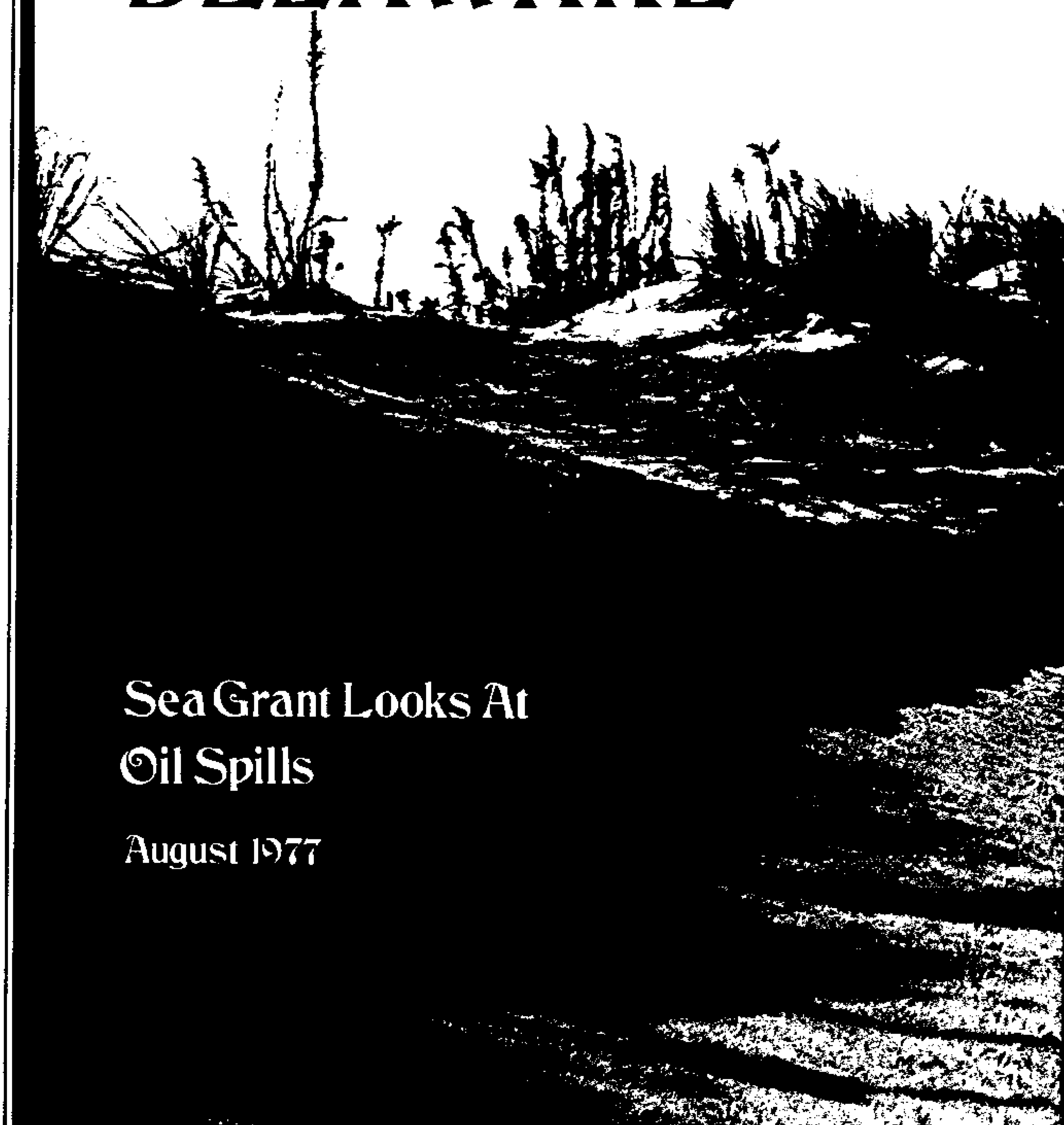
Decisions for DELAWARE



Sea Grant Looks At Oil Spills

August 1977

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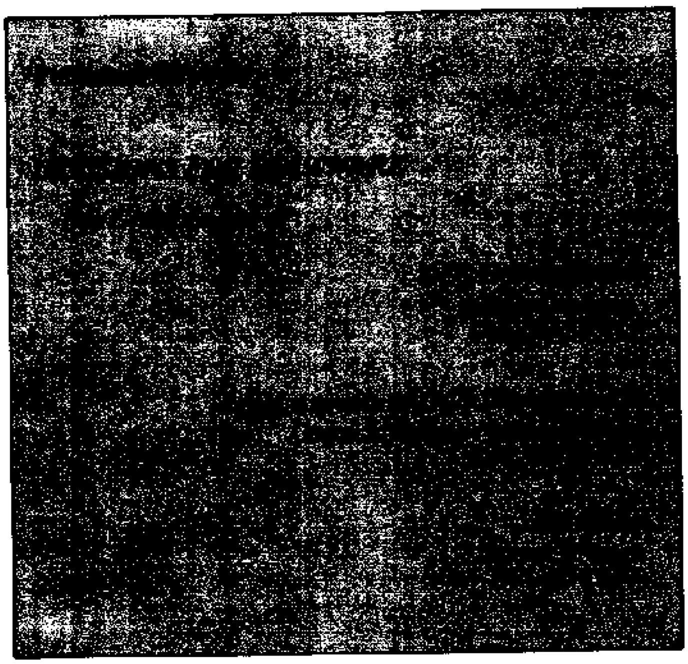
Foreword



The ***Decisions for Delaware*** Sea Grant report series provides legislators and the people they represent with alternatives and factual information on marine-related topics that have been identified by the Sea Grant Advisory Council as high-priority issues facing the state and the region. Authors are asked to . . .

- Define the issues clearly and concisely
- Explain the implications of existing information
- Assess the risk of relying on only existing information
- Suggest further research that would reduce the risk

Before publication, each report is reviewed to ensure that it not only contains accurate information, but that it also treats these important issues fairly and understandably.

This series is one facet of the Sea Grant College Program at the University of Delaware. Managed by the College of Marine Studies, this state-wide program comprises a broad spectrum of research and educational activities dedicated to the protection, use, and wise development of marine resources. The program is a federal, state, and university partnership supported by a grant from the National Oceanic and Atmospheric Administration's Office of Sea Grant; by an appropriation from the Delaware General Assembly; and by the University of Delaware. Program funds this year total almost $1.4 million.

William S. Gaither, Director
Sea Grant College Program

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Contents

We pity ducks dying of exposure, their feathers matted with tar. We lament poisoned fish washed ashore amid an oil slick. And disquieted, we wonder what unseen destruction an oil spill has caused. Who is to blame? The electric light that allows you to read this report and the ink used to print it both use petroleum. The car or boat that takes you to your favorite fishing spot runs on petroleum. We are all to blame. The risk of an oil spill is the price we pay to use petroleum. But we can reduce the risk through a plan of resource protection.

The Decisions We Must Make

To meet the demand for energy in the Delaware Valley, the seven major refineries along the Delaware River need almost a million barrels of oil each day. Because no crude-oil pipelines feed the Delaware Valley, this need must be met by tankers sailing up and down the Delaware estuary.

By the mid-1960's, tankers had become so large that their drafts exceeded the depth of the navigation channel. A fully loaded tanker entering the Delaware Bay now may have a draft of from 45 feet to 57 feet. These large ships may not proceed up river until their draft is reduced to less than 40 feet by pumping part of their cargo of crude oil into barges or smaller tankers in a process known as *lightering*. Of the 300 million barrels of crude oil that passed through the Delaware Bay in 1976, about 74 million barrels was lightered.

While this report focuses primarily on a hypothetical spill occurring at the lightering area in the lower bay, an oil spill could occur anywhere along the ship channel. Fortunately, however, because of the skill of vessel masters, pilots, and lightering personnel, no catastrophic oil spill has reached Delaware's shores. But perhaps we have been lucky.

The potential environmental consequences of an oil spill in the Delaware Bay are diverse. Policies, procedures, and jurisdictions for the prevention, control, and cleanup of oil spills are numerous and overlapping. Since spilled oil does not respect state boundary lines, these problems are important to citizens of both New Jersey and Delaware. This report is intended to stimulate thoughtful discussion of the issue and to provide new or overlooked data and perspectives so that you can make your *own* decisions on this critical matter. Here are the decisions we must make:

- Which resources of the estuary do we want to protect when a spill occurs?
- Who decides which resources to protect and how is the decision reached?
- May we reasonably expect that we can protect what we want to protect?
- How much will the protection cost and who is going to pay for it?
- Who will devise and execute a plan of protection?
- Should we evaluate other ways of getting crude oil to the refineries?

What Happens to Oil Spilled on Water?

Crude oil spilled on water is acted upon by a combination of processes known as *weathering*, in which its composition and form change over a period of time. Weathering comprises three major processes:

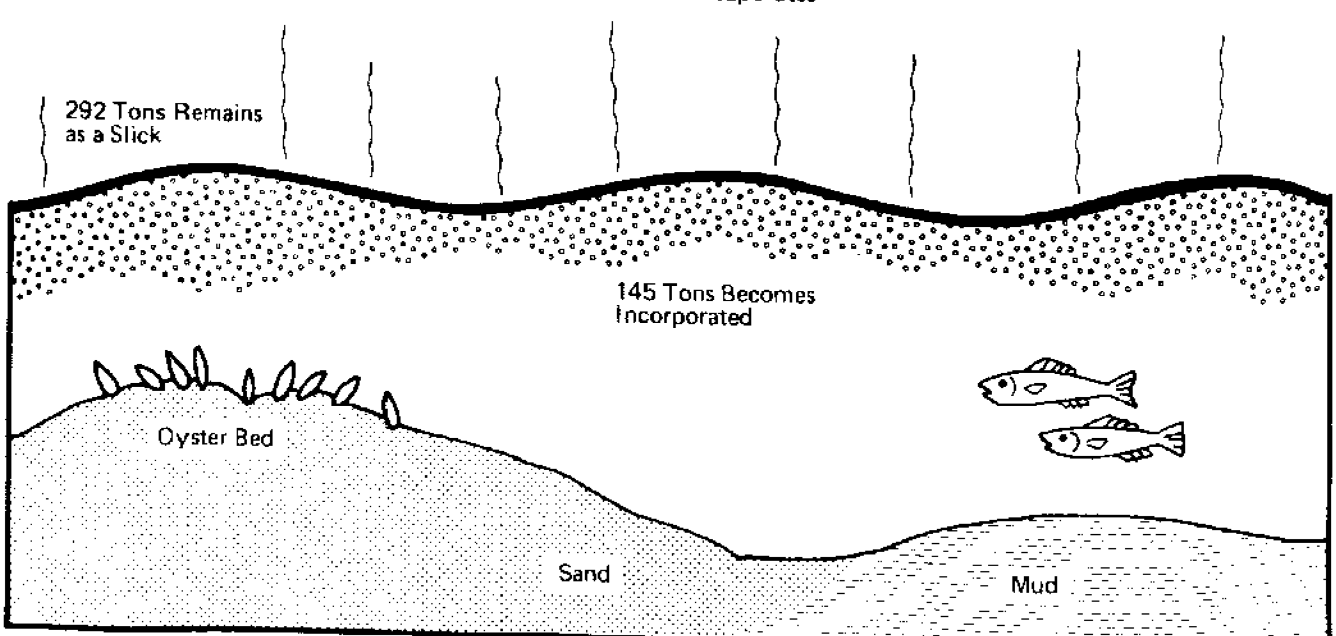
- Evaporation
- Incorporation
- Dispersion

Each process is dependent on the other, on the initial composition of the crude oil, and on environmental factors such as the temperatures of the air and sea, the speeds of the wind and currents, and the action of the waves. To illustrate these processes, we will examine what happens to a hypothetical spill of 500 tons, or 3,600 barrels, of light crude oil 12 hours after it occurred.

As soon as crude oil is exposed to the air, its more volatile components begin to evaporate. After 12 hours, about 63 tons of the crude oil in our example has evaporated.

