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REVIEW OF THE PROBLEM OF BIRDS CONTAMINATED BY OIL AND THEIR REHABILITATION

By

John W. Aldrich
Division of Wildlife Research
Bureau of Sport Fisheries and Wildlife

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An oil-soaked common eider on the New England coast.

HISTORY AND SCOPE OF CONTAMINATION

Bird casualties from oil pollution at sea on both sides of the North Atlantic and North Pacific have numbered many thousands each year.

Over 6,600 common murres and hundreds of other seabirds perished after becoming covered with oil from a tanker wreck off the California coast in 1937 (Moffitt and Orr, 1938). In the winter of 1951-52, approximately 100,000 birds were lost to oil pollution on the coasts of the British Isles (ZoBell, 1962). Hawkes (1961) estimated that a breeding colony of 250,000 seabirds nesting on Newfoundland was decimated by oil in a 2-year period. Beer (1968b) stated that the Torrey Canyon wreck caused the oiling of an estimated 30,000 birds in England and France, of which 8,000 were picked up alive and taken to centers for cleaning.

According to the Smithsonian Institution Center for Short Lived Phenomena, 15,000 to 25,000 oiled eiders came ashore on the Wadden Islands, Netherlands, in February 1969. On April 3, 1969, oil from the damaged Hamilton Trader off the River Mersey floated west along the North Wales coast and fouled the plumage of at least 1,500 guillemots and razorbills and a few red-throated divers. It seems likely that 70 to 80 percent of the guillemot colony on the Great and Little Orme Heads was affected.

Clark and Kennedy (1968) have given a complete and very alarming summary of birds destroyed by oil spills. The kinds of birds most frequently affected are auks, murres, guillemots, puffins, and other alcids; mergansers, eiders, scoters, oldsquaws, scaups, goldeneyes, and other open-water ducks; loons, grebes, gannets, pelicans, and petrels. Long-term effects of oil-induced mortality on birds are chiefly unknown because estimates of populations have not been correlated with conditions before and after oil spills.

These authors comment that there was a noticeable decrease in alcids on Ailsa Craig in the Clyde River, Scotland, which lies in a main shipping route, and that J. A. Gibson thinks that the present population of 5,000 pairs of guillemots is about a tenth of what it was 40 years ago. The pronounced decrease in guillemots at Skomer in Pembrokeshire, England, may be due to oil pollution in the Bristol Channel. Tuck (1960) observed that one colony of alcids in Newfoundland had declined by nearly a quarter of a million birds in 2 years.

As a result of loss from oil spilled by two wrecked tankers, the wintering population of common eiders off the Massachusetts coast dropped from 500,000 in 1952 to 150,000 in 1953 according to Burnett and Snyder (1954). A near disaster was the dumping of 1,000 gallons of bunker oil into the St. Lawrence River by an unknown ship in August 1963. According to Warner (1969) this oil drifted onto the Cap Tourmente marshes east of Quebec City where a large part of the total population of the greater snow goose pauses in migration. About 1,000 birds were in the area at the time, but fortunately the oil was discovered and cleaned up by concerted effort of the Canadian and Provincial Wildlife agencies before it contaminated the geese.

Clark and Kennedy (1968) pointed out that the extent of loss among oiled birds cannot be determined by those that wash ashore, which may be only a small fraction of those that disappear at sea. Correlating numbers of birds lost from breeding colonies with numbers involved in oil spills is a better method of appraisal, but this may take a number of years and may be confounded by other factors that affect abundance. Also, reduction in hatchability of eggs coated with oil from a parent's slightly soiled plumage is an indirect decimating factor. Alcids are particularly vulnerable since their low rate of reproduction (1 egg a year) prevents rapid recovery.

After considering other decimating factors, the general decline of alcids in Britain was thought to be due to oil pollution. The general conclusion of Clark and Kennedy was that, despite the lack of conclusive evidence, it seems clear that the high level of oil pollution at sea has serious immediate and long-term effects on a number of species of seabirds. The most vulnerable birds are the diving species that spend considerable time on the surface of the sea, frequently in large groups.

Despite the 1954 international convention to prevent oil pollution of the seas, signed by many countries including the United States, pollution not only continues but increases. The extent of this hazard, particularly as it refers to Canada and Alaska, has been reviewed quite completely by Warner (1969). Statistics from the Liverpool Underwriters Association list 19 tanker groundings (with 17 spillages) and 238 tanker collisions (with 22 spillages) from June 1964 to April 1967. Böös (1964) noted that 750 million tons of oil are shipped each year. Cleaning tanks on ships alone accounts for a yearly pollution of 3 million tons. Waste oil persists a long time at sea and experiments have shown that within 72 hours discharges of oil have been traced 90 miles from their origin. Other experiments showed that oil will float on water for at least 18 months (Clark and Kennedy, 1969). The fact that it persists much longer in cold than in warm water was pointed out by Warner (1969).

Erickson (1963) has reviewed the extent and effects of oil pollution on birdlife and has indicated the need for much more effort to control this damage. Increasing public concern over the plight of water birds that become fouled in oil slicks on the surface of the water from these spills requires more definite effort to develop practical methods of treating and salvaging large numbers of the victims.

Salvage efforts have been made in different parts of the world and have involved a number of species of water birds of widely divergent habits, different tolerances to captive conditions, and different degrees of contamination. A few of the results have been encouraging, but none have resulted in salvaging more than a small fraction of the treated birds. However, the experiences have revealed the main problems to be overcome. These are: (1) curing the initial poisoning from ingestion of oil;

(2) preventing chilling due to the loss of thermal insulation by the plumage; (3) removing the oil from plumage; (4) renewing the waterproofing characteristics of plumage; and (5) developing proper housing, feeding, and other care designed to keep that particular species in captivity long enough to rehabilitate it (Clark and Kennedy, 1968).

