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EFFECTS OF OIL ON AQUATIC BIRDS

Peter H. Albers

The lethal effect of spilled oil on seabirds was reported as early as 1910 (Bourne 1968). Large numbers of birds have since been killed or disabled by oil spills (National Academy of Sciences 1975), and the associated pathological conditions have been described (Hartung and Hunt 1966, Snyder et al. 1973). Birds that spend a great deal of time on the water, such as the Alcids and seaducks, are the most vulnerable to surface oil; birds that spend much of their time airborne, such as gulls and terns, are the least vulnerable (Bourne 1968, Vermeer and Anweiler 1975). The vulnerability of a given species to surface oil may vary seasonally according to breeding activities, migration, and feather molt. Although there are some cases where bird populations have apparently been severely reduced as a result of oil spillage, reliable population estimates for the affected species are usually scarce (Bourne 1968, Joensen 1972, and Vermeer 1976).

The plight of birds affected by oil spills attracts much public attention, but not more than 30 to 40 percent of the petroleum in the marine environment comes from accidental spills. Continual discharges from industrial plants, refineries, urban runoff, internal combustion engines, and natural oil seepage account for the remaining 60 to 70 percent (National Academy of Sciences 1975, Grossling 1976). Continual discharges from normal petroleum use are thought to account for an even greater proportion of the oil in inland waters (Grossling 1976). We have some evidence of the impact of direct mortality from oil spills on bird populations, but we know very little about the sublethal and indirect effects of oil on birds.

Research at the Patuxent Wildlife Research Center, Laurel, Maryland, is directed at (1) determining the effects of petroleum on the physiology and reproductive success of birds, and (2) developing the analytical methodology necessary for detection of petroleum in avian tissues.

PHYSIOLOGY

Physiological studies underway at Patuxent are evaluating the effects of petroleum on hepatic, cardiac, and renal functions. The effects of petroleum on hepatic function are under close scrutiny because the liver represents the primary site of detoxification and excretion of toxic compounds. Hartung and Hunt (1966) measured hepatic function of Pekin ducks (Anas platyrhynchos) 24 h after dosage with 3 to 24 ml/kg of diesel oil. They found dose-related evidence of liver damage and decreased liver function.

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Liver function is being monitored at Patuxent by the indocyanine green clearance technique. This technique is a sensitive measure of hepatic function in which removal of an injected dye from the blood is carried out entirely by the liver. In addition, tissue-specific enzymes that appear in the circulation because of organ damage are being measured, as well as triglyceride concentrations and cholesterol concentrations. For the past five months, mallard ducks (Anas platyrhynchos) have been fed a mixture of 10 aromatic hydrocarbons found in Southern Louisiana crude oil (SLC) at concentrations equivalent to the aromatic content of 2,500 and 25,000 ppm SLC. Preliminary results from this continuing study indicate that the ingestion of large amounts of aromatic hydrocarbons results in increased hepatic function with no biochemical evidence of cellular damage (Patton, unpublished data).

In another study at Patuxent, mallard ducklings were fed 250, 2500, 25,000, and 50,000 ppm of SLC mixed in feed. After 8 weeks, the body weights of ducklings fed 50,000 ppm of crude oil and the liver and spleen weights of ducklings fed 25,000 and 50,000 ppm of crude oil in feed were significantly different from those of the controls (Szaro, unpublished data) (Table 1). The increased liver size and decreased spleen size suggest hyperactivity of the liver and adrenal gland.

Table 1. Body, liver, and spleen weights of mallard ducklings fed Southern Louisiana crude oil from hatching until 8 weeks old

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Mean body weight after 8 weeks (g)</th>
<th>Mean liver weight (g)</th>
<th>Mean percent of body weight</th>
<th>Mean spleen weight (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>1118.5</td>
<td>34.5</td>
<td>3.2</td>
<td>0.81</td>
</tr>
<tr>
<td>250 ppm</td>
<td>1126.5</td>
<td>33.0</td>
<td>3.0</td>
<td>0.74</td>
</tr>
<tr>
<td>2500 ppm</td>
<td>1108.8</td>
<td>31.5</td>
<td>2.9</td>
<td>0.64</td>
</tr>
<tr>
<td>25,000 ppm</td>
<td>1069.1</td>
<td>51.4</td>
<td>4.8</td>
<td>0.39a</td>
</tr>
<tr>
<td>50,000 ppm</td>
<td>913.4a</td>
<td>69.7a</td>
<td>7.4</td>
<td>0.30a</td>
</tr>
</tbody>
</table>

* Different from the control (*P* < 0.05). Sample sizes: body weight, 50; liver and spleen weight, 10.

