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OCEANUS

ON THE COVER—

A Clean View

We must be eternally vigilant
and be
prepared to protect our environment

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COVER BY jh

Jan Hahn, *Editor*

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THE WOODS HOLE OCEANOGRAPHIC INSTITUTION
Woods Hole, Massachusetts

Man and his Environment

EXCEPT for this shocker, drawn by Albert Hahn, Sr. in 1914, (then to illustrate the danger of floating mines) the editor decided to use only a few dismal illustrations of pollution. All of us already have seen many examples. Instead, we used some photographs to show how pleasant and attractive our world ought to be.

A neuston net being towed alongside the R.V. 'Atlantis II' in July 1969 shows a blackened cod-end and other black spots due to oil particles. The mouth of the net skims the upper few centimeters of the water to collect plant and animal life of the sea surface.

About one million tons of oil
are lost annually at sea
which is the equivalent of one tenth of one percent
of all oil transported across the ocean.

Oil Pollution of the Ocean

by M. BLUMER

OIL Pollution is the almost inevitable consequence of the dependence on a largely oil-based technology. The oil reserves which have accumulated in the earth during the last 500 million years will be exhausted within a few hundred years. The use of oil without loss is impossible; losses occur in production, transportation, refining and use. The immediate effects of large scale spills in coastal areas are well known, but only through the recent introduction of skimming nets have we become aware of the degree of oil pollution of the open ocean. Thus, during a recent cruise of our R/V 'Chain' to the Sargasso Sea, many surface "Neuston" net hauls were made to collect surface marine organisms. These tows were made between 32°N – 23°N latitude (corresponding to a distance of 540 miles) at longitude 67°W. During each tow, quantities of oil-tar lumps, up to 6 cm in diameter were caught in the nets. After 2–4 hours of towing the mesh became so encrusted with oil that it was necessary to clean the nets with a strong solvent. On the evening of 5 December 1968, at 25°40′N, 67°30′W, the nets were so fouled with oil and tar material that towing had to be discontinued. It was estimated that there was 3 times as much tar-like material as Sargasso weed in the nets. Similar occurrences have been reported worldwide.

Much of the oil transport is concentrated in restricted lanes, as shown by this tanker in the busy traffic of the Straits of Gibraltar. Of the world's total oil production, some 25% passes through the English Channel.

The Extent of Oil Pollution

To find out how much oil enters the ocean from various sources we need figures for the total amount of oil produced, shipped, and for the fraction lost in shipping and handling. The world oil production is about 1800 million metric tons a year. Of this amount at least 60% or 1000 million metric tons per year is transported across the ocean. Much of the transport is concentrated in restricted shipping lanes; for instance, 25% of the world production passes through the English Channel!

A minimum estimate of the fraction of lost oil can be calculated from the extent of single large accidents and from operating records of oil ports. The tanker 'Torrey Canyon' alone carried and lost 100,000 tons or 0.01% of the annual sea transport. The recent accident at Santa Barbara has introduced into the ocean some 10,000 tons of crude oil. Reliable figures about oil losses in port are available from Milford Haven, a relatively new British oil port, adjacent to a national park. There, great efforts have been made to control and prevent oil pollution and to keep a record of the size of any spills. In 1966 the annual turnover at Milford Haven was 30 million tons. The losses in the same time period amounted to 2900 tons or 0.01% of the total amount handled. A single accident (the tanker 'Chrissi P. Goulandris') contributed between 10 and 20% of this total; the other losses are attributed to design faults, breakages, and mechanical failures, losses in transfer, and human error. This figure does not include losses outside the port due to accidents in shipping, (e.g. the 'Torrey Canyon') and from numerous other sources such as ballasting and flushing of the bilges, etc. With the less stringent operation of many other ports and the additional losses on the high seas, the loss in transport alone may amount to 0.1% of the total oil shipped, or 1 million metric tons! The actual oil spread on the ocean is higher, since these figures do not include accidents in production (Santa Barbara) return to the ocean of petroleum products (fuels and spent lubricants) in untreated municipal wastes and incomplete combustion of marine fuels.

Therefore, the oil influx to the ocean is at least 1 million tons per year (shipping losses only) and is likely to be ten to one hundred times higher.

