barbara, California (Redrawn from Drinkwater, Leonard, and Black [12]).

than the survival achieved following the Santa Barbara oil spill [cf. 12]. However, although this survival rate reflects improvements in the cleansing techniques that have occurred since 1969, these records nevertheless confirm that different species of seabirds show differential survival rates following contamination and cleansing (Fig. 3).

Members of the South African National Foundation for the Conservation of Coastal Birds have been particularly successful in cleaning and rehabilitating contaminated jackass penguins (Table 5). From 1968 to 1974 they released over 3,500 of the 5,550 birds cleaned and this represented each year a success rate of approximately 60%. Between 1971 and 1974, however, 1,440 of the released birds were marked with flipper

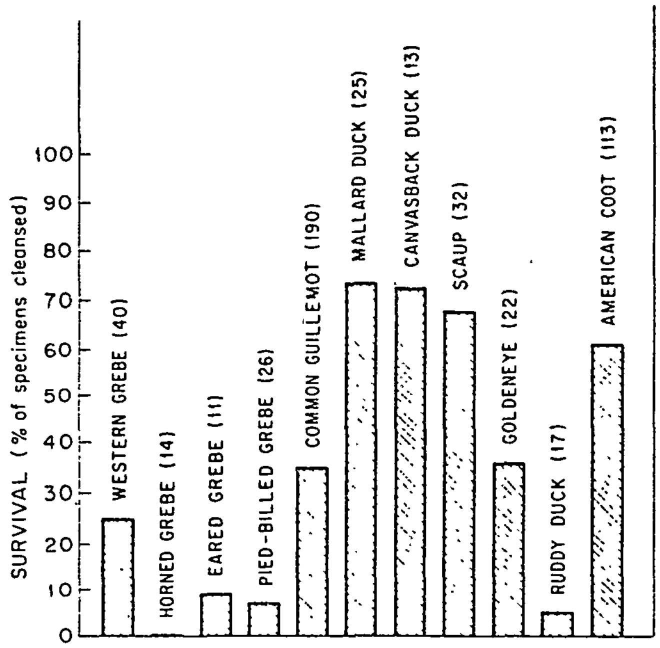


Fig. 3. The survival records among groups of 10 or more individuals of various species of seabirds that were cleansed following contamination with petroleum in the San Francisco Bay during 1973. Numerals in parentheses represent the number of surviving individuals. These data were derived from the records maintained by the International Bird Rescue Research Center, Berkeley, California and they wêre made available to us by the Director, Mr. David C. Smith.

bands and to date 1.8% of these birds have been recovered dead [34]. At the same time a banded control group consisting of 5,250 uncontaminated penguins were released but during the same period less than 1% of these banded controls have been found dead. These data suggest that the mortality among the rehabilitated birds may have been somewhat higher than it was among uncontaminated birds and the true successes of the rehabilitation procedures were probably lower than they appeared to be at the time the birds were released.

PHYSICAL AND SYSTEMIC EFFECTS OF PETROLEUM

The death of seabirds following petroleum contamination is in most instances not sudden and, especially among a cleansed population, mortality may continue for several weeks.

The precise reasons for these deaths may be numerous and they are not always clear. In general, however, they fall into two categories; some effects may be external and physical whereas others may be systemic and result directly or indirectly from the ingestion of petroleum. The external and physical effects are the most frequent consequences of acute contamination whereas systemic effects may result from either acute or chronic exposure of birds to petroleum contamination. For the purposes of this discussion, we have defined the physical effects of oil on birds to include only those effects that are directly and indirectly associated with contamination of the integument. The systemic effects, therefore, will include all those instances where ingested petroleum has been shown to either affect specific physiological processes or cause structural and pathological changes in tissues.

PHYSICAL EFFECTS

When seabirds become heavily contaminated with petroleum, the entrapped air between the feathers is eliminated and the resulting loss of buoyancy may lead to death through drowning. In instances where birds have sustained less severe contamination, such as when only the breast feathers become soaked with petroleum, the effective body weight may be increased substantially. For example, we have noted that even light to moderate smearing of the breast feathers with Bunker C oil increases the effective body weight of a 1.2 kg mallard duck by 7-18% and moderate smearing of a 2.5 kg Pekin duck increases its effective body weight by 25%. Such added burdens must surely contribute to the physical exhaustion of contaminated birds. Contamination of the flight feathers, even with small amounts of petroleum, may prevent them from sliding easily over one another as the wings change shape during flight. Thus, the aerodynamic properties of the wings will become less efficient and in some cases this may even prevent active flight. The added body weight and possible impaired flight of contaminated birds, therefore, may adversely affect their abilities to forage and these factors may account for the lean or emaciated condition of so many beached birds that are only lightly contaminated with petroleum.

In less extreme instances, and particularly after attempts have been made to cleanse the feathers of contaminated birds, the elimination of entrapped air from between the feathers leads to a loss of thermal insulation. The experimental application of quite small amounts of oil to the breast feathers of mallard and black ducks can eliminate sufficient air from between the feathers to cause their thermal conductivity to increase significantly. Therefore, the basal metabolism of the bird must increase to compensate for the resulting high rate of heat loss [45]. Similar metabolic responses occur when any one of a variety of petroleum products are applied to the feathers and in each case the increase in metabolism appears to be dose-dependent. The response in each case is believed to be due entirely to changes in the physical properties of the feathers and not due to systemic toxicity or irritation of the skin. Figure 4 illustrates the type of

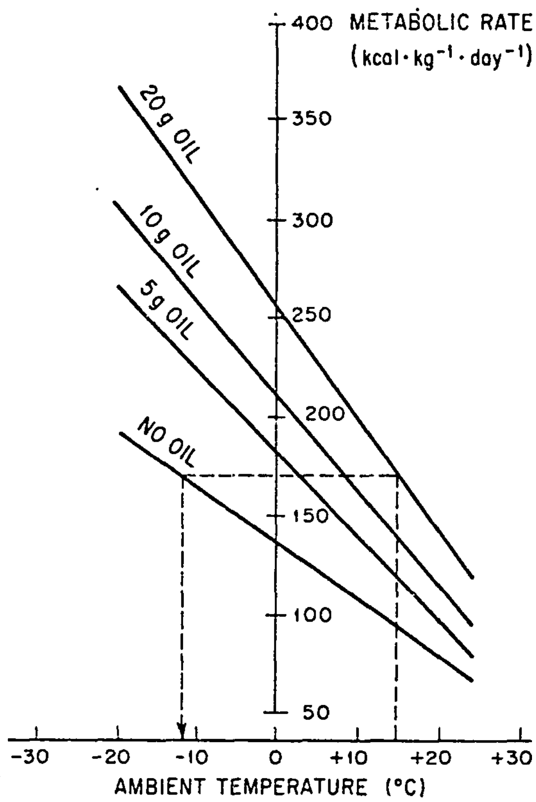


Fig. 4. The metabolic rates of black ducks following contamination of the breast feathers with different quantities of a lubricating oil (Redrawn from Hartung [45]).

changes observed in the basal metabolic rates of black ducks following contamination of the feathers with different doses of lubricating oil. These data show quite clearly that at an environmental temperature of 15°C, contamination of a 900 g black duck with only 20 g of oil will cause almost a twofold increase in metabolic rate and that this rate of energy consumption would be equivalent to that necessary to maintain the normal body temperature of an uncontaminated bird living at less than -10°C (Fig. 4). Thus, even a moderately contaminated bird would have to double its food intake to achieve the level of metabolism necessary to offset the loss of thermal insulation.

Field studies have frequently shown that oil-contaminated birds become isolated from their food supply and their food intake may be reduced to zero [46-48]. Under these conditions, the increased utilization of body fat will lead to accelerated starvation and death when the stores of fat are depleted; also survival studies of experimentally-contaminated birds maintained at low environmental temperatures have suggested that adverse weather may accelerate the death of birds contaminated at sea [45].

Although the topic has not been examined experimentally, the increased metabolism and the attendant increase in respiration rate of the oil-contaminated birds will also lead inevitably to higher rates of respiratory water loss; in some birds, particularly juveniles, this additional water loss will exacerbate the osmoregulatory imbalance that occurs following ingestion of petroleum (see section on "Effects on Juveniles").

SYSTEMIC EFFECTS

The domestic Pekin duck, and its ancestor the common mallard duck, can live equally well in either freshwater or marine environments. For this reason, these birds make good experimental models and have been used frequently for studies on the adaptive responses of birds exposed to simulated conditions of the marine environment and the possible effects of ingested petroleum on these adaptive mechanisms.

Laboratory studies have shown that both juvenile and adult ducks will eat food that has been contaminated with petroleum and petroleum products and, although concentrations of up to 3 ml crude oil per 100 g dry mash do not seem to diminish the palatability of the food, similar concentrations of petroleum products such as No. 2 fuel oil are not consumed with such characteristic voracity. In the wild, contaminated food may be ingested in the form of organisms that have themselves consumed petroleum or plant material to which petroleum may have adhered. Drinking water, particularly at the shoreline or other places where wave action occurs, may also contain droplets of petroleum in suspension. Ingestion of petroleum in the form of contaminated food and drinking water, however, is not the only way in which seabirds may ingest petroleum. Observers in the field have reported that birds attempt to clean their feathers immediately after they become contaminated by an oil slick on the surface of the ocean [e.g., 4] and it has been shown that ducks will preen up to 5% of the contaminating oil from their feathers during the first 8 days after exposure [49]. Studies using radioactively labelled crude oil have indicated that contaminated ducks may ingest up to 7 ml of oil per kg body weight per day in the course of preening their plumage [50].

The results of recent studies in these and other laboratories suggest that, at least in ducks, the apparent systemic effects of petroleum may be different at several stages of development. For reasons of clarity, therefore, we have summarized all experimental studies according to the effects that petroleum may have on birds during prenatal, juvenile, and adult phases of their life cycles.

Effects on Developing Embryos

The fact that further embryonic development is arrested in eggs that have been sprayed with oil has been known for many years [51]. This effect has been attributed mainly to the impaired passage of respiratory gasses through the shells of contaminated eggs. In the 1930's, A.O. Gross of Bowdoin College, Maine, suggested that spraying eggs with oil might be used as a method to control the herring gull populations in some parts of New England. His recommendations were adopted by the U.S. Fish and Wildlife Service and records suggest that some decline in population size occurred between 1940 and 1952 when the program was discontinued; some details of this program have been reviewed by Kadlec and Drury [52]. In 1956, Rittinghaus [53] also noted that eggs that had become contaminated with petroleum from the feathers of brooding Cabot's tern did not hatch, and a similar effect of petroleum was observed by Birkhead et al. in 1973 [54] for great black-backed gulls.

This effect was tested experimentally by Hartung [55] who smeared small volumes of mineral oil over the shells of fertile duck eggs that were being incubated artificially. He also applied the same material to the breast feathers of brooding mallard ducks. Coating the eggs with mineral oil reduced their hatchability to 20% compared to a value of 80% normally found among uncontaminated eggs. When fertilized eggs were incubated naturally by oil-contaminated females, none of the embryos survived. Also, in a study designed to evaluate the effects of herbicide and pesticide solvents, Kopischke found that when fertile pheasant eggs were sprayed with diesel oil, their hatchability was reduced to zero [56].

In Hartung's [55] and Kopischke's [56] experiments, most of the shell surfaces were coated with oil and there is little doubt that the embryonic mortality they observed was due to impaired gaseous exchange through the egg shell. However, recent studies by investigators at the Patuxent Wildlife Research Center at Laurel, Maryland, have focussed attention on the possibility that some petroleum hydrocarbons may penetrate the shell and affect embryonic development through a systemic action [57,58]. These workers, using fertile mallard and eider duck eggs, have applied very small volumes of a No. 2 fuel oil to only a portion of the total egg shell surface. Significant increases in mortality have been observed when less than 2% of the surface of mallard duck eggs are contaminated with 1 µl of this oil; when larger volumes of oil are applied, the mortality among the developing embryos is increased further (Table 6). They have also observed that, compared to the effect of a similar volume of fuel oil, the application of a mixture of saturated paraffins causes the death of fewer embryos at a much later stage of their development, even though samples of the paraffin mixture and the fuel oil covered similar areas of the egg shells (Table 6). These data provide convincing evidence that some constituents in fuel oil may penetrate the shell and arrest the development of embryos. Partial confirmation of these observations has been obtained from a similar series of experiments on eider duck eggs [58]. Eggs from this species, however, were collected in the field and the oil samples were applied to the shells at a later stage of embryonic development. Nevertheless, a significant increase in mortality occurred when the eggs were contaminated with very small volumes of No. 2 fuel oil and again it is improbable that the effect was due to impaired gaseous exchange.

Effects on Juveniles

Response to Dose

In earlier experiments we had observed that, although ducklings would eat contaminated food, the mortality rates were high. We therefore designed a series of experiments to examine more precisely the effect of different quantities of ingested crude oil on the mortality of seawater-adapted ducklings. Each group consisted of 30 birds that had been adapted to seawater for 3 days and during this time their daily food intake was monitored. On the fourth day, the uncontaminated food was replaced with weighed amounts of food containing known volumes of South Louisiana crude oil. Even at the highest concentrations of crude oil used in these experiments, the birds consumed normal quantities of food (10 g dry weight per 100 g body weight) during the first two days. Thus, although the intake of food containing the high concentrations of oil diminished markedly on the third day, we are confident that proportionate volumes of oil were consumed by each experimental group of birds during the first and second days.

Very few deaths occurred when birds were fed food containing only 5% crude oil and 87% of the experimental group was still alive at the end of the 6-day experiment (Fig. 5).

[redacted] [redacted]

TABLE 6

The survival of developing mallard duck embryos following contamination of the egg shell with various quantities of petroleum and petroleum hydrocarbons. After the fertility of the eggs had been confirmed on the eighth day of incubation, the shells were contaminated in the region of the air sac with the indicated volumes of either petroleum or the petroleum hydrocarbon mixture

Treatment	Area of shell contaminated with oil (% total shell area)	Mortality (% of total number of eggs incubated)	Mean age of embryos at death (days)	Mean body weight of survivors (g)	
				24 hr after hatching	29 days after hatching
Untreated controls	0	2-12	23.7	43.3	738
Paraffin mixture[a] (50 µl)	34.0	28	21.6	41.1	756
No. 2 fuel oil[b]					
1 µl	1.3	37	10.8	42.3	743
5 µl	5.0	55	11.1	43.0	756
10 µl	11.5	88	10.1	41.5	670
20 µl	20.2	98	9.4	-	-
50 µl	32.1	100	8.5	-	-

From Albers [57].

a The following paraffin compounds were mixed in equal proportions: pentadecane, hexadecane, heptadecane, octadecane, nonadecane, 2,2,4,6,6-pentamethylheptane, 2,2,4,4,6,8,8-heptamethyl-nonane, 2,6,10,14-tetramethylpentadecane, decahydronaphthalene.

b American Petroleum Institute Reference Oil No. III containing 38.2% aromatic hydrocarbons.

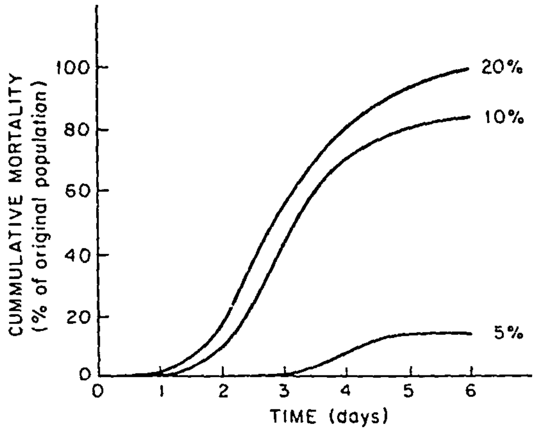


Fig. 5.. The cumulative mortality among groups of 30 Pekin ducklings given food contaminated with 5, 10, and 20% (v/w), South Louisiana crude oil (Holmes, Cronshaw, and Crocker, unpublished).