Waterfowl exposed to salt water increase the water taken in by the small intestine to compensate for osmotic water loss from tissues (Crocker and Holmes 1971). Crocker et al. (1974) used an *in vitro* system of sacs of small intestine and found that ducklings dosed with 0.2 ml of Santa Barbara crude oil prior to exposure to salt water failed to absorb water at a rate equal to undosed ducklings. Using similar techniques, they showed that the increase in intestinal water uptake that developed during prolonged exposure to salt water was abolished after a single dose of crude oil. Dr. Neil Holmes, University of California, Santa Barbara, has contracted with us to extend these studies with mallard ducks. Initially, his group will study electrolyte balance and adrenal hormone responses in mallards adapted to sea water and fed SLC in their food.
In addition to direct ingestion of oil through preening and drinking, petroleum may be transferred to birds in their food. Evidence indicates that petroleum is taken up, and at least partially eliminated, by a variety of invertebrates exposed to oil (Anderson 1975, Burns 1976, Corner et al. 1976, Fossato and Canzonier 1976). Nothing is known about the dynamics of accumulation and elimination of petroleum compounds by birds, however. After preliminary studies at Patuxent with several species of snails, clams, and crayfish, the crayfish (*Procambarus* spp.) was chosen as a food source for mallard ducks (Tarshis, personal communication). The crayfish will be exposed to petroleum-contaminated water before being fed to the ducks. Southern Louisiana crude containing $^{14}$C naphthalene will be used in an effort to establish the kinetics of oil transfer from water to invertebrate to duck.

**REPRODUCTION**

Aquatic birds nesting on the shore or in nearshore areas of oceans and lakes may be subject to high concentrations of petroleum from chronic urban and industrial runoff, oil tanker spills, and offshore drilling. Large numbers of birds at colonial nesting sites may be affected by a single oil spill. The low yearly reproductive potential of most marine birds means that recovery from a disastrous nesting season would be slow.

In addition to those birds that are killed by oil spills, many are presumably coated with sublethal amounts of petroleum. Gulls with oil spots on their plumage have been observed for up to 4 weeks after a major oil spill. Some of this oil may be transferred from the feathers and feet of incubating birds to their eggs. The effects of external applications of oil on avian eggs are not well known; however, previous studies and field observations indicate that eggs contaminated by crude or processed oil seldom hatch (Gross 1950, Rittinghaus 1956, Hartung 1965, Kopischke 1972, Birkhead et al. 1973). Egg-oiling experiments performed at Patuxent have shown that external applications of only microliter amounts of SLC, Kuwait crude oil, or No. 2 fuel oil were sufficient to produce very high embryonic mortality in artificially incubated mallard eggs (Albers 1976; Szaro and Albers, in preparation; and Szaro and Coon, unpublished data) (Table 2).

High mortality also occurred in artificially incubated common eider (*Somateria mollissima*) eggs treated with 20 μl of No. 2 fuel oil (Szaro and Albers 1976). Embryonic mortality was thought to be caused by toxic compounds in petroleum, rather than by interruption of normal gaseous exchange because the area covered by the oil was small. Furthermore, eggs treated with propylene glycol exhibited normal hatching success, and eggs treated with a mixture of 9 or 10 aliphatic compounds found in petroleum had normal or near-normal hatching success (Table 2). These results suggest that the toxic components probably are aromatic hydrocarbons or nonhydrocarbons. Mallard eggs have also been treated with external applications of SLC and No. 2 fuel oil at various stages during the incubation period. The petroleum was most toxic during the first 10 days of incubation (Albers, in preparation) (Table 3).
Table 2. Hatching success of 50 mallard eggs treated on the eighth day of incubation with petroleum, propylene glycol, or paraffin mixture

<table>
<thead>
<tr>
<th>Treatment</th>
<th>No. 2 fuel oil</th>
<th>No. 2 fuel oil</th>
<th>S. La. crude oil</th>
<th>Kuwait crude oil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>88</td>
<td>88</td>
<td>92</td>
<td>92</td>
</tr>
<tr>
<td>Propylene glycol (50 μl)</td>
<td>80</td>
<td></td>
<td>94</td>
<td></td>
</tr>
<tr>
<td>Paraffin mixture (50 μl)</td>
<td></td>
<td>72&lt;sup&gt;a&lt;/sup&gt;</td>
<td>96</td>
<td></td>
</tr>
<tr>
<td>1 μl oil</td>
<td></td>
<td>64&lt;sup&gt;a&lt;/sup&gt;</td>
<td>62&lt;sup&gt;a&lt;/sup&gt;</td>
<td>72&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>5 μl oil</td>
<td>45&lt;sup&gt;a&lt;/sup&gt;</td>
<td>18&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>24&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>10 μl oil</td>
<td>12&lt;sup&gt;a&lt;/sup&gt;</td>
<td>10&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>16&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>20 μl oil</td>
<td>2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>50 μl oil</td>
<td>0&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
<td>0&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup>Different from the control (P < 0.01).

