Anatomy of an oil spill: long-term effects from the grounding of the barge Florida off West Falmouth, Massachusetts

by Howard L. Sanders, J. Frederick Grassle, George R. Hampson, Linda S. Morse, Susan Garner-Price, and Carol C. Jones
Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, 02543

ABSTRACT

To determine carefully the effects on the marine and estuarine benthos of Number 2 fuel oil spilled by the barge FLORIDA off West Falmouth, Massachusetts, we sampled for many months along an onshore-offshore gradient of pollution, and less intensively at unoiled sites. Analyses of hydrocarbons established that pollution was greatest and most persistent in the intertidal and subtidal zones of Wild Harbor River, less severe in degree and duration at stations farthest from shore. A variety of concurrent analyses showed that disturbance of the fauna was most severe and longest lasting at the most heavily oiled sites, and least severe but perceptible at lightly oiled stations. Patterns of disturbance were not related to granulometry of the sediments. Plants, crustaceans, fish, and birds suffered both high mortality immediately after the spill, and physiological and behavioral abnormalities directly related to high concentrations of the fuel oil. Five years after the spill its effects on the biota were still detectable, and partly degraded #2 fuel oil was still present in the sediments in Wild Harbor River and estuary.

INTRODUCTION

Early in the morning of September 16, 1969, the barge Florida ran aground on a rocky shoal off Fassett’s Point, West Falmouth, Massachusetts, and spilled 650,000 to 700,000 liters of Number 2 fuel oil into Buzzards Bay (Figs. 1-3). Strong SSW winds, common to this region, churned the oil into an oil-water emulsion and drove it northeastward into Wild Harbor River in North Falmouth. The oil spread over more than 1000 acres, including four miles of coastline (Souza, 1969). Mass mortality of at least the larger marine animals occurred immediately in the intertidal and subtidal zones of the river.

Water-based emulsifiers, claimed by the manufacturers to be nontoxic, were initially used to clean up the oil. The company hired to remove the oil first applied these emulsifiers in Wild Harbor on the evening of September 16, and made further applications the next day. On September 18 and 19 the company introduced emulsifiers into the waters from the beach south of Wild Harbor before being restrained
by official act on the grounds that the emulsifiers were toxic to shellfish. The company poured a total of 17,072 liters of emulsifiers into the waters in less than four days. These chemicals were not, however, the chief cause of death, for animals had already begun to die in large numbers at least four hours before the first emulsifiers were applied. As Murphy (197) tillate fuel oils have resulted in 1936; Tegelberg, 1964; North, Croker, 1969).

This report may seem too detailed interpretations of insufficien
were applied. As Murphy (1970) states, "... most spills of any magnitude of distillate fuel oils have resulted in a significant kill of marine life". (See also Adam, 1936; Tegelberg, 1964; North, Neushul, and Clendenning, 1965; Gooding, 1971; Croker, 1969).

This report may seem too detailed. It is our conscious purpose to give details. We wish to counteract against the all-too-common conclusions that are, at best, equivocal interpretations of insufficient and ambiguous data. Such inadequacies are usual...
in many pollution-related studies of benthic ecology, including those on which important decisions are based. Through detailed presentation and analysis of the data, we aim to demonstrate more than adequately the persistent, deleterious effects of Number 2 fuel oil on marine benthos.

In the initial period of study we made several observations. Within only eight to ten days at the relatively high temperatures of 18 to 21°C, carcasses of most soft-bodied animals completely decomposed. Skeletons were soon disarticulated and scattered. Both intertidal and subtidal sediments, particularly sands, became physically unstable, probably owing to disintegration of animal secretions and tubes, and death of vegetation and benthic algae that bound the sediment. Marsh grasses, reached by water-borne oil during the first three weeks after the spill, died. The pollution-indicator polychaete, Capitella, occupied the river bottom in very dense concentrations. By late spring and early summer of 1970 this polychaete population crashed, and a few other species were able to occupy this area. In the spring of 1970 the gonads of blue mussels, Mytilus edulis, surviving in the affected area were thin and sterile, whereas gonads of blue mussels in unpolluted Sippewissett Marsh were plump and ripe. Some mortality always attended oil in the sediments; the greater the concentration of oil, the heavier the mortality. In sediments saturated with oil, almost all of the benthic life was killed.