Oil Composition and Biological Effects

To assess the biological effects of oil pollution we should discuss the composition of crude oil and the relative toxicity of its fractions. Crude oil is one of the most complex mixtures of natural products, extending over a wide range of molecular weights and structures. The low boiling* saturated hydrocarbons (gasoline range) have, until recently, been considered harmless to the marine environment. However, it has now been demonstrated that these hydrocarbons at low concentrations produce anesthesia and narcosis and, at greater concentration, cell damage and death in a wide variety of lower animals, and that they may be especially damaging to the larval and other young forms of marine life. Higher boiling* saturated hydrocarbons (kerosene and lube oil range) occur naturally in many marine organisms and are, probably, not directly toxic though they may interfere with nutrition and possibly with the reception of the chemical clues which are necessary for communication between many marine animals. Olefinic hydrocarbons probably are absent from crude oil, but they are abundant in oil products, e.g. in gasoline and in cracking products. These hydrocarbons also are produced by many marine organisms, and may serve biological functions, e.g. in communication. However, their biological role is poorly understood. Aromatic hydrocarbons are abundant in petroleum; they represent its most dangerous fraction. Low boiling aromatics (benzene, toluene, xylenes, etc.) are acute poisons for man as well as for all other organisms. It was the great tragedy of the 'Torrey Canyon' accident that the detergents which were used to disperse the oil spill had been dissolved in low boiling aromatics. Their application multiplied the damage to coastal life. It should be pointed out, however, that poisoning of marine life will occur even with non-toxic detergents or dispersants which are applied in non-toxic solvents, because they disperse the toxic materials of crude oil. This exposes organisms to these poisons through contact and ingestion. The high boiling aromatic hydrocarbons are suspected as long term poisons. Current research on the cancer producing hydrocarbons in tobacco smoke has demonstrated that the carcinogenic activity is not—as was previously thought—limited to the well know 3.4 benzopyrene. A wider range of related hydrocarbons can act as potent tumor initiators. While the direct causation of cancer by crude oil and crude oil residues has not yet been demonstrated conclusively, it should be pointed out that oil and residues contain hydrocarbons similar to those in tobacco tar. In their behavior and toxicity, the nonhydrocarbons of crude oil (nitrogen, oxygen, sulfur, and metal compounds) closely resemble the corresponding aromatic compounds.

*Different components of petroleum have different boiling points. This is the basis of refining, by heating crude oil to increasingly high temperatures and collecting the portions that boil off. (Ed.)

Oil Analysis and Law Enforcement

The great complexity of crude oil has an interesting consequence: The variety in the composition of different crude oils and oil products is so great that every oil has its own compositions which are typical and as permanent as fingerprints. Great efforts have been expended by many oil companies in utilizing this characteristic to determine the relationships or differences between oils produced from different oil bearing horizons or discovering a mutual relationship between oils and the sediments from which they originate. This fingerprinting technique is becoming available to the public and will lead to an improved and often conclusive way to tie an oil spill to oil from a particular oil field or from a particular vessel. The analytical techniques are simple and should be a great aid to law enforcement.

Long Term Effects of Oil Pollution

The immediate, short term effects of oil pollution are obvious and well understood in kind if not in extent. The oil pollution damage to coast lines and to bird populations is well known. As mentioned, oil pollution on the high seas is just being recognized, even though the amount of tar already exceeds the amount of plant life floating at the sea surface. We have discussed the short term toxicity for individual petroleum fractions. In contrast, we are rather ignorant about long term and low level effects of crude pollution. I fear that these may well be far more serious and longer lasting than the more obvious short term effects.