To attack these problems of decontaminating oiled birds, four different but overlapping lines of research are indicated and are discussed separately in the following sections:

1. Methods for cleaning plumage and renewing waterproofing characteristics.

2. Toxicological and physiological effects of oil on birds and treatments for these effects.

3. Methods of caring for recuperating birds in captivity after rehabilitation. (Care varies greatly among species).

4. Induction of premature molt to replace affected feathers as soon as possible.

METHODS OF CLEANING OILED BIRDS

Cleaning the plumage of birds that have been contaminated with oil has been attempted with many different cleaning agents. Some of the attempts have proved quite effective in removing the contaminating oil but, unfortunately, none has been successful in restoring waterproof qualities to the plumage.

Lincoln (1942) recommended mild white soap and water for removing oil. This does not irritate a bird's skin, and taxidermists have found that feather structure is only slightly disrupted when a bird is washed carefully and dried with a stream of compressed air flowing in the same direction as the feathers. However, natural oils that are presumed to aid in waterproofing the feathers are removed. The use of Esso's Brymul A removed No. 6 oil from a duck when it was immersed for 1 minute and then rinsed with water twice while being gently rubbed (Esso Oilways, 1942). The duck was placed under a drying lamp for half an hour. After several tests, the skin did not appear inflamed. The long immersion, washing, and drying exhausted the bird. Use of a sponge instead of immersion was recommended.

Stedman (1952) suggested a cleaning substance made of corn oil (Mazola), neatsfoot oil, oleic acid (Red Oil Tech), Span 40, Parawax, Solvesso #2, and water. The mixture has the consistency of butter. The oiled part of the bird was covered thoroughly with the cleaner and wiped off as thoroughly as possible in a minute or two. Then the area was coated again with the cleaner to about a quarter of an inch, and the bird was released in a pen. In each case the bird preened the surplus cleaner from its plumage and apparently swallowed quite a lot without ill effects. After 10 days the birds were reported to have behaved normally, and the treated feathers were shedding water although they still looked greasy. No report on eventual survival was given. Span is a detergent made by Atlas Powder Company, Wilmington, Delaware. Solvesso is an Esso solvent.

Tottenham (1958) used a dry shampoo to remove fuel oil. Affected birds were first padded with cotton under the wings and then swathed in cotton with only the head exposed. The birds (species not given) were kept in 75° F. temperature. Feeding was begun immediately with raw fish dipped in codliver oil. The next day the oil was removed with fuller's earth or prepared chalk powdered thickly over the feathers. Absorption of oil took about 24 hours. Treatment was repeated if necessary, and the high room temperature was maintained until the patients were clean and eating hungrily. The birds were gradually "hardened off" and released after 10 days. There was no information on what happened to the birds after that. When the birds were covered with thick or tarry oil, the removal process started with a liberal coating of butter, followed by a warm bath in pure soapsuds. The birds were then wrapped in a towel and laid in a warm place to dry. Next morning the dry shampoo treatment was applied as above.

Andrews (1964) found that Spill-Away, produced by the Yosemite Chemical Company and used to clean up oil spills in Louisiana, although not toxic when ingested by mallards, was unsatisfactory in removing the type of oil found in those spills from their plumage.

Brown (1968) described an experiment in which oiled ducks were cleaned by an ultrasonic device at the Alcor Instrument Plant in Trenton, New Jersey. Ducks were immersed to their necks for 5 minutes in water heated to 105° F. Ultrasonic waves were transmitted through the water, setting up a "bubbling action" which loosened the oil and dirt. Next the birds were rinsed for 2 minutes in a tank with changing warm water supply. After that they were immersed in a solution of alcohol and lanolin to reduce detergent burn and restore some of the oil to the feathers. Finally they were placed in a heated pen to dry. The cost of a portable machine to supply the ultrasonic vibrations was $2,800. The ducks, which were sent to the Philadelphia Zoo to recuperate, never did regain waterproof plumage (Griswold, 1969).

A circular of the Royal Society for Prevention of Cruelty to Animals (1967), gives the following instructions:

1. As soon as rescued, the bird should be covered with a cloth "poncho" to prevent preening, conserve body heat, and absorb some of the oil.

2. Weak or hypothermic birds should be killed.

3. Remove oil by immersing bird in sulphonated castor oil for a few seconds, then massage the oil into the plumage, followed by a rinse in warm water.

4. Place in a warm dry atmosphere for at least 2 days.

5. Feed with saline-dipped fish.

6. Spray birds twice daily with sea water or salt solution or allow to bathe.

A report on rehabilitation by this method notes that the plumage, upon losing its waterproofing quality, recovers it only after the next molt. It states that (in guillemots) the entire molt took 6 weeks. Tremalon was considered the best detergent. It was very effective and nonirritant.

Beer (1968b), describing efforts made to rehabilitate sea birds after the Torrey Canyon disaster, noted that Tremalon B, a cosmetic cleaning agent (mascara remover) was relatively easy to use, removed all oil stains, did not affect the eyes, and did not cause dermatitis. However, the cleaning process took a long time and, like others, left the bird without waterproofing.

Coté (1968) listed detergents used in cleaning oiled brown pelicans in Puerto Rico. Waterless Hand Cleaner, Magnus Brand, sold locally by Soilax International, C. A., took the oil out of feathers and at the same time left a lanolin base that protected the feathers. Clensol, a non-detergent, nontoxic liquid used at a rate of 1 kilo per 100 quarts of warm water is a Dutch product and one of the few permitted by the Dutch Humane Society to be used in cleaning oiled birds. It was handled locally by Salles Company. Cleaner Spray, Formula 409, is a nontoxic spray which agglutinates petroleum and is produced by Wilson Harel and Company, 50 West State Street, Westport, Connecticut. The success Coté had in cleaning the pelicans with these agents and in rehabilitating the birds afterwards was not mentioned.