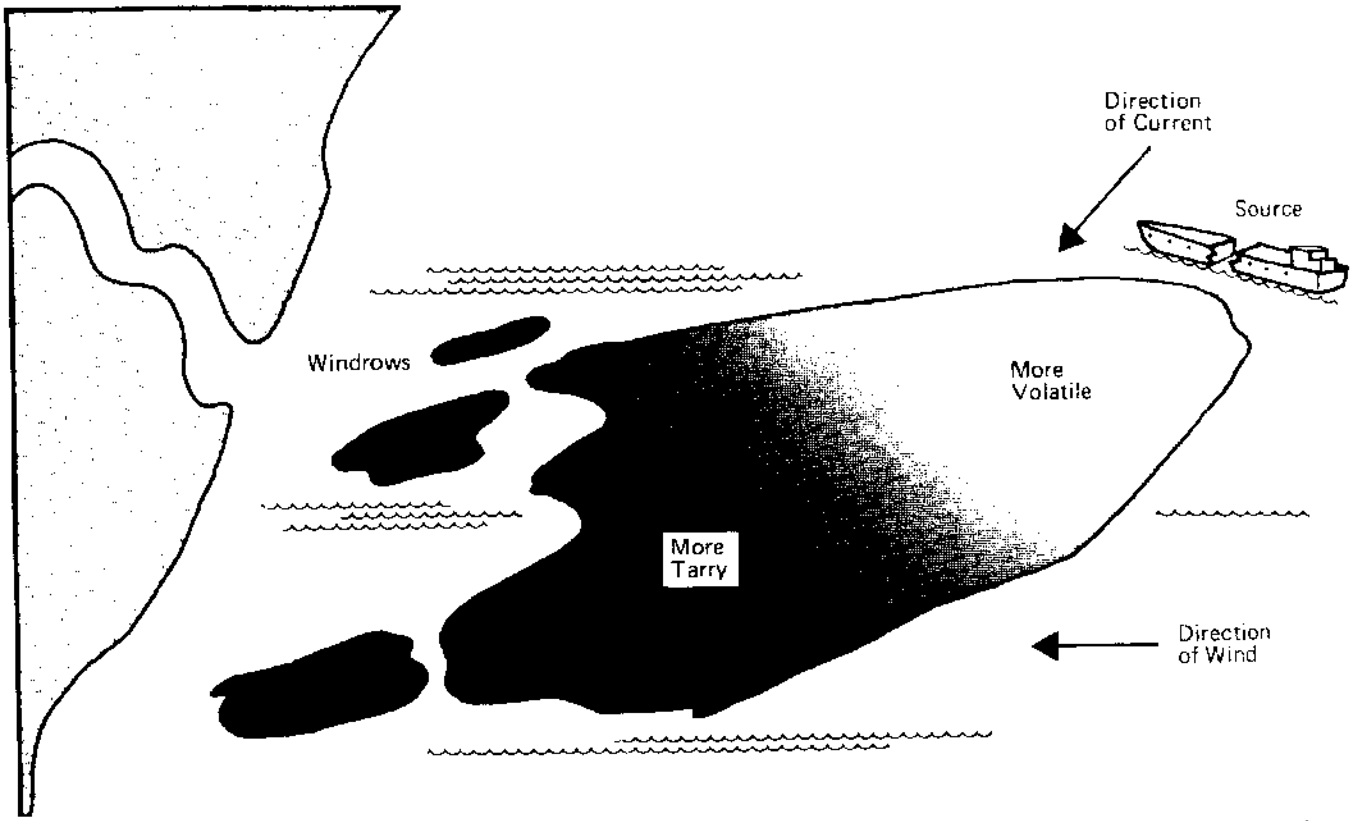
During this same period, about 145 tons of crude oil has become incorporated into the water. Some components of the crude oil are actually dissolved by the water. Additionally, tiny droplets of crude oil are stirred into the water, or emulsified, by the action of the waves. Other droplets adhere to particles suspended in the water and sink to the bottom.

Thus, after 12 hours, the quantity and quality of the crude oil is different from the material that was spilled. About 40 percent of the crude oil has evaporated or has been incorporated into the water. The other 60 percent—mostly tarry materials that will not evaporate nor dissolve—remains floating as an oil slick. In our example, about 292 tons of the 500 tons spilled remains on the surface of the water.*



Weathering of 500 tons of light crude oil 12 hours after a spill.

*For the proportions used in these calculations, see Maurer and Wang (1973).



Spill covers about 4 square miles after 12 hours.

The process of dispersion comprises many forces that spread the oil slick across the surface of the water. Immediately after a spill the predominant spreading force is gravity. Within 20 minutes after our hypothetical spill, gravity can spread the 500 tons of crude oil to a thickness of about 0.021 inches.

The extent to which the slick will spread further is determined by the proportion of surface-active compounds in the crude oil. At the point where any dissimilar substances meet, called an interface, similar molecules tend to attract each other and thereby form a boundary between the substances. This attraction is called *surface tension;* it impedes dissimilar molecules from mixing, as in the case of oil and water, and impedes groups of similar molecules from spreading. Surface-active compounds reduce surface tension. Therefore, crude oil which contains a relatively high proportion of surface-active compounds will spread over the surface of the water more readily than crude oil which contains a relatively low proportion of surface active compounds. The proportion of surface-active compounds in the crude oil also influences the rate of evaporation and incorporation.

The wind and sea influence the extent to which an oil slick spreads, too, and determine its shape and direction of drift. An oil slick moves in a direction determined by both the direction of the wind and the current, at about 1 to 3 percent of the speed of the wind.

As weathering proceeds, the slick is no longer uniform and continuous. Wind, waves, and currents pile the tarry residues into windrows, or pancake-like clumps, which float amid large patches of water covered by a thin sheen containing most of the surface-active compounds. Although the windrows contain 90 percent of the volume of the slick, they occupy only about 10 percent of the area covered by the slick. After 12 hours, the remaining 292 tons of spilled crude oil covers about 4 square miles.

Particular circumstances may significantly modify the distribution of spilled crude oil. Floating ice, for example, may force crude oil to move to areas of open water; oil may also move to the top of the ice or under the ice.

Short-Term Effects of an Oil Spill

An oil spill that comes ashore could immediately affect many natural, commercial, and recreational activities. This section describes the short-term effects of an oil spill and judges the effects in relative qualitative terms of *light*, *moderate*, or *severe*. The sole criterion for these judgments is the extent of the short-term inhibition of the normal use of an area.

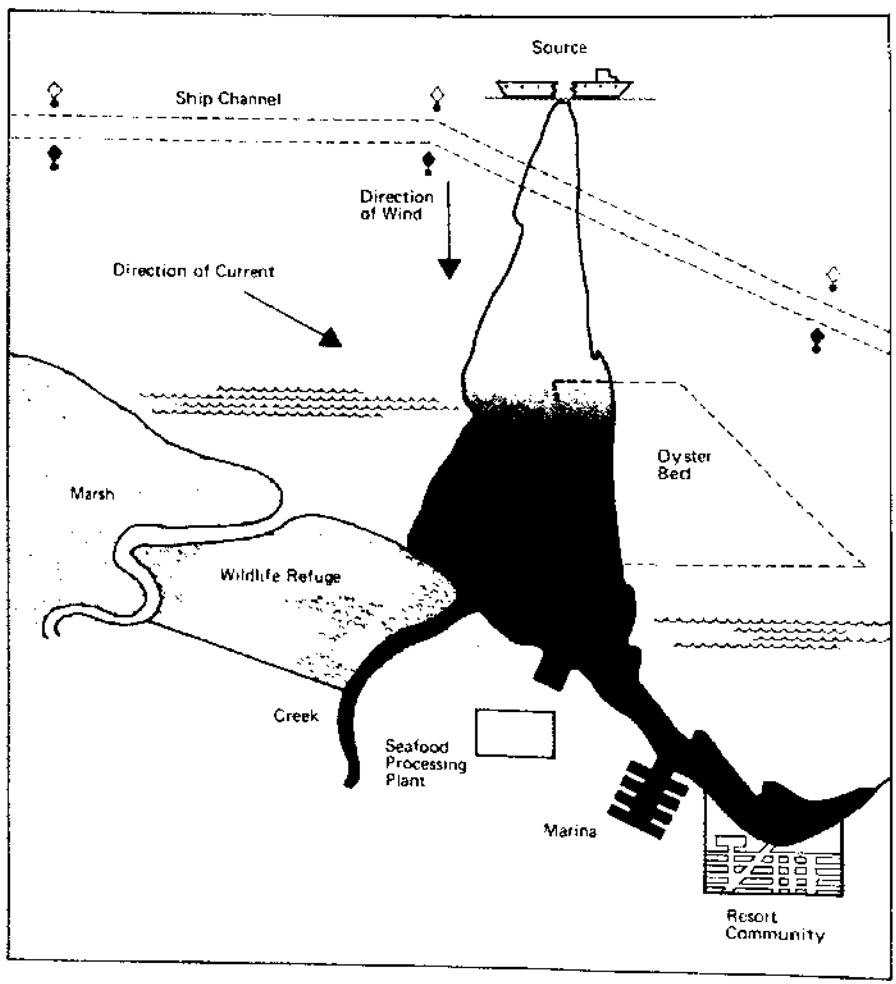
The degree to which an oil spill affects many of the areas discussed varies with the time of the year. For example, an oil spill reaching a beach resort on the Fourth of July weekend would no doubt drive away many vacationers and the area would suffer a severe economic loss; but a spill reaching the same resort in winter would not cause such an economic loss. We have expanded the judgments on the effects of an oil spill to include seasonal variations.

Unfortunately, though, many of these judgments are difficult to make because we simply do not have sufficient information in many areas. To assess the consequence of any event we must first know the conditions before the event occurred. Statistics collected over a relatively long period establish what is known as a *baseline*, which indicates the normal condition of a particular area of interest. A good example of a baseline is the normal body temperature of 98.6 degrees Farenheit; when we take our temperature we compare the reading of the thermometer with this baseline. However, the baseline that exists for a marsh, for example, is markedly inadequate and we cannot predict accurately the consequences of an oil spill on a marsh. To indicate that much work needs to be done in some areas, this section also evaluates the quality of the baseline data upon which the effects of an oil spill were judged. For this purpose we have used the qualitative terms of *poor*, *fair*, and *good*.

Let us see, then, how a major oil spill could affect some components of an estuarine system. The illustration shows a hypothetical oil spill coming ashore along a typical estuary such as Delaware Bay. Many activities on the shore have been affected.

Marsh and Creek

The marsh and creek are distinctive environments. Estuarine marshes occur in the intertidal region, the area between the highest and lowest tides. Crude oil could cover a wide area as a rising tide pushes



An oil spill could affect many activities.

For a summary of our state of knowledge in crude-oil spills, see National Academy of Sciences (1975).

the slick higher and higher. The greatest area of the marsh would be covered during spring tides, the highest of the high tides, which occur roughly every two weeks. (Spring tides occur throughout the year and the name has nothing to do with the season.) Direct effects could last for a considerable time if the oil were stranded high on the marsh and refloated and redistributed by each spring tide.

In the summertime, marsh grasses grow profusely. Crude oil spilled on these grasses kills them within 2 to 3 days. Mammals such as muskrats, nesting shore birds, and the many organisms living in the creek could be killed, harmed, or driven out of the area. The tidal creeks serve as spawning areas for commercially important organisms and as the habitat for juvenile fish during the springtime and summertime. Data are available on the effects of crude oil on the adult stage of a number of commercially important finfish and shellfish from the East Coast. The little we know of the toxicity of crude oil on the egg and larval stages of these organisms seems to indicate that they are more sensitive than the adult animals. Marsh grasses seem to recover by the following season, but animals may take considerably longer to recover. Sport crabbing and fishing could be affected for no other reason than the aesthetic degradation of the marshes. Studies have shown that people judge the quality of the water by visual criteria and a sheen of oil on the water is a frequently mentioned objectionable characteristic. The overall short-term effect of crude oil on the marsh seems to be moderate during the summer, but the baseline data for a marsh are poor.

During the wintertime, activity of some of the marsh organisms is greatly reduced; the grasses and most of the invertebrate animals are dormant. But mammals such as muskrats are still active and waterfowl have migrated to the area. Hunters of waterfowl, because of both aesthetic degradation and poor hunting may not want to use an affected area, and commercial trappers, particularly those of muskrats, would not be able to make a living in the area. As with summertime effects, though, the baseline data upon which these conclusions are reached are poor.

Wildlife Refuge

The wildlife refuge the spill touches includes a large area of marsh; thus, many of the effects experienced by the marsh would also be experienced by the wildlife refuge. In the summertime, the natural population of animals that live in a marsh would be present. The mammals, birds, and water organisms of the marsh would be affected. In addition, recreational activities could be affected; witness the number of people who enjoy birdwatching at Bombay Hook during the summer. The relative overall short-term effects of a summertime spill on a wildlife refuge would be moderate.

During the wintertime, the immediate effect of an oil spill of a wildlife refuge could be much more severe. Whether or not the refuge is managed to attract waterfowl, such a marshy shoreline refuge free from hunting pressure will invariably serve as a haven for waterfowl. Spilled oil and waterfowl spell disaster. Waterfowl do not recognize the danger of spilled oil and will land in slicks, particularly the thin sheens which contain surface-active compounds. Just as they help oil and water to mix, surface-active compounds also break down the substances that waterproof the feathers of waterfowl. Without a waterproof coating, the birds become wet and die of exposure. Some birds attempt to preen the oil from their feathers, but in the process they ingest some of the oil and are poisoned. Procedures for cleaning birds have become more effective. As late as 1968, for example, only 5 percent of birds which were cleaned survived; the survival rate today -while typically 10 percent- can be as high as 50 percent of those birds which are treated. But mortality of waterfowl contaminated by an oil spill is still very high because most of the birds die before they can be cleaned. The information base upon which effects on a refuge can be judged is fair to good.