In order to study spatial and temporal changes in concentration and composition of the fuel oil, and like changes in density and character of the benthic fauna, our long-term strategy was monthly or bimonthly sampling at stations along a gradient from most severe effects in Wild Harbor River to least effects at offshore stations in Buzzards Bay. For the intensively sampled stations we considered granulometry of sediments, composition of hydrocarbons, and quantitative and qualitative changes in the fauna (including pad diversity).

In a paper that will be svide a broader perspective of oil pollution studies that as a base for decision-mak

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1. Methods

Field work

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Treatment of biological sam

We washed the samples (opening = 0.297 mm), pre
in the fauna (including patterns of dominance, constancy, numerical variability, and diversity).

In a paper that will be submitted to the Journal of Marine Research, we will provide a broader perspective for the Florida oil spill by making a critique of findings of oil pollution studies that are widely available, frequently cited, and often serve as a base for decision-making in public policy.

Throughout the body of this report, No. and # will be used interchangeably for “Number” as, for example, No. 2 fuel oil or U.S. Standard #50 mesh sieve.

1. Methods

Field work

On September 19, 1969, three days after the spill, we began to collect samples in the intertidal zone of Wild Harbor River, at six sites marked with stakes. Within the next week, we began collecting at many subtidal stations in the affected area. Within two months after the spill we were able to determine the onshore-offshore gradient of effects, and limited further sampling to stations along that gradient. These stations, 31, 9, 10, 5, 20, and 35, we marked with anchored buoys (Fig. 3). The three most offshore and minimally oiled stations 5, 20 and 35 served as reference or control stations for the more heavily oiled stations 9 and 10 and severely oiled station 31. Even though the buoys disappeared during the second winter, we were able to relocate stations to within a few feet by fathometer, bearings, compass bearings, and fixed-range radar. We later established a control area in the unoiled intertidal area of Sippewissett Marsh, well to the windward of Fassett’s Point where the barge Florida ran aground (Fig. 2). Ice and rough seas sometimes prevented collecting during the winter. We collected 413 sets of samples, 42% of which were picked for animals. Each set of intertidal samples consisted of a principal 1/128 m² core for faunal analysis, a replicate sample of the same size, and surficial sediment for hydrocarbon and granulometric analyses. This third sample was taken with a spoon or trowel from a square 15 cm on a side to a depth of 4 cm (900 cc). Each set of subtidal samples consisted of one or two 1/25 m² Van Veen grab samples for faunal analysis, and another such sample for hydrocarbon and granulometric analyses. The uppermost 4 cm of this last grab sample was retained, the rest was discarded. In the field we noted the presence of oil in the sediments and on animals, the anaerobic condition of some substrata, and the presence or dead animals and plants. A total of 142 benthic faunal samples forming the critical information base of this study are listed chronologically by station in Table 1. The actual faunal composition of these samples can be obtained from the senior author.

Treatment of biological samples

We washed the samples for biological analysis on a U.S. standard #50 mesh (opening = 0.297 mm), preserved them in 5% buffered formalin, transferred them
of fine sediment from also reflect the recolonizations capable of bindingometric data showed that ng or skewness; and that e characters. The succe

and stabilized does not fauna in the area affected animals to turn from the ogically more costly, and ven lethal modes.

orida spill on populations over a span of seven years. than 20% aromatics and ant-water interface, killed of 100 to 200 ppm killed at lower concentrations. suffered impaired activity, ation, the shorter the life moment, immobilized andirst two year-classes after which sediments contained gher the concentration of ears following the oil spill, in the amount of petroleum 4.2 ± 4.7 mg/100 g body concentrations they could in Wild Harbor Marsh for after the spill, many sur out of season. Because of the crabs were very vulnert least four years after the mit of the crab’s range of ut of or going into winter ts dug burrows too shallow eniles, and the locomotory indicate that oil caused the

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reduction of fiddler crab populations in Wild Harbor Marsh for at least seven years after the spill.

Chronically exposed Fundulus heteroclitus, a small estuarine fish, from Wild Harbor Marsh contained in its tissues as much as 75 ppm petroleum hydrocarbons from the 1969 Florida oil (Burns, 1976). The fish from the control area in unpolluted Sippewissett Marsh did not have residues of #2 fuel oil in their tissues. Unlike the fiddler crab Uca, Fundulus showed dramatic reduction in the concentrations of petroleum hydrocarbons in the body tissues; 75 ppm in 1970 to a mean of 6.67 ± 2.40 ppm in 1974 (Burns and Teal, 1979). By 1974 Fundulus developed high levels of hydrocarbon metabolizing enzymes relative to controls as probable adaptations to the oil residues (Burns, 1976).

