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Effects of a Chemical Dispersant and Crude Oil on Breeding Ducks

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Large numbers of aquatic birds are killed each year by oil spills (e.g., BOURNE 1968). Oil transferred from the plumage and feet of sub-lethally oiled birds to their eggs can cause a severe decrease in egg hatchability (GORDON 1929, RITTINGHAUS 1956), but the oil does not appear to affect nest attentiveness or nest and egg temperature (KING & LEFEVER 1979, ALBERS 1980). Chemical oil dispersants are used throughout most of the world to combat oil spills, but consideration for their use in United States territorial waters has only recently begun. Dispersant sprayed on oil from aircraft or boats causes oil to break into tiny particles that disperse into the water column. The oil particles are less likely to adhere to objects in the water than is undispersed surface oil. Wave action of the ocean helps keep the particles in suspension so that movement of the dispersed oil is reduced and physical and biological degredation are enhanced.

Several ocean tests of dispersants have been conducted in the United States during 1978-80 (McAULIFFE et al. 1980, 1981). These ocean tests and earlier experiments and tests (e.g., WELLS & DOE 1976, MACKAY et al. 1979) were designed to evaluate dispersant effectiveness, application procedures, and the effects of dispersants on marine aquatic organisms, but not the impact of dispersants on birds.

A widely used chemical oil dispersant, Corexit 9527 (Exxon Chemical Company U.S.A.) (Reference to trade names does not imply government endorsement of commerical products), when applied to the egg shell in small amounts (5 and 20 μl), is as toxic to mallard (*Anas platyrhynchos*) embryos as crude oil itself (ALBERS 1979). However, nothing is known about the effects of oil chemically dispersed in water on bird eggs or on the nesting behavior of breeding birds; nor is it known if dispersants can keep oil from adhering to birds. This study was conducted to evaluate the effects of Corexit 9527 and crude oil sprayed with Corexit 9527 on breeding mallard ducks.

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METHODS

Fifty-four pairs of 2-year-old mallard ducks were placed in outdoor pens (ALBERS, 1980) at the Patuxent Wildlife Research Center, Laurel, Maryland, in early February 1979. The pens were randomly divided into two groups of 14 pens each and two groups of 13 pens each. The ducks were fed commerical duck breeder pellets throughout the experiment.

Complete clutches of eggs were candled every other day to monitor embryonic development. During the first 10 days of incubation, usually day 5 or 6, infertile eggs and eggs with retarded development were removed and water in the troughs was converted to a 3% saltwater solution by use of a commerical marine salt mix. This conversion was done because Corexit 9527 is formulated for use in salt and brackish water. The water troughs in one group of pens received 100 ml of Prudhoe Bay (Alaska) crude oil per m^2 of water surface (107 gal/acre; a light to moderate oil spill). A second group of pens was treated with 100 ml of Prudhoe Bay crude oil per m^2 and then sprayed with 10 ml of dispersant per m^2 of water surface. One part dispersant was mixed with nine parts fresh water and applied with a pressurized sprayer. The water in the troughs was agitated with a stirring rod to maximize dispersion of the oil. A third group of pens received 10 ml of Corexit 9527 per m^2 of water surface. The fourth group of pens was an untreated control. Oil, dispersant, or the oil-dispersant mixture remained on the water for 48 hours, after which the troughs were drained, cleaned with petroleum ether and acetone, and refilled with fresh water. Water troughs in control pens were managed the same way. The 10:1 oil to dispersant ratio used was a compromise between the results of field tests (WELLS & DOE 1976, 3:1 diluted and 30:1 undiluted in cold water; GILL 1977, 8.5:1 diluted in warm water; SMITH & HOLLIDAY 1979, 10:1 diluted and undiluted) and the recommendations of the manufacturer (EXXON CHEMICAL COMPANY 1978, 10:1 through 50:1 diluted or undiluted).

Four control, five crude oil, five oil-dispersant, and five dispersant nests were monitored for nest and egg temperature. A thermocouple was placed in the wood shavings and straw beneath each clutch and another thermocouple was placed in the air cell of one of the eggs in each nest (ALBERS 1980). Probes were placed in nests and eggs the day before treatment and the probes were removed the day after the water troughs were drained and cleaned, a total of 4 days of monitoring. The egg containing the probe was removed from the clutch at this time, candled, and destroyed.

After the water troughs were cleaned, the females completed incubation and remained with their ducklings for 1 week. Eggs that did not hatch were opened and examined after the female moved the ducklings out of the nest box. Clutches of unhatched eggs were opened after 30 days of incubation.