A marsh and creek typical of lower Delaware.

A year's supply of film for the typical amateur photographer requires the energy of 1.5 gallons of crude oil. That comfortable pair of hiking shoes costs the energy in 6.7 gallons of crude oil.

Marina

During the summertime, when water-oriented activities are intense, a spill could cause considerable direct loss of revenue for a marina. For any time from a few days to a few weeks, water-contact sports would be eliminated and aesthetic values would decrease appreciably. People won't spend money for fuel, food, and bait, and may haul their boats out of the water to prevent fouling by the slick. A pleasure boat contacted by a slick may need to be cleaned or even repainted. Further, crude oil trapped in a marina basin could pose a serious, short-term fire hazard. Thus, on a relative basis, the effect of a summertime spill on a marina would be severe. During wintertime, the effect would be light because presumably fewer boats would be in the marina. Given knowledge of the location of each marina and the number of slips available, we could judge the effects of an oil spill with good accuracy.

Resort Community

Like the effect of a spill on a marina, the effect of a spill on a resort community is highly seasonal. A summertime spill would halt water contact and beach activities and businesses would lose considerable revenue: vacationers could go to other resort areas. Although the immediate slick would soon disappear and the beach could be cleaned up in a week or so, there could be a serious effect lasting several months from crude oil that had been stranded in the marsh and along tidal creeks. This oil could foul the beach each time a spring tide refloated and redistributed it. During the winter season, the effects of oil reaching a recreational area would be much reduced. Sufficient time may be available for cleaning up the beach and for crude oil stranded by the tide to be dissipated. The information for assessing the effects of a spill on a resort community is quite good.

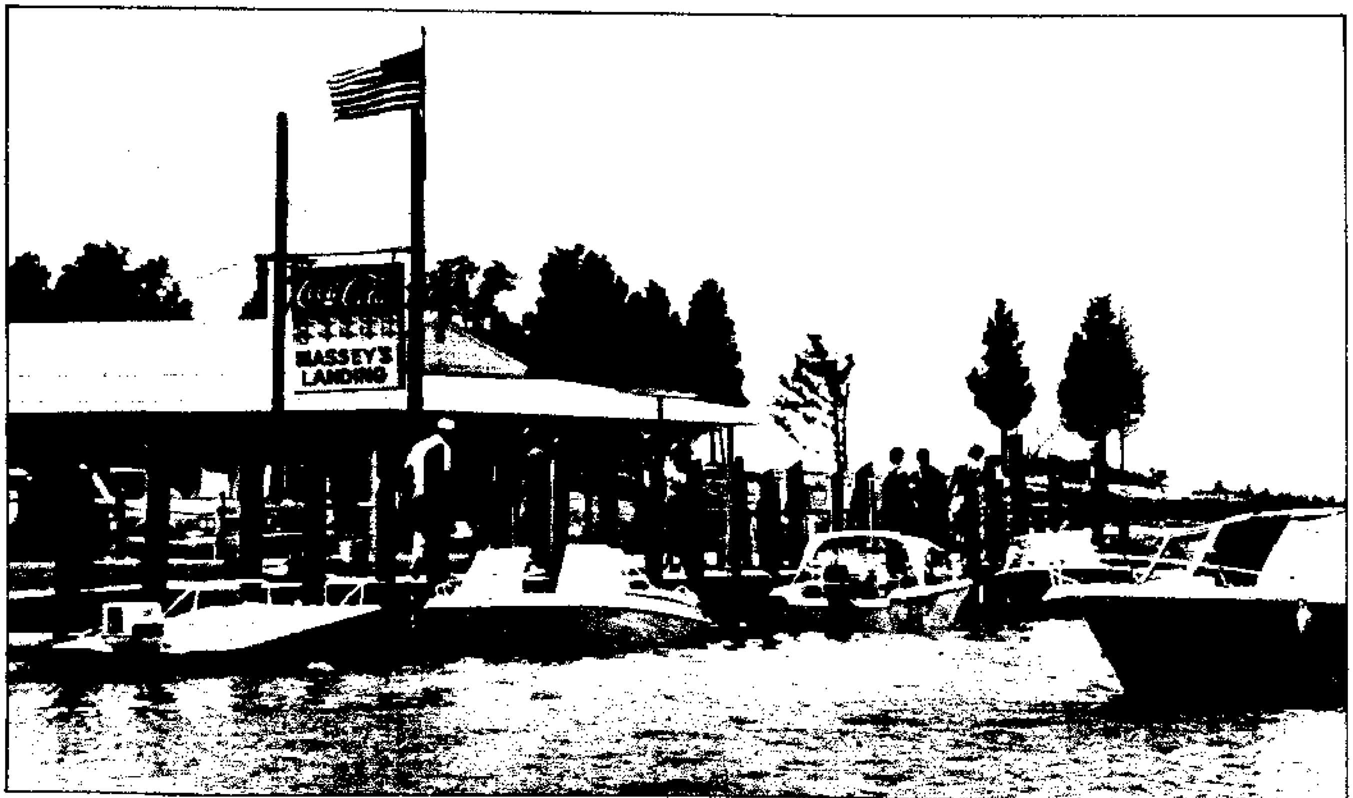
Shipping

Unless the source of the spilled crude oil were a ship blocking the navigation channel, commercial shipping in the area would experience only a small inconvenience. Ships may have to slow down to reduce the possibility of wake damage to cleanup equipment and exercise precautions to prevent fires, but these effects are negligible.

Oysters

We know quite a bit about the effects of spilled oil on oysters. For the most part, adult oysters can tolerate oil. However, oysters assimilate some of the components of crude oil dispersed or dissolved in the water, which gives them an unpleasant taste. A number of studies have shown that oysters can eliminate the contaminants, or depurate, in 10 to 15 days. Alternatively, oysters moved to clean areas can depurate in a relatively short time. But in at least one reported instance, oysters did not depurate oil even after considerable time.

Oyster larvae are much more sensitive to concentrations of crude oil than are adults. If a spill occurred during the summertime, when larvae were in the water, many could be killed outright. Larval distribution in the water is not uniform and it is very difficult to estimate the number of larvae killed or the effect of larval mortality on oystering in an



Each sportfishing trip on Delaware Bay could easily use all the gasoline in a barrel of crude oil.

estuary. It is clear, though, that considerable mortality of larvae will occur in the affected area during the summer months.

During the season for commercial oystering, the winter, an oil spill could have a severe effect on the livelihood of oystermen. If the adult oysters assimilate contaminants from the spilled crude, the oyster beds would have to be closed. Furthermore, if some of the crude oil adhered to sediment particles and sank to the bottom, adult oysters could have an unpleasant taste for several months.

Coastal Industries

If a seafood-processing plant does not process seafood from the area affected by the spill, the direct effects of the spill would be light. However, even the threat of tainted seafood may well reduce the desirability of the product in the mind of the consumer. A plant may use water from the estuary for processes such as cooling, but if the water intake is well below the surface of the water or if the process water does not contact the products, the products should not be affected. Nor would oil along the waterline of boats docked at the plant have serious effects. But crude oil trapped in the plant's boat basin could pose a serious, short-term fire hazard.

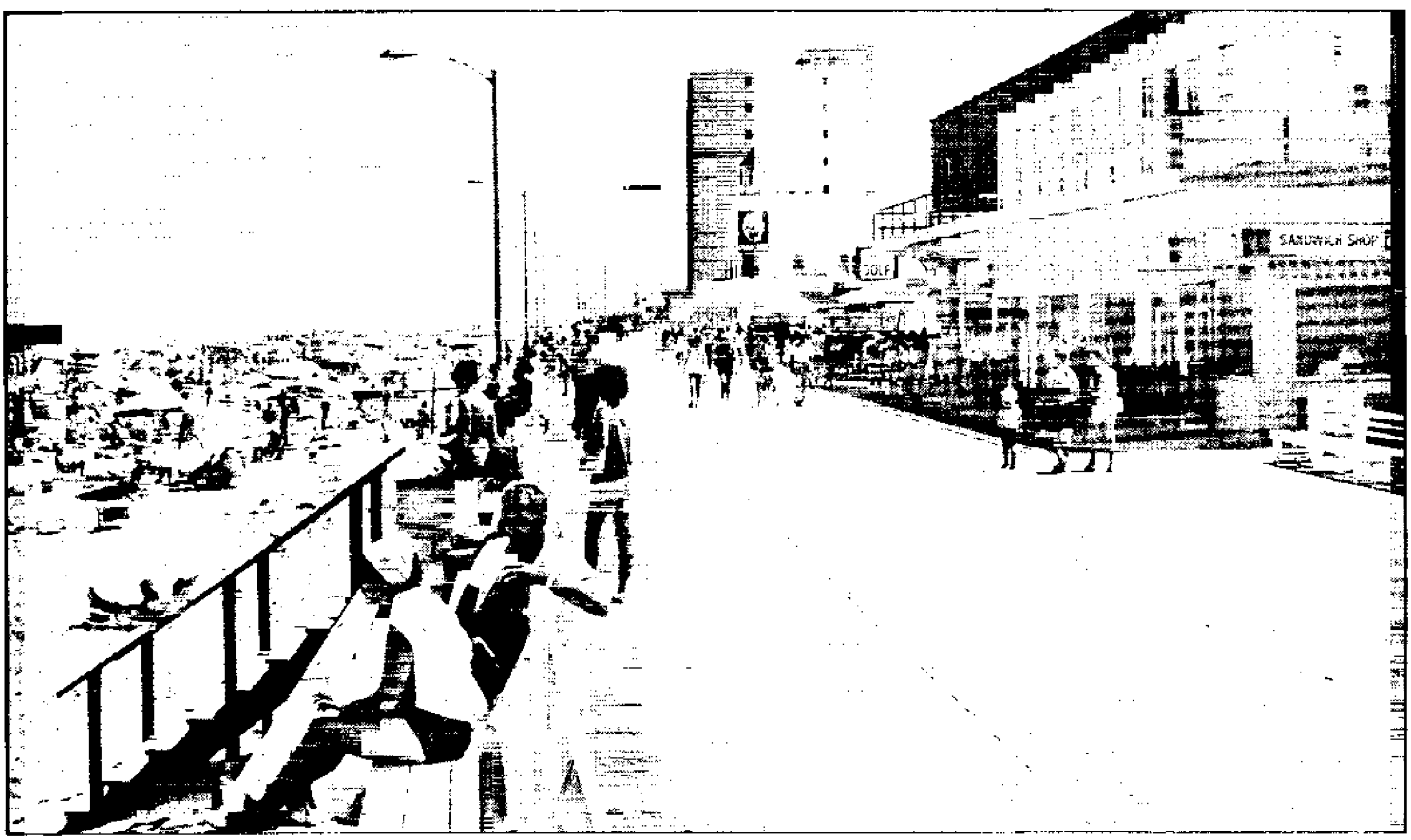
Other industries along the coast extract materials such as bromine, magnesium, and salt from seawater. Some of these operations may have to be halted until the oil incorporated in the water has been dispersed. The information available for assessing the effects of a spill on coastal industrial activities is good.

Natural Values

Natural values are those components of an ecosystem which are not immediately valuable to man for commercial or recreational purposes. Since these aspects of our environment appear to be of no direct importance to us, these are the aspects about which we know the least. No one, for example, can place an ecological price tag on 100 acres of salt-marsh grass. Can the destruction of this grass reduce the oyster population? We don't know.

On a relative scale, it is fairly easy to measure the effect of a major oil spill on commercially important estuarine organisms. If analysis shows oysters to have a high phenol content, we know that the oyster beds will be closed because the contaminated animals pose a health hazard and we can then estimate the lost income to the oystermen. Similarly, we can estimate the loss of revenue to operators of marinas and beach concessions. But even if we knew the effects of crude oil on estuarine animals and plants which are not commercially or recreationally important—which we don't—we still could not predict how the loss of these organisms affects the ecological balance of an estuarine system and ultimately those components of the system we see as important to us.

Despite our lack of knowledge, though, it seems reasonable to say that the effects of an oil spill on natural values in the summer will be more severe than in winter if for no reason other than the higher level of biological activity induced by the higher temperatures. But to reiterate, both the baseline data and our ability to predict are poor.



On one good summer weekend, 200,000 people in 50,000 vehicles make a round trip of over 200 miles to reach Delaware's beaches. These vehicles will burn the gasoline from 31,500 barrels of crude oil. Each 200-square foot motel room uses all the energy in one barrel of crude oil for services like hot water, air conditioning and ice making.