Stanton (1969) described what was considered a successful operation in cleaning oil from sea ducks in Massachusetts. The oil came from an Esso-Colon tanker wrecked off the Massachusetts coast in January 1968. On the basis of his experience, he reçommended that oiled birds be cleaned immediately after recovery with Polycomplex A-11 distributed by Oceanwide Industries, Inc., 50 Elm Street, Huntington, New York 11743. As much oil as possible should be removed in the beginning. The chemical is usually mixed in proportions of 1 part Polycomplex to 100 parts water. By dipping the waterfowl in the solution and swishing and working it through the feathers, most birds can be cleaned in 2 or 3 minutes.

Reese (1969) summarized the results of efforts to rehabilitate seabirds affected by oil from the same wrecked tanker off the Massachusetts coast. A total of 1,000 birds were affected; 95 percent of these were eiders, and the remainder were goldeneyes, scoters, and loons. More than 400 waterfowl were salvaged and divided between the Angel Memorial Hospital of the Massachusetts Society for the Prevention of Cruelty to Animals, and Mr. Philip Stanton, Framingham State Teachers College, for rehabilitation. Mortality among the birds was high during transportation to the rescue stations and during early treatment, and the number was reduced to about 135 during the first 4 months of the rehabilitation effort. The cleaning at both stations was the same as that described by Stanton above, with Polycomplex A-11. The cleaning operation at the animal hospital was under the direction of the administrator, Paul W. Gilpin, and involved 13 nurses, 20 ward attendants, 2 job corps workers, 6 incidentals, and 3 veterinarians including Dr. Margaret L. Petrak, a bird specialist. No report is yet available on the details of the cleaning operation at the hospital. It is known that about a year after these operations began, 50 eiders, rehabilitated at the hospital and by Stanton, were released and behaved like normal ducks. Although there is no evidence that waterproof conditions had been restored to the old feathers, the birds had gone through the annual molt and so had acquired new, presumably waterproof, feathers before release.

MacDonald (1969) described an operation in which the method described by Stanton (1969) and Reese (1969) was used on birds contaminated by the Santa Barbara, California, oil well leak. Loons, grebes, cormorants, and sea ducks each had a pat of butter forced down its throat to clean it out before receiving a bath of Polycomplex A-11. They were given a warm place to sit and pieces of fish to eat.

Hendrick (1969), describing the same event, referred to rehabilitation activities at the Santa Barbara Childes Estate Zoo. Ted McToldridge, curator and administrator of the zoo, announced that the staff would use Polycomplex A-11, developed by Dr. Alfred R. Globus, president of the Guardian Chemical Corporation, Long Island City, New York, and tested by the American Association of Zoological Parks and Aquariums. Chemists called it a complexing agent because it is different from solvents, emulsifiers, or their combinations. It is described as causing oil to flow away from anything it might otherwise cling to or clog.

Hemphill (1969) has supplied the most detailed account of the cooperative attempt to rehabilitate birds that became oiled off Santa Barbara. One treating station at Carpenteria State Park, California, was operated by Union Oil Company personnel. The other treating station was at the A. Childes Estate Zoo. All together 1,731 oiled birds were treated, including cormorants, pelicans, loons, grebes, sea ducks, and shorebirds.

Polycomplex A-11 was agreed upon for joint use primarily because it had been used "successfully" on sea ducks in Massachusetts as described by Stanton (1969) and Reese (1969). The treatment effectively removed the oil and appeared to be nonirritating to the skin and nontoxic. Birds showing symptoms of toxicity to the oil by trembling or excessive weakness were not cleaned until the symptoms abated. They were kept warm and quiet while waiting for sufficient improvement for cleaning.

The concentrated Polycomplex A-11 was applied manually to loosen heavy accumulations of oil, then a bird was scrubbed quickly but as gently as possible in warm water containing 1 percent Polycomplex to remove remaining oil. After oil removal, the bird was rinsed thoroughly under the tap and toweled dry. Less contaminated birds were washed in a dilute solution of the Polycomplex followed by rinsing and drying. Although no irritation of the skin occurred, grebes whose heads were immersed in the washing solution showed severe inflamation of the eyes. The polycomplex was effective in removing heavy coatings of fresh oil but not dry tarry deposits. Feathers coated with the latter were clipped with scissors. This washing procedure was believed "undoubtedly" to have removed natural oil from the feathers, but no evidence was given. Also the feather conformation was believed to have been "obviously altered although microscopic examinations were not made."

Attempts were also made to clean Santa Barbara oil victims with ultrasonic devices described above by Brown (1968). This proved to be more time consuming and less effective than manual washing.

Odham (1968) developed Larodan 127, a 3-component cleaning agent said to clean and waterproof in one operation. It consists of surface active monoglyceride crystals, Pur-cellin, and water. Its action is comparable to that of car waxes, which remove oil at the same time they redeposit wax (Clark and Kennedy, 1968).

Griner (1970) found Larodan inferior to Polycomplex A-11 for cleaning oil from mallard plumage, and it was not quite as effective in restoring waterproof qualities to the plumage as a 1-percent mixture of lanolin in water following cleaning with Polycomplex. However, neither method achieved the reconditioning of feather structure necessary for complete waterproofing.