The Food Chain

The great complexity of the marine food chain and the stability of the hydrocarbons in marine organisms, lead to a potentially dangerous situation. The food chain of those terrestrial organisms, which are important for human nutrition, is simple. Man either eats plant material or meat products from animals that have been raised on plant food. Human food derived from the sea is much more remote from its origin in plants. Few marine plants are used directly for human nutrition. Except for shellfish, we consume few marine animals that have fed directly on marine plants. Most larger marine animals derive their food from other marine animals already remote from the original plant source. We have studied the fate of organic compounds in the marine food chain and have found that hydrocarbons, once they are incorporated into a particular marine organism are stable, regardless of their structure, and that they may pass through many members of the marine food chain without alteration. In fact, the stability of the hydrocarbons in marine life is so great that hydrocarbon analysis serves as a tool for the study of food sources. In the marine food chain, hydrocarbons may not only be retained but they can actually be concentrated. This is a situation akin to that of the chlorinated pesticides which are as refractory as the hydrocarbons. These pesticides are concentrated in the marine food chain to the point where toxic levels mays be reached. It is likely that the treatment of oil spills with detergents or dispersants, or the natural dispersion of oil in storms, produces oil droplets of such small sizes that they can be eaten and consequently taken up in the body of many sea animals. Once assimilated, this oil passes through the food chain and eventually reaches marine products that are harvested for human consumption. The incorporated oil particles may produce an undesirable flavor. A far more serious effect is the potential accumulation in human food of long term poisons derived from crude oil, for instance of cancer causing compounds.

Another concern is the possible long term damage by pollution to the marine ecology. Many biological processes important to the survival of marine life are

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affected by extremely low concentrations of chemical messengers in the sea water. Marine predators are attracted to their prey by organic compounds which are present at less than one part per billion. Such chemical attraction—and in a similar way repulsion—plays a role in the finding of food, the escape from predators, in the homing of many commercially important species of fishes, in the selection of habitats, and in sex attraction. There is good reason to believe that pollution interferes with these processes in two ways: by blocking the taste receptors and by mimicking natural stimuli; the latter leads to false responses. Those crude oil fractions likely to interfere with such processes are the high boiling saturated and aromatic hydrocarbons and the full range of the olefinic hydrocarbons. It is obvious that a simple —and seemingly innocuous—interference at extremely low concentration level may have a disastrous effect on the survival of any marine species and on many other species to which it is tied by the marine food chain.

Countermeasures Against Large Oil Spills

It must be clear from this discussion that I do not consider the use of detergents or dispersants, toxic or nontoxic, as a solution for pollution problems. The introduction by dispersants of toxic components of crude oil into the sea and the marine food chain constitutes a risk that should not be taken lightly.

Sinking of an oil spill by treatment with hydrophobic minerals, (e.g. chalk treated with stearic acid or refractories treated with silicones) may be preferred; however, we do not know whether the oil remains on the sea floor or whether it will return to intermediate or shallow waters where it can enter the food chain. Also, we do not know enough about the effect of oil on bottom communities.* Sedimentation rates in the open ocean are quite low, and oil that has been sunk will remain exposed on the bottom for long periods of time.

*See page 8 of this issue.

In my opinion, burning of the oil where possible or containment and rapid recovery are the only acceptable solutions for managing large spills.

The Long-Term Outlook

Mankind is depleting the natural oil reserves rapidly. Therefore, it is unlikely that oceanic oil transport will increase by several orders of magnitude. In spite of this, there are several good reasons to anticipate an increase in the seriousness of the marine oil pollution. Marine oil transport through more hazardous waters will increase, (e.g. transport of the Alaskan oil through the Bering Straits). Oil production will shift increasingly to the continental shelves and to oil reserves in deep water; for instance, the Sigsbee Deep in the Gulf of Mexico may be tapped. This will lead to an increasing risk of accidents. Oil products and synthetic oil, (coal hydrogenation products, shale oil) which are more toxic than crude oil, will make up a larger fraction of the oil transported, used, and spilled.

We are convinced of the great value of oceanic food production for mankind. In the future, a larger fraction of human nutrition must be derived from the sea. Farming of the sea (aquaculture) will become an important pursuit for man. If we do not take care of the present biological resources in the sea, we may do irreversible damage to many marine organisms, to the marine food chain and thus eventually may destroy the yield and the value of the food which we hope to recover from the sea.

This article is a version of a paper to be published in: "Oil on the Sea", edited by D. Hoult. Plenum Publ. Corp., Dec. 1968, as part of the new series: "Ocean Technology", edited by J. P. Craven. Published by permission.

SAUNDERS

DARE I GO IN . . . ?

Days after the spill, bubbles of oil came up from the bottom and spread out over the surface of Wild Harbor, Cape Cod, Massachusetts.