Case Studies – Long-Term Effects of an Oil Spill

After the surface slick has dissipated or has been cleaned up, there may be longer-term effects of the spill, particularly on estuarine organisms. Some of the 30 percent of the crude oil incorporated into the water mixes with suspended material and sinks to the bottom. When this happens, estuarine animals living on the bottom can stir this oil-contaminated sediment into the natural materials; thus situated, toxic materials may be released slowly over a long period. Virtually no systematic field work has been done on this subject and it is difficult to make more than a qualitative guess about the rates of sedimentation or the quantity of oil to be found in sediments. This is just one of the many topics which need to be studied further.

To illustrate some of the type of work that has been done, however, we present some case studies on the effects of oil on marine life. None of the existing literature can provide conclusive answers, though, and much of it offers conflicting opinions.

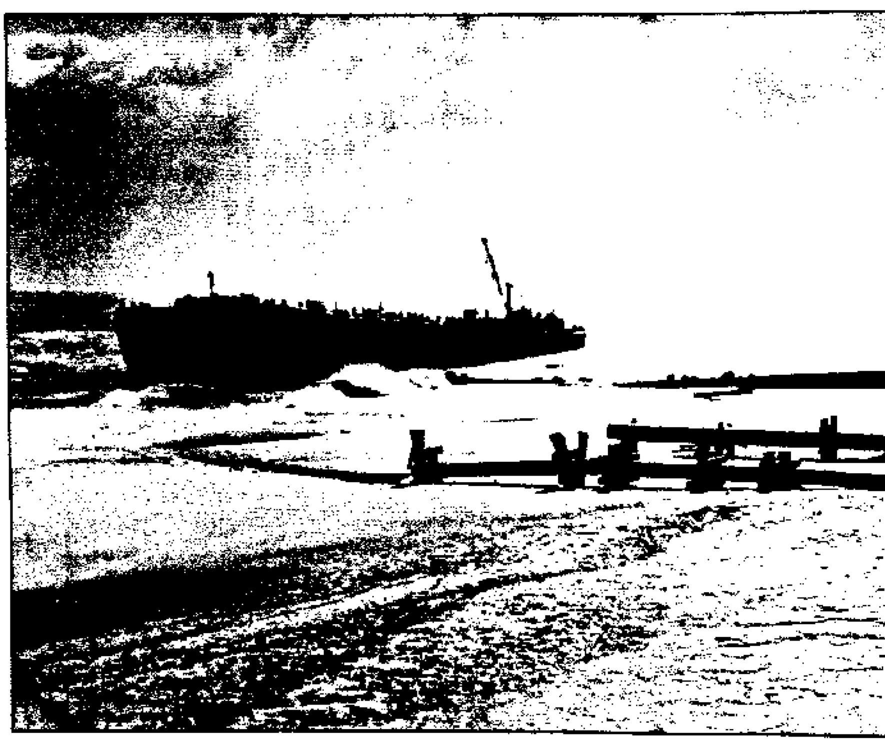
Golden Gate Spill

On January 18, 1971, two tankers collided under the Golden Gate Bridge and spilled 840,000 gallons of ship's fuel oil into the San Francisco Bay. In the following days, tidal currents carried the oil to nearby reefs and beaches. G. L. Chan (1977) reported the effects of this spill on the organisms along a section of beach he had studied since 1958. In heavily oiled areas, Chan observed a 25-percent die-off of marine invertebrates. In subsequent observations from 1972 to 1976, Chan reports that the sample counts of invertebrates had returned to, and in some cases surpassed, the levels before the spill. Chan also noted that there have been no lingering effects in any of the species examined.

General M. C. Meigs Spill

On January 7, 1972, the General M. C. Meigs, an unmanned troopship, went aground on the northwest coast of Washington, rupturing its fuel tanks on the shallow, rocky shore. For at least ten months after the incident, new spills came ashore periodically as the hulk broke up. R. C. Clark et al. (1973) studied the effects of this long-term spill on the coastal environment. They concluded that "... population studies comparing numerical abundance in March, 1972, with those of August, 1973, showed no significant differences other than those attributable to normal seasonal variations."

In addition, they also stated that "... lack of dramatic change in speciation or numerical abundance of intertidal or motile animals suggests the oil spill had few pronounced or long term adverse effects that our method detected. The August, 1974, survey indicated that the area affected by the impact of the grounding and oil spillage from the General M. C. Meigs has returned to an apparently normal state as determined by our level of investigations."



This barge ran aground at Rehoboth Beach during a northeaster in 1968, but the oil she spilled was cleaned up quickly.

Lake Maracaibo, Venezuela

Lake Maracaibo has been producing oil commercially for 60 years. The production available from the lake (actually an estuary) is about 2.5 million barrels per day (about 2.5 times the quantity imported to Delaware Bay). In 1972, about 100,000 to 120,000 barrels was spilled. There are no relevant chemical or biological baseline data from early or pre-production eras with which to compare present-day data. Studies of Lake Maracaibo by W. L. Templeton et al. (1975) conclude that . . .

> There is no question that significant discharges of oil and oil compounds incidental to the production of petroleum in the Lake Maracaibo Basin have occurred over the last 4 decades in addition to that material from natural seeps. However, the data obtained during the course of this program from both laboratory and field studies would indicate that present operations have not caused discernible damage. The rapid loss, in a few hours, of light hydrocarbons from surface films of oil to the atmosphere has been shown to reduce the toxicity to organisms significantly. The low concentrations of oil measured in lake water have not contributed to a detectable buildup of hydrocarbons in the muscle tissue of selected commercial species. The occurrence of bituminous residues in the sediments, particularly in the production areas, would suggest that the natural processes of volatilization, biodegradation, and sedimentation are the major mechanisms for removing weathered oil from the biologically productive zone. Examination of the limited fisheries data available does not suggest that the resources are being depleted. Consideration of the potential impact of nonpetroleum wastes, both domestic and industrial, indicates that nonpetroleum materials are contributing to the degradation of the water quality which, consequently, may reduce the biological resources of the lake.

Gulf of Mexico Oil Spill

Over a period of three weeks in 1970, an estimated 65,000 barrels of crude oil was discharged from an oil production platform, Chevron Main Pass Block 41, located 11 miles east of the Mississippi River Delta. Two thousand barrels of chemical dispersants were sprayed on the platform and surrounding water surface. C. D. McAuliffe et al. (1975) assessed the effects of this spill:

> It is estimated that between 25-30% of the oil evaporated during the first 24 hours, 10-20% was recovered from the water surface, less than 1% dissolved, and less than 1% of the oil was identified in sediments within a 5-mile radius of the platform. The remaining oil emulsified and dispersed to undetectable levels, biodegraded or photo-oxidized.
>
> Spilled oil, identified in bottom sediments by gas chromatography, showed rapid weathering after 1 week to 1 month and at the end of 1 year was reduced to a few percent of the amount after the spill. Spilled oil was not found in the sediment below 1.5 inches.
>
> Over 550 species of benthic organisms were identified in 233 benthic samples. The number of species and number of individuals of benthic organisms showed low values in some samples near the platform. However, seasonal variations, bottom sediment type, and possibly other environmental parameters made it impossible to determine whether these locations had been affected by the spilled oil.
>
> There was no correlation of number of species, number of individuals, or other biological parameters with the hydrocarbon samples from within a 10-mile radius of the platform. This lack of correlation suggests lack of significant effect of oil on benthic organisms.
>
> Extensive trawl samples showed no alteration in the annual life cycle of commercially important shrimp. Blue crabs were observed throughout the area, and the number of species of fish collected were comparable to a prior survey.

West Falmouth, Massachusetts Spill

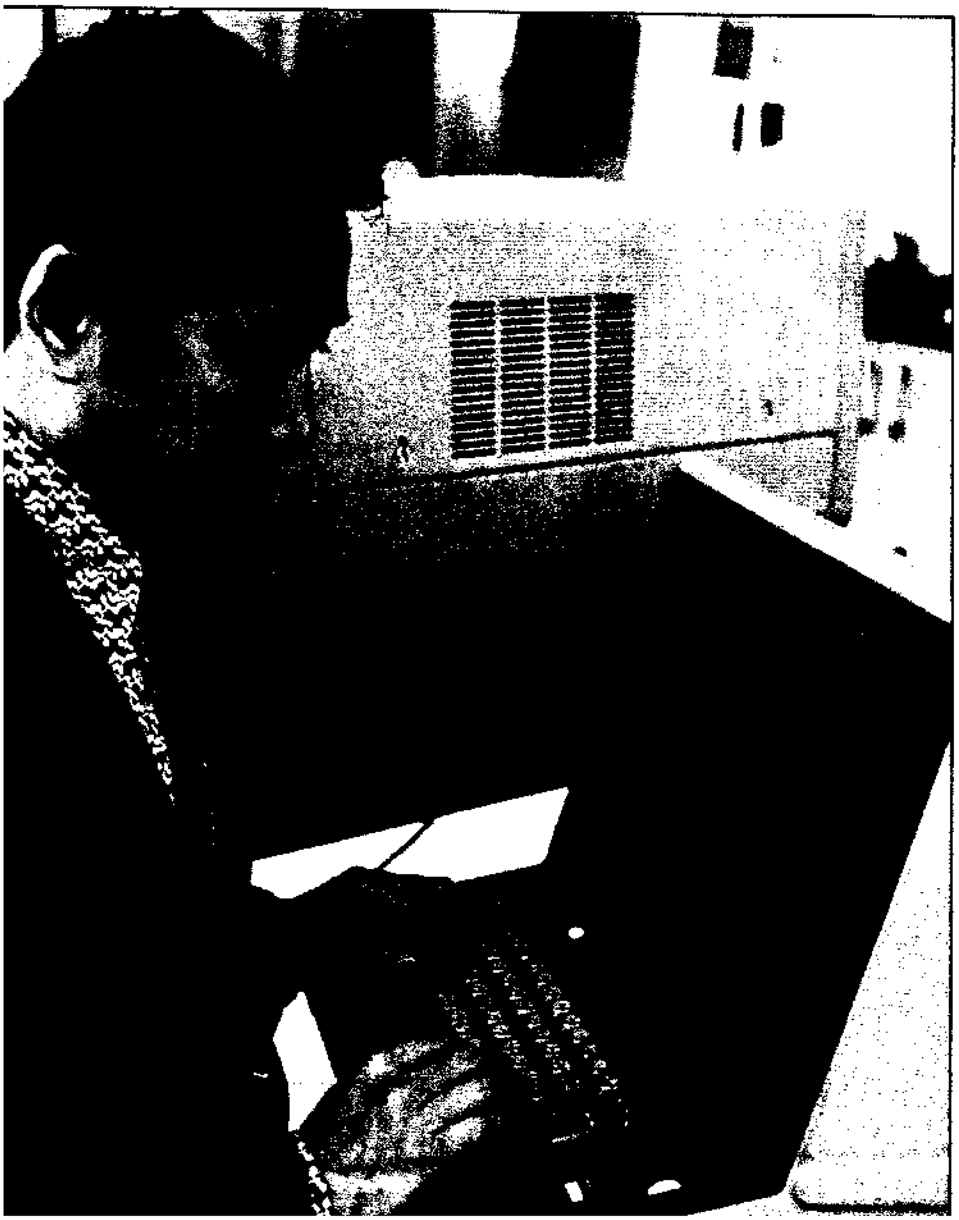
A. D. Michael et al. (1975) studied the effects of a small spill of number-2 fuel oil that occurred in September 1969 at Wild Harbor, Massachusetts. Even in the fourth and fifth years after the spill, they found that ". . . the number of benthic species at the offshore stations and the marsh were slightly, but significantly, lower than those found at control stations. Population densities were similar to control areas for the offshore stations but not in the case of the marsh. . . ."

What We Need to Know

Studies of the biological effects of a major oil spill need to consider a wide range of organisms. One would like to have baseline data, but this information is usually not available. When baseline data are not available, areas similar to affected areas—control areas—should be examined. Most studies of accidental spills use different techniques for sampling and for measuring effects and most of the studies are incomplete. It is difficult to correlate directly the results of one of these studies with another.

Prediction–
The First Step in Protection

To assess the effects of a spill in the Delaware Bay and to take the steps necessary to protect our shore, we must first predict where the spill will go. The Massachusetts Institute of Technology performed a study for the federal Council on Environmental Quality which examined the movement of a hypothetical spill from two sites in the Delaware Bay. One of these sites, the upper-bay site, is located about 2 nautical miles upstream from the present lightering area.



As part of this study, MIT developed a computer program, the "Nearshore Spill Tracking Model," which predicts the landfall the location where an oil spill comes ashore--and the time of landfall of an oil spill occurring at the upper-bay site. Using historical data on the speed and direction of tidal currents and winds in its computations, the model evaluated 200 hypothetical spills occurring at the upper-bay site for each quarter of the year. For the purposes of this study a grid of 3-mile squares was superimposed on the Delaware Bay; the model computed the probability of a spill coming ashore for each grid square along the shore.*

But in addition to the capability of predicting landfalls, we also need the capability of predicting the path of an oil spill over the open bay because some of the areas we need to protect—oyster beds, for example -are located in the open bay. To provide this capability we have extrapolated from MIT predictions, which deal only with the shoreline, to include the open bay. This extrapolation assumes that on a straight-line trajectory the probability of a spill originating in the vicinity of the lightering area and traversing the open bay is the same as the probability of a spill coming ashore.

