ARCTIC
VOL. 36, NO. 1 (MARCH 1983) P. 1-4

Commentary: What Impact Will the Oil Industry Have on Seabirds in the Canadian Arctic?

E.M. LEVY[1]

THE THREAT FROM OIL

The potential for destruction of the seabird colonies of the Canadian Arctic as a consequence of the exploration and eventual production of hydrocarbons has been widely recognized and considered in most, if not all, of the relevant Environmental Impact Statements prepared to date. Because these birds nest in densely populated colonies, concentrate to feed at ice edges and in open leads, and winter in restricted localities, they are particularly vulnerable to oil. Whether from a major blow-out or shipping accident or from a much smaller spill, oil in the wrong place at the wrong time could seriously reduce or even eliminate some of these colonies and have a lasting impact on the entire population of seabirds in the region. Concern over this threat has resulted in research that has vastly improved our knowledge of the location, size, breeding success or failure, feeding habits, and migration patterns of Northern Fulmars, Black-legged Kittiwakes, Thick-billed Murres, and non-breeding visitant Dovekies in Lancaster Sound and Jones Sound, and an appreciation of the roles of ice and other environmental factors has gradually emerged. What has not been adequately addressed in these Environmental Impact Statements, however, is the impact on seabirds and other arctic marine life of oil at levels that do not cause immediately discernible toxicological responses. Of particular importance in this regard is the effect of oil at sublethal levels on individuals and populations that are already stressed at or near their levels of tolerance, i.e. under conditions where any additional stress, however small, could be the "straw that breaks the camel's back".

THE EFFECT OF OIL AS A COMPONENT OF STRESS

Stress is the result of all the physical, chemical, emotional, and other factors that cause physiological or mental tension in an individual or, collectively, in a population. For seabirds and other marine life to achieve maintenance, production, and growth, a combination of ecological requirements must be met. Any factor that interferes with the attainment of the overall ecological balance (e.g., adverse oceanographic and/or meteorological conditions, habitat deterioration, competition for food and space, disease and parasites, pressure from predation or human disturbance, exposure to pollutants) contributes to the level of stress to which the individual organisms (or, collectively, the population) are subjected. Since the various components of stress may interact in an additive or subtractive, synergistic or antagonistic manner with respect to their cumulative effects on the individual, it is not a simple matter, if indeed it is possible, to predict the effect of either an incremental increase in any one component of stress or the introduction of an additional new component. Therefore, to consider the potential effects of oil in isolation from all other forms of stress could lead to a gross underestimation of the resulting impact. It is necessary to consider the potential impact of oil in the context of its being an additional component to the overall level of stress to which the individual or the population is already subjected. To complicate the matter still further, it is not clear how local population fluctuations caused by oil will affect populations of marine organisms, relative to the fluctuations that occur in response to the vagaries of the marine environment. Although the impact of oil, in terms of adding more stress to already highly-stressed populations of arctic seabirds and other marine life, may be fully as important as that of a catastrophic event, this point of view has not been addressed by existing Environmental Impact Statements. Yet both field and laboratory evidence indicate that this should be a matter of real concern.

During a prolonged period of particularly severe winter conditions during 1976-77 following the sinking of the tankers *Argo Merchant* and *Grand Zenith*, oiled seabirds appeared on the beaches of Nova Scotia (Levy, 1980). While some of these birds were heavily oiled, many of them bore only small patches of oil or slight staining of their breast feathers. All of the lightly oiled birds were extremely emaciated, suggesting that they were not killed immediately by the oil but lingered until a series of responses triggered by the oil brought about their demise. It is well known (e.g. Bourne, 1976; Brown, 1980) that even a very small amount of oil alters the feather structure and may degrade the insulating and water-repelling properties of a bird's plumage sufficiently to bring about a substantial increase in heat loss. To offset this, an involuntary shivering process is initiated and the bird's metabolic processes are accelerated. These reactions result in a further increase in the bird's energy requirements, and if this energy demand cannot be satisfied by increased food intake the bird's fat reserves are rapidly utilized. As a consequence, a diving seabird becomes progressively more buoyant, and the procurement of food becomes more and more difficult as both the depth to which the bird can dive and the time it can remain submerged decrease. In the case of a surface-feeding seabird, the increase in energy required to meet the increased heat loss and accelerated metabolic processes results in less energy being available for foraging, and if this coincides with a scarcity of food the bird's fat reserves are consumed. In either case, once feeding efficiency decreases and fat reserves are consumed, the bird's muscle tissue is mobilized and it soon dies. A more