This low mortality rate was in marked contrast to that observed in the group of birds given food containing 10% crude oil. In this group, 73% of the colony died during the first 4 days and although the mortality rate declined thereafter, only 4 birds survived to the end of the 6th day (Fig. 5). When the concentration of crude oil in food was doubled once more, 80% of the colony died during the first 4 days and none survived after 6 days (Fig. 5).

To our surprise, many of the surviving birds seemed to be able to withstand contaminated food indefinitely, although their growth rates were somewhat lower than those of control birds. This was particularly apparent among the survivors of the group fed 5% crude oil in their food. These birds were fed the oil-contaminated food for a further 2 weeks after the experiment and no further deaths were recorded.

Changes in Intestinal Transfer

During the course of these experiments, we noted that those seawater-adapted ducklings that died following the ingestion of crude oil often showed signs of impaired electrolyte balance. Furthermore, their symptoms resembled those seen in birds that failed to adapt to a seawater diet. This failure is associated with an acute dysfunction of one or more of the interdependent osmoregulatory mechanisms that have evolved in marine birds. These mechanisms enable the birds to absorb ingested seawater from the gut and excrete the large amounts of salt, particularly Na^+, without incurring an excessive loss of water. To this end the nasal glands have developed as extrarenal excretory organs and by augmenting the limited excretory capacity of the kidney, successful adaptation to a marine habitat is assured. Both neural and hormonal regulators are involved in the initiation and continuation of the renal, extrarenal, and intestinal homeostatic mechanisms [59-61]. Included among these regulators are the adrenal steroid hormones. We have shown that when ducklings are fed seawater, the rates of Na^+ and water transfer across the intestinal mucosa are increased and the development of this increase seems to be stimulated through the action of the adrenocortical hormones [62]. Furthermore, the ingestion of a specific corticosteroid inhibitor, such as spironolactone, prevents the development of this increase and the survival of seawater-fed ducklings is threatened [62,63]. As a working hypothesis, therefore, we proposed that the necessary development and continuation of increased mucosal transfer in seawater-adapted ducklings might also be sensitive to the presence of petroleum hydrocarbons in the small intestine.

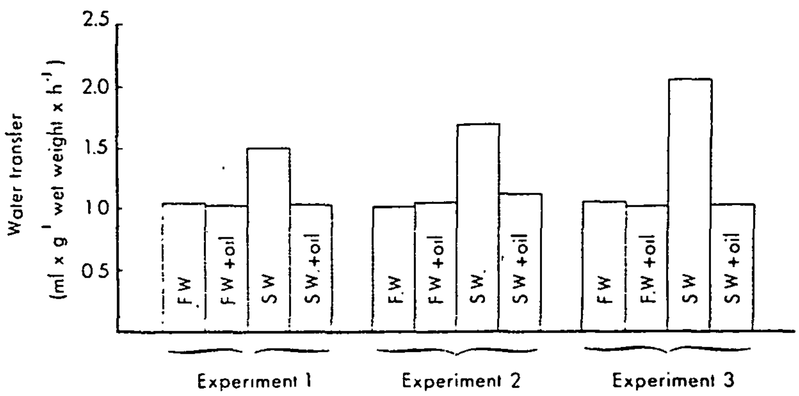


Fig. 6. The effect of a single oral dose (0.2 ml) of Santa Barbara crude oil on the rates of mucosal transfer in the small intestine of ducklings maintained on either fresh water or seawater. In Experiments 1 and 2 the transfer rates were measured 24 hr and 4 days respectively after the oil was given, and in Experiment 3 the birds were allowed to adapt to seawater for 3 days, the oil was given at the beginning of the fourth day of adaptation and the mucosal transfer rates were determined 24 hr later (From Crocker, Cronshaw, and Holmes [64]).

In these experiments we fed small volumes of ingested crude oil to ducklings and its acute effect on the intestinal mucosa was measured *in vitro* [64]. Although the administration of crude oil had no effect on the basal rate of mucosal transfer found in ducklings maintained on fresh water, the adaptive response in birds given seawater was inhibited (Fig. 6). This effect was apparent 24 hr after the oil was administered, and the effect of a single dose persisted for at least 4 days (Fig. 6). Furthermore, the increment in mucosal transfer that had developed during a previous 3-day exposure to seawater was abolished 24 hr after a single dose of crude oil had been given (Fig. 6). The degree to which the adaptive response of the intestinal mucosa was inhibited by different crude oils varied according to their geographic origins

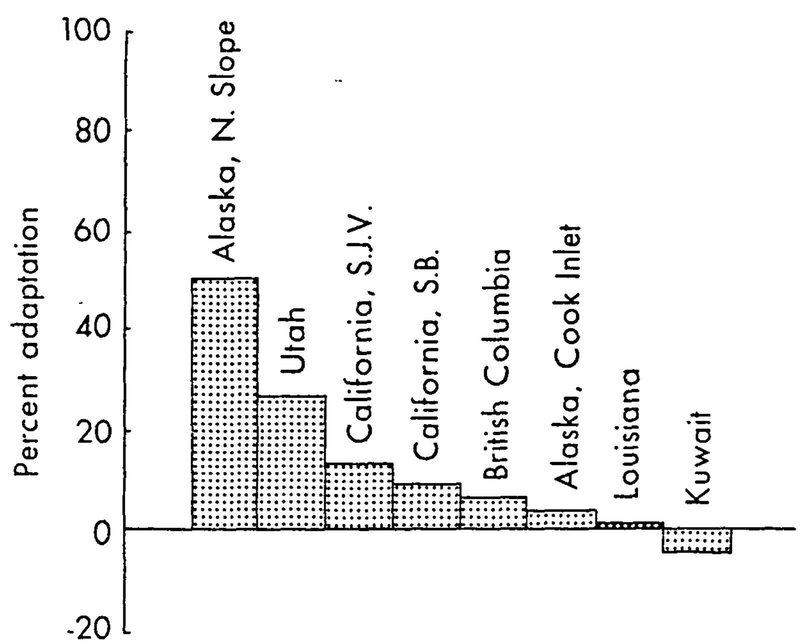


Fig. 7. A comparison of the effects of crude oils from different locations on the adaptive responses occurring in the small intestinal mucosa of ducklings maintained on seawater. Each bird received 0.2 ml of a crude oil at the time of transfer to seawater and the increase in mucosal water transfer observed 4 days later was expressed as a percentage of the increase which occurred in untreated birds similarly adapted to seawater.

$$\% \text{ Adaptation} = \frac{\left(T_{SW+oil} - T_{FW}\right)}{\left(T_{SW} - T_{FW}\right)} \cdot 100$$

where T_{FW}, T_{SW} *and* T_{SW+oil} *represent respectively the mucosal water transfer rates (ml/g wet tissue per hr) in untreated birds maintained on fresh water and seawater or seawater-maintained birds given a single dose of crude oil (From Crocker, Cronshaw, and Holmes [65]).*

(Fig. 7). Furthermore, when the effects of distillation fractions prepared from two crude oils of disparate composition were compared (Table 7), the inhibition was not associated

TABLE 7

Relative abundances of the distillation fractions derived from two chemically different crude oils. The values in parentheses indicate the volumes of each distillation fraction present in 0.2 ml of the San Joaquin Valley, California, and Paradox Basin, Utah, crude oils

Source	Relative abundance of distillation fractions (% weight)			
	Fraction 1 <240°C	Fraction 2 245°-399°C	Fraction 3 399°-482°C	Fraction 4 >482°C
San Joaquin Valley, Calif.	2 (0.004 ml)	31 (0.062 ml)	20 (0.04 ml)	47 (0.094 ml)
Paradox Basin, Utah	27 (0.054 ml)	32 (0.064 ml)	13 (0.026 ml)	28 (0.056 ml)

exclusively with the same distillation fraction of each oil. The combined effects of these fractions were in each case approximately equal to that of the whole oil from which they were derived. Most of the inhibitory effect of the oil from the San Joaquin Valley, California, however, was found in the least abundant low molecular weight fraction whereas in the oil from Paradox Basin, Utah, it was associated with the highest molecular weight fraction (Fig. 8).

We have recently observed that the adrenal steroid hormone, corticosterone, will induce high rates of mucosal transfer in the small intestine of freshwater-maintained ducklings [63]. In this context, therefore, it is interesting to note that if seawater-maintained ducklings are treated with this hormone prior to receiving small doses of crude oil the mucosal transfer rates are not suppressed (Fig. 9). In addition, to providing a circumstantial insight into the nature of the inhibitory action of ingested crude oil, these findings suggest that a simple therapy based on the administration of corticosterone may be effective in increasing the survival rate of some oil-contaminated birds.

(Fig. 7). Furthermore, when the effects of distillation fractions prepared from two crude oils of disparate composition were compared (Table 7), the inhibition was not associated

TABLE 7

Relative abundances of the distillation fractions derived from two chemically different crude oils. The values in parentheses indicate the volumes of each distillation fraction present in 0.2 ml of the San Joaquin Valley, California, and Paradox Basin, Utah, crude oils

Source	Relative abundance of distillation fractions (% weight)			
	Fraction 1 <240°C	Fraction 2 245°-399°C	Fraction 3 399°-482°C	Fraction 4 >482°C
San Joaquin Valley, Calif.	2 (0.004 ml)	31 (0.062 ml)	20 (0.04 ml)	47 (0.094 ml)
Paradox Basin, Utah	27 (0.054 ml)	32 (0.064 ml)	13 (0.026 ml)	28 (0.056 ml)

exclusively with the same distillation fraction of each oil. The combined effects of these fractions were in each case approximately equal to that of the whole oil from which they were derived. Most of the inhibitory effect of the oil from the San Joaquin Valley, California, however, was found in the least abundant low molecular weight fraction whereas in the oil from Paradox Basin, Utah, it was associated with the highest molecular weight fraction (Fig. 8).

We have recently observed that the adrenal steroid hormone, corticosterone, will induce high rates of mucosal transfer in the small intestine of freshwater-maintained ducklings [63]. In this context, therefore, it is interesting to note that if seawater-maintained ducklings are treated with this hormone prior to receiving small doses of crude oil the mucosal transfer rates are not suppressed (Fig. 9). In addition, to providing a circumstantial insight into the nature of the inhibitory action of ingested crude oil, these findings suggest that a simple therapy based on the administration of corticosterone may be effective in increasing the survival rate of some oil-contaminated birds.

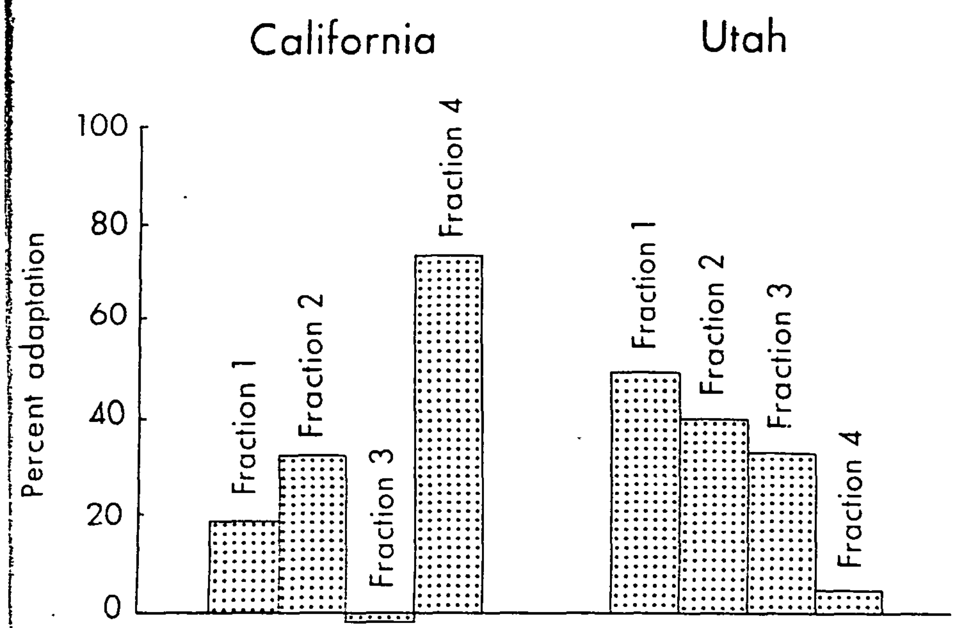


Fig. 8. A comparison of the effects of distillation fractions derived from a California (San Joaquin Valley) and a Utah (Paradox Basin) crude oil on the adaptive responses occurring in the intestinal mucosa of ducklings maintained on seawater. At the time of transfer to seawater each bird received a single oral dose equivalent to the volume distilled from 0.2 ml of crude oil (see Table 7). The mucosal water transfer was measured 4 days later and the adaptive response was calculated as in Figure 7 (From Crocker, Cronshaw, and Holmes [65]).

Effects on Mature Birds

Responses to Environmental Stress

In an earlier section, we have mentioned that the ducklings which survived an initial period of exposure to oil-contaminated food seemed to be able to tolerate this diet almost indefinitely. These birds, however, were maintained in a relatively protected environment where two or three birds were housed together in cages. But when some of them were transferred to open runs, where the population was comparatively dense, many died within a few days and at autopsy, we found that the adrenal glands were enlarged and the lymphoepithelial tissues were atrophic. These observations suggested that the prolonged consumption of oil-contaminated food may have

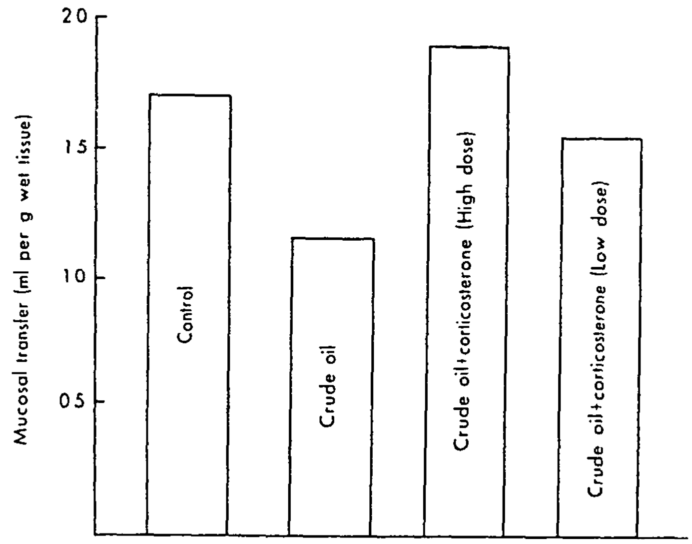


Fig. 9. The effect of 0.2 ml of ingested crude oil (Kuwait) on the mucosal water transfer rates of ducklings given seawater to drink. The suppression of water transfer, that characterizes the effect of crude oil ingestion in ducklings, did not occur when the birds were pretreated with the adrenal steroid hormone, corticosterone (From Crocker and Holmes [63]).

constituted a physiological stress to these birds and that when they were exposed to an additional stress, such as that imposed through competition with other birds, they succumbed.