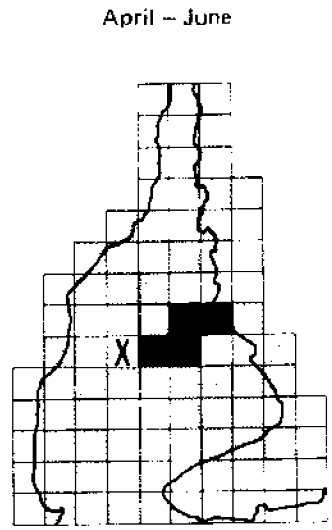
These predictions have nothing to do with the probability of a spill occurring at the lightering area; they predict only the likelihood of a spill reaching a given grid square *if* a spill were to occur in the lightering area.

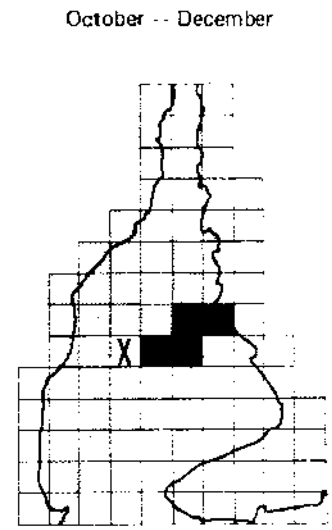
Dr. Hsiang Wang of the University of Delaware operates computer terminal that displays the location of a hypothetical oil spill based on predictions from a program Dr. Wang and his colleagues developed.

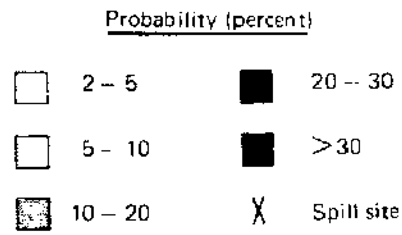
*For a technical discussion of the model, its assumptions and implications, see Stewart et al. (1974).

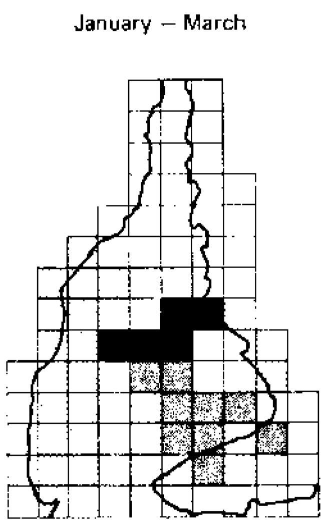
From January to March, the bay shore of New Jersey has the highest probability of receiving spills. From April to June, the pattern is not so clear. From July to September, landfall probabilities are highest for the upper bay but very low for the lower bay. From October to December, virtually the entire bay shore of Delaware is subject to a 2-percent to 10-percent probability of receiving a spill from the lighering area.

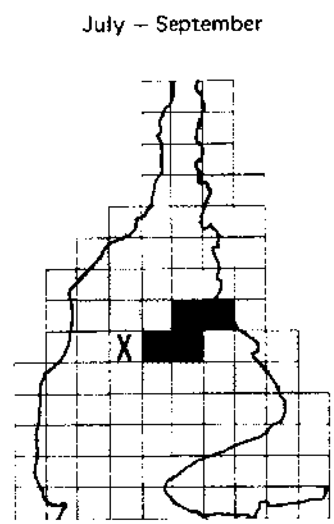
Given that a spill occurred in the vicinity of the lightering area, how long would it take to reach shore? Based on the 800 hypothetical spills evaluated by the model, the minimum time to landfall ranged from 10 hours to 50 hours, depending on currents, winds, and distance to shore. The average time to landfall is always greater than 50 hours, with 50 percent of the spills landing within 75 hours, 60 percent within 100 hours, and 80 percent within 150 hours.











Probability of areas in the Delaware Bay being affected by an oil spill in the vicinity of the lightering area.

Another computer model, developed at the University of Delaware, predicts movement of an oil spill in the Delaware Bay. Given an estimate of the quantity of oil spilled, the time at which the spill occurred, the temperatures of the water and air, and a forecast of the speed and direction of the wind, the computer predicts the location of the spill in say 24, 48, or 72 hours. It takes the computer only a few minutes to perform the calculations; thus, work crews can be dispatched to the location–or predicted location–of the spill to initiate protective measures.

What Protection Methods Can We Use?

At present, mechanical methods are the least damaging methods of cleaning up oil spills. Such methods involve the use of booms and skimmers or absorbents. Retrieval of spilled oil by booms and skimmers is not effective if the current exceeds 1.7 to 2.0 knots, if the wave height is greater than 1 to 2 feet, or if the oil is a distillate product. The use of absorbents is also limited. Proper techniques and equipment for evenly distributing large quantities of sorbents over wide areas of open water, for properly agitating and mixing the sorbents with the oil mass, for harvesting the oily agglomerate, and for processing or disposing of the recovered oil-absorbent mass are not available.

Sinking agents such as sand and stearated chalk are another method of cleanup. These materials were used by the French to sink large masses of oil that spilled from *Torrey Canyon* incident in the Bay of Biscay and have been developed further in Holland. Although no adverse effects on fisheries and benthic life were reported, the lack of knowledge on the precise fate of the oil would indicate that further experiments are needed before this method can be recommended. Sinking may extend the period that the benthic fauna may be affected.

The use of dispersants is another controversial method. According to Cowell (1971) and Smith (1968), most of the damage that occurred at the *Torrey Canyon* spill was caused, not by the use of dispersants, but by their misuse. Specifically, the dispersants were applied undiluted to oil after it had come ashore. Moreover, Beynon (1970) and Canevari (1971) point out that since the *Torrey Canyon* incident, dispersants have been developed that are far less toxic and, if properly used, pose a minimum threat to or burden on the marine environment.

Men of the U.S. Coast Guard's National Strike Force scoop up oil-laden Absorbent-C, a powdery chemical which swells upon contact with water and absorbs spilled crude oil.
(Photograph courtesy of U.S. Coast Guard.)

This summary has been taken directly from National Academy of Sciences (1975).

The U.S. Coast Guard deployed the boom in the foreground to contain spillage from the mangled stern section of the Corinthos, *a 754-foot Liberian tanker which exploded and burned for days after being rammed by another ship at the British Petroleum dock at Marcus Hook, Pennsylvania.*

Those opposed to the use of dispersants claim that dispersing the oil into the water column renders the oil easier for marine organisms to assimilate. Dewling et al. (1971) point out that the use of dispersants, especially in rivers and estuaries, imposes an add burden on the assimilative capacity of the river or estuarine system to biodegrade the oil/dispersant mixture.

Straughan (1972) points out that in certain circumstances such as the protection of an endangered species of birds, the use of low-toxicity dispersants may override all other considerations. Beynon stresses the advantage of using dispersants on oil spills to prevent the oil from washing ashore and killing intertidal organisms because of its toxicity or by smothering. The application of the dispersant must be while the oil slick is still far enough from shore so that the concentration of the oil/dispersant mixture is quickly diluted below its toxic level. Further, several spills that used low-toxicity dispersants were subsequently surveyed and showed no apparent biological damage.

Gatellier et al. (1973) report that for a number of years in France, dispersants have been used routinely with minimal environmental effect. The advantage of using dispersants is the dilution effect that reduces toxicity and facilitates biodegradation. Straughan expresses doubt as to the effectiveness of many of these dispersant products in the open sea if inadequate mixing occurs. However, Canevari (1973) reports the recent development of low-toxicity dispersants that do not require the use of mixing energy to effect dispersal of the oil. The dispersant has a driving force to diffuse across the oil water interface and, in effect, achieves spontaneous dispersion of the oil.

Because opinion is polarized concerning the use of dispersants, research under field conditions is needed to establish the conditions and circumstances under which dispersants can be used effectively.

What Should Delaware Protect?

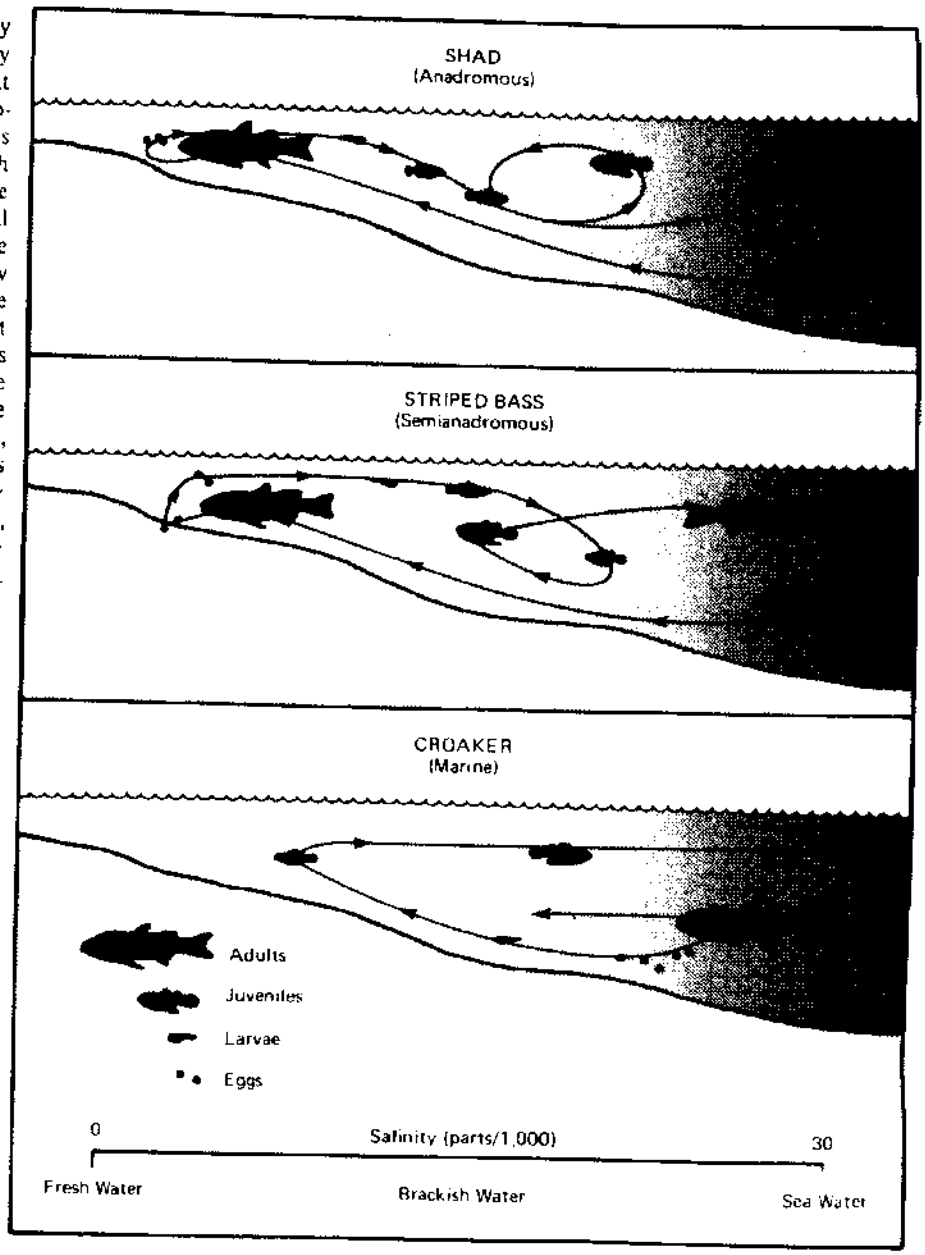
If a spill were to occur in the vicinity of the lightering area in the Delaware Bay and we know where it's headed, what areas should we protect and what protection methods should we use? Priorities may change with the seasons. Lewes Beach may be a high-priority area during the summer: we may want to keep the oil off the beach at all costs. But during the winter months, it may be wiser to allow the beach to become contaminated while we devote the major effort to protect Primehook Wildlife Refuge and its population of wintering waterfowl; the contaminated sand on the beach can be hauled away later. While sinking agents, dispersants, or microbiological surfactants may put the oil on the bottom of the bay and threaten valuable shellfish beds, booms to contain the spill on the surface won't work in rough seas or strong currents.

The decisions an oil spill forces upon us are difficult to make, but they must be made. The decisions will probably be more rational if conducted in the luxury of advanced planning; they may be less rational if conducted in the 10 to 50 hours after a spill has occurred and before it reaches shore. Here are some of Delaware's resources that may some day be affected by these decisions.

Fish Spawning and Nursery Areas

Most people who live along an estuary such as the Delaware Bay know that the estuary is valuable as a spawning and nursery area for fish. But this fact alone is not sufficient to decide how to protect an estuary. Differing migratory and spawning patterns make the question more complex.