[1]Atlantic Oceanographic Laboratory, Bedford Institute of Oceanography, Dartmouth, Nova Scotia, Canada B2Y 4A2

heavily oiled bird will preen its contaminated feathers and down in a futile attempt to rid itself of its affliction — many of the birds examined during this study had a denuded patch of approximately 1 cm in diameter. Removal of this insulation not only accelerates the loss of heat, bringing on the consequences described above, but also results in ingestion of oil and accompanying metabolic and other internal disorders (e.g., Miller *et al.*, 1978; Peakall *et al.*, 1980; Holmes, 1981). Only in the most heavily oiled of the birds studied, which died soon after contact with the oil, were body tissues and fats intact. Thus, the seabirds of this study provided a stark demonstration of the small amount of oil — an amount that might even be inconsequential under more favourable environmental conditions — that can initiate a spiral of increasing energy requirements that soon results in death when the birds are already highly stressed from adverse environmental conditions. Another example of this phenomenon is the 1969 die-off of Common Murres off the coast of Oregon, involving more than 51 000 birds (comprising 7.6% of the adult breeding population and 42.6% of the young-of-the-year) (Scott *et al.*, 1975). In this case, the death of birds was attributed to the stresses imposed by exposure to sublethal levels of organochlorine pesticides, superimposed upon those from environmental conditions, possible local failure in the preferred food organisms, restricted foraging movements because of the adult/chick association, and possibly other factors. In both these examples, the birds might have been able to cope with the stress arising from the contaminant under more favourable environmental conditions or, conversely, with the environmental stresses in the absence of the contaminant. In neither case could they tolerate the combined stresses.

Low levels of oil can stress marine organisms in many ways other than those discussed above. For example, it may interfere with chemical signals that control the biological processes crucial to the survival of the species, e.g. food detection, feeding impulses, predator avoidance, territory definition, homing of migratory species, susceptibility to physiological disorders, disease resistance, growth rates, reproduction, and respiration. Much of the available information on these responses has been obtained from laboratory experiments with laboratory animals under laboratory conditions. Since a well-designed laboratory experiment strives to examine each of the variables independently of the others, it is often difficult to extrapolate the results of such experiments to the marine environment where all the components of stress act simultaneously. However, at least one laboratory study has demonstrated the synergism that exists between the stresses from oil and those from environmental conditions. Ducks that were "acclimatized" to a diet of oil-contaminated food were able to tolerate the stress imposed by their diet when they were kept under carefully maintained environmental conditions, but when subjected to additional stresses caused by competition from other birds for space, a reduction in ambient temperature, or an increase in the salinity of their drinking water, the resultant was more than the birds could tolerate and they soon died (Holmes and Cronshaw, 1977; Holmes, 1981).

Thus, both field and laboratory evidence support the concept that a small additional stress applied to organisms that are already at or near their limit of stress-tolerance can have effects that are vastly out of proportion to the apparent size of the increment. As Dickens put it: "Annual income twenty pounds, annual expenditure nineteen six, result happiness. Annual income twenty pounds, annual expenditure twenty pounds ought and six, result misery." (*David Copperfield*, Ch. 12).