Rapid restoration of waterproofing is the crux of the whole problem of rehabilitating oiled birds. Experience shows that birds have to be kept for many months before this is achieved. Beer (1968b), referring to Rijke (1968), noted that for a feather to be waterproof, its components must have a regular structure and a water-repellent surface. It is possible that, as in some plants, a micro-rough surface is needed for strong water repelling (Amsden and Lewins, 1966; Hartung, 1969). Handling and cleaning disarrange feathers and probably damage their fine structure. Even if a bird is able to preen its feathers back into a reasonable shape, they are not fully waterproof until the water-repellent substances in or on the kerotin of the feathers is replaced. The preen gland produces secretions which contain a great variety of ester waxes (Odham, 1967). Commercial ester waxes (Pur-cellin) sprayed in aerosol form onto the feathers improved waterproofing temporarily. Too large a dose clogs the feathers and the value of these waxes is largely lost. Hartung (1969) suggests the removal of petroleum oils with nonpolar solvents of low toxicity (Hexane for instance) and the temporary replacement of natural feather waxes with very low concentrations (100 ppm for example) of a substitute wax such as spermaceti applied in hexane.

Clark and Kennedy (1968) noted that the process of repelling water by the plumage is a complex one and many factors may be involved. Although the factors are inseparable, they may be considered under two categories: The role of the preen gland, and the structure of the feathers as they relate to water repellency.

The function of the preen gland is unknown; it may be different in different species. It is important to determine in detail the function of this gland in the species concerned and particularly its relation to water repellency by plumage. In Anatidae the secretions of the preen gland were found by Odham (1967) to consist of wax esters of fatty acids, the exact composition being different in different species.

Rutschke (1960) asserts that preen gland oil serves exclusively to keep feathers smooth and flexible and that water repellency is conferred by feather structure. Ducks from which the preen gland was removed avoided water only after feather structure began to fail and the feathers became rough and inflexible. Feathers defatted with ether and alcohol were as water repellent as normal feathers. Rutschke assumed that all preen oil had been removed, but this may not have been the case. Clark and Kennedy (1968) believe that study of the preen gland is highly relevant to rehabilitation. It is likely that oiling, treatment with detergents, and captivity have deleterious effects on the preen gland, and its histology after treatment should be studied. It would be worthwhile to measure the amount of preen oil on the feathers after removal of the foreign oil and correlate this amount with degree of water repellency. Work must be done to determine exactly how natural water repellency is achieved before much hope can be held for reproducing it artificially.

The structure of the feathers (arrangement of the barbules) is strikingly similar in water birds irrespective of phylogenetic relationship. This would argue that water repellency is structural rather than a product of preen gland secretions. Hartung (1969) believes this to be the case. It is possible that the barbule hooklets of oiled birds are damaged both by the method of oil removal and by the subsequent excessive preening by the bird. This damage may be irreversible, and correction may be possible only by growing new feathers.

The conclusion gained from all of these experiments is that oil of varying sorts can be cleaned from the plumage of birds with several kinds of cleaners, but so far there is no convincing evidence that the natural water repelling qualities can be restored to the cleaned feathers by known methods.

TOXICOLOGICAL AND PHYSIOLOGICAL EFFECTS OF OIL AND RELATED STRESSES ON BIRDS

Among the serious problems involved in rehabilitating water birds incapacitated by becoming contaminated with floating oil are those related to health which are many and diverse. A very special group of pathological effects, not ordinarily encountered in avicultural practices, are met at the outset of the salvaging process. These are the toxic effects of the oil itself, and the debilitation from exposure to cold after oil-soaked plumage loses its insulating qualities.

Determining the effects of oil toxicity is a major problem because of the great chemical differences between commercial crude oils and between various refined fractions. Treatment of toxic conditions is therefore likely to be a complex problem.

It is known that industrial emulsifiers used to disperse oil slicks are far more toxic to fish and marine life than the oil itself. Clark and Kennedy (1968) found that emulsifiers are important to birds in three ways: (1) they may cause a loss of food supplies and an alteration of habitat; (2) they may have a direct toxic effect on the oiled bird; and (3) they may concentrate birds which come to eat fish and invertebrates affected by the treatment; such food may possibly have long-term effects. Herring gulls were seen feeding on marine life killed by the emulsifier at Cornwall, and there were indications of delayed and unsuccessful breeding. Also, the emulsifier may affect a bird's taste buds. This may render the bird incapable of distinguishing between edible and nonedible material. Because of these toxic effects, Clark and Kennedy also advised against use of emulsifiers, such as detergents, in the removal of oil from a bird's plumage.

Beer (1968b) found that alcids brought in for removal of oil are usually already in poor physical condition. They preen and ingest oil which damages the gut, and this effect is worsened by the surfactants used to disperse oil. Waterproofing and insulating qualities of the plumage are mostly lost, and body temperature tends to fall. To maintain body temperature birds should increase food intake, but instead they spend a disproportionate amount of time preening (Hawkes, 1961). They therefore become emaciated.

Hartung (1967) showed experimentally that energy metabolism of oiled ducks increases markedly to make up for extra heat loss from destruction of feather structure. As it would require twice the normal food intake to maintain this rate of metabolism, their body fats are used up instead. Only if internal damage is not severe and body fats are still present may a bird survive.

Hartung and Hart (1966) showed that many internal organs are affected by certain kinds of oil. Enlarged adrenals indicated stress conditions. The lethal dose of oil was lower for birds additionally stressed by overcrowding and cold.

Beer (1968a and 1968b) described mortality and postmortem findings on alcids salvaged from the Torrey Canyon oil spill. The rate of loss of the birds followed approximately an exponential curve and could be divided into four phases.