Adult shad and herring, for example, live in the ocean but move up the



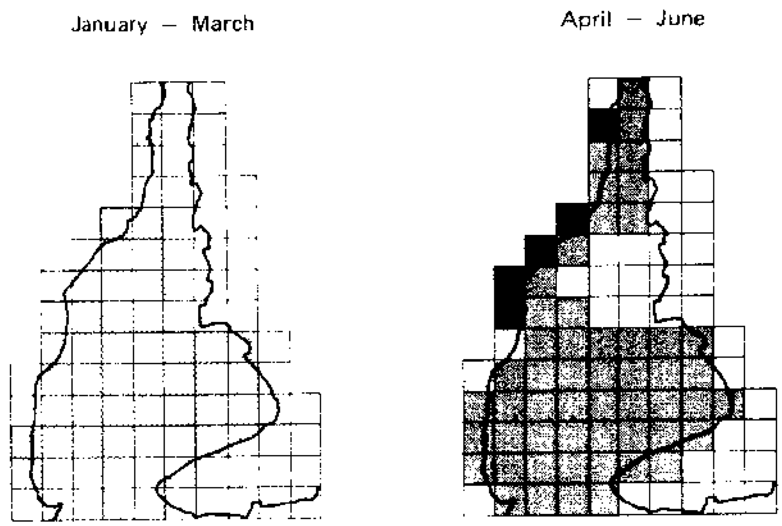
An estuary serves as a spawning and nursery area for fish. (Adapted from Cronin and Mansueti, 1971.)

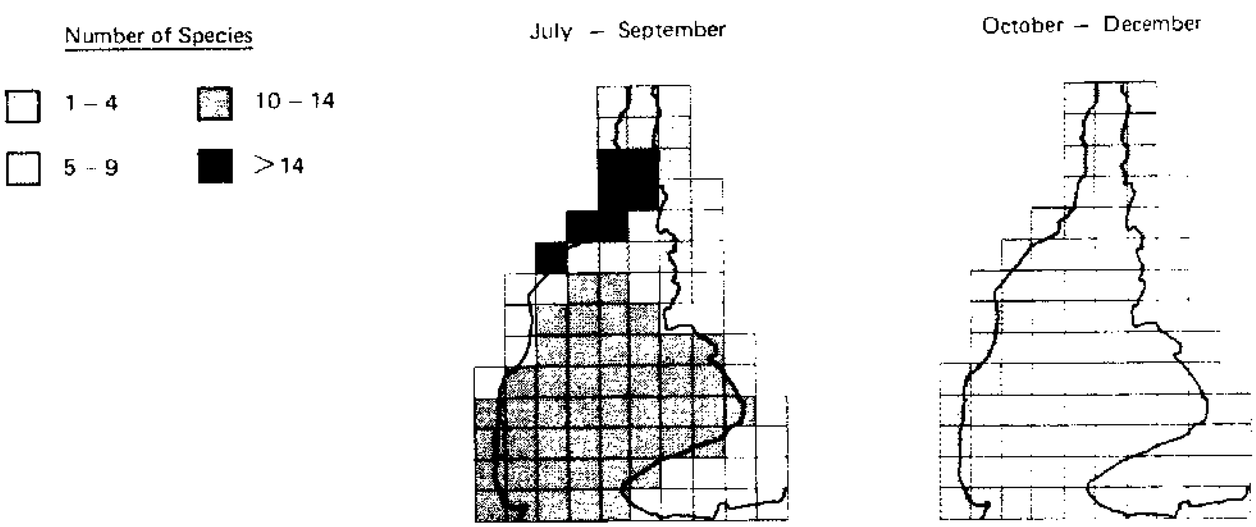
estuary well into fresh water to spawn during the early spring. Their eggs hatch in fresh water and the hatchlings move slowly through the estuary, frequently taking the entire summer to reach the ocean. The hatchlings spend 3 or 4 years at sea maturing, then most of them return to spawn in the stream in which they were hatched. Fish which spend their adult lives in the ocean and return to fresh water to spawn are said to be *anadromous*.

Fish like the adult striped bass and white perch move from the lower, saltier portions of the estuary to, or almost to, fresh water to spawn. Eggs and the larvae that hatch from them drift downstream and the growing juveniles use the estuary as a nursery area. The adults—especially the white perch—may spend all or most of their life in the estuary. Fish which spawn in or very close to fresh water and spend most of their adult lives in the estuary are called *semianadromous*.

The croaker follows yet another migration and spawning cycle: it spawns in coastal marine waters and its larvae are carried by currents into the estuary, where they grow rapidly. Juveniles migrate back to the open ocean. The adults, the basis of an important sport and commercial fishery in the past, move into the estuary during the summer to feed on the rich supply of food.

F. C. Daiber and R. Smith (1972) at the University of Delaware have assessed the distribution of fish-spawning and nursery areas of the Delaware Bay. Their data have been plotted on the same grid system used to predict the probability of a spill coming ashore. From January to March, yellow perch, winter flounder and the little skate each use portions of a broad area of the bay. From April tc June, spawning and nursery activities arc at their peak over a broad range of the estuary. Up to seventeen species of fisl are active. Some of the more well knowr of these fish are the sea trout, whit perch, spot, winter flounder, and blue back herring. These same species occur i great abundance from July to September but their distribution is concentrated i the upper part of the estuary. Fron October to December, as the water cools most spawning activity ceases and larva and juveniles begin to leave the estuary.

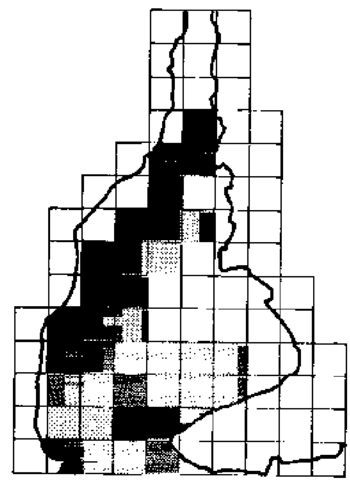


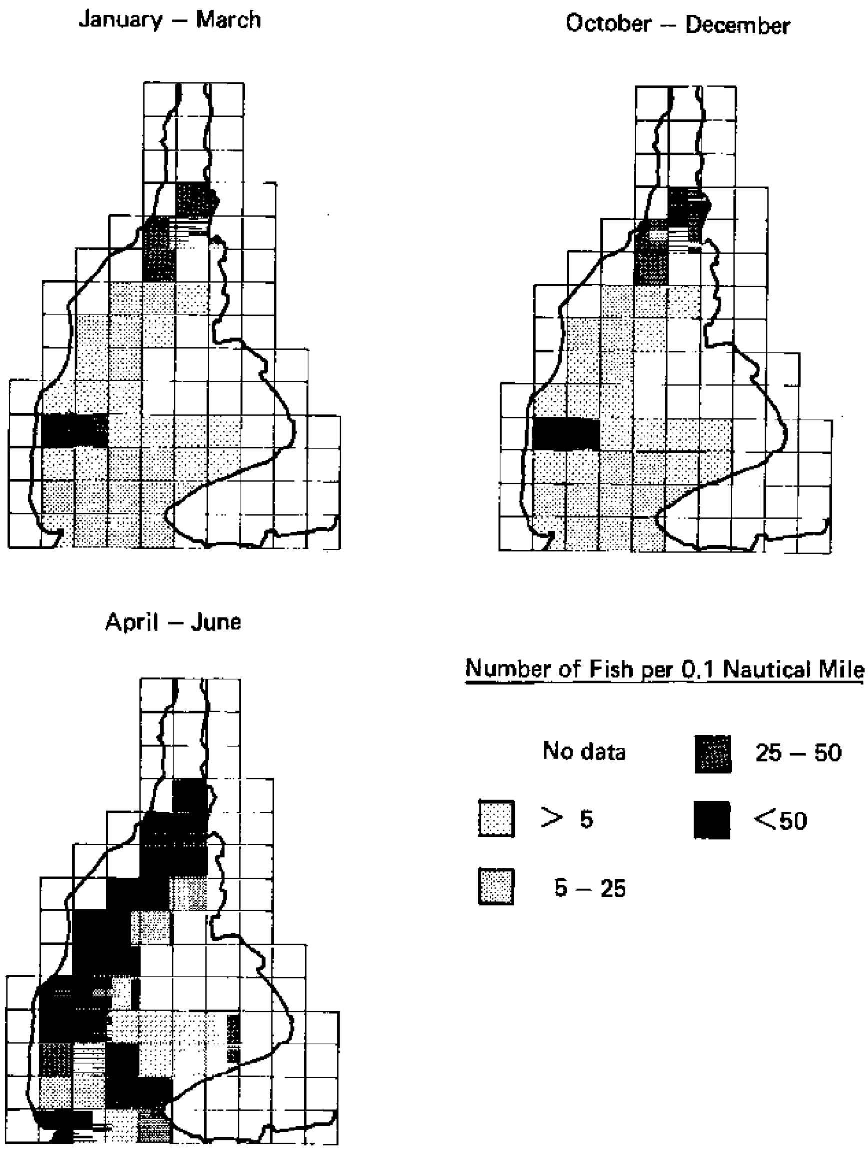


Number of Species using the Delaware Bay as spawning and nursery areas. (Data from Daiber and Smith, 1972.)

Habitats of Sport and Commercial Fish

As would be expected, the density of sport and commercial finfish in the Delaware Bay is highest in the summer and lowest in the winter, although high densities of fish in the winter are found in the vicinity of the anchorage and farther up the bay near Bombay Hook. The illustrations show the number of fish per 0.1 nautical mile plotted on the grid system for summer (April to September) and for winter (October to March); both illustrations include year-round residents.





Distribution of sport and commercial finfish in Delaware Bay. (Data from Daiber and Smith, 1972.)

These data are taken from Daiber and Smith (1972), who summarized 5 years of data on bottom-dwelling fish collected by an otter trawl in the Delaware Bay. They found that 28 species of sport and commercial fish account for 60 percent of the total fish caught during the survey period. These fish are listed in the table. Since the otter trawl catches mostly bottom-dwelling fish, species such as shad and bluefish which do not live on the bottom are probably underestimated; furthermore, species such as the white perch which live in the shallow water inshore were not sampled adequately. And finally, some areas of the bay simply were not sampled.

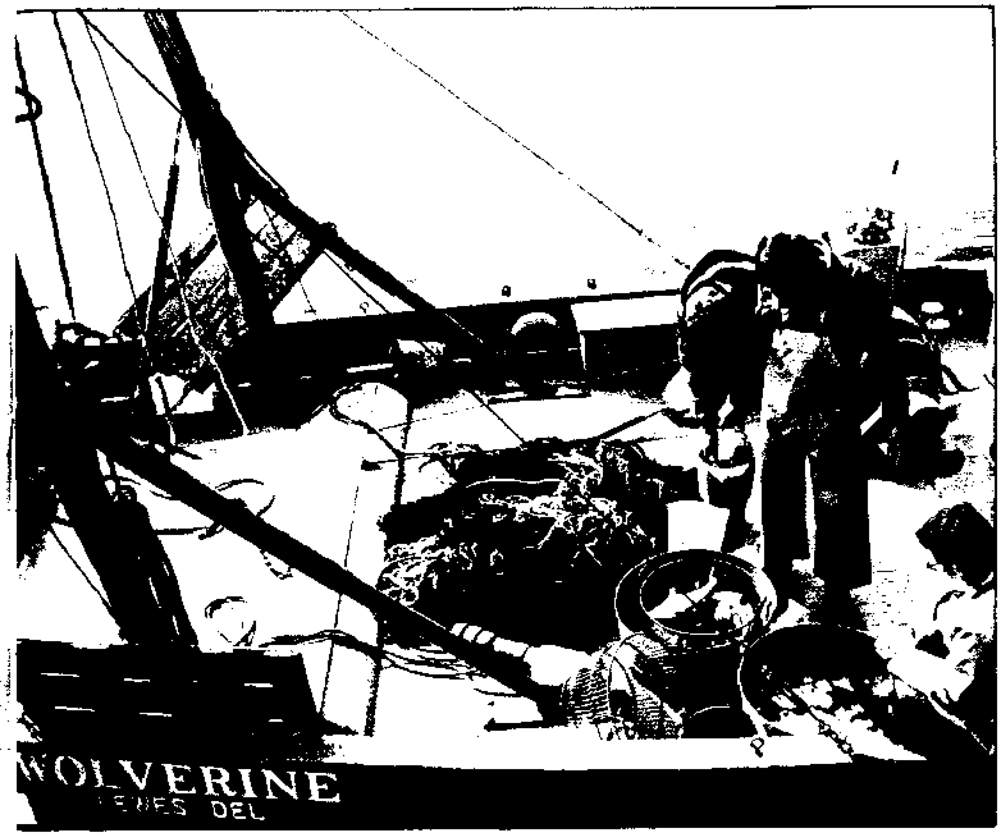
Trawl-Caught Sport and Commercially Important Finfish In Delaware