To test this hypothesis, a series of experiments was planned to examine the effects of ingested petroleum on groups of seawater-adapted ducks maintained under stressful and nonstressful environmental conditions. Known volumes of Kuwait and South Louisiana crude oil were mixed each day with weighed amounts of dry poultry food and the experimental groups were given their respective mixtures of contaminated food at 0800 hours each day. At 1600 hours the food remaining in the trays was weighed and the daily intakes of food and petroleum were estimated. The birds were maintained on this feeding regimen for 100 days and during this period their mean daily food intake was similar to that of the birds fed uncontaminated food (70 g dry food/kg body weight per day). For the first 50 days the birds were maintained in a room at 27°C. During this period no deaths occurred among either the control birds or those given food mixed with Kuwait crude oil and only one died in the group fed South Louisiana crude oil (Fig. 10). After

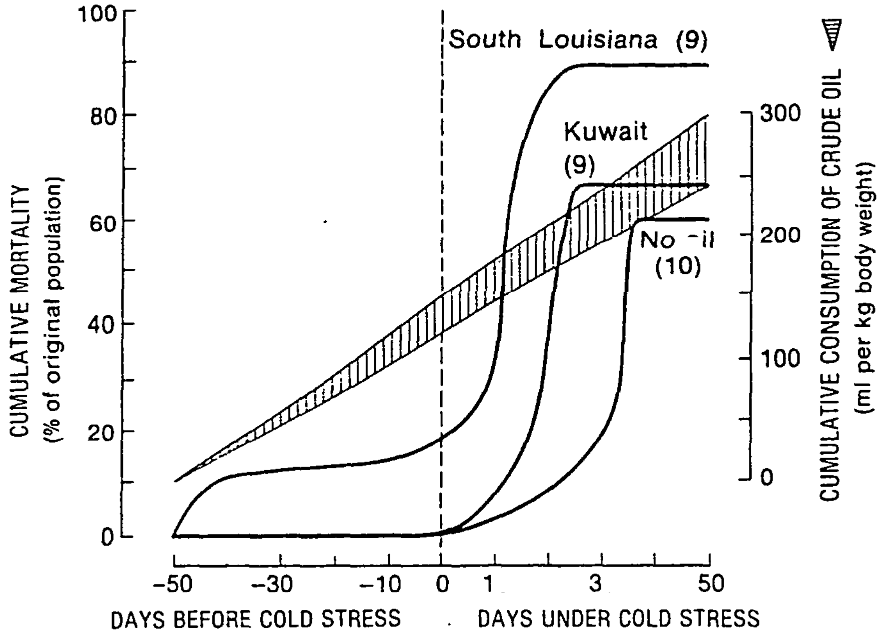


Fig. 10. A comparison of the cumulative mortalities observed among groups of mature Pekin ducks fed uncontaminated food and constant daily amounts of either South Louisiana or Kuwait crude oil. After each group of birds had been maintained at 27°C for 50 days the temperature of the room was lowered to 5°C. Throughout the 100-day experimental period the mean daily consumptions of petroleum by the birds given food containing South Louisiana and Kuwait crude oils were 3.0 and 2.4 ml per kg body weight. Numerals in parentheses indicate the number of birds in each group (From Holmes, Cronshaw, and Gorsline [66].

each group of birds had been maintained at 27°C for 50 days, the temperature of the room was lowered to 5°C. Three days later the birds fed South Louisiana crude oil started to die, and the mortality continued until only one bird was alive after 23 days of exposure to cold (Fig. 10). The birds fed Kuwait crude oil started to die after 10 days of exposure to cold and after 25 days of exposure to cold two-thirds of the group had died (Fig. 10). However, the birds fed uncontaminated food were also unable to tolerate prolonged exposure to cold, although compared with the birds fed oil-contaminated food, the onset of mortality occurred later and fewer birds died during the experimental period (Fig. 10). In summary, therefore, the effects of cold-stress on birds subjected to the prolonged ingestion of petroleum-contaminated food seemed only to accelerate the onset of mortality and diminish the period of sustained cold that the birds could withstand.

We have also shown that stresses other than cold may cause similar changes in the patterns of mortality among birds fed chronic low doses of crude oil (Holmes, Cronshaw, and Crocker, unpublished). For example, Pekin ducks that have consumed petroleum-contaminated food for 2 mo start to die within a few days after the salinity of their drinking water is abruptly increased from 60 to 75% standard seawater and graphic representation of the mortality rates among these birds are congruent with those of the birds exposed to cold stress (cf. Fig. 10).

Ovarian Dysfunction

There is also some evidence to suggest that ingested petroleum may affect the fecundity of birds. Hartung [55] showed that following the ingestion of small amounts of lubricating oil (2 g/kg body weight), both Pekin and mallard ducks ceased to lay for about 2 weeks and during this time they displayed much less reproductive behavior than did birds that received no oil. However, very few birds were used in this study and the topic has recently been reexamined in more detail by Grau and his associates [67]. Using the Japanese quail as their experimental model, these workers have shown that a single large dose of Bunker C fuel oil will completely inhibit laying for 6 to 8 days and that smaller doses not only reduce the rate of laying but the hatchability of the eggs laid during the days immediately following the administration of oil is also reduced. Indeed, when the dose of Bunker C fuel oil was insufficient to reduce the rate of laying, the hatchability of the eggs was still slightly lower than normal for several days whereas comparable doses of mineral oil and refined safflower seed oil affected neither the rate of laying nor the hatchability of the eggs. Differential effects on oviposition and hatchability were also identified following the ingestion of a crude oil. Thus, when a relatively high dose of Kuwait crude oil was given, the rate of laying remained almost normal but the hatchability of the eggs laid during the next 3 days was reduced below 50% of that found among eggs laid by the control birds. The results of these studies are summarized in Table 8.

When quail are maintained on a simulated daylight schedule (14 hr light, 10 hr dark), they normally deposit a ring of dark-staining yolk during the daylight hours and a ring of light-staining yolk during the hours of darkness [68]. However, the eggs laid during the few days following ingestion of

TABLE 8

The egg production and hatchability of eggs laid by Japanese quail following the administration of single oral doses of petroleum or vegetable oil on day zero. Production is expressed as eggs laid per day per 100 birds and hatchability is expressed as the percentage hatched from eggs containing live embryos after 7 days incubation.

Oil administered	Egg production	Hatchability
Mineral oil or safflower oil	>90%	>80%
500 mg Bunker C	Zero for 6-8 days	Zero
200 mg Bunker C	Reduced to 40% on day 2, 30% on day 3; and returned to normal by day 6	<70% on day 1 <50% on day 2 <30% on day 3 <70% on day 4 Normal on day 5
100 mg Bunker C	Normal (>90%)	Slightly reduced for 3 days (>80%)
800 mg Kuwait crude	Slightly reduced for 3 days	<50%
800 mg Prudhoe Bay crude	Reduced to 52% on day 1, 44% on day 2, 72% on day 3; returned to normal by day 4	Unaffected
800 mg Cook Inlet crude	Reduced to 58% on day 1, 50% on day 2, 71% on day 3; returned to normal by day 5	Unaffected

From Grau, Roudybush, Dobbs, and Wathen [67] and unpublished data of these authors.

a single dose of petroleum show irregularities in these patterns of yolk deposition [67]. Less than normal amounts of yolk, consisting of abnormally small yolk spheres (10-30 microns in diameter), are deposited during the first night after dosing and during the next day a narrow band of dense staining yolk is deposited. Also, during formalin fixation, prior to staining with potassium dichromate, cracks often develop between the spheres of yolk deposited in the days immediately following ingestion of petroleum. After high doses of petroleum, when laying and hatchability of eggs are diminished, this pattern of yolk deposition may persist for at least 2 days [67].

Although the mechanism of petroleum action on ovarian function is not known, the effects are clearly systemic. It is possible that some components of petroleum are absorbed from the intestinal tract and following transportation to the liver and the ovary they may be deposited in the yolk. In seabirds, however, it is also possible that ingested petroleum may act indirectly to modify ovarian function; partial inhibition of the Na^+ and water uptake mechanisms in the intestinal mucosa may cause changes in the ion composition of yolk and thus influence embryo survival [64,65,67].

PATHOLOGICAL EFFECTS

There have been several pathological examinations of tissues collected from oil-contaminated seabirds. Some workers have described conditions that may have been caused by the ingestion of crude oil or petroleum derivatives but others have been unable to show any pathological symptoms attributable to petroleum.

Hartung and Hunt [50] claimed to identify several pathological conditions both in dead birds that had been contaminated with crude oil in the wild and in birds that had been fed commercial crude oil derivatives in the laboratory. Several oils caused irritation of the gastrointestinal mucosa and these birds showed a slight anemia that was attributed to hemorrhage. A high incidence of lipid pneumonia was observed in birds that had ingested oil and other conditions reported included fatty degeneration of the liver, acinar atrophy of the pancreas, adrenocortical hyperplasia, and toxic nephrosis. Laboratory studies also showed that the plasma glutamic-oxalacetic transaminase levels were increased significantly and the bromsulphalein liver function tests showed significantly increased retention of the dye after the ingestion of high doses of diesel oil.

Clark and Kennedy [8] reported that Beer examined over a hundred oil-contaminated birds that had died in captivity following the *Torrey Canyon* disaster and the most common diseases he found were enteritis, aspergillosis, and infective arthritis.

Necropsies were also performed on 119 birds that died in captivity after exposure to the Bunker C fuel oil that was spilled in the San Francisco Bay in 1971 [69]. These birds, which had been captured by volunteer workers and had been subjected to initial cleansing, were further cleansed with mineral oil, Basic H, and poly complex A-11. Severe tissue damage was found in the intestinal tract, liver, and kidneys. However, these workers also found that Bunker C fuel oil was not lethal when fed to juvenile chickens and mallard ducks.

In another experimental study over a hundred mallard ducks were contaminated with Santa Barbara crude oil [70]. Some of these birds were later cleansed and at autopsies performed during a subsequent one-month period no pathological changes were observed. We also have been unable to detect any histological differences between intestinal tissue from control and oil-treated ducklings even though Na^+ and water transfer by the intestinal mucosa of these birds had been severely attentuated through oil ingestion [64,65].

In another experimental series we gave 90 successive daily doses of petroleum to a group of mature Pekin ducks that had been previously adapted to seawater. The petroleum was given by stomach tube each day immediately before feeding. Two birds received 5 ml of Santa Barbara crude oil and similar doses of Kuwait crude oil and No. 2 fuel oil were given to two other pairs of birds. One of the birds received 10 ml of Santa Barbara crude oil. With the exception of one of the birds given Kuwait crude oil, all birds ate normal quantities of food and they either maintained or increased their body weights during the period of treatment. Occasional regurgitation of oil caused some contamination of the feathers and in the birds given crude oil a characteristic dark colored material that resembled petroleum was seen in the feces, and feathers around the cloaca became stained by a black contamination.

At autopsy, none of the birds showed any gross abnormal clinical conditions and, except for the liver and adrenal weights in some birds, all organ weights were within ranges found normally in seawater-adapted birds. The liver and adrenal weights of birds given No. 2 fuel oil were low and resembled those found in birds maintained on fresh water. The adrenal weights of the birds given Santa Barbara and Kuwait crude oils were high and there was a corresponding reduction in the lymphoepithelial tissues suggesting possible high levels of adrenocortical activity.

In all birds, the lungs, liver, and intestine appeared normal, healthy, and indistinguishable from these tissues in untreated birds. Although occasional regurgitation of administered oil occurred, none of the birds showed symptoms of lipid pneumonia and none died during the experimental period. In the case of birds treated with the Santa Barbara and Kuwait crude oils, an accumulation of black bituminous material was found in the caecal pouches; these oils contained ap- [illegible] 5.0% by weight of asphaltenes. In contrast, there was no black deposit in the caecal pouches of birds given No. 2 fuel oil and this product contained no asphaltenes.

The intestines of birds treated with the crude oils showed changes in the organization of the villi. Mucosal tissue from uncontaminated control birds normally show elongated villi with rounded or pointed tips but many of the birds given petroleum showed villi with flattened tips and the mucosal epithelial cells were frayed-out at the tips. There was no evidence of granuloma or necrosis and there was no evidence of inflammation as judged by the normal population of plasmocytes, eosinophils, or polymorphonuclear leucocytes in the mucosal region of the gut. There was a distinct increase in the number of lymphocytes in the *lamina propria* and also the number of muscle fibers in this region appeared greater than in the control birds. The crypts of Lieberkühn appeared normal in all specimens and contained many mitotic figures.

The adrenal glands of birds given either a crude oil or No. 2 fuel oil showed a distinct zonation which was not apparent in the control birds. This zonation was due to an increase in the size and number of lipid droplets in the interrenal cells of the subcapsular zone of the glands. In the inner parts of the glands the interrenal cells were smaller and polygonal.

These pathological studies seem to indicate that mature ducks maintained under laboratory conditions tolerate well the chronic administration of at least two crude oils and one petroleum distillation product. The increase in body weight of some of the birds and the absence of mortality in any of the groups studied was remarkable and quite unexpected. This is especially so since one of the birds consumed almost a liter of Santa Barbara crude oil and the remainder of the birds consumed 450 ml of either Kuwait crude oil or No. 2 fuel oil during the 90-day experimental period. The histological patterns of the adrenal glands in birds treated with oil, however, suggest a higher than normal level of adrenocortical function occurs under conditions of chronic petroleum ingestion. The development of this hyperadrenocortical condition may account for the high mortality seen when the birds fed petroleum-contaminated diets were exposed to cold-stress (cf. Fig. 10).

SCIENTIFIC NAMES OF BIRDS CITED

Coot, American, *Fulica americana*
Cormorant, Brandt's, *Phalocrocorax penicillatus*
Cormorant, double-crested, *Phalocrocorax auritus*
Guillemot, Brunich's, *Uria lonvia*
Guillemot, common, *Uria aalge*
Duck, black, *Anas rubripes*

Duck, canvasback, *Aythya valisineria*
Duck, eider, *Somateria mollissima*
Duck, golden eye, *Bucephala clangula*
Duck, long-tail, *Clangula hyemalis*
Duck, mallard, *Anas platyrhynchos*
Duck, Pekin, *Anas platyrhynchos*
Duck, ruddy, *Oxyura jamaicensis*
Grebe, eared, *Podiceps caspicus*
Grebe, horned, *Podiceps auritus*
Grebe, pied-billed, *Podilymbus podiceps*
Grebe, western, *Aechmorphorus occidentalis*
Gull, *Larus sp.*
Gull, great black-backed, *Larus ridibundus*
Gull, herring, *Larus argentatus*
Kittiwake, *Rissa tridactyla*
Loon, common, *Gavia immer*
Loon, red-throated, *Gavia stellata*
Merganser, *Mergus merganser*
Murre, common, *Uria aalge*
Penguin, jackass, *Spheniscus demersus*
Puffin, *Fratercula arctica*
Quail, Japanese, *Coturnix coturnix*
Razorbill, *Alca torda*
Scaup, *Aythya marila*
Scoter, surf, *Melanitta perspicillata*
Scoter, velvet, *Melanitta fusca*
Tern, Cabot's, *Thalasseus sandvicensis*

REFERENCES

1. Mothersole, J. (1910). The Isles of Scilly, Their Story, Their Folk and Their Flowers. Religious Tract Society, London.
2. Parslow, J.L.F. (1967). A census of auks. Br. Trust Ornithol. News 23:8-9.
3. Parslow, J.L.F. (1967). Changes in status among breeding birds in Britain and Ireland. Br. Birds 60:2-47, 97-122, 177-202.
4. Bourne, W.R.P. (1968). Oil pollution and bird populations. In: The Biological Effects of Oil Pollution on Littoral Communities (J.D. Carthy and D.R. Arthur, eds.), Suppl. to Field Studies, Vol. 2, p. 99-121. Obtainable from E.W. Classey, Ltd., Hampton, Middx., England.
5. Aldrich, J.W. (1938). A recent oil pollution and its effect on the water birds in the San Francisco Bay area. Bird Lore 40:110-4.
6. Goethe, F. (1968). The effects of oil pollution on populations of marine and coastal birds. Helgol. Wiss. Meeresunters 17:370-4.