Table 3. Hatching success of mallard eggs treated with No. 2 fuel oil or Southern Louisiana crude oil at different times during incubation

<table>
<thead>
<tr>
<th>Treatment</th>
<th>No. 2 fuel oil (5 μl)</th>
<th>S. La. crude oil (5 μl)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of eggs</td>
<td>Percentage hatching success</td>
</tr>
<tr>
<td>Control</td>
<td>40</td>
<td>80&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>2-day</td>
<td>40</td>
<td>13&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Control</td>
<td>38</td>
<td>84</td>
</tr>
<tr>
<td>6-day</td>
<td>40</td>
<td>33&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Control</td>
<td>38</td>
<td>84</td>
</tr>
<tr>
<td>10-day</td>
<td>40</td>
<td>68&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Control</td>
<td>38</td>
<td>84</td>
</tr>
<tr>
<td>14-day</td>
<td>40</td>
<td>83</td>
</tr>
<tr>
<td>Control</td>
<td>38</td>
<td>84</td>
</tr>
<tr>
<td>18-day</td>
<td>40</td>
<td>80</td>
</tr>
<tr>
<td>Control</td>
<td>37</td>
<td>86</td>
</tr>
<tr>
<td>22-day</td>
<td>40</td>
<td>93</td>
</tr>
</tbody>
</table>

<sup>a</sup>Different from the control (P < 0.01).
<sup>b</sup>Different from the control (P < 0.05).
Hatching weights of ducklings from the oiled eggs were not significantly different (P < 0.01) from the weights of the control ducklings. Ducklings from the oiled eggs did not have an unusual amount of gross external malformations nor did they exhibit unusual behavior.

Female mallard ducks on a diet containing 25,000 ppm SLC have laid significantly fewer eggs (P < 0.05) than females on clean feed. The number of eggs laid by mallards on a diet containing a mixture of 10 aliphatic compounds or 2,500 ppm of SLC was not significantly different from the controls (Coon, personal communication).

Herring gulls (Larus argentatus) from Lake Ontario were examined by Fox, et al. (1975) because they displayed almost totally depressed reproduction and represent a top level consumer in the food chain. One of the factors suspected was poor embryonic survival, which may be caused by embritoxins. Compounds from lipid extracts identified by gas chromatography/mass spectrometry, or by gas chromatography alone, included 14 polycyclic aromatic hydrocarbons that were not of biogenic origin.

Crude oils contain high concentrations of metals. The National Academy of Sciences (1974) reported that different types of crude oils contain as much as 1,400 ppm vanadium. Scientists at Patuxent Wildlife Research Center have completed the initial phases of a study of the kinetics of vanadium and found that it greatly altered lipid metabolism in laying mallard females (White and Dieter, unpublished data).

**CHEMICAL ANALYSIS**

The analytical methodology for detecting and quantitating petroleum in avian tissues is in the early developmental stages, and standardization of techniques has not been accomplished. However, petroleum hydrocarbons have been reported in tissues of birds from oil spill areas. Brain and muscle of an immature herring gull from the West Falmouth oil spill site contained around 500 ppm of total hydrocarbons, as compared to 10 ppm in the brain and muscle of an immature gull collected 15 km away in a clean area (Burns and Teal 1971). Snyder et al. (1973) collected tissues from three different aquatic birds at the San Francisco Bay oil spill. Two laboratories in Texas and Massachusetts, which analyzed the samples by gas chromatography, identified petroleum hydrocarbons in a composite sample of liver, kidney, fat, heart and brain of a common murre (Uria aalge aalge), in the liver and kidney of a surf scoter (Melanitta perspicillata), and in the liver of a western grebe (Aechmophorus occidentalis). Comparison with gas chromatograms of Bunker C fuel oil indicated that the tissues of the common murre contained 8,820 ppm of C15+ aliphatic hydrocarbons; the tissues of the surf scoter, 1,250 ppm; and tissues of the western grebe, 9,100 ppm.

Patuxent chemists, and Dr. John Laseter, University of New Orleans (contractual studies), are establishing extraction procedures, checking recoveries, and quantitating petroleum hydrocarbon fractions in avian tissues. Procedures for the detection of petroleum hydrocarbons in liver and muscle tissue have been established; procedures for fat and brain tissue are being developed. Quantitation of specific hydrocarbons in liver and muscle tissue has been
achieved (Gay and Belisle, personal communication). Dr. John Laseter (personal communication) has detected petroleum hydrocarbons in the liver, heart, kidney, brain, skin, fat, breast muscle, and uropygial gland of mallard ducks which were dosed with crude oil.

ACKNOWLEDGMENTS

Research on the effects of petroleum on aquatic birds is being performed at the Patuxent Wildlife Research Center by seven people in addition to myself: Dr. Michael Dieter, physiologist and leader of the oil research team; Nancy Coon, biologist; Andre Belisle, chemist; Dr. Martha Gay, chemist; Dr. Jon Patton, physiologist; Dr. Robert Szaro, biologist, and Dr. Barry Tarshis, zoologist. I thank all of them for their assistance in preparing this paper.

LITERATURE CITED