Specie	Percentage of Total Annual Catch
Summer	
Weakfish	32.29
Scup	11.83
Spot	4.85
Butterfish	1.81
Puffer	1.69
Black Drum	1.39
Summer Flounder	0.47
Northern Kingfish	0.32
Atlantic Menhaden	0.05
Hickory Shad	<0.05
Black Seabass	<0.05
Bluefish	<0.05
Blue Runner	<0.05
Atlantic Croaker	<0.05
Harvestfish	<0.05
Striped Mullet	<0.05
American Shad	<0.05
Winter	
White Perch	1.08
Atlantic Herring	0.92
Striped Bass	0.10
Blueback Herring	<0.05
Year-Round	
Spotted Hake	1.45
Tautog	1.03
Squirrel Hake	0.80
Silver Hake	0.75
White Flounder	0.41
Alewife	0.12
Atlantic Sturgeon	<0.05

Commercial Fishing

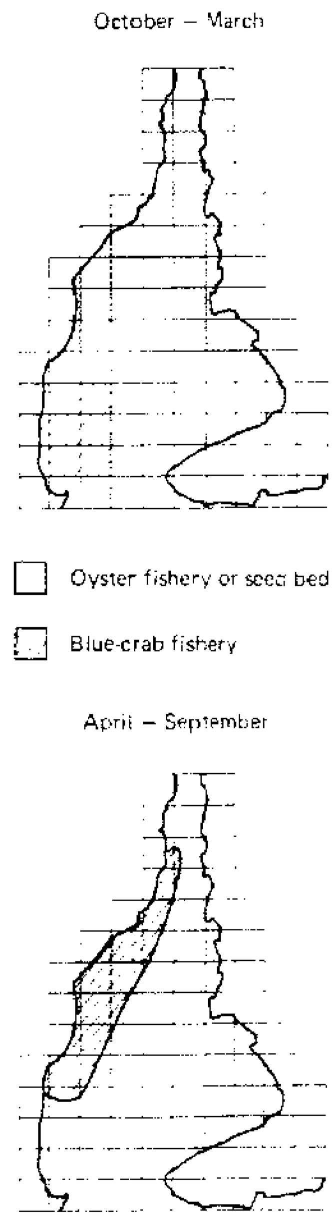
The commercial fishing industry in Delaware Bay experienced a dramatic decline in both catch and value in the 1960s. Available data for the early 1970s indicate a modest recovery in oyster harvest, an excellent recovery of the crab fishery, but a persistent low yield in the finfishing.

We have not been able to uncover data on the specific areas which are fished commercially, nor on the intensity of fishing or the harvest from specific areas. The generalized distribution of oyster beds in the bay as well as the Delaware blue-crab fishery are shown in the figure.



Scientists aboard the University of Delaware's research vessel Wolverine *examine samples of marine life caught in the Delaware Bay as part of a fish-population study.*

Commercial Fishing in Delaware							
		Catch					
		Finfish		Oysters		Crabs	
Year	Fisherman (number)	Weight (pounds)	Value (dollars)	Weight (pounds)	Value (dollars)	Weight (pounds)	Value (dollars)
1954	1,189	979,000	127,000	4,340,000	2,725,000	2,912,000	253,000
1955	1,321	2,841,000	243,000	3,290,000	1,603,000	2,748,000	240,000
1956	1,257	1,521,000	111,000	1,893,000	782,000	3,580,000	424,000
1957	1,434	1,822,000	126,000	4,194,000	2,226,000	4,922,000	411,000
1958	1,384	877,000	96,000	2,410,000	1,717,000	2,455,000	186,000
1959	894	577,000	61,000	295,000	158,000	1,650,000	125,000
1960	719	204,000	26,000	176,000	119,000	2,109,000	230,000
1961	781	465,000	69,000	32,000	18,000	813,000	67,000
1962	742	510,000	58,000	81,000	60,000	1,910,000	128,000
1963	662	520,000	65,000	40,000	25,000	522,000	34,000
1964	631	502,000	60,000	44,000	27,000	313,000	33,000
1965	520	589,000	69,000	34,000	28,000	557,000	47,000
1966	449	409,000	60,000	45,000	36,000	571,000	49,000
1967	445	215,000	30,000	61,000	40,000	788,000	34,000
1968	433	161,000	24,000	43,000	41,000	223,000	40,000
1969	462	1,153,000	289,000	50,000	37,000	462,000	57,000
1970	623	810,000	141,000	216,000	130,000	608,000	106,000
1971	524	432,000	92,000	313,000	199,000	1,023,000	206,000
1972	667	300,000	59,000	505,000	409,000	2,500,000	664,000
1973	541	143,000	20,000	381,000	326,000	2,351,000	654,000



Right, Important commercial shellfishing areas in Delaware Bay. (Data from Maurer and Wang, 1973; and Goodman, 1973.)

Recreational Activities

Rising family income, increased leisure time, and greater mobility have increased people's desires and abilities to participate in outdoor recreational activities. Along the shores of the Delaware estuary, hunting, picnicking, birdwatching, nature walks, swimming, fishing, and crabbing take place at public and private natural and recreational areas which occupy over 72,000 acres of conservation holdings within the states of Delaware and New Jersey. Fishing accounts for most of the recreational use of the open waters of Delaware Bay.

A good indication of the extent of recreational fishing in the state of Delaware is the number of launchings of small private boats. At state-owned ramps alone in 1973, almost 80,000 small boats were launched. Of these launchings, only 55 percent were by residents of Delaware; the other 45 percent were by visitors from Pennsylvania, New Jersey, Maryland, and Virginia. Most of the launchings by nonresidents occur in coastal Sussex County.

Over 400 rental slips for private boats are available within the state and Delaware also offers the angler charter boats and head boats with a total of nearly 900 seats. If we include the number of boats operating from commercial facilities within Delaware and the number of boats operating out of New Jersey, we can safely say that hundreds of thousands of fisherman use the Delaware Bay each year.

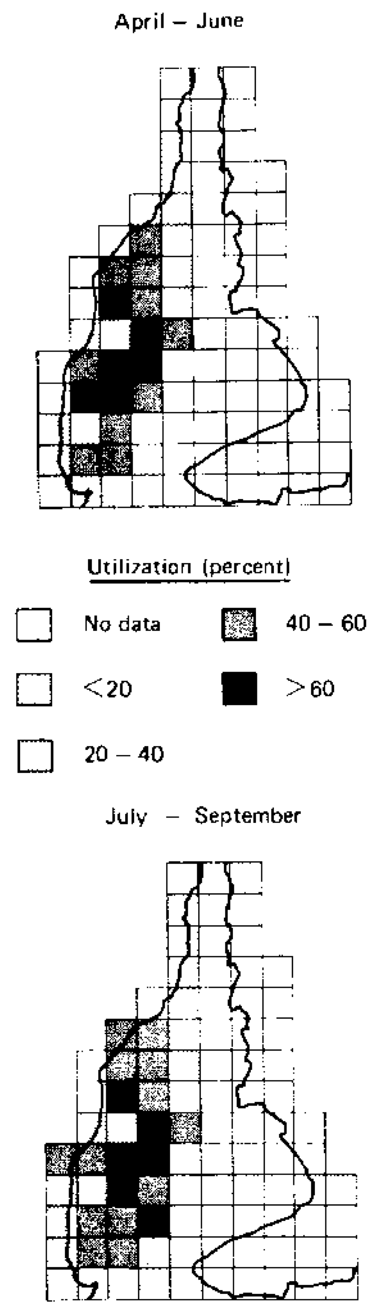
While we would want to protect from oil spills the shore facilities which serve recreationalist and fisherman, certain areas of the bay itself may deserve special consideration. From a survey conducted by Smith (1975), we have plotted the frequency of use of particularly good fishing areas within the Bay. Although no activity is shown for October through December in the illustration, some fishing occurs in October and even into November.

Small-Boat Launchings, Available Slips, And Headboat Capacities in Delaware

	Small-Boat Launchings at State Ramps* (number)	Available Slips** (number)	Head and Charter-Boat Seats (number)
Woodland Beach	721	0	0
Port Mahon	4,909	0	0
Bowers	27,906	0	329
Cedar Creek	32,292	235	203
Lewes	12,440	170	351
	78,268	405	883

*Data from Martin, 1973, for 1973.
**Data from William, 1976.

A "head boat" returns to port after a successful day of fishing on Delaware Bay.



Use of Delaware Bay by party boats originating in Delaware. (Data from Smith, 1975.)

Three birds prowl the marshland in search of a tasty morsel.

Birds

Birds using the Delaware estuary include ducks and geese, shorebirds, gulls, terns, and marsh and water birds. We don't have good data on the bay-wide distribution of water birds other than waterfowl. However, excellent data are available on the kinds and numbers of water birds at both Bombay and Primehook refuges; the data, presented in the table, may provide some insight into the seasonal distribution of water birds over the entire bay.

The illustration shows an estimate of the abundance of waterfowl along the Delaware shore of the bay. We're confident that this estimate of the distribution can be improved by adding data from the New Jersey and Delaware cooperative migratory bird census and banding programs.

Peak Daily Population of Fowl During 1976 At Bombay Hook and Primehook Refuges

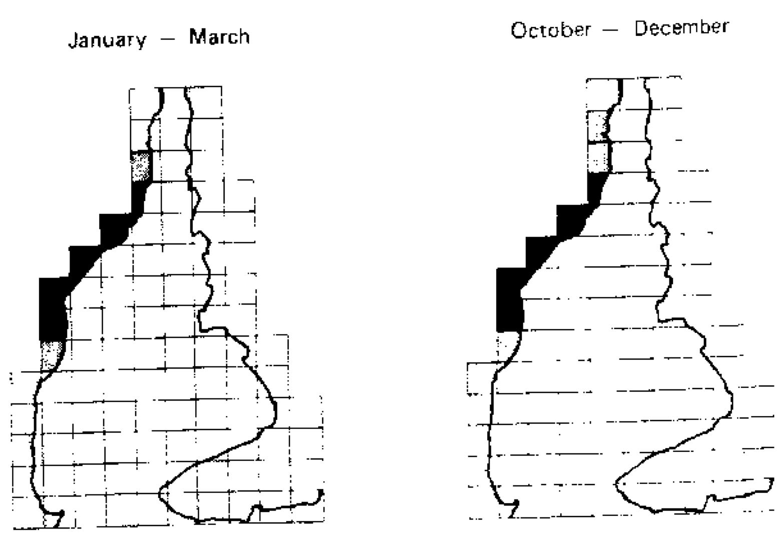
Month	Bombay Hook				Primehook			
	Waterfowl	Shorebirds*	Waterbirds*	Raptors*	Waterfowl	Shorebirds*	Waterbirds*	Raptors*
Jan	59,393				7,616			
Feb	13,330	881	236	164	3,155	← No data →		
Mar	14,272				5,050			
Apr	3,265				2,645			
May	1,072	11,486	974	54	490	← No data →		
Jun	978				440			
Jul	1,595				340			
Aug	1,712	13,765	2,534	48	440	1,907	1,388	56
Sep	3,976				5,970			
Oct	43,252				24,000			
Nov	73,825	2,430	1,304	110	26,170	1,285	465	106
Dec	55,640				16,920			

Data provided by Mr. Ralph Keel, U.S. Fish and Wildlife Service
*Data tabulated quarterly

Waterfowl: geese, ducks
Shorebirds: gulls, terns, sandpipers
Waterbirds: heron, egrets, rail
Raptors: hawks, eagles, owls

Percentage of Total Estuary Population

- No data
- 0 – 5
- 5 – 15
- 15 – 60
- >60



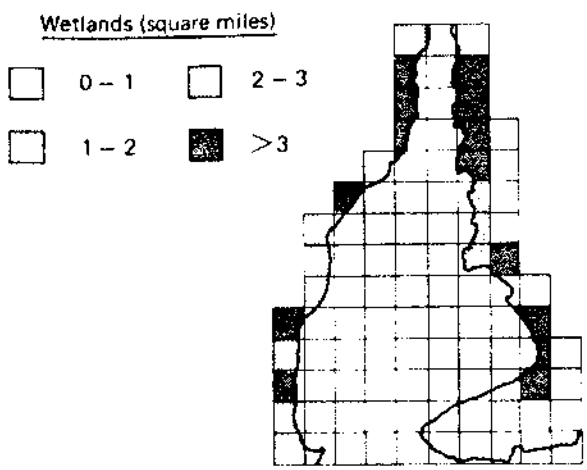
Seasonal distribution of waterfowl along the Delaware Bay. (Data from Goodman, 1973.)