TABLE 1

The effect on egg hatchability of exposing breeding mallard ducks to a water source contaminated with Prudhoe Bay crude oil, Corexit 9527 dispersant, or a crude oil-dispersant combination

					% of clutch alive		
						Significance	
Treatment	Clutches	Eggs used	Eggs hatched	% hatched	Mean %[a]	Overall[b]	Pairwise[c]
Control	13	181	164	90.6	91.8	0.006	1x2 = 0.003
Crude oil	13	166	83	50.0	42.3		1x3 = 0.076
Corexit 9527	14	177	142	80.2	81.9		1x4 = 0.026
Oil + Corexit	14	203	121	59.6	59.1		2x3 = 0.023
							2x4 = 0.453
							3x4 = 0.155

[a] Arcsine transformation for binomial proportions; mean of transformed percentages converted back to percent.

[b] One-way analysis of variance, significant when $P \leq 0.05$.

[c] t-test, significant when $P \leq 0.01$. Overall level of significance must be apportioned among the pairwise comparisons when the t-test is used in this manner; $0.05/6 = 0.0083$ or approximately 0.01 per comparison.

Percent hatching success, egg loss, and duckling survival were calculated for each clutch and then transformed with an arcsine transformation for binomial proportions (SNEDECOR & COCHRAN 1967). A one-way analysis of variance and *t*-tests were performed on the transformed data to detect differences among experimental groups. Two-way analysis of variance was used to evaluate clutch size and age of embryos at the time of oil treatment with respect to the presence or absence of temperature probes. Egg and nest temperatures among experimental groups were analyzed with one-way analysis of variance and Duncan's Multiple Range Test (DUNCAN 1955).

After the termination of the breeding study, we conducted a supplemental test to determine the adherence potential of crude oil sprayed with diluted Corexit 9527. Two female mallards were manually placed, one at a time, into water troughs containing salt water, crude oil on salt water, or crude oil sprayed with dispersant on salt water less than 1 min before the duck was placed in the trough. Each duck was then sacrificed and immersed in methylene chloride to remove the oil. Four procedural blank samples and two recovery samples were also taken. The recovery samples consisted of one duck wing treated with 100 μl of crude oil and one duck wing treated with a mixture of 100 μl oil, 10 μl Corexit 9527, and about 200 μl salt water. Each wing was immersed in methylene chloride. Procedural blank samples were taken by going through the oil extraction procedure, on two separate occasions, with the two sets of solvent containers and stainless steel funnels used for the ducks and duck wings. All samples were analyzed on a capillary gas chromatograph/mass spectrometer (30 m glass capillary, OV-101; Finnigan 3200 GC/MS) according to procedures established for quantifying hydrocarbons (GAY et al. 1980).

RESULTS

Crude oil treated with diluted Corexit 9527 never completely disappeared from the water surface and oil dispersed into the water column began to rise and coalesce into small surface patches within minutes of spraying. Consequently, ducks in the oil-dispersant pens had chemically dispersed oil in their troughs for less than 2 hours. The two ducks in the supplemental test that were placed on crude oil immediately after it was sprayed with dispersant were exposed to partially dispersed crude oil.

Oil was easily detected by sight and smell on ducks in some of the pens treated with crude oil and oil-dispersant. Four instances of abnormal incubation behavior were observed, one in each of the four groups.

Hatching success among the four groups was significantly different ($P \leq 0.05$, analysis of variance; Table 1). The hatchability of eggs in the control group was significantly greater ($P \leq 0.01$, t-test) than that of the crude oil group but not signficantly greater than the dispersant group or the oil-dispersant group. The difference in hatchability between control and oil-dispersant eggs was large and approached significance ($P = 0.026$), as was the difference between the dispersant and the crude oil nests ($P = 0.023$). The difference in hatchability between crude oil nests and oil-dispersant nests was not significant. Six females in the crude oil group and five females in the oil-dispersant group failed to hatch any of their eggs. The other females (seven for crude oil, nine for oil-dispersant) hatched 86% and 90% of their eggs. No female in the dispersant group or the control group failed completely; the controls hatched 91% of their eggs. This "all or nothing" result suggests that some females avoided the oiled water completely or contacted it only slightly during the 48-hour exposure period (ALBERS 1980; CUSTER & ALBERS 1980). Visual examinations of females after 30 days of incubation or when the young were 1 week old revealed obvious oil stains on females that failed completely and no oil or minor traces of oil on females that hatched some eggs.

Eggs were occasionally removed from nests by the adults. The percent of each clutch lost from this cause in the four groups (means: 2.9 - 9.8%) were compared by the method used for egg hatchability to determine if this phenomenon was affected by the treatment; differences among groups were not significant nor were any pairwise comparisons significant.

The percent of each duck brood dying before 1 week of age (means: 3.0 - 5.5%) were also compared by the method used for egg hatchability; no significant differences were found among groups or between pairs. No physical abnormalities were seen.

The presence of temperature probes in eggs and nest boxes did not adversely affect hatchability or the number of missing eggs. Seventy-six percent of the eggs in the 19 probed clutches hatched; 68% hatched in 35 unprobed clutches. Missing eggs made up 7% of the eggs used (eggs laid minus infertile and abnormal eggs) for both probed and unprobed clutches.