LOCAL OIL SPILL

An oil spill practically on the doorstep of our Institution is providing a "laboratory experiment" of oil pollution and its aftermath.

by G. R. HAMPSON and H. L. SANDERS

EARLY on the morning of September 16, 1969, the barge "Florida" came ashore off Fassett's Point, West Falmouth, Massachusetts, and ruptured her steel hull spilling an estimated 250,000 to 280,000 liters (60,000 to 70,000 gallons) of No. 2 fuel oil along the shores of West and North Falmouth. As a result of this disaster, some basic questions on the effects of oil pollution may be partially answered.

Within a few days after the spill we investigated the area that seemed most affected, Wild Harbor and the Wild Harbor River. The toll taken on the marine life was obvious—the oil soaked beaches were littered with dead or dying fish as well as worms, crustaceans, and mollusks. Windrows of fish, crabs, and other invertebrates covered the shores of the Wild Harbor River and large masses of marine worms, forced from their natural habitat in the sediments, lay exposed and decaying in the tidal pools.

Bottom life affected

The lobster and certain species of fish (scup, *Stenotomus versicolor,* and tomcod, *Microgadus tomcod*) washed up on Silver Beach, North Falmouth, are primarily bottom-living forms. This was surprising for it implied that the impact of the oil spill must have been felt not only between the tide levels, but also on the bottom below low tide (subtidal bottom). To ascertain the possible effects on the subtidal bottom fauna, we trawled about 300 meters off New Silver Beach on September 19, 1969 in 3 meters of water. Our catch contained several species of fish, worms, and crustaceans and various other invertebrates. Approximately 95% of the animals were dead and in various stages of decay. Those still alive were moribund. It now became critical to learn the extent the oil penetrated into the offshore sediments and its possible biological implications. Therefore, over the last several weeks we collected both biological and sediment samples for oil analysis in the West and North Falmouth regions believed to be most affected. Also additional control samples were taken well outside these areas.

MR. HAMPSON and **DR. SANDERS** are respectively Research Associate and Senior Scientist in our Department of Biology.

Our preliminary observations suggest that the oil may have consistently penetrated the sediments at water depths of 7-10 meters in the heavily polluted zones. The bottom samples from the same areas contained many dead crustaceans, snails, and clams. These preliminary findings strongly suggest that the oil either directly or indirectly has had a major adverse effect on some of the offshore bottom dwelling animals as well as the intertidal forms. Our long range program is to monitor selected sites to determine the rate at which the oil is leached from the sediments and the time required for the repopulation of these bottoms.

FROM A KODACHROME BY HAMPSON

Dead fish, crustaceans and marine worms concentrated in tidal pools at West Falmouth, Massachusetts. One week after the oil spill none of this evidence was left; only a few empty shells remained. If it were not for the nearness of our laboratories we could not have known the extent of the marine kill.

FALMOUTH ENTERPRISE

Nature works for man and man works against it.

High tide line at Silver Beach, West Falmouth, Mass., shows evidence of the oil spill. At lower left various dead marine invertebrates found clustered in subtidal pools in Wild Harbor River. Again, none of this evidence remained one week later. An oil boom was installed across the width of the Wild Harbor River and is shown at low tide. The view is toward the north.

FROM A KODACHROME BY HAMPSON

OF all inorganic substances, acting in their own proper nature, and without assistance or combination, water is the most wonderful. If we think of it as a source of all the changefulness and beauty which we have seen in clouds; then as the instrument by which the earth we have contemplated was modelled into symmetry, and its crags chiselled into grace; then as, in the form of snow, it robes the mountains it has made, with that transcendent light which we could not have conceived if we had not seen; then as it exists as the form of the torrent — in the iris which spans it, in the morning mist which rises from it, in the deep crystalline pools which mirror its hanging shore, in the broad lake and glancing river; finally, in that which is to all human minds the best emblem of unwearied, unconquerable power, the wild, various, fantastic, tameless unity of the sea; what shall we compare to this mighty, this universal element, for glory and for beauty? or how shall we follow its eternal changefulness of feeling? It is like trying to paint a soul.

John Ruskin

Natural Oil Seepage

NAVIGATORS, in making the Santa Barbara Channel from the northwest, readily recognize their approach in thick, foggy weather *by the peculiar odor of the bitumen,* which, issuing from the bottom or the shore about eight miles west, and floating upon the water, works against the summer winds far beyond Point Concepcion.

Vancouver* was the first who called attention to the bitumen, using the following language. (Vol. XI, p. 449.)