Phase 1 (94 live birds, 14 deaths, mean mortality rate 20 percent per day) was the day of a 200 mile journey by truck from the Cornish Centers to Slimbridge, England. The journey placed additional stress on the sick birds.

Phase 2 (80 live birds, 33 deaths, 13 percent per day) lasted from arrival at Slimbridge to the fourth day when half the original birds had died. Effects were similar to those of phase 1; birds emaciated, gut severely affected by enteritis, with coagulative necrosis and hemorrhage in many cases. The lungs were often congested and the air-sacs were clouded. Gross renal changes were more frequent in phase 2.

Phase 3 (47 live birds, 11 deaths, 1.4 percent per day) lasted from the fourth day until 3 weeks, and was characterized by a transition from the acute condition of phase 1 and 2 to the chronic condition of phase 4.

Phase 4 (36 live birds, 25 deaths, 0.4 percent per day) started at 3 weeks and terminated at 28 weeks when most of the survivors were released. The acute enteric conditions were no longer important, but aspergillosis, a secondary condition arising from stress and debilitation, predominated. Another serious disease was infective arthritis. Since the feet and ankles of alcids are not adapted to long periods on land, their skin became calloused and cracked by contact with hard surfaces, while the joints developed arthritis, often becoming infected with staphylococcus and other bacterial organisms. Renal disease was common, reflecting stress and early toxic effects of oil and detergents.

Infrared heating was provided by Beer (1968b) to reduce chilling and resultant respiratory conditions. Scott's Emulsion was given for 6 weeks to treat toxic effects of oil and detergents on the gut, and neomycin liquid was given for a week to control bacterial invasion of the gut wall (100 cc and 10 cc/3 kg of fish respectively). At one station an intestinal disinfectant, Dianimal, was used.

Beer found that aspergillosis cannot be successfully treated. However, the use of Erosan 125 or Polysan as general disinfectans or in aerosol form can reduce the number of fungal spores and improve the birds' chances of avoiding the disease.

This investigator also found that prevention of arthritis presents a serious problem and ideal flooring for auks has yet to be devised. The best at present is Weldmesh with a soft plastic coating. If, despite general hygienic measures, the ankle joints became infected, Ampcillin, 1/2 ml on each of 2 days, was injected intramuscularly. If tests showed staphylococci to be resistant, streptomycin (Dimycin) was also used. When the webs were involved, antibiotic powders and antiseptic creams were rubbed into the lesions.

Hunt (1957) reported that 3 ducks, oiled experimentally with an aromatic oil, died during the period from 2 to 9 days after treatment, apparently from toxic properties of the oil. Hartung (1963) found that two mallards which were fed 2 grams of high pressure cutting oil per kg of body weight showed highly significant reduction of mobility (about 50 percent) accompanied by diarrhea, loss of balance, and muscular coordination and some tremors. Both recovered after about 10 days. Twenty-four ducks killed by oil on the Detroit River had digestive tracts mostly free of food. Linings of gizzards of many were stained dark. Intestines were frequently hyperemic and hemorrhagic, and lumens were frequently filled with scattered amounts of a dark tarry substance identified as blood. In other cases lumens were filled with mucoid material. Livers, kidneys, spleens, and gall bladders were frequently enlarged. The livers of all experimental ducks and one control showed fatty degeneration.

Hartung and Hunt (1966) reported that industrial oils ingested by several kinds of ducks caused lipid pneumonia, gastrointestinal irritation, fatty livers, and adrenal cortical hyperplasia. Ingestion of cutting oil and diesel oil also resulted in acinar atrophy of the pancreas, toxic nephrosis in some of the birds, and inhibition of cholinesterase activity. Diesel oil depressed cholinesterase activity slightly. Gross study of ducks killed by oil in the wild indicated that they died from the same causes as in the laboratory.

In discussing Hartung and Hunt's (1966) experiments with toxicity of oils fed to lesser scaups, Clark and Kennedy (1968) pointed out that the experimental oils were unweathered, having retained the volatile toxic elements that are lost by oils on the sea (Pilpel, 1968; Smith, 1968). However, added stress in the wild might increase susceptibility to toxins over that under laboratory conditions.

The importance of knowing what kinds of oil are involved before predicting toxic effects was pointed out by Griner (1970) who found that the crude oil which escaped in the Santa Barbara, California, oil well leak was not toxic to mallards.

Clark and Kennedy (1968) noted that salt metabolism presents extremely complicated and difficult problems in the rehabilitation of oiled seabirds. Stressed birds, particularly in captivity, are likely to suffer salt deficiency.

Stress, which is inevitable in oiled birds, results in so many physiological modifications that it must be regarded as a disease in itself and measures must be taken to reduce it and counter its effects. Stressed and debilitated birds have low resistance to secondary diseases. Overcrowding is a well-known stressor in both wild and captive mammals and probably also in many birds. Tranquillizing drugs such as Librium have not been given to captive birds.

Behavior problems, particularly of sea birds, caused by the stresses of captivity are little known. Overcrowding is thought to aggravate these problems, and separation of the captives into small groups is recommended.

Several first aid measures would allow oiled birds to reach rehabilitation centers in better shape than hitherto: (1) rescue birds from the sea at as early a stage as possible, preventing death from exposure or drowning; (2) take measures to restrict damage to the gut from ingested oil and weakening of the birds by a rapid loss of body fat and other food reserves; and (3) experiment with tranquilizers to reduce stress and with energy-rich liquid foods that can be easily assimilated. Anything that would shorten the period of rehabilitation would reduce expense and the chance of secondary complications such as diseases.