Natural Values

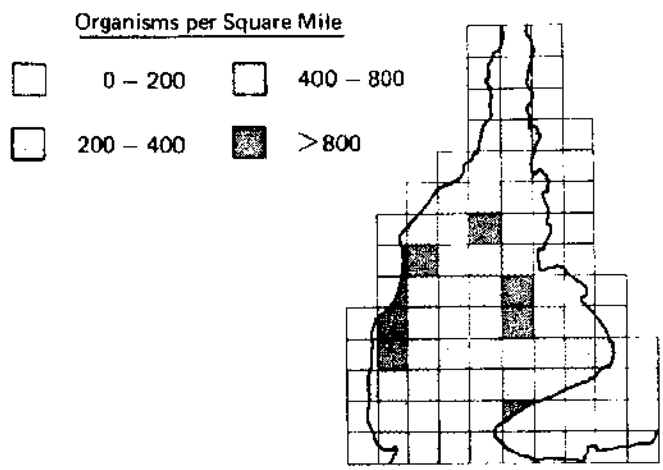
Natural values of the Delaware Bay include rays, searobins, myriad small clams, worms, and minnows, the microscopic plants and animals, and the marsh itself. Again, though, we cannot quantify the relationship between these natural values and recreational or commercial resources. But since we do not know the consequences, it would be prudent not to sacrifice too readily any of these values.

We feel certain that our wetlands are vital. Wetlands surrounding the estuary were mapped as defined in the Delaware River Estuarine Marsh Survey. The illustration shows the percentage of each shoreline block of the grid system which consists of wetlands.

Bottom-dwelling, or benthic, organisms constitute an important part of the natural values of the bay. Maurer and Watling (1976) at the University of Delaware have studied the distribution of benthic organisms in the bay; from this work, we can plot the average number of benthic organisms per square meter during the summer, as shown in the illustration. Presumably, the winter distribution of benthic organisms is similar to the summer distribution. It is important to recognize that the total population of benthic organisms is subject to wide variations and—like the distribution of fishfish—is subject to short-term changes.



Wetland areas along Delaware Bay.



Summer abundance of bottom-dwelling organisms in Delaware Bay. (Adapted from Maurer and Watling, 1976.)

Fishing boats tied up at Fleming's Landing along the Smyrna River. (Photograph courtesy of Delaware Nature Education Society, 1976.)

Critical Natural Areas and Natural Vistas

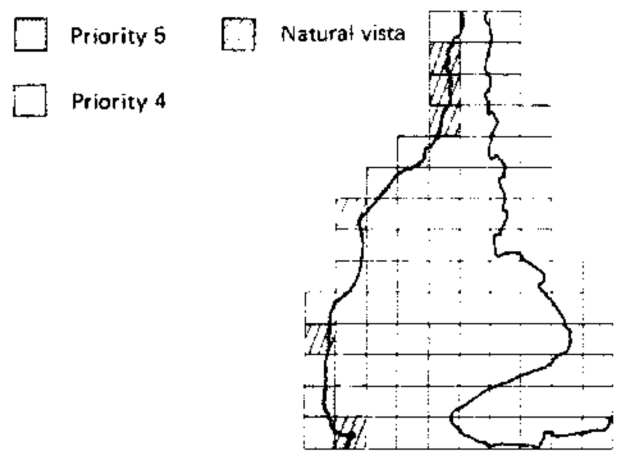
In a 1976 study authorized by the Delaware State Planning Office and funded by the U.S. Office of Coastal Zone Management, the Delaware Nature Education Society (1976) identified critical natural areas and natural vistas within Kent and Sussex Counties. For many reasons, these areas deserve special protection. According to the study, "a natural area contains some feature(s) of unique or typical natural occurrence in its situation, type of plant life, animal-plant community, or geological, archaeological, aesthetic features, or combinations thereof." Based on field study and evaluation by a research team, the study ranked the importance of these areas on an ascending scale from 3 to 5. The table shows those natural areas which are located along or near the shore of the Delaware Bay. Two-thirds of these areas are assigned the highest priority.

As an "enticing addition," the study also presents a subjective sampling of natural vistas: "Words fail to adequately convey the refreshing sensation which may be experienced by the viewer. . . . It is strongly recommended that the appropriate private organizations and governmental agencies take the necessary steps to enable the general public to safely enjoy the vistas. . . ." Those vistas which are located along or near the bay shore are also shown in the table.

Critical Natural Areas and Natural Vistas of Delaware Bay

DNES* Designation		Priority**
	Critical Natural Areas	
1	Woodland Beach Wildlife Area	5
3	Bombay Hook	5
10	Island Field Site	5
13	Murderkill River	4
15	Milford Neck Marshes	4
20	Prime Hook Creek	4
21	Beach Plum Island	5
23	Canary Creek and Old Mill Creek Marsh	5
24	Cape Henlopen	5
	Natural Vistas	
Ia	Flemings Landing	–
Ib	Obs. Tower, Woodland Beach Wildlife Area	–
Ic	Leipsic Bridge	–
Id	Barkers Landing	
Ie	Murderkill River	–
II	North Woodland Beach Wildlife Area	–
V	Cape Henlopen	–

*Delaware Nature Education Society
**5 is highest priority



Critical natural areas and natural vistas along Delaware Bay in Kent and Sussex counties. (Data from Delaware Nature Education Society, 1976.)

Shoreline vegetation along the Prime hook Creek features red maples and green ash. (Photograph courtesy of Delaware Nature Education Society, 1976.)

Who's in Charge?

A major aspect of the problem of protecting Delaware's shoreline from an oil spill is to determine who will decide what to protect and how the decision will be implemented. Frequently, authorities and responsibilities of various state, regional, and federal agencies overlap.

Federal Government

The United States Coast Guard, under the provisions of the Water Pollution Control Act of 1972 (PL 92-500), is the primary authority in all aspects of waterborne oil transport. Its responsibilities include surveying the estuary to locate oil spills, assessing the magnitude of spills, and supervising and coordinating cleanup activities. The Coast Guard can enlist the services of other federal agencies and request the cooperation of state governments in cleanup activities, and it may also contract the services of private cleanup organizations. The Coast Guard maintains its own limited cleanup facilities, but its jurisdiction is so extensive that it is often more feasible to have local contractors do the work.

Also by authority of the Water Pollution Control Act of 1972, the Coast Guard has issued a series of regulations to reduce the probability of accidental discharge of oil during a vessel's normal operations, including the transfer of cargo to a lighter or to a shore facility. Under these regulations, the Captain of the Port—in our case, Philadelphia—may prohibit the transfer of oil whenever he feels that the conditions of a facility violate the regulations and further operations would threaten the environment. These regulations include general rules concerning facilities and equipment such as hoses, loading arms, and closure devices used in the transfer of oil. Each operator of a facility engaged in the transfer of oil on navigable waters must submit to the Coast Guard an operations manual that describes the procedures used to meet the Coast Guard regulations. Personnel involved in transfer operations are tested and licensed by the Coast Guard and before a facility can receive crude oil from a vessel, a declaration of the facility's having been inspected must be submitted to the Coast Guard.

The Corps of Engineers and Environmental Protection Agency are directed to cooperate with the Coast Guard in the control of oil and other hazardous substances as potential pollutants. In the event of a spill, both agencies can provide personnel, equipment, and technical expertise. The Bureau of Customs of the Department of the Treasury has wide authority over foreign vessels entering U.S. ports and is responsible for reporting dangerous conditions to the Coast Guard. The Occupational Health and Safety Administration of the Department of Labor regulates the safety of personnel engaged in lightering operations. The Federal Disaster Assistance Administration of the Department of Housing and Urban Development can assist if a major spill affects a wide area and if the governors of the affected states request the assistance. The Federal Maritime Commission is responsible for obtaining financial-responsibility statements from any vessel over 300 tons operating in U.S. waters. These certificates of responsibility cover charges of cleanup in the event of a spill.

Interstate Agencies

The Delaware River Basin Commission is an administrative agency, formed under the Delaware River Basin Compact, and consisting of representatives from Delaware, New Jersey, Pennsylvania, New York and the federal government. The commission is responsible for developing plans, policies, and projects relating to the water resources of the basin. The commission does not control lightering or crude-oil unloading, but does check antipollution devices and serves as a communications center in the event of a spill.

The Delaware River and Bay Authority is a bistate agency created in 1961 by the action of both New Jersey and Delaware. Most of the early activities of the authority focused on transportation crossings of the bay (Delaware Memorial Bridge and Cape May-Lewes Ferry). Within the last several years, the Authority has attempted to establish itself as an implementer and regulator of crude-oil movement and transfer in the bay.

State Governments

The federal Water Pollution Control Act specifically calls upon the state governments to cooperate in developing antipollution programs. The states have concurrent jurisdiction in maintaining water quality, subject, of course, to the doctrine of national supremacy.

The state of Delaware has long had statutes aimed at preventing pollution of its air and water with particular emphasis on soil conservation, and preservation of wildlife and shellfish. In 1973 the legislature amended the environmental control laws making the Department of Natural Resources and Environmental Control (DNREC) the primary agency in the state for oil-spill cleanup and pollution prevention. To this end, the DNREC has established regulations covering, among other subjects, the bulk transfer of any hazardous material, including crude oil. Any facility used for purposes of transferring 20,000 gallons or more per day

This section is based on the work of Dolan (1975), which conof such material is subject to these regulations. The regulations apply to vessels using the river and bay, and if the vessels discharge oil into the waterways they are subject to prosecution by the state before the superior courts. The DNREC, under contract with the Delaware River Basin Commission, samples the water quality of the estuary. All oil spills in the estuary must be reported to the DNREC, but some confusion exists between the department and the Coast Guard on responsibility for minor cleanups. DNREC has assumed the task in the waters off the Delaware shoreline. Spills of 10,000 gallons or more become the object of coordinated efforts on the part of federal and state authorities working usually with private cleanup organizations.

The State of New Jersey, whose shoreline has been seriously ravaged by oil spills, has also attempted to deal with pollution through surveillance of crude-oil shipment on the estuary. The New Jersey Water Quality Improvement Act of 1971 established the Department of Environmental Protection. The department has promoted several programs aimed at the elimination of pollutants from the state's waterways, including the Delaware River and Bay. One of these programs deals with oil and hazardous gas. The superintendent of this program has weekly contact with the Coast Guard in Philadelphia.

Cooperatives

Some areas have set up non-profit corporations, or cooperatives, to work with federal, state and local government agencies in the event of an oil spill. These corporations usually have industry and agency representation on the board of directors and are established to provide a reasonable capability to contain and harvest oil spills. The operating budget is usually shared by government and industry.

A Question of Responsibility

The passage of legislation and delineation of authority may not be sufficient to ensure the protection of the Delaware Bay. Indeed, the overlapping responsibilities of the various agencies involved may result in tasks undone. The licensing of the lightering area seems to indicate at least one task undone.

Sometime before 1965, the Coast Guard established an anchorage in the Delaware Bay off Big Stone Beach; tankers whose drafts are too great for the river channel northward must be partially unloaded. The Coast Guard is responsible to monitor the lightering operations. No vessels with drafts greater than 39 feet are permitted beyond the Big Stone Beach area and no lightering is permitted except at this anchorage. Sometime between July 1974 and June 1975, the anchorage area was expanded by 40 percent and the amount of crude oil lightered has steadily increased.

The Interstate Oil Transport Company (now IOT Corporation) conducts most of the lightering and their operational record is admirable. Their on-site personnel exercise extreme caution in the lightering task and suspend operations when conditions become marginal. No significant oil spill has resulted from the lightering activity.

Crude Oil Lightered at Big Stone Beach Anchorage Area

Year	Oil Lightered (barrels)
1968	11,100,000
1969	12,600,000
1970	10,000,000
1971	12,300,000
1972	24,000,000
1973	41,000,000
1974	56,000,000
1975	65,000,000
1976	74,000,000
1977	80,000,000*

Source: IOT Corp.
*Projected

The point, though, is that the National Environmental Policy Act of 1969 (42 USC 4321) states that each federal agency which conducts or licenses any project with the potential of affecting the environment must prepare an environmental-impact statement concerning the effects of the project on the environment. The lightering area, designated by the Corps of Engineers or the Coast Guard, was expanded after the passage of the National Environmental Policy, but apparently no environmental-impact statement was prepared.

A Final Question

Each of us reflects our personal perception of the value of the bay. Motel owners, hunters, summer vacationers, sport fishermen, marina operators, commercial fishermen, harvesters, and developers all have interests in how the bay is managed. Those who want the bay returned to "what it used to be" and those who want the bay "developed" both want the bay to be managed. Each of us, then, has a perspective of the most important resources to be protected in the event of an oil spill. If we are going to devise a plant to protect the bay, we must be willing to identify what should be protected.

This report began with a series of questions regarding the environmental consequences of an oil spill in Delaware Bay. Some of the bay's resources and the potential effects of a spill were explored. When one examines the web of jurisdictions, it is clear that the Coast Guard has responsibility for spill prevention and cleanup, but who is responsible for protection?

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