A RECONSIDERATION OF THE POTENTIAL EFFECT OF OIL ON SEABIRD POPULATIONS

The concept of the disproportionate effects of additional stress on an individual that is already near its capacity to cope with stress can be extended to provide some insight into the effects that such incremental additions might have on populations. Collectively, if the level of stress on the individuals is well within their capacity, the population will flourish and possibly extend its geographical distribution; if the individuals can barely tolerate the stresses to which they are subjected, the population will attain an equilibrium with its environment; and if stresses exceed the capacity of the individuals, the population will diminish in numbers and its geographical distribution will decrease. Thus, the number of individuals in a population, its density and geographical range can be considered as being determined by the cumulative effects of stress; that is, somewhere there is a boundary beyond which it is too hot or too cold, too wet or too dry, or where there is too little food, too much competition, or too few breeding sites. Superimposing an additional stress on such a system will result in a reduction in either the numbers of the individuals or their range, or both. An illustration of this phenomenon is the case of the bowhead whale and the Atlantic walrus in the eastern Canadian Arctic. The former seems to occupy much of its historical range but at a much reduced population density, while the latter maintains fairly high densities at some sites but exists over a greatly reduced range (Davis *et al.*, 1980). The indication is that neither of these species can withstand much additional stress — from increased exploitation, disturbance, or exposure to oil. In general, an expansion of man's activities increases the level of stress on seabirds, and the decline in Common Murres in the northeast Atlantic over the last 40-50 years is thought to be largely the result of increasing oil pollution from shipping (Cramp *et al.*, 1974). In some instances, however, the level of stress may be reduced; for example, the provision of an increase in food supply in the form of offal from an expanding fishing industry and an abundant supply of consumable garbage lowered the stress on Larus Gulls and allowed an explosion of their numbers on both sides of the North Atlantic. This, in turn, has resulted in greater stress on terns through harassment from larger gulls, and the numbers of both Arctic and Common terns have been declining along the Atlantic coast of North America (Nettleship, 1977; Nisbet, 1973). Clearly, a change in the level of stress on a given species not only can have unpredictable consequences on the species directly affected but can also give rise to repercussions that manifest themselves elsewhere in the ecosystem.

At the fringes of its geographical distribution, a species is in a fine balance (or a fine imbalance) with the stresses to which it is subjected, and it is there that the first indications of the effects of changes in the level of stress on a population of seabirds are discerned. These colonies may be successful in some years but suffer serious losses in others, depending on seemingly minor variations in one or more of the components of total stress. Since the time available for breeding and rearing of young in the Canadian Arctic is so short, timing is particularly critical for these colonies and any delay can have a marked effect on the productivity for that year. For example, when an additional stress was applied by abnormal ice conditions and the associated environmental regime in 1978, the production of young at the Lancaster Sound colonies was so low that they were considered to have suffered a "reproductive failure" (Nettleship *et al.*, 1979). Provided such failures are not too frequent, their effects are offset by intervening successful years that enable the colonies to regain their numbers; over an extended period of time the population fluctuates about a level that is determined by the long-term "integrated" level of stress. However, the introduction of new stresses, however small, will hinder this recovery and might even prevent it. For example, it is well established that several of the Lancaster Sound colonies have been declining in recent years (Nettleship, 1977, 1978). In particular, the colony of Thick-billed Murres at Cape Hay on the north shore of Bylot Island is thought to have declined by about 30% since 1957 because of losses resulting from human persecution and drowning in salmon nets along the west coast of Greenland (Brown *et al.*, 1975). There is strong evidence that the Lancaster Sound seabird colonies are already stressed beyond their capacity and any additional stress, regardless of its source, will result in further, possibly drastic, declines. Also, it is currently thought that a minimum colony size is crucial to the survival of the remaining birds (Gaston and Nettleship, 1981), and that once a colony is reduced beyond this critical size it will be impossible for it to recover its losses *even if* the level of stress is subsequently reduced, and sooner or later it will no longer exist. (Perhaps this is what has already happened to the bowhead whales of Baffin Bay, as their population has not recovered appreciably since the early 1900s when the stress of commercial exploitation was removed.)