7. Richardson, F. (1956). Sea birds affected by oil from the freighter *Seagate*. Murrelet 37:20-2.
8. Clark, R.B. and J.R. Kennedy (1968). Rehabilitation of oiled seabirds. Report to the Advisory Committee on Oil Pollution of the Sea (U.K.), p. 1-57. Department of Zoology, The University of Newcastle upon Tyne, England.
9. Bourne, W.R.P., J.D. Parrack, and G.R. Potts (1967). Birds killed in the *Torrey Canyon* disaster. Nature 215: 1123-5.
10. Joensen, A. (1971). Olieforureninger 1970. Dansk Vildtforskning 1970-71:53-5.
11. Swennen, C. and A.L. Spaans (1970). De Sterfte van Zeevogels door Olie in Februari 1969 in het Waddengebied. Het Vogeljaar 18:233-45.
12. Drinkwater, B., M. Leonard, and S. Black (1971). Oil pollution and sea birds. In: Biological and Oceanographical Survey of the Santa Barbara Oil Spill (D. Straughan, ed.), p. 313-24. Allan Hancock Foundation, University of Southern California, Los Angeles.
13. Straughan, D. (1971). Oil pollution and seabirds. In: Biological and Oceanographic Survey of the Santa Barbara Oil Spill 1969-1970 (D. Straughan, ed.), Vol. I, p. 307-12. Allan Hancock Foundation, University of Southern California, Los Angeles.
14. Hope-Jones, P., G. Howells, E.I.S. Rees, and J. Wilson (1970). Effect of *Hamilton Trader* oil on birds in the Irish Sea in May 1969. Br. Birds 63:97-110.
15. Woikkeli, M. and J. Virtanen (1972). The *Palva* oil tanker disaster in the Finnish south-western archipelago. II. Effects of oil pollution on the eider population in the archipelagos of Kökar and Föglö, south-western Finland. Aqua. Fenn., p. 122-8.
16. Greenwood, J.J.D., R.J. Donally, C.J. Feare, N.J. Gordon, and G. Waterston (1971). A massive wreck of oiled birds: northeast Britain, Winter 1970. Scott. Birds 6:235-50.
17. Clark, R.B. (1973). Impact of acute and chronic oil pollution on seabirds. In: Background Papers for a Workshop on Inputs, Fates, and Effects of Petroleum in the Marine Environment II, p. 619-34. Ocean Affairs Board, National Academy of Sciences, Washington, D.C.
18. Brown, R.G.B. (1970). Bird mortality caused by the *Arrow* and *Irving Whale* oil spills. Can. Wildl. Serv., unpublished administration report, 23 p.
19. U.S. Department of the Interior (1970). Kodiak oil pollution incident, February-March 1970: Summary Report, Federal Water Quality Administration, Washington, D.C., 23 p.
20. Orr, R.T. (1971). Oil, wildlife and people. Pac. Discovery 24:24-9.

21. Joensen, A.H. (1973). Danish seabird disasters in 1972. Mar. Pollut. Bull. 4:117-8.
22. Bourne, W.R.P. and T.R.E. Devlin (1969). Birds and oil. Birds 2:176-8.
23. Bourne, W.R.P. and T.R.E. Devlin (1971). The pollution plot thickens. Birds 3:190-2, 207.
24. Bibby, C.J. and W.R.P. Bourne (1971). More problems for threatened birds. Birds 3:307-9.
25. Bibby, C.J. and W.R.P. Bourne (1972). Trouble on oiled waters. Birds 4:160-2.
26. Bibby, C.J. and W.R.P. Bourne (1974). Pollution still kills. Birds 5:30-1.
27. Croxall, J.P. (1975). The effect of oil on nature conservation, especially birds. In: Petroleum and the Continental Shelf on North West Europe, Environmental Protection, Vol. 2, p. 93-101. Applied Science Publishers, Ltd., Barking, England
28. IMCO (1973). The environmental and financial consequences of oil pollution from ships. Report of Study No. 6, submitted by the U.K. Appendix 3, The biological effects of oil pollution of the oceans, U.K., Atomic Energy Authority, Programmes Analysis Unit, Chilton, Didcot, Berks.
29. Joensen, A.H. (1972). Oil pollution and seabirds in Denmark 1935-1968. Dan. Rev. Game Biol. 6(8):1-24.
30. Joensen, A.H. (1972). Studies on oil pollution and sea birds in Denmark, 1968-1971. Dan. Rev. Game Biol. 6(9): 1-32.
31. Joiris, G. (1972). The behavior of oil covered birds at sea. Aves 9:136-7.
32. Vermeer, K. and G.G. Anweiler (1975). Oil threat to aquatic birds along the Yukon Coast, Canada. Wilson Bull. 87:467-80.
33. Vermeer, K. and R. Vermeer (1975). Oil threat to birds on the Canadian West Coast. Can. Field-Nat. 89:278-98.
34. Frost, P.G.H., W.R. Siegfried, and J. Cooper (1976). Conservation of the jackass penguin (*Speniscus demersus (L)*). Biol. Conserv. 9:79-99.
35. Westphal, A. and M.K. Rowan (1971). Some observations on the effects of oil pollution on the jackass penguin. Ostrich Suppl. 8:521-26.
36. Percy, J.F., A. Westphal, and E.O.J. Westphal (1972). The rescue and cleaning of oil polluted seabirds in South Africa, Aug. 1969-July 1972. Report to SANCCOB, South African National Foundation for the Conservation of Coastal Birds, Cape Town, 23 p. (Mimeograph).
37. Upenskii, S.M. (1956). Bird bazaars of Novaya Zemlya Academy of Sciences, Moscow, USSR. Eng. Translation: Can. Wildl. Serv., Transl. Russ. Game Report No. 4.

38. Southern, H.N., R. Carrick, and W.G. Potter (1965). The natural history of a population of guillemots (*Uria aalge* Pont.). J. Anim. Ecol. 34:649-65.
39. Tuck, L.M. (1961). The murres: Their distribution, populations and biology, a study of the genus *Uria*. Can. Wildl. Ser. 1, Monogr. Nat. Parks Branch, Ottawa.
40. Cramp, S., W.R.P. Bourne, and D. Saunders (1974). The Seabirds of Britain and Ireland. Collins, London, 287 p.
41. Fisher, J. and R.M. Lockley (1954). Seabirds. Collins, London.
42. Giles, L.A. and J. Livingston (1960). Oil pollution on the seas. Trans. N. Am. Wildl. Nat. Resour. Conf. 25: 297-302.
43. Lemmetyinen, R. (1966). Damage to waterfowl in the Baltic caused by waste oil. Suom. Riista 19:63-71.
44. Monnat, J.Y. (1969) Statut actuel des oiseaus marins incheurs en Bretagne 6 ème partie, Haut Trégor et Grelo (de Trebeurdon à Paimpol). Ar. Vran. 2:1-24.
45. Hartung, R. (1967). Energy metabolism in oil-covered ducks. J. Wildl. Manage. 31:789-804.
46. Hawkes, A.L. (1961). A review of the nature and extent of damage caused by oil pollution at sea. Trans. N. Am. Wildl. Nat. Resour. Conf. 26:343-55.
47. Hunt, G.S. (1961). Waterfowl losses on the lower Detroit River due to oil pollution. In: Proceedings of the Fourth Conference, Univ. Mich., Great Lakes Res. Dir., Inst. Sci. Technol. Publ. 7, p. 10-26.
48. Erickson, R.C. (1963). Oil pollution and migratory birds. Atl. Nat. 18:5-14.
49. Hartung, R. (1963). (Wildlife) Ingestion of oil by waterfowl. Pap. Mich. Acad. Sci. Arts Lett. 48:49-55.
50. Hartung, R. and G.S. Hunt (1966). Toxicity of some oils to waterfowl. J. Wildl. Manage. 30:564-70.
51. Bourne, W.R.P. (1969). Chronological list of ornithological oil-pollution incidents. Seabird Bull. 7:3-8.
52. Kadlec, J.A. and W.H. Drury (1968). Structure of the New England Herring gull population. Ecology 49:644-76.
53. Rittinghaus, H. (1956). Etwas über die "indirekte" verbreitung der Ölpest in einem Seevogelsschutzgebeit. Ornithol. Mitt. 8:43-6.
54. Birkhead, T.R., C. Lloyd, and P. Corkhill (1973). Oiled seabirds successfully cleaning their plumage. Br. Birds 66:353.
55. Hartung, R. (1965). Some effects of oiling on reproduction of ducks. J. Wildl. Manage. 29:872-4.
56. Kopischke, E.D. (1972). The effect of 2,4-D and diesel fuel on egg hatchability. J. Wildl. Manage. 36:1353-56.

57. Albers, P.H. (1976). Effects of external applications of oil on hatchability of mallard eggs. In: Proceedings of Symposium on Fate and Effects of Petroleum Hydrocarbons in Marine Ecosystems and Organisms (D. Wolfe, ed.). In press. Pergamon Press, New York.

58. Szaro, R.C. and P.H. Albers (1976). Effects of external applications of oil on common eider eggs. In: Proceedings of Symposium on Fate and Effects of Petroleum Hydrocarbons in Marine Ecosystems and Organisms (D. Wolfe, ed.). In press. Pergamon Press, New York.

59. Holmes, W.N., J.G. Phillips, and I. Chester Jones (1963). Adrenocortical factors associated with adaption of vertebrates to marine environments. Recent Prog. Horm. Res. 19:619-72.

60. Holmes, W.N. (1972). Regulation of electrolyte balance in marine birds with special reference to the role of the pituitary-adrenal axis in the duck (*Anas platyrhynchos*). Fed. Proc. 31:1587-98.

61. Holmes, W.N. and J.G. Phillips (1976). The adrenal cortex of birds. In: General, Comparative and Clinical Endocrinology of the Adrenal Cortex (I. Chester Jones and I.W. Henderson, eds.), p. 293-420. Academic Press, London.

62. Crocker, A.D. and W.N. Holmes (1971). Intestinal absorption in ducklings (*Anas platyrhynchos*) maintained on fresh water and hypertonic saline. Comp. Biochem. Physiol. 40A:203-11.

63. Crocker, A.D. and W.N. Holmes (1976). Factors affecting intestinal absorption in ducklings (*Anas platyrhynchos*). Proc. Soc. Endocrinol. (May, 1976) 71:88P-89P.

64. Crocker, A.D., J. Cronshaw, and W.N. Holmes (1974). The effect of a crude oil on intestinal absorption in ducklings (*Anas platyrhynchos*). Environ. Pollut. 7:165-78.

65. Crocker, A.D., J. Cronshaw, and W.N. Holmes (1975). The effect of several crude oils and some petroleum distillation fractions on intestinal absorption in ducklings (*Anas platyrhynchos*). Environ. Physiol. Biochem. 5:92-106.

66. Holmes, W.N., J. Cronshaw, and J. Gorsline. The effects of cold stress on seawater-maintained ducks given food contaminated with petroleum. Manuscript in preparation.

67. Grau, C.R., T. Roudybush, J. Dobbs, and J. Wathen (1977) Altered yolk structure and reduced hatchability of eggs from birds fed single doses of petroleum oils. Science 195:779-81.

68. Grau, C.R. (1976). Ring structure of avian egg yolk. Poult. Sci. 55:1418-22.

REVIEW OF WATERBIRD DETERRENT AND DISPERSAL SYSTEMS FOR OIL SPILLS

PACE REPORT NO. 76-6

Prepared for

Petroleum Association for Conservation
of the Canadian Environment
130 Albert Street
Ottawa, Ontario

by

William R. Koski and W. John Richardson
LGL Limited
Environmental Research Associates
44 Eglinton Avenue West
Toronto, Ontario

December 1976

Price $5.00

Summary of Potential Deterrent Methods

High-energy Electro-magnetic Waves

Intense *microwave* radiation (10 to 50 mW/cm^2) causes at least some birds to collapse temporarily or to avoid the irradiated area. Carefully aligned microwave beams might, in theory, prevent birds from entering the area of a spill. However, heavy and expensive equipment would be needed to produce effective power densities, and safety levels for human exposure to microwaves would be exceeded. Hence microwaves are apparently impractical as deterrents.

Laser beams of sufficient intensity cause birds to move. To be effective they must be directed at unfeathered areas (eyes, legs), and even then the power necessary to obtain a response exceeds safe exposure levels for humans. Hence laser beams are apparently not useful as deterrents.

Coloured Dye and Flags

One test has suggested that waterfowl tended to avoid water that contained greenish-yellow *dye*. If true (further tests are needed), oil-soluble dyes would be useful in reducing numbers of birds that land in or swim into oil. Advantages would include the facts that the dye could be applied quickly and over a wide area from an aircraft, and that an oil-soluble dye would remain in the oil as the oil drifted. The possibility that certain birds would be attracted to the dyed oil (particularly at night if fluorescent dye or lights were used) should be tested.

Available evidence suggests that if flags or pennants are used as deterrents, *coloured material* should be used in order to obtain maximum effectiveness.

Light

Searchlights are at least partially effective in dispersing feeding and flying waterfowl at night. Some other birds are attracted to light at night, especially during conditions of rain, fog or heavy cloud. *Flashing lights* and *strobes* may also be useful in dispersing waterfowl at night, and are apparently less likely to attract other birds. Neurophysiological tests on three species suggest that the optimal colour may be red and the optimal flashing rate may be 6 to 12 Hz. Field trials in situations related to oil spills are warranted.

Vision-based Deterrents

Available data suggest that shiny *reflectors* suspended from poles or wires may sometimes be useful in deterring birds, particularly ducks. If illuminated by lights, reflectors might be useful at night as well as by day. However, reflectors appear to attract some birds. Tests are needed in situations related to oil-spills.

Flags, balloons, kites and *smoke* have all been reported to be effective as deterrents in some trials but not in others. None of these methods appears as promising as various other approaches.

Vision-based Biological Deterrents

Hawks and *falcons* have been successfully used to disperse birds from airports. However, raptors are useful only by day and during fair weather, require extensive care and training, and are not readily available. Furthermore efficacy over water is unknown but suspected to be less than at airports. Additional trials are being conducted at Vancouver airport in 1976. The desirability of trials in situations related to oil spills should be assessed after completion of the 1976 airport trials.

Scarecrows and *models of predators* are widely used but their effectiveness has not been evaluated adequately in any situation. They are unlikely to be useful in oil-spill situations unless complemented by other methods. Similarly, unless complemented by other methods, the presence of *humans* and/or *trained dogs* is likely to be useful in dispersing birds only in the case of small, confined oil spills.

Actual or model dead birds in unnatural postures (*crucified birds*) may be useful on small water bodies or along beaches. Gulls apparently can be dispersed by this method, although accommodation is likely to occur.

In general, vision-based deterrents (both biological and non-biological) are likely to be ineffective at night unless artificial lighting is used; if lights are used, some birds may be attracted, especially in poor weather. By day, most vision-based deterrents (with the exception of raptors) need to be complemented by other deterrent methods.

Sound-based Biological Deterrents

Recorded *distress and alarm calls* of various species, when broadcasted in the vicinity of the same species, often cause the birds to disperse. Distress calls are generally effective longer than most other deterrents, since birds do not accommodate to distress calls very rapidly. The most important limitations of this method are that distress calls are rarely effective against any species other than the one whose call is played back, and that some species rarely if ever utter distress calls. Attempts should be made to identify and record distress and alarm calls of the numerous aquatic and marine species for which such calls are not known to exist, and thereafter field trials should be conducted in situations relevant to oil spills.

The deterrent value of *sounds of predators* has not been adequately tested. Underwater broadcasting of Killer Whale vocalizations may be of value in dispersing some marine birds. Above-water broadcasting of calls of hawks or falcons may also be useful in certain situations. However, neither of these methods has been tested in relevant situations.

Abstract Sounds

Av-Alarm, a proprietary device that broadcasts loud synthetic sounds, is sometimes effective as a deterrent in agricultural applications and has been reported to be partially effective against waterbirds in coastal areas. The frequencies used are chosen on the basis of similarity to the frequencies of calls produced by the birds of concern. Additional trials in situations related to oil spills are warranted.

Ultrasound is advertised as being useful as a method of dispersing birds, but we know of no independent confirmation of its efficacy. Furthermore, most if not all birds cannot hear the frequencies that are involved. Hence ultrasound is apparently not a useful deterrent.

High-intensity sound has been reported to be partially effective as a deterrent in one field experiment involving ducks. However, the requisite intensities are probably hazardous to humans, and the method is considered to be impractical.