"The surface of the sea, which was perfectly smooth and tranquil, was covered with a thick, slimy substance, which, when separated or disturbed by any little agitation, became very luminous, while the light breeze that came principally from the shore brought with it a strong smell of tar or some such resinous substance. The next morning the sea had the appearance of dissolved tar floating upon its surface, which covered the ocean in all directions within the limits of our view, and indicated that in the neighborhood it was not subject to much agitation."

The following remarks of Sir Edward Belcher, in October 1839, are taken from the account of his voyage. (Vol. 1, p. 320.)

"Off this part of the coast to the westward (of Santa Barbara) we experienced a very extraordinary sensation, as if the ship was on fire, and after a very close investigation attributed it to a scent from the shore, it being more sensible on deck than from below; and the land breeze confirming this, it occurred to me that it might arise from naphtha on the surface. The smell of this asphaltum appears to be occasionally experienced quite far from the land."

From: *History of Santa Barbara and Ventura Counties, California, etc., by T. H. Thompson and A. West, 1883? Howell-North, Berkeley, California, second edition? 1961*

*__George Vancouver__

Sailed on Captain Cook's second voyage as a seaman, and as a midshipman on Cook's third voyage. In 1791, a Commander, he set out for the Northwestern coast of America, charged to take over the territory at Nootka Sound, where he arrived in 1792 and for 3 years (1792-94) he thoroughly explored and surveyed the North Pacific coast.

A bit of digging in historical records often provides interesting information. In our last issue we asked: "Does some of the oil on the ocean come from natural seepage?" This may be true in unstable geological areas. One record of fouling in the Santa Barbara Channel in 1793 was discovered in a curious way when our Mr. A. C. Vine was visiting Dr. C. Hollister's house and idly picked up a book and opened this on the page shown here. The editor turned up the reference to Gulf of Mexico seepage. Both reports, of course, were made long before any offshore drilling took place, or better—in Vancouver's case—before earth oil became in use as a fuel.

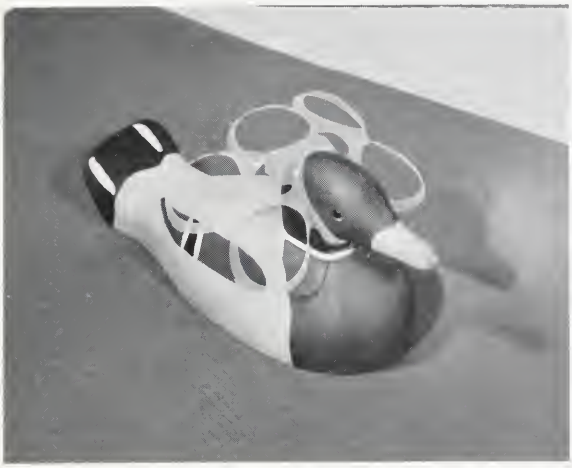
IN the Gulf of Mexico, nature provides many examples how bituminous oil floating up to the sea surface can cause well known "flat spots," as described by local seamen. Such an oil spot exists at 27½°N. and 91°W. in an area of 5000 km^2; two smaller spots are found nearer the coast east of Galveston. At the border between the States of Louisiana and Texas is an area in the Sabine Pass, known to coastal sailors, where an undersea oil spring provides a secure anchorage even during onshore winds and where subsequently the Pilot Boat tends to lie to.*

Cloué mentioned a similar oil spot on the southerly coast of the Gulf somewhat easterly of Coatzacoalcos, which provides a secure anchorage for fishing boats, and he attributes this to submarine oil wells in the neighboring river delta.

(Translated by jh)

From: Krümmel. Handbuch der Ozeanographie, Stuttgart, 1911. 2d Edition. Vol. II, page 102.

*Krümmel also indicates that this information was found on the backside of the Pilot Chart of the U.S. Hydrographic Office, 1906, and the Hydrographic Bulletin No. 920, Washington, 17 April 1907.



MEDEIROS

COURTESY: B. VALAITI (THE SEVEN SEAS)

New Forms of Pollution!