The number of eggs laid, number of eggs used, and age of embryos at the time of treatment were not significantly different ($P > 0.05$) among experimental groups nor between probed and unprobed clutches.

The incubation temperatures of the four experimental groups were compared for each day. Neither the daily means, minimums, maximums, ranges, or variances for egg or nest temperatures were significantly different ($p > 0.05$). Pairwise comparisons also failed to reveal differences ($P > 0.05$) among groups. The mean temperatures over the 4-day period were not significantly different ($P > 0.05$). Day and night temperatures for eggs and nests were not significantly different for any group ($P > 0.05$).

The chemical analysis of the solvent washings for 14 aliphatic and 12 aromatic hydrocarbons found in petroleum revealed that crude oil sprayed with diluted Corexit 9527 (10:1 oil to dispersant ratio) can adhere to birds. Combined aliphatic and combined aromatic hydrocarbons for the two ducks placed in dispersed crude oil were 76% and 79% of those for the two ducks placed in undispersed crude oil. Analysis of the procedural blanks and solvent washings from two control ducks indicated that there was very little contamination of the solvent containers and funnels, and naturally occurring hydrocarbons from the ducks were insignificant. Washings from the two duck wings treated with crude oil or crude oil mixed with dispersant in water (recovery samples) yielded similar quantities of aliphatic and aromatic hydrocarbons. Thus, partially dispersed crude oil can be extracted from bird feathers with the same efficiency as undispersed crude oil.

DISCUSSION

Recent studies have shown that diluted Corexit 9527 is much less effective at dispersing crude oil than undiluted Corexit 9527 (WELLS & HARRIS 1979, McAULIFFE et al. 1981) and that the effectiveness of chemical oil dispersants depends on many factors, some of which are still undergoing investigation (1981 OIL SPILL CONFERENCE). The failure of diluted Corexit 9527 to effectively disperse the crude oil in our water troughs means that we were not able to evaluate the effects of chemically dispersed oil on breeding mallards as intended, only the effects of a mixture of oil and dispersant.

If females without obvious oil stains after 30 days of incubation are eliminated from the crude oil and oil-dispersant groups, then the results indicate that the egg hatchability of both groups (0%) is significantly lower than that of the control (92%) but not different from each other. If the previously deleted females are retained (Table 1), because a visual examination cannot disprove the presence of some oil on a bird 30 days previously, then the egg hatchability of the oil-dispersant group (59%) is no longer significantly lower than that of the control but is still not significantly different from the crude oil group. We conclude that a crude oil-Corexit 9527 mixture will probably pose the same threat to eggs of nearby birds as will crude oil alone. The lack of any effect on egg hatchability caused by the sprayed Corexit 9527 alone supports this conclusion.

The absence of any differences among groups in general parental and incubation behavior, egg and nest temperatures, and duckling survival indicate that neither a light to moderate slick of undispersed oil or oil-Corexit 9527 mixture nor Corexit 9527 at a concentration up to 53 ppm in the water can be expected to reduce breeding success through behavioral alteration (see also ALBERS 1980). Incubating birds that are seriously oiled or physically ill from oil ingestion, particularly under less benign conditions than those existing in our pens, would undoubtedly exhibit reduced reproductive success, however. Greater quantities of dispersant than we used may be applied to oil slicks but it is doubtful that the average concentration in water would exceed the 53 ppm in our water troughs (CANEVARI & LINDBLOM 1976).

The supplemental test showed that bird oiling can be reduced by dispersing part of the surface oil into the water column. The 21-24% reduction in oil adhering to the two ducks placed on oiled water sprayed with dispersant was probably an approximation of the initial amount of oil dispersion. Ocean tests of aerially delivered dispersants have shown that dispersion of 50% or more of the oil is possible with proper application (McAULIFFE et al. 1980, 1981). A reduction in surface oil of this magnitude would probably reduce the amount of adult mortality from oiling and reduce the chances of endangering reproduction if the oil spill occurred in the spring.

The poor oil dispersion in our water troughs prevented us from determining whether chemically dispersed oil can adhere to bird feathers. This issue may be unimportant, however, because even if chemically dispersed oil particles adhere to plumage, the oiling that resulted from contact with water containing up to 41 ppm dispersed oil (McAULIFFE et al. 1981) would not be as bad as that resulting from contact with undispersed oil.

Effective chemical dispersion of surface oil may reduce the immediate danger to birds of direct oiling, egg oiling, and oil ingestion, but the remaining undispersed oil will still pose a threat. At present, it is not known whether a specific reduction in surface oil will result in a similar reduction in lethal and sublethal effects, nor is it known whether chemically dispersed oil poses a threat to bird habitat significantly different from that of undispersed oil.

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