Biochemical differences between Fundulus populations from the two marshes were obvious. Tissues of the fish from contaminated Wild Harbor showed a lower net rate of hepatic lipogenesis than did those fish in uncontaminated Sippewissett Marsh. Incorporation of acetate-1-14C in the gill, muscle, and brain tissues was 40-50% lower in the Wild Harbor Fundulus than in fish from Sippewissett Marsh. The pronounced decrease in the rate of hepatic phospholipid synthesis suggests that the oil affected the cell membranes on the cytoplasmic or intracellular surface, for phospholipids and cholesterol are the major constituents of most membranes (Sabo and Stegeman, 1977). The rate of synthesis of triglyceride was also much lower. Serum of oil-contaminated Wild Harbor Fundulus contained less nitrogen as urea, glucose, triglycerides, and cholesterol than did serum of the Sippewissett controls. Oil-induced physiological stress draws heavily on several stores of energy (Sabo, Heineke, and Stegeman, 1977).

Studies on polluted animals from other areas show that physiological stress is also manifested in higher energy demand. Mya arenaria and two species of mussels living in sediments contaminated with petroleum hydrocarbons showed changed carbon flux (Gilfillan, 1975; Gilfillan, et al., 1976). The higher the concentrations of petroleum hydrocarbons, particularly of aromatics, the higher the metabolic demand, the lower the rate of assimilation, the slower the growth, and the lower the fertility. It is clear that increasing environmental stress so elevates metabolism and reduces assimilation as to leave too little energy for growth and reproduction. As a result, most species disappear from such an environment, leaving only those few tolerant species typical of chronically polluted habitats.

4. Conclusions

1. The petroleum hydrocarbons in the sediments of Wild Harbor River and adjacent areas offshore came from the #2 fuel oil spilled by the Florida on September 16, 1969. Concentrations were highest and degradation slowest in the intertidal and subtidal zones of the river. Concentrations were lowest at stations farthest from shore.
2. Oil spread seaward from the areas of highest concentration for at least five years. After this span of time, fuel oil which was only somewhat degraded was still detectable in the peat and sediments of the river.

3. Within twelve hours after the spill, marine animals began to die in great numbers. Mortality was most severe and longest lasting in the river, less at nearshore subtidal stations, and least and of shortest duration at the more distant offshore stations. This trend in mortality was especially evident among amphiliscid amphipods.

4. The opportunistic polychaete, *Capitella*, monopolized the biologically denuded substrata at the heavily oiled stations for the first eleven months after the spill, then crashed. At the offshore stations, *Mediomastus ambiseta*, another capitellid polychaete, became common nearly a year after the spill, and remained so during the second year at intermediately oiled stations, but soon declined in numbers at lightly oiled stations.

5. Faunal changes matched in intensity and duration the gradient of pollution by #2 fuel oil from the *Florida*, but were only occasionally related to granulometry of the sediments.

   The fauna in Wild Harbor River was unstable in density, diversity, and composition. Fluctuations in composition were successional. After more than five years the fauna there had only slightly recovered.

   At the nearshore subtidal stations, faunal fluctuations were rapid and very broad in the first year, and successively less in later years. After the first year, changes in composition began to alter in character from successional to seasonal. Recovery had begun, but was not very far advanced by the end of two and one-half years.

   Faunal changes at stations farthest from shore were relatively slight and seasonal in nature. The fauna recovered in density, number of species, and diversity after about a year.

   At unoiled stations, faunal changes were slight and seasonal.

6. Increased species richness usually contributed more to recovery of diversity than did increase in the evenness with which individuals were distributed among species.

7. Even if the fauna began to recover in diversity and density, the animals continued to suffer the ill effects of the oil. Physiological and behavioral disorders caused by the oil resulted in impairment of growth and reproduction, and in death.

8. Bacterial seeding in areas heavily polluted by oil is probably inadequate to hasten the degradation of petroleum hydrocarbons.

9. Faunal surveys undertaken more than a week after an incident of oil pollution probably will not find any of the larger soft-bodied animals killed by the oil.

10. Most necessary are carefully conducted, quantitative, long-term studies, especially those designed to detect physiological and behavioral damage, of the effects of oil spills on all levels of the marine trophic structure, the apical member of which is often man. Mathematical techniques, particularly diversity indices, must be used with comprehension and care. Only through such studies can society appreciate the true price paid for the und which disrupts and alters ince

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