Pyrotechnics

Shotguns, when fired into the air using either live ammunition or blanks, will frighten birds. *Shell crackers* are, however, more likely to be effective than standard shells or blanks because they explode 100m or more from the shotgun. Use of shell crackers in conjunction with other approaches is a standard deterrent method. *Verey flares* and *tracer shells* are also fired from guns, and produce a flare and trail of smoke as well as a 'bang'.

Rockets have been recommended as deterrents at airports and in agricultural areas. *Mortar shells* and fireworks fired from a 127 mm launcher appear promising as deterrents because of the wide area over which they would be conspicuous. However, neither rockets nor mortars have been properly tested for efficacy.

Firecrackers strung together along fuse rope are sometimes used in agricultural areas, but are effective only within a small area. Other pyrotechnic devices ranging from *cap guns* to *dynamite* have been used as deterrents, but these appear to be either ineffective or dangerous and are unlikely to be as useful as alternate pyrotechnic or noise-making devices. *.22 Rifles* have also been used as deterrents in agricultural areas, but are unsafe in areas where people are present.

Other Sound Techniques

Gas exploders periodically produce a loud explosion by igniting acetylene or propane gas. They are partially effective as deterrents in agricultural areas, but must be supplemented by other approaches in order to maintain their effectiveness. An *'electronic exploder'* that is currently being developed would probably have similar effects and might require less maintenance. Neither gas nor electronic exploders have been adequately tested in situations related to oil spills. *Air horns* have been suggested as deterrent devices but are apparently not very effective.

Aircraft

Fixed-wing aircraft commonly cause water birds to disperse. Ducks and geese can sometimes be 'herded' out of large areas rapidly, especially if other deterrent methods are used simultaneously. *Helicopters* are likely to be even more effective because of their maneuverability and noise. The effectiveness of aircraft as deterrents will vary with species; many sea birds dive rather than fly when an aircraft approaches, and waterfowl may be incapable of flight during the moulting period in summer. Nonetheless, because of their mobility and wide availability, aircraft are one of the most useful deterrents, especially in the early stages of the clean-up and deterrent operation.

Standard radio-controlled *model aircraft* have not proven to be very effective in dispersing birds, and long-endurance television-equipped Remotely Piloted Vehicles are too expensive to have any advantage over full-size piloted aircraft. *Falcon-shaped model aircraft* are more promising, but the reaction of many water birds would probably be to dive into the water.

Lure Areas

Food is the most common attractant used to lure birds away from one area to another. In special circumstances this approach might have some application for waterfowl, gulls and seabirds, but luring will probably attract birds to the general area and ultimately increase rather than decrease mortality. Furthermore, waterfowl and gulls are likely to feed at the lure area by day and return to their normal roosting sites in the contaminated area for the night. Hence lure areas should only be established after careful assessment by biologists, and deterrent efforts in the contaminated area must be maintained.

Trapping

Because of its difficulty and the uncontrolled movements of birds that are likely to result from failure, trapping is unlikely to be useful. However, trapping might, as a last resort, be a feasible method of saving some colonial sea birds or moulting and flightless waterfowl.

Mechanical Barriers

Netting is effective only in very small areas because it is difficult to set up. *Fences* are ineffective against birds that can fly. *Water spray* requires considerable equipment and would be impractical in all but the smallest areas.

Use of *foam* may be an effective method of camouflaging pools of oil on ice or in small leads and polynias. Further investigation is needed.

Chemical Methods

Avicides and *Wetting Agents* are used in agricultural areas but are not applicable in oil-spill situations. *Avian Dispersants* such as Avitrol (in low concentrations) can be fed to birds in order to cause unusual behaviour among some individuals, and thereby to frighten these or other individuals out of the area. This method is of doubtful utility--it has not been tested in situations analogous to oil spills, the direction of movement could not be controlled without supplementary scaring devices, some types of birds might not eat any type of food that could be treated, and some birds might be poisoned--but it might occasionally be useful as a last resort.

EVALUATION OF USEFULNESS IN DIFFERENT TYPES OF AREAS

General Considerations

As indicated in the preceding review, a wide variety of potentially useful methods exists for dispersing birds from the area of an oil spill and for preventing birds from returning to the hazardous area. Unfortunately, few systematic studies of the value of the techniques as deterrents have been conducted in any type of area. Even the extensive anecdotal information about deterrents that exists in published and unpublished form contains little information that relates directly to the aquatic, coastal and marine areas that are of most concern; most of the trials to date have instead been on airports, in croplands and in orchards.

The effectiveness and logistical practicality of individual deterrent methods are known or suspected to differ among habitats, species of birds, weather conditions, seasons, ages and sexes of birds, and time of day or night. Precise assessments of the effectiveness and practicality of each method in each conceivable situation cannot be made because of the limited nature of the available information and the enormous variety of circumstances that could arise. Indeed, *no* deterrent methods have ever been tested against the majority of the species that are likely to occur in coastal and offshore marine areas. Nonetheless, existing knowledge of

1) the responses of some species to most of the deterrent methods that have been suggested,
2) the types of birds that occur in different types of areas (ponds and small lakes, rivers, coasts, marshes, offshore areas, leads in ice),
3) the behaviour of these species, and
4) the difficulties involved in use of each deterrent method in different types of areas

permits a general assessment of the probable utility of each method in each type of area. It must be emphasized that most of these assessments are subjective and are based largely on general knowledge of birds, animal behaviour and logistical considerations rather than on specific evidence of efficacy and practicality. The assessments are probably most reliable for ponds, small lakes, marshes and coasts; some deterrent methods have been applied or tested in these types of areas, and the responses to deterrents of some of the species that occur in the habitats have been observed on airports and croplands. The assessments are doubtless less reliable for offshore open-water areas, leads and holes in ice, and seabird colonies; deterrent methods have not been tested in these types of areas, most of the species that occur there have not been encountered during deterrent trials in other habitats, and logistical difficulties are generally greater than in onshore and nearshore areas. The need for well-planned field trials of deterrent methods is especially obvious in the case of the offshore and ice-related habitats.

The various deterrent techniques are likely to be most effective if used together in a co-ordinated manner. Techniques that are obviously complementary to one another have been identified in the preceding review. Such complementary pairs or groups of techniques include

1) falcons, distress calls, and 'crucified' birds,
2) searchlights and reflectors (for nighttime use),
3) intermittent firing of rockets and mortars interspersed with shellcrackers and/or exploders, and
4) aircraft herding and lure areas.

The value of a deterrent may be less in some types of areas than in others, especially if the complementary method is impractical in some of the types of areas.

Assessment of the effectiveness and practicality of various combinations of deterrents is often more difficult than assessment of the factors for individual deterrents. Only a small fraction of the possible combinations have been tested in any situation, and the practicality of the combination is often difficult to assess because the logistical requirements of both (or all) methods must be considered together. Although these problems limit the reliability of any assessment of the utility of combinations of deterrents, it has been possible to identify certain combinations that are known to be or very likely to be effective and practical in particular types of areas. Nonetheless, until further research has been completed, most devices and combinations of devices that are apparently effective and practical can only be used on a trial and error basis.

The practicality of deterrent methods depends on the period of time over which the area is hazardous to birds. Methods that cannot be implemented rapidly are not likely to be useful in situations where the spill is small and can be cleaned up rapidly. Aircraft are likely to be the most useful approach in those cases, since aircraft are usually readily available and mobile. On the other hand, aircraft may be too expensive for long term use, and cannot be used effectively at night or in inclement weather.

Ponds and Small Lakes

It will probably be easier to disperse and deter birds from a small lake or pond than from any of the other types of areas discussed below. Small lakes and ponds are likely to be more accessible than most other areas, shore-based deterrents may prove to be sufficient (especially on the smallest water bodies), the oil is likely to be relatively easy to contain, and many of the birds are likely to be dabbling ducks (whose responses to deterrents are better known than are the responses of most other groups). Methods applicable to ponds and small lakes are also likely to be applicable to pools of oil on land.

A wider range of deterrent devices is applicable to small lakes and ponds than to other types of areas (Table 1). By *day*, shotguns with shell crackers, rockets, mortars and helicopters are likely to be the most useful devices; fixed-wing aircraft, exploders, hawks or falcons, falcon-shaped model aircraft and distress or alarm calls are also likely to be effective by day. By *night*, shell crackers, rockets and mortars are again likely to be most effective; helicopters would be effective at night but probably could not be used safely at the low speeds and altitudes that would be necessary. Searchlights, flashing lights, Verey flares, and exploders are also likely to be effective at night, although some birds might be attracted to lights--especially in poor weather.

TABLE 1. Probable Usefulness of Various Deterrent Methods for Oil Spills in Pond and Small Lake Situations.

	Effectiveness			Attractant			
	Day	Night	Habituation	Day	Night	Logistical Practicality	Complementary Methods
1. Microwaves and lasers	Impractical	Impractical	-	-	-	Hazard to humans	-
2. Dyes (Oil Soluble)	Possible	*c.* Lights	Probable	Poss.	-	Simple to apply	3,4
3. Searchlights	Doubtful	Good	Possible	-	Variable	Very good	10,14,16,20,22
4. Flashing lights	Possible	Good	Possible	-	Doubtful	Very good	10,14,16,20,22
5. Hawks and falcons	Good	No	Nil	No	-	Maintenance difficulties; Availability limited	7,9,12
6. Falcon-shaped model aircraft	Good	No	Slow	No	-	Requires trained operator	5,7,9,12
7. Models of predators	Fair	No	Rapid	Doubt.	-	Very good	5,9,12
8. Other predators (man, dogs)	Fair	No	Rapid	Doubt.	-	Depends on pond size	16,17, etc.
9. Crucified birds	Fair	No	Yes	Poss.	-	Very good; occasional re-positioning needed	5,6,12, etc.
10. Reflectors	Fair	*c.* Lights	Yes	Poss.	-	Good; depends on pond size; posts needed	3,4, etc.
11. Flags, balloons, smoke	Doubtful	No	Rapid	Poss.	-	Good but doubtful effectiveness	-
12. Distress and alarm calls	Good	Variable	Slow	No	No	Calls of relevant species needed	5,9, etc.
13. Sounds of predators	Unlikely	Unlikely	-	-	-	Good but effectiveness unlikely	-
14. Av-Alarm	Fair?	Fair?	Probable	No	No	Very good	Unknown
15. Ultrasonics	None	None	-	-	-	Few if any birds can detect ultrasonics	-
16. Shotguns and shellcrackers	Very Good	Very Good	Nil	No	No	Very good; safe shellcrackers often unavailable	17,20,22
17. Verey flares and tracer shells	Fair	Good	Possible	No	No	Very good	16,20,22
18. .22 rifle	Unsafe	Unsafe	-	-	-	-	-
19. Firecrackers	Doubtful	Doubtful	Probable	No	No	Good but doubtful effectiveness	-
20. Rockets and mortars	Very Good	Very Good	Nil	No	No	Training, permits and caution needed	16,22, etc.
21. Other pyrotechnics	Variable	Variable	Variable	No	No	Alternate methods easier and/or safer	-
22. Exploders	Good	Good	Slow	No	No	Very good	16,17,20, etc.
23. Fixed-wing aircraft	Good	Unsafe	Slow	No	-	Readily available	-
24. Helicopter	Very Good	Unsafe	Nil	No	-	Readily available	-
25. Lure areas	Unpredict.	Unpredict.	-	-	-	Variable *c.* situation; alternate methods better	-
26. Trapping	Not Applic.	Not. Applic.	-	-	-	-	-
27. Nets	Impractical	Impractical	-	-	-	Manpower intensive; alternate methods available	-
28. Foam	Untried	*c.* Lights	?	Doubt.	Doubt.	-	3,4?
29. Avian dispersants	Not Applic.	Not Applic.	-	-	-	Alternate methods better; see text	-

The first objective in all situations should be to disperse all birds that are already in the vicinity of the spill. On a pond or small lake (maximum diameter approximately 1 mi) a combination of shell crackers and mortars could be used to disperse the birds. A motorized boat would be required to permit access to areas not accessible from shore. On a slightly larger water body an aircraft would be advisable to disperse the birds more rapidly.

Once the birds have been dispersed from the area of the oil spill deterrent devices must be set up to prevent birds from returning to the area. Devices that are not species specific would be most useful. However, if only one species were of concern in an area, emphasis should be placed on one or more methods that are most effective for this species. Distress and alarm calls and perhaps 'crucified' birds are the most obvious examples of species-specific methods. Acetylene exploders and revolving searchlights (or flashing lights) placed around the perimeter of the pond or small lake would deter most birds from re-entering the area. In the case of small lakes, a few of these devices should be set up on rafts on the lake. Personnel should patrol the area constantly and supplement these devices (where necessary) with shell crackers or mortar shells.

Shell crackers, mortars, exploders, aircraft, boats and lights should be considered the basic equipment necessary to disperse and deter birds from ponds and small lakes. Various other devices mentioned above in Table 1 might be particularly useful in special circumstances, however, and should be used where practical and desirable. If available, trained falcons or falcon-shaped model aircraft could be efficient at deterring birds from entering an area, but only if they could intercept birds before they were near the oil-contaminated water. Falcons would also be impractical if they would not perform efficiently without experience in the area. If a single species of bird were threatened by the oil spill, the broadcasting of distress and alarm calls of that species and (in some cases) the display of 'crucified' corpses of that species would probably be more efficient at dispersing and deterring the birds than a device of general applicability.

Other devices of unproved utility (e.g. Av-Alarm) could, if available, be tested on the scene of the spill and deployed operationally if they proved to be effective. A person with biological training and extensive knowledge of potential deterrent approaches should be present at the site of the oil spill in order to decide the optimal deterrent strategy.

Techniques with unpredictable and potentially negative effects (luring; use of avian dispersants such as Avitrol) are unlikely to be appropriate when oil has been spilled into a pond or small lake. Various other methods that are more dependable are easier to implement in this situation.

Marshes

In general, the methods recommended above for ponds and small lakes would also be the most applicable methods in marshes. However, birds would often be less conspicuous among the emergent vegetation of marshes than on the open water of ponds and lakes, and would often be less likely to fly. Increased emphasis (relative to ponds and small lakes) on aircraft is recommended for initial dispersal of birds.

Development of lure areas (e.g. feeding) in suitable marshes near the contaminated marsh might be useful, but only if there were few other marshes nearby and if few transient birds were moving through the area. (If there were other marshes in the area, or if many transients were passing through, the lure area would probably attract more birds into the general area of the spill, and increase rather than decrease mortality.) Luring should only be attempted if biologists on the scene have carefully evaluated the probable consequences and concluded that alternate methods are ineffective and that the consequences of luring would definitely be beneficial.

It will be difficult to prevent birds from attempting to roost in oil-contaminated marshes during the evening, even if they are lured to alternate feeding areas by day. A greater density of pyrotechnics, exploders and flashing or revolving lights will therefore be required in a marsh than on a pond or small lake. It is suggested that pyrotechnics, exploders and lights be supplemented with numerous scarecrows and reflectors.

Rivers

If oil that had been spilled into a river were contained by booms and/or trapped in a bay, the applicable deterrent techniques would be similar to those useful around ponds and small lakes. However, many devices would be more difficult to deploy. Aircraft would be very useful because of the rapidity with which they could be brought into use. Mortars and rockets would be especially useful because of their long range (relative to shell crackers and flares) and the consequent reduction in the need for boats. Except in the case of small contaminated areas from which birds could be deterred by shore-based techniques, it would be difficult to deploy 'short-range' devices such as 'crucified' birds and reflectors, which would have to be mounted on booms or rafts. Boats would be necessary for proper use of shell crackers and Verey flares.

If the oil were floating downriver, highly mobile techniques would be necessary in order to disperse birds from areas ahead of the advancing contaminated area. The most efficient method would be through use of aircraft and boat- and/or shore-based crews firing shell crackers, flares and mortars (Table 2). It would also be necessary to deter birds from entering the already contaminated area. The difficulty of accomplishing this would be highly dependent upon the width of the river and the length of the contaminated section. The leading portion of the contaminated area would require intensive deterrent effort from aircraft, boat-based crews and shore-based crews in order to prevent birds that were being flushed from the area just ahead of the oil from landing in the oil.