Clark and Kennedy (1968) concluded, from a comparison of all accounts of rehabilitation, that although varying in detail three matters of great importance to the birds are warmth, reduction of stress, and prevention of oil ingestion. Nevertheless, attempts to mitigate these problems invariably have been disappointing, and the majority of the birds have died. As in so many other aspects of this problem, progress is hampered by the acute lack of information about the normal condition of the birds. Many more postmortems of oil-soaked birds are needed, but these must be complemented with histological work on both normal and oiled birds. The changes in physiology that lead to death are relatively unknown, and they are of great importance. No real progress can be expected unless a systematic study is made of the pathology of oiled birds and this means also a study of the normal bird.

Curing oiled birds of the original toxic effects of ingested oil and of the ills developing from rehabilitation is basic to the success of any salvage effort and must be perfected for each species concerned. Much information is already in the literature on this subject.

CARE OF CLEANED OILED BIRDS

Many problems which arise in the process of rehabilitating oiled birds stem from taxonomic differences. Although having the common characteristic of spending considerable time on the surface of the open ocean, the species involved represent several orders of birds and they, therefore, vary in physiology, behavior, and morphology. The orders represented are the Gaviiformes including the loon family, the Podiciformes including the grebe family, the Pelicaniformes including the pelicans, gannets, and cormorants, the Anseriformes including the swans, geese, and ducks, and the Charadriiformes including the shorebirds, gulls, and alcids. Different methods of feeding, housing, and other procedures are required to restore this variety of species to the health and energy necessary for survival in the wild when released.

Beer (1968b) experimented with rehabilitating birds cleaned after oiling by the Torrey Canyon incident. After removal of oil, the birds were partly dried with absorbent material and then placed in a small pen with a hot-air fan. When completely dry they were transferred to a larger pen.

Alcids and cormorants were fed sprats or sand eels and often required force-feeding at first. Birds were housed in concrete pens containing covered heated areas fitted with raised wire-mesh floors. Outside the covered area was a small freshwater pond for bathing. Washing and preening by the birds often had to be stimulated by giving them showers with a hose on warmer days. The floors were regularly hosed down and periodically disinfected with Erasan 125, a disinfectant with a very low avian toxicity. In summer the survivors were transferred to a larger grassed pen with a covered heated area having a raised floor of plastic-coated half-inch weldmesh. In the open part was an oval freshwater pond 12 by 8 feet by 20 inches deep.

Artificial cliffs were constructed of blocks covered with Softboard and Polythene sheeting to reduce leg and wing abrasion in alcids and cormorants.

Initially birds were fed sliced coley fish but after 2 weeks they were given thawed sprats that were deep-frozen in a 3.5 percent weight-to-volume solution of sea salt. Every effort was made to keep food fresh. Even hungry birds refused tainted fish. Cormorants ate sprats for 3 weeks but ignored them when they learned to take live eels from the pond.

Supplements were added to food to compensate for probable deficiencies in the diet. Vitamins A and D (Scott's Emulsion), B (in Abidec), and B_{12} (Cytacon) were initially added to the fish, but later it was found easier to place a capsule inside the sprat. In this manner each bird received daily three quarters of a gram of Bloom, a multivitamin and mineral food supplement with additional vitamins, B_2 and B_{12}.

Stanton (1969), as a result of experience in rehabilitating oiled ducks in Massachusetts, made the following recommendations for general care. Place cleaned birds in a dry roomy area not much warmer than 60°. Cover the floor with 4 inches of Serval (crushed sugarcane) to avoid Aspergillosis spores prevalent in straw. Include one heat-lamp brooder for every eight birds in the enclosure. The hot spot under the heat lamp should be from 85° to 90°F. Birds should be able to leave the heated area at will.

Water should be supplied during the first 2 weeks for drinking only. Waterers should be covered with grates allowing birds to drink but not immerse. After 2 weeks, shallow pans or ramped swimming pools should be supplied.

Stanton found that a preferred food of eiders was Gamebird Chow (pelleted form) and Trout Chow (Purina Developer), but that after a few months in captivity eiders ate almost any type of game-bird feed. The first choice of scoters was Trout Chow (Purina Developer). Second choice was soaked dog biscuit and chopped lettuce (very messy). Scaup and goldeneyes desired 100 percent Trout Chow at first, then game-bird chows and grains could be supplemented. For dabbling ducks (black ducks, mallards, pintails, teal, etc.) game-bird chows, green feed, corn, and other grain were satisfactory.

It is necessary to provide grit and crushed oystershells mixed with food for all types of waterfowl.

For general medical treatment, Stanton offered the following suggestions. For clouded or milky eyes, listlessness, lightness of body, and lack of appetite, give one 126-mg capsule of terramycin every 12 hours until the condition improves (watch droppings because treatment may cause diarrhea). For dry legs and feet or lameness, use A and D Ointment (White Laboratories, Inc., Kennelworth, N. J.) until normal condition returns. This treatment seems to improve frostbitten areas of legs and feet also.

Hemphill (1969) reported that the procedure used at the rehabilitation centers in Santa Barbara, California, was adopted from Philip Stanton's experience at Framingham, Massachusetts, (see above recommendations).

Birds were each force-fed a small amount of butter followed by 2 drops of liquid vitamin concentrate (Avitron) and one or two small fish (smelt). Later in the program, milk of magnesia or codliver oil was administered in lieu of butter to clean out the intestine and alleviate gastrointestinal disturbance caused by ingested oil. The vitamin supplement and fish were given to help the birds regain strength and overcome the effects of exposure and shock.

Following washing and feeding, birds were placed in pens in a house trailer. Pens at Childes Estate were warmed with ordinary heat lamps suspended over the birds so that they could seek an optimum temperature themselves. At Carpenteria, the trailer house was heated by a small forced-air furnace which produced a more uniform heat.