THE FUTURE OF SEABIRDS IN THE CANADIAN ARCTIC

Since neither the absolute level of stress that an individual or population can endure nor the effects of each of the individual "stress vectors" and how they are combined into the overall level of stress is known, it is not possible to quantify these concepts; any attempt to interpret stress levels is a highly subjective exercise. Nevertheless, it is possible to make some general predictions regarding the effects of the oil industry on seabirds and marine life in the Canadian Arctic. First, it is certain that there will be extensive mortality in the event of a major spill in any of the areas where large numbers of seabirds congregate. Also, there is little doubt that in some areas there will be low levels of oil pollution from time to time despite the most conscientious efforts by the industry to minimize losses during its day-to-day operations. Further, the presence of additional humans, along with ships, aircraft and other technological creations in the region will result in more extensive disturbance of marine life. It is inevitable that these new sources of stress will have detrimental effects on the colonies of arctic seabirds. The reductions in numbers will first become apparent in those colonies that are already marginal in nature but they will also take place in the remaining colonies. As marginal colonies are reduced below their critical size, they will disappear; other colonies will become marginal, and so on. Thus, the future of seabirds in the Canadian Arctic is at best precarious and demands immediate attention and concern. Unfortunately, the situation is undoubtedly far more serious than has been depicted by the "worst case" scenarios considered by existing Environmental Impact Statements. For example, the EIS prepared by Norlands Petroleums Limited (1978) in support of its request for permission (which was subsequently denied on environmental grounds) to drill in eastern Lancaster Sound provided an excellent account of the distribution of the various species of seabirds at different times of the year and made it very clear that a blow-out in this area could result in extensive mortality. Most seriously threatened was thought to be the Northern Fulmar population, and it was estimated that as many as 120 000 might die as a result of a $6000\text{-bbl}\cdot\text{d}^{-1}$ blow-out for a year at the proposed site (Norlands, 1978). Also placed in serious jeopardy was the colony of 400 000 Thick-billed Murres at Cape Hay. Another estimate was that more than 2/3 of the total Canadian population of Northern Fulmars could be affected by petroleum exploration in Lancaster Sound and Baffin Bay (Milne and Smiley, 1978). What these statements failed to consider, however, is that comparable losses might be incurred from the cumulative effects of much smaller spills, chronic discharges of wastes, increased human disturbance, and other ancillary factors, if the birds' total capacity for stress is exceeded when the stresses from these sources are superimposed, perhaps synergistically, upon those to which they are already subjected. Future EIS's would be of considerably more value if they were to address the impact of oil from the point of view of stress, though it must be realized that a fully satisfactory quantitative assessment is impossible because of the lack of a fundamental understanding of stress levels and how they interact. It must also be appreciated that, if the balance should be tipped by these additional stresses, it will be possible to attribute the disruption to oil only if the changes in populations are sudden and of catastrophic proportions — indeed, even these will only be detected if adequate information is available beforehand concerning their pre-development populations. More likely the effects will be insidious and it will be exceedingly difficult, if not impossible, to isolate the impact of the oil industry from that of unusual but natural environmental conditions and other sources of stress. In any event, it seems that the development of an oil industry in the Canadian Arctic will result in still further reductions in both the numbers and geographical distribution of seabirds.

Nevertheless, annihilation of arctic seabirds and other wildlife need not be the inevitable consequence of hydrocarbon-related industrial development. If the concepts presented in this paper are valid (and they are undoubtedly a gross simplification of a very complex interrelationship), it should be possible through intelligent management of stress levels to minimize the impact of industrial development. It is certainly within our capability to control the stress created by disturbance from aircraft and ships by identifying and, to the extent possible, avoiding sensitive areas at critical times of the year. Human harassment can be essentially eliminated through a program of education or, if necessary, coercion. Accidents arising from the failure of engineering structures can be reduced by design, construction and maintenance and by taking adequate precautionary measures, while those resulting from human carelessness can be made less frequent through good training and motivation of workers and by avoiding monotony. Yet, despite the best of intentions an accident will eventually occur. In that event, men and equipment must be immediately available to retain and clean up the spill to the extent possible. Since all these factors will increase the level of stress on seabirds, in order to maintain some semblance of balance it will be necessary to reduce some of the other factors contributing to the overall level of stress; for example, it should be possible to reduce the stress on the Thick-billed Murres of Lancaster Sound by restricting the harvest of this species while on their winter range off West Greenland. Presumably, factors that currently contribute to stress in other species can be identified and reduced to offset the increase from industrial development.

It might seem trite to conclude with a statement that "more research is needed..." but this is, nevertheless, the case. A better understanding of the population sizes and variations for the various species of seabirds, the seasonal patterns of their distributions, their reproductive success/failure, their mortality during winter,...; that is, a better understanding of their general ecology must be attained. Attempts should also be made to understand how seabirds and other wildlife react to changes in the level of one or more of the components of total stress, what their tolerance levels are, and whether there is any margin to accommodate additional stress. It is unrealistic to demand that complete answers to these and related questions be obtained before exploration is allowed to proceed further or before development can commence. It must, however, be insisted that every effort be made to ensure that these developments do not proceed at the expense of irreversible loss of wildlife or wanton degradation of the arctic environment.

ACKNOWLEDGEMENTS

The constructive comments and criticism of Drs. D.N. Nettleship and R.G.B. Brown of the Seabird Research Unit of the Canadian Wildlife Service are gratefully acknowledged. Much of the information on which these ideas are based is the result of their research — the responsibility for the interpretation given, however, rests solely on the author.

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