Oil would be expected to remain along the shores of the river after the central portions of the river had become relatively oil-free. If the shores were attractive to birds, the techniques applicable to coastal areas (see below) should be used to deter birds until the oil along the riverbanks could be removed.

TABLE 2. *Probable Usefulness of Various Deterrent Methods for Oil Spills in Rivers.*

	Effectiveness			Attractant			
	Day	Night	Habituation	Day	Night	Logistical Practicality	Complementary Methods
1. Microwaves and lasers	Impractical	Impractical	-	-	-	Hazard to humans	-
2. Dyes (Oil Soluble)	Possible	c. Lights	Possible	Poss.	-	Easy to apply	3,4 ?
3. Searchlights	Doubtful	Good	Possible	No	Variable	May not be portable enough	14,16,20,22
4. Flashing lights	Doubtful	Good	Possible	No	Doubtful	May not be portable enough	14,16,20,22
5. Hawks and falcons	Good	No	No	No	-	Maintenance difficult; availability limited	12
6. Falcon-shaped model aircraft	Good	No	Slow	No	-	Requires trained operator	5,12
7. Models of predators	Impractical	No	Rapid	Doubt.	-	Difficult to keep with oil	-
8. Other predators (man,dogs)	Variable	No	Rapid	Doubt.	-	Depends on river width	16,17, etc.
9. Crucified birds	Impractical	No	Yes	-	-	Difficult to keep with oil	-
10. Reflectors	Impractical	Impractical	Yes	-	-	Difficult to deploy and keep with oil	-
11. Flags, balloons, smoke	Impractical	No	Rapid	-	-	Difficult to deploy and keep with oil	-
12. Distress and alarm calls	Good	Variable	Slow	No	No	Calls needed; poss. difficult to keep with oil	5,6,8
13. Sounds of predators	Unlikely	Unlikely	-	-	-	Good but effectiveness unlikely	-
14. Av-Alarm	Doubtful	Doubtful	Probable	No	No	Difficult to keep with oil	-
15. Ultrasonics	None	None	-	-	-	Few if any birds can detect ultrasonics	-
16. Shotguns and shellcrackers	Good	Good	Doubtful	No	No	Good; safe shellcrackers often unavailable	17,20
17. Verey flares and tracer shells	Fair	Good	Possible	No	No	Good	16,20
18. .22 rifle	Unsafe	Unsafe	-	-	-	-	-
19. Firecrackers	Doubtful	Doubtful	Probable	No	No	Effectiveness doubtful; deployment difficult	-
20. Rockets and mortars	Good	Good	Nil	No	No	Good; training, permits and caution needed	16
21. Other pyrotechnics	Variable	Variable	Variable	No	No	Alternate methods easier and/or safer	-
22. Exploders	Good	Good	Slow	No	No	May be difficult to keep with oil	16,20
23. Fixed-wing Aircraft	Good	Unsafe	Slow	No	-	Readily available	-
24. Helicopter	Very Good	Unsafe	Nil	No	-	Readily available	-
25. Lure areas	Impractical	Impractical	-	-	-	Difficult because oil moves	-
26. Trapping	Not Applic.	Not Applic.	-	-	-	-	-
27. Nets	Impractical	Impractical	-	-	-	Deployment impossible	-
28. Foam	Untried	c. Lights	?	Doubt.	-	Unknown	-
29. Avian dispersants	Not Applic.	Not Applic.	-	-	-	-	-

If either dyes or foam could be shown to be an effective method for preventing birds from landing in oil, they would be especially useful in rivers since they would move downstream with the oil. Field trials are needed.

Coastal Areas

Methods applicable in coastal areas would be similar to those applicable on ponds and small lakes. However, because of the less confined nature of coastlines, aircraft would probably be of most value for the initial dispersal of birds. If the section of coastline that was contaminated or about to become contaminated was long, use of aircraft would probably be the only practical dispersal method, and numerous aircraft might be necessary.

Deterrent methods and devices would need to be deployed along the shore in order to prevent birds from entering the contaminated water. Table 3 evaluates the probable usefulness of various approaches. Shell crackers, exploders, lights, reflectors and mortars, together with continued use of aircraft, would be the standard approaches. Distress and alarm calls would be useful if calls of the appropriate species exist and were available. The major limiting factors would be the logistical problems of deploying and operating a sufficient number of devices.

In unusual circumstances it might be possible to employ lure areas to advantage. However, the chances of attracting more birds to the general area of the oil spill are considerable (see Marshes section, above), and luring should only be attempted after careful evaluation.

Similarly, as a last resort use of an avian dispersant such as Avitrol might be effective in dispersing some birds from the hazardous area. However, Avitrol is a poison, at least when consumed in sufficient amounts, and the responses of birds that consume Avitrol or observe other individuals that have consumed Avitrol are unpredictable.

TABLE 3. Probable Usefulness of Various Deterrent Methods for Oil Spills in Coastal Areas.

	Effectiveness			Attractant			
	Day	Night	Habituation	Day	Night	Logistical Practicality	Complementary Methods
1. Microwaves and lasers	Impractical	Impractical	-	-	-	Hazard to humans	-
2. Dyes (Oil Soluble)	Possible	*c.* Lights	Possible	Poss.	-	Aircraft required	3,4
3. Searchlights	Doubtful	Good	Possible	No	Variable	Variable; perhaps good	10,14,16,20,22
4. Flashing lights	Possible	Good ?	Possible	Doubt.	Doubtful	Variable; perhaps good	10,14,16,20,22
5. Hawks and falcons	Good?	No	Nil	No	-	Maintenance difficult; availability limited	7,9,12
6. Falcon-shaped model aircraft	Good?	No	Slow	No	-	Requires trained operator	5,7,9,12
7. Models of predators	Fair	No	Rapid	Doubt.	-	Good	5,9,12
8. Other predators (man, dogs)	Variable	No	Rapid	Doubt.	-	Manpower intensive; ineffective offshore	16,17,20
9. Crucified birds	Fair	No	Yes	Poss.	-	Good; occasional repositioning needed	5,6,12, etc.
10. Reflectors	Fair	*c.* Lights	Yes	Poss.	-	Good; ineffective offshore	3,4, etc.
11. Flags, balloons, smoke	Doubtful	No	Rapid	Poss.	-	Good but effectiveness doubtful	-
12. Distress and alarm calls	Good?	Variable?	Slow	No	No	Calls of relevant species needed	5-9, etc.
13. Sounds of predators	Unlikely	Unlikely	-	-	-	Good but effectiveness unlikely	-
14. Av-Alarm	Fair?	Fair?	Probable	No	No	Good	Unknown
15. Ultrasonics	None	None	-	-	-	Few if any birds can detect ultrasonics	-
16. Shotguns and shellcrackers	Good	Good	Doubtful	No	No	Good; safe shellcrackers often unavailable	17,20,22
17. Verey flares and tracer shells	Fair	Good	Possible	No	No	Good	16,20,22
18. .22 rifle	Unsafe	Unsafe	-	-	-	-	-
19. Firecrackers	Doubtful	Doubtful	Probable	No	No	Good but doubtful effectiveness	-
20. Rockets and mortars	Good	Good	Doubtful	No	No	Good; training, permits and caution needed	16,22
21. Other pyrotechnics	Variable	Variable	Variable	No	No	Alternate methods easier and/or safer	-
22. Exploders	Good	Good	Slow	No	No	Good	-
23. Fixed-wing aircraft	Good	Unsafe	Slow	No	-	Readily available	-
24. Helicopter	Very Good	Unsafe	Slow	No	-	Readily available	-
25. Lure areas	Unlikely	Unlikely	-	-	-	Variable *c.* situation, species, season	23,24 etc.
26. Trapping	Not Applic.	Not Applic.	-	-	-	-	-
27. Nets	Impractical	Impractical	-	-	-	Deployment impractical except in small areas	-
28. Foam	Impractical	Impractical	?	Doubt.	Doubtful	Would probably drift ashore	-
29. Dispersants	Doubtful	Doubtful	?	Poss.	Possible	Possibly useful as last resort; see text	-

Offshore

No tests of the effectiveness of deterrent methods in offshore situations have been conducted. It is clear, however, that many of the devices and methods that are useful on and near shore are impractical in offshore areas, at least until the oil can be surrounded by booms. Such devices would include 'crucified' birds, reflectors, scarecrows of various kinds, and probably exploders (Table 4). Shell crackers, Av-Alarm, flares and distress or alarm calls (if they exist for the species concerned) would also be of limited value unless the spill covered only a small area; even then logistics would often be difficult. Even if hawks or falcons would fly and hunt effectively over open water it is doubtful whether they would be useful; many birds would be likely to dive into the water when the raptor approached. The same limitation would apply to use of falcon-shaped model aircraft.

The most effective dispersal method offshore would probably be use of aircraft. However, some species of seabirds are more likely to dive than to fly when an aircraft approaches, and some moulting waterfowl would be unable to fly. Twin-engined aircraft would be necessary for safety, and effective (i.e. low altitude) operations would be impossible at night. Searchlights mounted on boats and mortars, rockets, flares and shell crackers fired from boats would be useful at night, but their effectiveness in cases of large spills would be limited. Because of their larger area of coverage, rockets and mortars would probably be more useful than shell crackers and flares both by day and by night.

It is possible that creation of lure areas away from the contaminated area might attract birds out of the hazardous zone. The obvious approach would be to feed seabirds by throwing fish and other foods into the sea from a boat. However, it is quite probable that this would attract more birds into the general area of the oil spill, and ultimately increase rather than decrease mortality. It is also possible that boats working in or near the spill for clean-up or even deterrent purposes might unintentionally attract

TABLE 4. Probable Usefulness of Various Deterrent Methods for Oil Spills in Off-Shore Situations.

	Effectiveness			Attractant			
	Day	Night	Habituation	Day	Night	Logistical Practicality	Complementary Methods
1. Microwaves and lasers	Impractical	Impractical	-	-	-	Hazard to humans; heavy equipment for μ waves	-
2. Dyes (Oil Soluble)	Possible	e. Lights	Possible	Poss.	-	Aircraft required	3,4 (?)
3. Searchlights and expanded lasers	Doubtful	Good	Possible	Poss.	Variable	Difficult; boats needed	14,16,20,22
4. Flashing lights	Doubtful	Good	Possible	Poss.	Doubtful	Difficult; boats needed	14,16,20,22
5. Hawks and falcons	Doubtful	No	Nil	No	-	Maintenance impractical	-
6. Falcon-shaped model aircraft	Doubtful	No	Slow	No	-	Difficult; requires trained operator	-
7. Models of predators	Impractical	No	-	-	-	Difficult to deploy	-
8. Other predators (man,dogs)	Doubtful	No	Rapid	Poss.	-	Difficult; boats needed	16,20 etc.
9. Crucified birds	Impractical	Impractical	-	-	-	Difficult to deploy	-
10. Reflectors	Impractical	Impractical	-	-	-	Difficult to deploy	-
11. Flags, balloons, smoke	Impractical	Impractical	-	-	-	Difficult to deploy	-
12. Distress and alarm calls	Untried	Untried	Slow	No	No	Calls needed; difficult to deploy	13
13. Sounds of predators	Untried	Untried	?	No	No	Fair	12
14. Av-Alarm	Doubtful	Doubtful	Probable	No	No	Difficult to deploy; depends on area	-
15. Ultrasonics	None	None	-	-	-	Few if any birds can detect ultrasonics	-
16. Shotguns and shellcrackers	Variable	Variable	Some	No	No	Good if deployment is possible	20
17. Verey flares and tracer shells	Doubtful	Fair	Possible	No	No	Difficult to deploy	16,20
18. .22 Rifle	Unsafe	Unsafe	-	-	-	-	-
19. Firecrackers	Impractical	Impractical	-	-	-	-	-
20. Rockets and mortars	Good	Good	Doubtful	No	No	Boats required (see Table 1)	-
21. Other pyrotechnics	Impractical	Impractical	-	-	-	Alternate methods easier and/or safer	-
22. Exploders	Impractical	Impractical	-	-	-	Difficult to keep with oil	-
23. Fixed-wing aircraft	Good?	Unsafe	Slow?	No	-	2 engines required; depends on remoteness	-
24. Helicopter	Good;	Unsafe	Slow	No	-	2 engins required; nearby ship or land support	-
25. Lure areas	Unlikely	Unlikely	-	-	-	Variable with situation	23,24 etc.
26. Trapping	Impractical	Impractical	-	-	-	-	-
27. Nets	Impractical	Impractical	-	-	-	Deployment impossible	-
28. Foam	Doubtful	Impractical	?	Doubt.	Doubtful	Unknown	-
29. Avian dispersants	Unlikely	Unlikely	?	Poss.	Possible	Possibly useful as last resort; see text	-

seabirds, which commonly fly towards boats. It would be essential that garbage and other potential foods not be dumped into the water from boats near the oil spill.

There is evidence that penguins may be repelled by underwater broadcasting of Killer Whale sounds (Frost *et al.* 1975). Killer Whales occur off much of the Canadian coast, and so it is possible that species of birds that dive might be dispersed by Killer Whale sounds. Because underwater sounds attenuate slowly, this method might be effective over a substantial area. Field trials are needed.

Leads and Ice

Areas of open water that are surrounded by ice are likely to contain birds. Areas of open water and pools of oil that look like open water are also likely to be attractive to passing birds, particularly if little or no open water is available nearby.

No tests of methods of dispersing or deterring birds from oil spills in leads, in other areas of water surrounded by ice, or on ice have been conducted. However, available evidence indicates that the potential for dispersing and deterring birds from such areas will depend upon the size and remoteness of the oil spill and on whether alternate areas of open water are available.

If oil is spilled into a small area of open water, any birds that are already there are likely to become oiled before any attempt to disperse them can be made. However, it is likely to be possible to prevent other birds from landing in the oil. If surface access is possible, or if an aircraft can land near the area of open water, standard methods can be employed (pyrotechnics, Av-Alarm, exploders, human presence, lights, balloons, falcon-shaped model aircraft, etc.; see Table 5). If surface access is not possible, aircraft can be used to deter birds temporarily, but only by day and during fair weather. Furthermore, if surface access is impossible and aircraft cannot land, the oil may remain indefinitely. If the oil could be camouflaged by a white dye or by a white substance (e.g., foam), birds would be much less likely to be attracted to the area of oil-covered water. The potential usefulness

TABLE 5. Probable Usefulness of Various Deterrent Methods for Oil Spills in Leads and on Ice.