Food (usually smelt) and water were available at all times. Granulated cornmeal was used as litter in the pens to avoid contamination of food which fell on the floor and was subsequently eaten.

As indoor areas became crowded, the healthier birds were moved to outside pens approximately 18 by 8 feet in size with frames constructed from 2 by 4-inch lumber and covered with 1-inch mesh chicken wire. Three sides and the top were also covered with transparent plastic sheeting. The bottoms of the pens were covered with gravel, clumps of sod with long grass, or artificial mats resembling grass. Some of the pens were constructed with woven-wire bottoms to allow passage of droppings and debris.

An arthritic condition in legs and feet of scoters and grebes was noted, particularly in birds kept in wire-bottomed pens. A and D Ointment (containing vitamins A and D) was applied for this disorder. Heat lamps were used in all outdoor pens. Fresh water was supplied in long, shallow pans, poultry feeders, or sunken plastic tubs. Perches fashioned from tree trunks or limbs were supplied for cormorants.

Fish, mainly smelts and Pacific mackerel, was the principle food, supplied generally twice or three times a day. Pelicans and cormorants received mackerel up to 8 inches long. Grebes, loons, mergansers, and scoters received smelt. Murres preferred small chopped pieces of smelt. Australian crickets, a common zoo food that is commercially available, were also supplied. Trout Chow was given to scoters and mergansers, which accepted it but did not seem to prefer it to fish.

Routine maintainence included frequent water changes and removal of uneaten food and debris. Removal of waste was difficult on gravel.

No diseases were noted during the entire incident.

It was thought that birds might be suffering from the effects of thiaminase, so Pacific mackerel were obtained since they do not contain this enzyme which is present in smelts. That thiaminase might be toxic to certain species of birds was suggested by Naviaux (1969). He experimented with powdered thiamine sprinkled on the smelts fed to birds in an attempt to counteract the effects of the enzyme (thiaminase). Analysis of these results is not yet available.

A few attempts were made to replace natural oils of feathers with mineral oil and olive oil, but no satisfactory results were achieved.

Dampening the feathers 3 or 4 times daily was attempted to induce preening to help restore natural oils and conformation of feathers. Birds immersed in water died of exposure, while those sprinkled with a fine spray apparently were not hurt. Results of experiments were inconclusive because they were not continued long enough.

It was concluded from the rehabilitation work in the Santa Barbara area that the very large requirements of manpower and facilities made the operation impractical. The restoration of natural oils and natural structure of the feathers was not achieved. Development of an arthritic condition of the legs and feet from the abnormal substrate complicated rehabilitation. The implication was that the operation was not successful.

Van Weelden (1968), commenting on the Massachusetts operation by Stanton and the Massachusetts Society for the Prevention of Cruelty to Animals, said that losses appeared to follow paralysis of the feet and legs of birds treated by the MSPCA. He said that paralysis occurred also among those birds treated by Stanton but they recovered. This difference in results indicates that the MSPCA treatment may have been different from that recommended by Stanton (1969). Van Weelden (1969), in commenting further on the Massachusetts operations, noted that eiders under treatment molted, but somewhat later than usual. He observed that ducks released after a year in captivity appeared to have normal buoyancy on the water.

Griner (1970), after working on rehabilitation of experimentally oiled mallards, concluded that loss of body heat from deranged plumage may not be harmful if sufficient food intake can be maintained to supply the energy requirements of metabolism. He also believed that heat supplied artificially might do more harm than good by encouraging development of infections.

Clark and Kennedy (1968) believe that the key to success in holding birds in captivity for postcleaning treatment must be reduction in stress and the likelihood of infection, and an increase in nutritional intake. For alcids this means much better avicultural methods than we have at present.

Metabolic rate and heat production are controlled chiefly by thyroxin, perhaps acting synergistically with adrenalin. The thyroxin requirement is high over long periods of cold exposure, and thyroid is essential in both birds and mammals for survival at low temperatures. If heat loss is sustained for a long time the birds may ultimately suffer from thyroid exhaustion. Evidence suggests that nutritional reserves rather than hormones ultimately determine the animal's resistance to prolonged cold stress. It is essential to build up the fat reserves in birds before release, but we still need to know more about the manipulation of hormone administration with diet. The normal diets of species principally affected by oil are fairly well known, so presumably food supplied in captivity should reproduce as closely as possible natural diet supplemented with various additives such as vitamins and essential minerals. Alcids and penguins may be quite choosy about the kinds of fish they eat. Ducks are fed successfully with commercially available food pellets for turkeys and chickens. Evidence points to the likelihood of a vitamin A deficiency in oiled birds. The value of comprehensive liquid foods, such as Nutrasol and Complan, in these feeding problems is worth investigating.

Aside from the special pathological problems resulting from the initial poisoning and exposure, soiling of the feathers by the oil, and the problem of restoring waterproofing to the plumage, the problems involved in the care of cleaned oiled birds are largely avicultural. Their difficulty depends on the reactions of different species of birds to captive conditions and the knowledge of the aviculturist about the requirements of any one species in captivity. Concerning these problems aviculturists and zoo personnel of the world have an expertise which can be tapped.

It has been stated by persons with experience that the difficulties of rehabilitating oiled birds appear insurmountable (Beer, 1968b; Griswold, 1969). The chief difficulty is the adequate restoration of the essential waterproof condition of plumage that has been cleaned after becoming oiled.