	Effectiveness			Attractant			
	Day	Night	Habituation	Day	Night	Logistical Practicality	Complementary Methods
1. Microwaves and lasers	Impractical	Impractical	-	-	-	Hazardous; heavy equipment needed for μ waves	-
2. Dyes (Oil Soluble)	Possible	*c.* Lights	?	Poss.	-	Durability variable (e.g., current dependent)	3,4
3. Searchlights	Impractical	Possible	Possible	No	Doubtful	Difficult; variable	14,16,20,22
4. Flashing lights	Doubtful	Good?	Possible	Poss.	Doubtful	Difficult; variable	14,16,20,22
5. Hawks and falcons	Impractical	No	-	-	-	Maintenance impossible	-
6. Falcon-shaped model aircraft	Possible	No	Variable	No	-	Difficult; requires trained operator	7,9,12
7. Models of predators	Doubtful	No	Rapid	Doubt.	-	Difficult; variable	12
8. Other predators (man,dogs)	Variable	No	Rapid	Doubt.	-	Small areas only	16,17,20
9. Crucified birds	Doubtful	No	Yes	Prob.	-	Variable; occasional repositioning needed	Unknown
10. Reflectors	Impractical	Impractical	-	-	-	Difficult to deploy and maintain	-
11. Flags, balloons, smoke	Doubtful	No	Rapid	Poss.	-	Difficult to deploy; doubtful effectiveness	-
12. Distress and alarm calls	Untried	Untried	Slow?	No	No	Calls needed; difficult to deploy	6-9, etc.
13. Sounds of predators	Untried	Untried	?	No	No	Difficult; underwater broadcasting needed	12
14. Av-Alarm	Variable	Variable	Probable	No	No	Difficult to deploy; depends on area	Unknown
15. Ultrasonics	No	No	-	-	-	Few if any birds can detect ultrasonics	-
16. Shotguns and shellcrackers	Variable	Variable	Doubtful	No	No	Depends on size of area	17,20,22
17. Verey flares and tracer shells	Variable	Variable	Possible	No	No	Depends on size of area	16,20,22
18. .22 rifle	Unsafe	Unsafe	-	-	-	-	-
19. Firecrackers	Doubtful	Doubtful	Probable	No	No	Deployment may be difficult	-
20. Rockets and mortars	Good	Good	Doubtful	No	No	Deployment may be difficult (see Table 1)	16,22 etc.
21. Other pyrotechnics	Variable	Variable	Variable	No	No	Alternate methods easier and/or safer	-
22. Exploders	Variable	Variable	Slow	No	No	Deployment may be difficult	16,17,20 etc.
23. Fixed-wing aircraft	Good	Unsafe	Slow?	No	-	2 engines desirable; depends on remoteness	-
24. Helicopter	Good	Unsafe	Slow?	No	-	2 engines desirable; depends on remoteness	-
25. Lure areas	Unlikely	Unlikely	-	-	-	Difficult (e.g., break up thin ice elsewhere)	23,24 etc.
26. Trapping	Doubtful	Doubtful	-	-	-	Difficult; drive birds into nets	16,24
27. Nets	Impractical	Impractical	-	-	-	Deployment impossible	-
28. Foam	Untried	*c.* Lights	?	Doubt.	Doubtful	Promising for small areas	-
29. Avian dispersants	Doubtful	Doubtful	?	Poss.	Possible	Possibly useful as last resort; see text	-

of foam, particularly its usefulness in cold and remote areas and the practicality of application from the air, should be investigated further; if foam appears promising field trials should be conducted. The utility of underwater broadcasting of Killer Whale sounds should also be investigated, although this would only be useful as a method of dispersing birds that were already in the water.

If oil is spilled onto the ice, similar methods (except for Killer Whale sounds) would be appropriate.

If a large lead or polynia became completely covered by oil, it is unlikely that any known method of dispersing or deterring birds would be very effective. Aircraft could be tried, but it is unlikely that the frequency of intense disturbance could be sufficient to cause most water birds to leave the area, especially if no other areas of open water were available nearby. In addition, aircraft are not useful by night or in inclement weather. Pyrotechnics, exploders and (by night) lights might be useful along the edges of the area of open water, but it is unlikely that sufficient numbers of deterrent devices could be deployed in arctic or winter conditions to disperse and deter birds from a large polynia. Logistical problems would be less formidable in the case of a long narrow lead, where deterrent devices mounted on the ice could cover much or all of the area of open water and boats would be unnecessary. However, the efficacy of standard deterrent devices in such conditions has not been demonstrated.

It is probable that only a fraction of the area of a large polynia would be covered by oil in the event of a small spill. If so, the same methods as were suggested for offshore areas could be employed in an attempt to move the birds to the oil-free area. In addition, pyrotechnics, exploders, lights and other devices could probably be deployed on the ice around the ice-covered area.

The potential usefulness of dye and foam in situations involving oil spills into large leads and polynias warrants consideration, but it would be a formidable logistical problem to cover a large and remote lead or polynia with dye or foam, and to date neither substance has been tested for effectiveness in such circumstances.

It is apparent that three major classes of problems limit the ability to disperse and deter birds from leads and polynias:

1) Logistics are difficult in remote areas and in open water.
2) Techniques have not been developed or tested in offshore or ice-bound waters or against the types of birds that would occur in such areas.
3) The deterrent effort would have to continue over a long period because of the extreme difficulty of clean-up operations on ice-bound waters.

Alleviation of any of these problems could markedly improve the potential for minimizing bird mortality as a result of oil spills near or on ice.

Near a Sea Bird Colony

Sea bird colonies that occur in Canada range in size from a few pairs of birds to hundreds of thousands of birds. If oil is spilled near a large sea bird colony during the breeding season, it is inevitable that large numbers of birds will be killed.

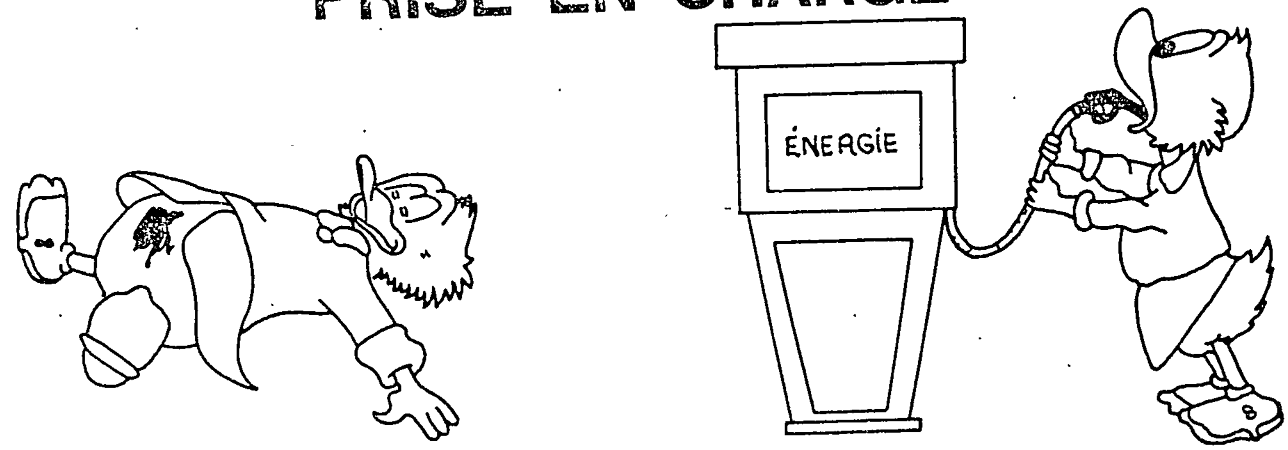
Sea birds commonly land in the water near their colonies, and are especially likely to do so if the nest sites are disturbed. Research into the efficacy of oil-soluble dyes as bird deterrents is especially desirable for this situation. Standard deterrent methods may also be effective against sea birds in some situations, but no trials have been conducted. Such information is needed before a realistic contingency plan to deal with the case of an oil spill near a colony can be prepared.

The primary goal of any attempt to reduce mortality from an oil spill near a colony should be to minimize the number of adults that are oiled, and thereby to maintain the potential for productivity in future years. Because most sea birds are long-lived, long-term productivity and population size are unlikely to be significantly affected by complete failure of a colony to produce young in any one year. Hence, if it were possible to cause the adults to desert a colony that was surrounded by spilled oil, mortality of adults might be reduced. This would only be possible, however, if the spill were sufficiently confined and the deterrent effort at the spill sufficiently intense that the adults could be prevented from landing in the oil after they were driven from their nest sites. Furthermore, it is possible that the colony might not be reoccupied in subsequent years. Drastic action of this nature must not be undertaken without detailed evaluation of its consequences by sea bird biologists and concerned regulatory agencies, nor until deterrent measures effective against sea birds have been demonstrated.

The situation involving an oil spill near a colony is one situation where it might be advisable to use oil dispersants in an attempt to sink the oil. The advisability of this action would depend on the nature and severity of the spill, the time of year and the potential for clean-up operations. Use of oil dispersants may reduce immediate mortality to birds but losses may occur in subsequent years due to secondary poisoning effects that reduce the productivity of marine organisms in the area (Nat. Acad. Sci. 1975).

The immediate needs in relation to the possibility of oil spills near sea bird colonies are for identification of effective deterrent procedures and strategies and for minimization of the probability of an oil spill near sea bird colonies.

PRISE EN CHARGE



Proceedings

1987 Oil Spill Conference

(Prevention, Behavior, Control, Cleanup)

Tenth Biennial

April 6–9, 1987
Baltimore, Maryland

Sponsored by: American Petroleum Institute, Environmental Protection Agency, and United States Coast Guard

USCG API EPA

OIL POLLUTION CONTROL A COOPERATIVE EFFORT

AN OVERVIEW: REHABILITATION OF OIL CONTAMINATED BIRDS

Lynne Frink
Tri-State Bird Rescue & Research, Inc.
2920 Duncan Road
Wilmington, Delaware 19899

ABSTRACT: *This illustrated talk reviews twenty years of efforts of oiled bird rehabilitation in this country and abroad. The internal and external effects of oil on waterbirds are presented. Planning for oil spill crises, agency interactions following an oil spill, and techniques for dealing with the public and media are discussed.*

Oil has long been known to have a negative effect on birds, both as a result of contamination from chronic oil pollution and from major oil spill incidents on oceans and waterways around the world.[8] It has been estimated that over one million birds die annually just in the European North Atlantic as a result of oil spills; the extent of world-wide mortality is not known.[2]

A major concern is that the ocean-dwelling species most commonly affected are not prolific breeders and their populations are not easily monitored in the wild.

Scientific literature documents decades of frustrated efforts to rehabilitate oiled birds. Citizens of the United States, in particular, are a people conditioned to respond to crisis situations. In major oil spills, average citizens often are adamant about being allowed to initiate an oiled bird rescue—a strategically and medically complex operation about which, unfortunately they have no technical knowledge.

When Tri-State Bird Rescue & Research (TSBR) was founded in 1976, we began periodic literature searches and uncovered scores of disastrous efforts to rehabilitate oiled birds. There was the "dusty penguin" method, wherein Jackass penguins were rolled in Fullers earth, left to sit for days, then rubbed with detergent.[3] Rolling in cornmeal or sawdust, or dipping in liquid paraffin or hot butter, and rubbing with lard or cooking oil (which we call the "Mazola duck" treatment) have all been tried with varying claims of success but *no* available documentation to support the claims.[7,9,14,15] We have heard of 100 percent release rates in oiled birds; further investigation usually discloses that the oiled birds have been washed and tossed out the door the same day: no data were kept on individual birds, no weights, temperatures or pre-release evaluations were recorded. These cannot be considered successful rehabilitation efforts.

Oiled bird rehabilitation is difficult; it is a time-consuming, urgent, laborious job, requiring special materials and procedures. Nevertheless, the general public demands that these birds be cared for. If oiled birds are to be rehabilitated, the effort should not be a token attempt, but a responsible undertaking which incorporates all the information we now have about successfully rehabilitating oiled birds.

Oiled bird rehabilitation has been successfully carried out, time after time, with a number of species and dealing with a variety of oils. The secrets to rehabilitating an oiled bird are simple: (1) Understand both the internal and external effects of oil on birds; and (2) Treat both the internal and external effects of oil on birds.

This paper will discuss briefly the adverse effects of oil on birds and how to treat those effects. It will then proceed to discuss a major difficulty in rehabilitating oiled birds: the fact that oiled birds usually don't occur in "ones." Birds generally become oiled in large numbers following a major oil spill. The magnitude of the problem is not a linear function, and it is often complicated by media pressure, lack of interagency planning, and a well-intentioned but obstructive public.

The effects of oil on birds

Some of the difficulties in rehabilitating oiled birds concern the numerous ways that oil affects birds. These effects can be broadly categorized as behavioral, environmental, internal, and external. A current review article is available which discusses these types of effects in more detail.[6] In this paper, we will review only the external and internal physiological effects of oil on birds.

The external effects of oil are the most noticeable and most immediately debilitating. Oil destroys the waterproofing and insulating properties of plumage. The bird may suffer from chilling; it is often unable to fly or remain afloat in the water. The bird has difficulty obtaining food or escaping predators. In addition to the decreased foraging ability of the animal, the presence of oil in the environment usually results in a loss of available food.[10] Irritation and ulceration of the eyes, and clogging of the nares and mouth often accompany oil contamination. The weakened bird becomes susceptible to secondary infections, both bacterial and fungal.

Internal effects of oil, while not as apparent, are equally life-threatening. Direct toxic effects on the gastrointestinal tract, pancreas and liver have all been documented.[6] These effects frequently result in ulceration and hemorrhaging in the gastrointestinal tract with a severe loss of digestive and absorptive ability. Oil aspiration pneumonia is not uncommon in oiled birds. Visceral gout due to kidney damage as a direct toxic effect of oil or due to dehydration has been documented.[4]

Tri-State staff have rehabilitated over 27 species of oiled birds, ranging from Common Loons to Eastern Bluebirds, and including Peregrine Falcons, Barred Owls, and Northern Flickers. Every oil spill we encounter brings a new discovery. Different oils or different species of birds can reveal previously undocumented problems.

Our release rates vary with species, type of oil, and most importantly, the speed of retrieval of the affected birds. We have returned 90 percent of our *Anseriformes* (Canada Geese, Snow Geese, Black Ducks, Mallards) to the wild, and 73 percent of our rehabilitated diving ducks (Ruddy Ducks, grebes), while our release rates with *Gaviformes* (loons) remains just under 50 percent, despite our utmost efforts.

ent f oiled birds

ɔird rehabilitation can be thought of as five basic procedures:
ɔilizing the bird
nov . the oil from the feathers
nov ; the cleaning agent from the feathers
ıtoriug the waterproofing
:limating the bird for release

zing t'.e bird. In addition to the complete standard physical eve: ɔiled bird, the examiner should band each bird with a :y, mbered plastic leg band and maintain individual ɔn each animal. The amount and distribution of oil on the d the weight and cloacal temperature should be recorded. Oil ed f n the mouth and the nares. The vent is checked for oil .ed ıthers causing impaction. The eyes are flushed with a alinı olution or ophthalmic irrigation. If possible, blood e taken at this time to check packed cell volume and total

ıbeı oiled birds are dehydrated as a result of enteritis. Tube the d with a warm electrolyte solution (such as Lactated and 2.5 percent dextrose, or Normosol) serves to rehydrate while flushing the oil from the gut. An enteric coating agent ılso lministered orally by tube. We suggest Pepto-Bismol ma sia and mineral oil are not recommended) at 2–5 cc/kg. s aı ater added to the tubing solution, and tube feeding is every 4–6 hr until the bird is permitted free access to food er a r cleaning.

ird kept warm and quiet, away from people and other . O d bird mortality is affected by the stress they experience ilitation.[12]

sive preening of oil-covered feathers is prevented (especially ıtar ation with highly refined oils) by making a poncho for wit disposable diaper or a pillow case loosely taped around H s should be cut in the pillow case for the head and legs, ɔpening left for the cloaca.

bir benefit by being placed with a conspecific, but overg c be stressful. Curtains are hung to limit visual contact maı People should not speak in loud voices when in the ding area.

ıird should not be washed until it is alert, responsive, and to rmal fluid balance. Efforts should be made to stabilize an ash it within 8–24 hours. The longer the oil is allowed in c he feathers, the more difficult it is to remove, and the ımage may be done to the skin. Highly refined oils can be d tl ugh the skin, intensifying internal problems.

Tri- ate study conducted on 56 Ruddy ducks *(Oxyura ısis* ound a strong correlation between body weight and nperature for survival in washed birds.[5] The average weight ıperature of the affected birds was determined. Those birds ed or above the norm in weight and temperature for their a 1 percent release rate. Those birds under the norm in one arc evidenced reduced release rates (temperature, 66 per- ight, 75 percent; both, 38 percent). These parameters might ider d if triage becomes necessary.

vin he oil from the feathers. Oil must be removed from the wi ut damaging the delicate feather structure. We find the nost effective cleaning method to be a detergent bath. Oiled ould not be washed unless large amounts of hot water are e. F hty to one hundred gallons of 103–105° F water are ovı 20 minute period to wash one duck. This type of water bı ssured through a series of hot water heaters or a steam ɔr. The water must be above 102° F in order to lift the oil. who has tried to wash a greasy frying pan in cold water will and is necessity.

roı cleaning agents have been tested for their ability to oil from feathers.[1] Only a few of them meet the requirements: ergent must suspend the oil and hold it in suspension; the at st be minimally irritating to the body and must not th ructure of the feathers; the detergent must rinse easily bir Any detergent residue will impede the waterproofing. urrently use Lux Liquid Amber industrial detergent (Lever or awn dishwashing detergent (Procter & Gamble). The pı edure should be done in a warm, quiet area, free from

ıe actual cleaning process, a single bird is placed in a 10 gallon tub containing 4–15 percent detergent in 103°–104° F water. A ten-gallon tub is adequate for birds ranging in size from small ducks to a small Canada goose. Swans and large geese must have larger containers. We suggest kiddie pools or human bath tubs holding at least 15–20 gallons of water. Little (3–5 gallon) plastic dishwashing tubs are too small to hold enough detergent solution to clean waterbirds effectively.