Beer (1968b), who had extensive experience with attempting to rehabilitate bird victims of the Torrey Canyon oil spill in England, said that despite cleaning, preening, and the application of waxes, full waterproofing is not often regained until a new set of feathers has been grown. This may not happen for a long time after cleaning. Meanwhile, the birds are likely to die of conditions resulting from captivity. It was Beer's opinion that anything that hastens the molt would be very helpful in rehabilitation. On the theory that photoperiod is involved in molt, he subjected alcids being treated at The Wildfowl Trust to artificial light at night to simulate 24-hour daylight. This was continued until mid-June, when the total light was reduced by 1 hour a week until the end of July. Comparison with untreated birds suggested that molt was only slightly advanced by the light treatment. Beer suggested that another approach might be to use hormones or drugs such as the commercial product ICI33828 which was shown by Sykes (1964) to stimulate and shorten the molt period in chickens.

King and Farner (1961) said that the well-known association of molt and increased thyroid activity and especially the ability of certain thyroid-active preparations to induce molt (Maqsood, 1952) suggest that molt and increased metabolic rate are not necessarily associated in cause and effect relation, but may have a common basis in thyroid function.

Höhn (1950, 1961) gave considerable evidence of the relation between thyroid gland secretion and molt in some species of birds. Höhn (1950) found that a period of increased thyroid activity precedes the annual molt. This has been observed in several species of birds; in chickens, it is indicated by increased metabolism before the molt. The association is particularly convincing in the mallard, where increased thyroid activity occurs about a month earlier in males than in females. Male mallards have their main molt about a month earlier than females.

Höhn (1961) wrote that considerable experimental work has been done on the hormonal factors which can induce molting out of season in domestic fowl. He pointed out that the main facts relating to this species are as follows:

(1) Thyroid hormone injected, given in food in the form of a thyroid gland powder, or administered after stimulation of the thyroid, as the pituitary TSH, produces a striking molt.

(2) Progesterone injections produce a molt and simultaneously depress the gonads.

All other induced physiological effects which produce molt suggest a common causative factor, namely, inhibition or reduction of pituitary gonadotropic hormone secretion.

The role of the thyroid is twofold: (a) At rather high levels it inhibits pituitary gonadotropic activity. (b) It is required for the stimulation of the growth of new feathers, an essential factor in the molting mechanism. Different species of birds react differently to hormonal stimuli. Pituitary gonadotropics induce a molt in the mallard. Thyroid or TSH promotes molt in quail and greenfinch but not in mallard, house sparrow, crow, or herring gull.

In the herring gull, androgens can induce a premature molt from juvenal into adult plumage. Unseasonal molts can be brought about by exposure to increased or decreased daily periods of illumination (which, incidentally, cause gonadal stimulation or regression).

If, as suggested by experiments, a reduction of gonadal hormone secretion, generally brought about by pituitary inhibition, is involved in the main summer molt, its repression until reproduction is completed may be due to the molt-suppressing effect of prolactin secreted during the period of brooding eggs or young.

Farner (1955) found that, with the lengthening photoperiod in the spring, the activated pituitary appears to influence the development of favorable metabolic balance and quite possibly regulates the ways in which excess energy is used. Also, it begins to exert a gonadotropic effect. There is possibly also an increase in thyroid activity which may be associated with the prenuptial molt.

Farner (1969) warned that although the best controlled experiments suggest that there is no change in thyroid activity before and during the molt, this is not to say that the thyroid is unnecessary. Clearly thyroid hormone is required for normal development of feathers. It is true also that the use of thyroid hormone, perhaps in pharmacologic doses, will induce molt and might hold out some promise in rehabilitating oiled birds. In this connection, energy reserve is very important not only for synthesis of proteins but also for the extra energy required for thermoregulation.

Clark and Kennedy (1968), in summarizing studies of molt, point out that molting is a severe strain on birds. The metabolic rates of buntings and chaffinches rise to about 25 percent above normal during molt. It is thought that molt and increased metabolic rate have a common basis in increased thyroid function, and it may be feasible to induce molt by thyroxin administration. If thyroxin is administered to normal birds, barbule formation becomes excessive (Höhn 1950). This may be advantageous for waterproofing. Thyroid administration in certain birds can bring about a striking unseasonal molt, probably by increasing metabolic rate, by causing papillal mitosis in the feather germs, and by increasing the proliferation of feather germ mitochondria. The latent period of a thyroid-induced molt is 5 to 7 days, and intensity of molt depends on dosage. Thyroxin acts selectively, causing molting of the body feathers but not of head, neck, wings, and tail to any marked degree.

Sex hormones inhibit molt, and the following substances induce molt by inhibiting the gonads: anheptin, progesterone, mammalian growth hormone, and high levels of thyroxin.

Since the only cases where birds cleaned of oil have apparently been successfully returned to the wild are those in which the birds had been held in captivity through the annual molt (Beer, 1968b; Reese, 1969; Van Weeldon, 1969), it is believed that the inducement of a premature molt might be the most effective way of rehabilitating victims of oiling. Efforts to clean feathers of oiled birds in such a way as to prevent the loss of waterproofing qualities of the plumage and to restore waterproofing qualities that have been lost in the cleaning processes have been unsuccessful so far. J. V. Beer (1968b), a leading and experienced experimenter in this field, seems quite pessimistic about the possibilities of restoring waterproofing to cleaned plumage. A leading zoo aviculturist who has had experience with rehabilitating oiled birds (Griswold, 1969) also believes that it is probably impossible to rewaterproof a bird's feather once it has been fouled with oil, and that inducement of premature molt is the best hope for successful rehabilitation of these victims.

Donald Farner, a leading student of bird physiology, has told me that, despite the above work, the phenomenon of molt is the least known of all physiological events in the annual life cycle of birds. A thoroughgoing approach to the study, involving a number of endocrine and metabolism manipulations, seems to be indicated if success is to be achieved.

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