One worker ladles the detergent solution over the bird's body and wings, while a second person gently strokes the bird in the direction of feather growth. A third worker may be needed to hold a large bird. It is important that the feathers never be rubbed or scrubbed, since this could damage the delicate feather structure which is vital to waterproofing. A container of clear water or normal saline should be kept handy and the bird's eyes should be flushed with eyedroppers frequently to prevent detergent irritation. The bird's head must be gently restrained during washing; many birds attempt to duck their heads under the water.

The bird should be removed from the tub when the water gets dirty. The entire washing process is then repeated.

An oiled bird may require three or more tub washings. Weathered and heavy crude oils are particularly difficult to hold in suspension. If the oil is not lifting easily, at Tri-State we will try the following. First, remove the bird, dripping wet with detergent solution, from the tub; then wrap the body in a large dry towel, and place it in a quiet, dark box for 4–6 minutes. This allows the bird to calm down slightly and also provides time for the detergent solution to soak into the oiled feathers. Very stubborn oils may require softening with a warm mineral oil. This should only be used as a *last* resort, since mineral oil itself is a contaminant which will then have to be washed out of the plumage.

Removing the cleaning agent from the feathers. The feathers must be *completely* rinsed if the bird is to be rehabilitated. Any detergent residue can impede waterproofing.[13]

Rinsing is carried out with a combination of spray rinses and tubs of clean water. The water temperature is still 102–105° F. Special attention should be given to the under tail coverts, under wings, and neck of the bird. The bird is not acceptably rinsed until *diamond-like beads of water roll freely* from the feathers. This is the one sign of a successfully cleaned oiled bird, and once you see it, you will recognize it as the end point in every oiled bird cleaning effort.

The failure to rinse the bird adequately is probably the most common cause of unsuccessful rehabilitation efforts—do not succumb to the impulse to give up the rinsing process prematurely. Finally, the bird's feathers are blotted dry with a clean towel, and the eyes are flushed one last time.

If all the materials and tubs of water are assembled in advance, the entire cleaning time should take from 15 to 30 minutes. A bird that becomes extremely stressed during washing should be rinsed and put in a pen separate from clean birds to dry. After stabilization (12 or more hours) the bird will need to be rewashed.

Restoring feather structure. The newly-washed bird is placed in a clean holding pen to dry. The pen should be lined with sheets or towels, curtained to minimize human intrusion, and provided with heat lamps to allow the bird to find a comfortable ambient temperature. The heat lamps should be at two heights from the bottom of the pen (approx. 24 in and 36 in for a mallard-sized bird) with an unheated area also available. We find that birds don't respond well to forced hot air from driers and prefer the ambient warm air of heat lamps, immediately beginning to preen their feathers back into alignment.

Diving ducks require as much as three inches of foam padding under the sheeting to prevent breast abrasions and open sores. For birds which are totally unable to walk on dry land (e.g., common loons), we provide small plastic bags stuffed with shredded foam to make slightly flat pillows; these bags are placed under the sheeting. The birds soon learn to position these pillows under their keels in a comfortable position. Scrupulous care must be given to the pens of those birds which are not mobile on land. The birds can incur serious feather damage if they become contaminated with feces and old food.

Free access to water and a variety of foods can now be provided. The birds are checked to see which ones are self-feeding. The droppings are monitored for blood and oil, and these birds are treated for enteritis with more Pepto-Bismol and tubings of easily absorbed nutrients.

After 24 hours, the birds are allowed to swim. They are provided with sufficient water to actually swim and preen. For birds that are smaller than Canada geese, we use 4 ft × 8 ft pens with a sloped ramp which allows the birds to enter the water and leave it at will. Our pens are curtained and the elevated platform has a heat lamp on one side to prevent chilling. Kiddie pools with access ramps can be used, but must be changed 3–4 times a day, or more. Tepid water is used for the first swim, cool to cold water thereafter.

Waterbirds usually take to the water readily; when they begin to get wet, they leave the water to preen. As the bird continues its efforts to swim, then preen, it realigns its feathers and restores original feather structure.

This alignment of the feathers is what insures the bird's waterproofing. The feather structure does not require, but is further enhanced by, the application of oil from the bird's own uropygial gland; this natural oil seems to assist in maintaining the feather structure, much as hair spray might hold a hairstyle.[11]

Birds which are waterproof will demonstrate the diamond beading of water on their feathers. They also will be able to remain in the water, depending on species, anywhere from 10 to 50 minutes without getting wet. Certain diving birds (loons, scoters, grebe sp.) may have slightly wet outer contour feathers, but the down should remain *absolutely* dry.

Acclimating the bird for release. A bird which is waterproof should slowly be exposed to temperatures comparable to outside weather. This, of course, is critical in cold winter months.

A rehabilitated oiled bird should be of average weight for its species and sex. It should be adequately muscled so that it can forage normally in the wild. The bird should not show signs of disease. Birds should be banded with Fish & Wildlife Service bands and released early in the day in proper habitat.

Seabirds must be prepared for return to the ocean by being fed a tubing solution of normal saline (0.9 percent) for three days before release. This stimulates the function of the nasal salt gland.

Major oil spill crises

For those rehabilitators who are not equipped for an oil spill response, even five or six oiled birds can present a serious challenge. The intense human labor, the immediacy of the effort, and the need for special equipment (such as water supply, detergent, and pools) can make the job seem a Herculean task. A spill involving fifty, one hundred or more birds taxes the resources of even those of us who like to think we are always prepared for oil spills. Organization and planning are the key factors in the success of a major oiled bird rehabilitation effort.

Determining protocol. We have been rehabilitating oiled birds for a decade, yet we still know of only one successful way to deal with oiled birds. Some article published in 1948, suggesting plucking the bird, may be read by an earnest citizen and become dogma etched forever in stone. During a major oil spill, someone will *always* show up at the facility with a new wonder method, a miracle soap, letters of testimonial for his/her pet theory. And, in desperation and under the pressure of the moment, these people are often, tragically, allowed to determine treatment protocol.

There are certain steps that can be taken to ensure a more smoothly running rehabilitation effort; most of these steps should take place before any oil spill occurs.

TSBR maintains a corps of volunteers–laypersons and professionals—who have been trained in advance of an oil spill. These people are given an overview of an oil spill response. They have been introduced to Fish & Wildlife, Coast Guard and industry representatives. The volunteers are given basic instruction in oiled bird treatment, then assigned to one of the following committees for further training: Operations Control, which deals with all administrative matters, including scheduling, safety, records keeping and public relations; Cleaning, which operates the cleaning area; Medical—Rehabilitation, which cares for the birds before and after cleaning; and Supplies—Set-Up, which acquires supplies and maintains the physical facility.

It is very beneficial to have already established an open and clear working relationship with the other agencies which will be responding to the spill. In Delaware, for example, Tri-State Bird Rescue & Research, state and federal fish and wildlife agencies, all the industries utilizing the Delaware, and the Captain of the Port of Philadelphia and his staff established a structured oil spill response protocol over a decade ago, and we have maintained a good working relationship even during the years when there were no major oil spills.

The *Grand Eagle* oil spill response. A recent example of our interagency communications is the *Grand Eagle* oil spill which occurred on Sunday, September 29, 1985 when 450,000 gallons of light crude oil was spilled into the Delaware River. The Coast Guard was notified of the spill just after 11 p.m. At 4 a.m. the Coast Guard contacted Tri-State and alerted us as to the extent and location of the spill. By 7 a.m., we had spoken with state and federal fish and wildlife agents, and we had coordinated our efforts for the day. While they set up land, water, and aerial reconnaissance of the area, Tri-State staff began to schedule workers and set up the facility to deal with the type of oil and types of birds we anticipated receiving. By noon, we had started the first of our daily updates with the manager of the Delaware Bay & River Cooperative. The Cooperative is a consortium of industries which use the Delaware River for transport, and maintain a sophisticated oil spill response mechanism. It has been a major supporter of Tri-State.

Public relations. Because oiled bird rehabilitation lends itself, visually and emotionally, to media presentation, the press tends to converge on the rehabilitation center. During the *Grand Eagle* spill, press coverage was continual, with representatives from the New York Times, CNN News, the Chicago Tribune, AP, UPI, national environmental groups, and all the local newspapers and television and radio stations in attendance at all hours. We make it a policy to have every news person sign in, with affiliation and phone number. Press movement in the center is restricted.

Our staff at the rehabilitation facility confines all of its media comments to the condition and care of the birds at the center. No speculation is made as to the extent of the environmental or financial loss, or the alleged culpability of the pilot, captain, or refinery.

The plight of oiled wildlife frequently touches even these news-hardened professionals, and they come back to assist in running errands, to bring donuts or pizza, or just to drink our coffee and wait for new developments.

The friendliness with which the media regard us often enables us to communicate with them where others have not had equal success. For example, the *Grand Eagle* spill occurred during a time when very few birds were on the Delaware River. The summer nesting birds had left the area, and the wintering birds from the north had not yet arrived. While the public, the media, and environmental groups were expecting tens of thousands of birds to be contaminated in this massive spill, in reality, only a few hundred birds were in the area. This was confirmed by aerial overflights, state and federal fish and wildlife ground teams, and our own field observers. Reporters, who were prevented from going out on the river, couldn't believe the industry and government claims that so few birds were affected. However, as these newsmen and women spent time with us and watched the dedication and the skill with which we cared for those birds that did come to us, they believed our evaluation of the situation.

In fact, media pressure dropped off considerably after a news conference was held at the cleaning facility with the Captain of the Port, and representatives from NOAA, industry, and the state and federal wildlife agencies all demonstrating a united front.

Oiled bird rehabilitation receives so much media attention during a spill that, despite government hotline numbers, most calls from the general public come to the rehabilitation facility. During the *Grand Eagle* spill, our phones began ringing at 6 a.m. and continued until after midnight, so continuously that we had difficulty making outgoing calls. In response to this need, our Operations Control Section is trained to deal with the public.

We have a system of maps and color coded pins, and telephone log sheets to record bird sightings, oil sightings, and locations where birds have already been picked up. This information is passed on to the Coast Guard and the fish and wildlife agents two to four times a day.

The rehabilitation facility is not open to the public during an oil spill response. Oiled bird rehabilitation is a complex medical and technical procedure, not a spectator sport. Visitors are greeted at the door and given a flier updating them on our work, and advising them of the next training workshop. We also record the name and address of every visitor and caller and mail out a newsletter at the end of the oil spill response, describing the efforts to minimize the oil spill damage to birds and property.

Conclusion

At Tri-State Bird Rescue & Research, we have, over the past 10 years, spent many thousands of dollars and hours investigating the effects of oil on birds. We have studied the published papers and informal accounts of other rehabilitation efforts, and we have conducted carefully planned research on oiled birds and published our findings in numerous medical and scientific journals.

We find that most oiled birds can be rehabilitated successfully using the techniques covered briefly in this paper, although certain modifications must be made for passerines and raptors.

The secret to successful oiled bird rehabilitation is a commitment to follow documented procedures to the letter, avoiding shortcuts and last minute alterations in protocol. As with many procedures, experience is the greatest tool for carrying out the job quickly and efficiently.

We also recognize that rehabilitating a single oiled bird is a simple procedure compared to responding to a major oil spill crisis, when oiled birds may come in in great numbers, media and public pressure is great, and governmental agencies and industry are trying to cope with dozens of on-scene problems ranging from explosion and fire hazards, to loss of beach recreation areas and legal liability.

In any geographical area prone to oil spill crises a structure must be established and maintained which:

1. encourages interagency communication and support
2. recognizes and utilizes the special skills of each organization
3. insures that the many steps needed to minimize the effects of an oil spill are all carried out quickly and efficiently

Tri-State Bird Rescue & Research is very proud to be a part of what we feel is an outstanding interagency oil spill response team in the mid-Atlantic area.

Acknowledgments

We extend our appreciation to Bob Lobou (SUNY) for literature searches on oiled bird rehabilitation methods, and to the Delaware Bay and River Cooperative, and Texaco, Inc. for funding to develop rehabilitation methods.

References

1. Berkner, A. B. and D. C. Smith, 1977. Cleaning agents for oiled wildlife. *Proceedings of the 1977 Conference on Prevention and Control of Oil Pollution,* American Petroleum Institute, Washington, D.C.
2. Croxall, J., 1979. Birds and oil pollution. *in* First Aid and Care of Wild Birds, J. Cooper and J. T. Eley, eds. David and Charles, North Pomfret, Vermont, pp174–191
3. Edwards, R. A., 1963. Treatment of "washed up" penguins. *Bokmakerie,* v15, n8
4. Langenberg, J. A. and F. J. Dein, 1983. Pathology of ruddy ducks contaminated with #6 fuel oil. *in* The Effects of Oil on Birds: Physiological Research, Clinical Applications and Rehabilitation, D. G. Rosie and S. A. Barnes, eds. Tri-State Bird Rescue & Research, Wilmington, Delaware
5. Lauer, D. M., J. A. Frink, and F. J. Dein, 1982. Rehabilitation of ruddy ducks *(Oxyura jamaicensis)* contaminated with oil. *Journal of the American Veterinary Medical Association,* v181, pp1398–99
6. Leighton, F. P., 1983. The pathophysiology of petroleum oil toxicity in birds: A review. *in* The Effects of Oil on Birds: Physiological Research, Clinical Applications, and Rehabilitation, D. G. Rosie and S. A. Barnes, eds. Tri-State Bird Rescue & Research, Wilmington, Delaware
7. Martini, E., 1953. Oil plague—Observation on the North Sea island Spiekeroog. *Ornithologische Mitteilungen,* v5, n3, pp44–48
8. Michael, A. D., 1977. The effects of petroleum hydrocarbons on marine populations and communities. *in* Fate and Effects of Petroleum Hydrocarbons in Marine Ecosystems and Organisms, D. A. Wolfe, ed. Pergamon Press, New York, pp129–137
9. *New York Times,* April 4, 1985
10. Percy, J. A. and T. C. Mullin, 1977. Effects of crude oil on the locomotory activity of arctic marine invertebrates. *Marine Pollution Bulletin,* v8, n35
11. Rijke, A. M., 1970. Wettability and phylogenetic development of feather structure in water birds. *Journal of Expl. Biology,* v52, pp469–479
12. Rowan, Eileen, 1983. Stress: its effect on the pituitary/adrenocortical axis and its importance in latent infections. *in* The Effects of Oil on Birds: Physiological Research, Clinical Applications, and Rehabilitation, D. G. Rosie and S. N. Barnes, eds. Tri-State Bird Rescue & Research, Inc. Wilmington, Delaware
13. Russell, W. C., G. L. Choules, and D. A. Gauthier, 1981. Detergents and waterfowl. *Journal of Zoo Animal Medicine,* v12, pp10–13
14. Tottenham, K., 1959. The oil menace. *Audubon,* v61, pp28–30
15. Westphal, A., 1969. Jackass penguins: their treatment, care and release after contamination by crude oil and other oil products. *Marine Pollution Bulletin,* v14, pp2–7
16. Williams, A. S., 1978. Saving Oiled Seabirds. American Petroleum Institute, Washington, D.C.