ONE morning last winter we noticed a seagull which flew so erratically that we thought it needed some flying lessons. When the gull came closer to the ship, we saw that it had stuck its neck through one ring of the plastic holder which keeps a "six pack" of beer or soft drinks together. Later, we learned that ducks and other seabirds have been observed in the same distress. Obviously, such birds are doomed. We urge all our readers who go to sea to cut each of the six rings, if they must throw their refuse overboard. All oceangoing ships ought to have garbage shredders on board, such as are carried by naval vessels, while coastal shipping has no excuse for discarding any material.

Plastic bags also will float and have been known to clog water intakes. This summer we picked up a double form of pollution. A plastic tube encrusted with oil particles.

And what about "ghost nets" of which we have written before elsewhere?* The modern fisherman's nets, made of synthetic materials, do not sink and disintegrate when lost, as did the old rope nets. Last year, Bruno Valaiti, an Italian diver and film producer, found and filmed a huge synthetic net which had caught on the superstructure of the 'Andrea Doria.' Floating vertically, the net contained hundreds of fish, mostly cod, in all stages; from skeletons to those newly caught and struggling. How many of such "ghost nets" are fishing without benefit to man and to the detriment of the fish populations?

Finally, there are many other synthetic products, including tens if not hundreds of thousands of fiberglass boats. Although long lasting, these are going to be abandoned sometime. What are we going to do with these wrecks? Unlike wooden vessels they will not disintegrate with time, nor are picturesque while breaking up.

Fortunately, there is one bit of good news. We understand that a moth has been found which likes to nibble away on plastic products. Perhaps this insect can be used, as others mentioned by Dr. Ketchum in this issue. How to train the moths to attack only *discarded* synthetic material will be a nice problem for the ecologists!

Cassandra (jh)

*National Fisherman/MCF., September 1965.


AMBULANCE
SOUND POLLUTION
VOTE FOR ME
ULTRA VIOLET RAYS FILTERED OUT
OXYGEN
IF YOU'VE SEEN ONE TREE YOU'VE SEEN ALL
NITRATES
FERTILIZER RUN-OFF
HOMO SAPIENS R·I·P.
DRINKING WATER
OXYGEN
CARBON DIOXIDE
PHOTOSYNTHESIS
UTAH NERVE GAS TESTING
POLLUTION CO.
PESTICIDES
DDT

An ecological view of Environmental Management

by B. H. KETCHUM

"We must consider nature as part of a living whole which must be kept in balance if the body of nature is to function healthily."

L. Trachtenberg

MAN is only one of several million species of organisms on earth. Each of these species has some impact upon the environment. For several million years man's impact was no greater than that of any other large and predatory mammal, but the development of our highly technical society has changed this situation drastically. Our technology and our rapidly increasing population is modifying our environment on a global scale in ways which would have been impossible a mere century ago.

Nature has a tremendous capacity to recover from abuse. Prior to the industrial revolution the modifications that man caused in the environment had short term effects from which nature could recover. Although man is the only species that has mastered the use of fire, the effect was negligible so long as wood, which is replaceable by forest growth in 50 years or so, was the principal fuel. No doubt there were forest and brush fires started by man which affected large areas and required considerable time for recovery, but similar fires were also started by lightning. Man's impact was still minor in character.

With the use of the fossil fuels, coal, oil, and gas, man started to deplete resources, which had accumulated over millions of years, at a rate far in excess of the rate of replenishment. This may have far reaching effects as we add to the carbon dioxide content of the atmosphere.* It is, however, only one of the many problems, some others may have more rapid and more disastrous consequences.

Vigorous complaint

At this point I would like to enter a vigorous ecological complaint, but I trust that the remainder of my article will be in a more positive and constructive vein. The ecologist is not often asked for advice about new developments and, even when he is, he is asked only after all the important decisions have been made. For example, industry would not consider developing a new plant without the early advice of economists, engineers, and architects. On the basis of their advice the decision to proceed is made and generally the plant is designed and decisions are made about the disposal of waste materials both into the atmosphere and into the water. The engineer certainly considers the impact of such wastes upon the environment, but to be frank, generally from a shortrange point of view. Economic factors are predominant in deciding how to dispose of wastes, provided intense public uproar can be avoided

In a minority of cases, an ecologist may be consulted after all these decisions have been made. The consultation is generally in the hope that the ecologist simply will acquiesce and give his blessings to the proposed activity. It should not be surprising that, when the ecologist does object, he is considered an obstructionist and an opponent to economic and technological advances.

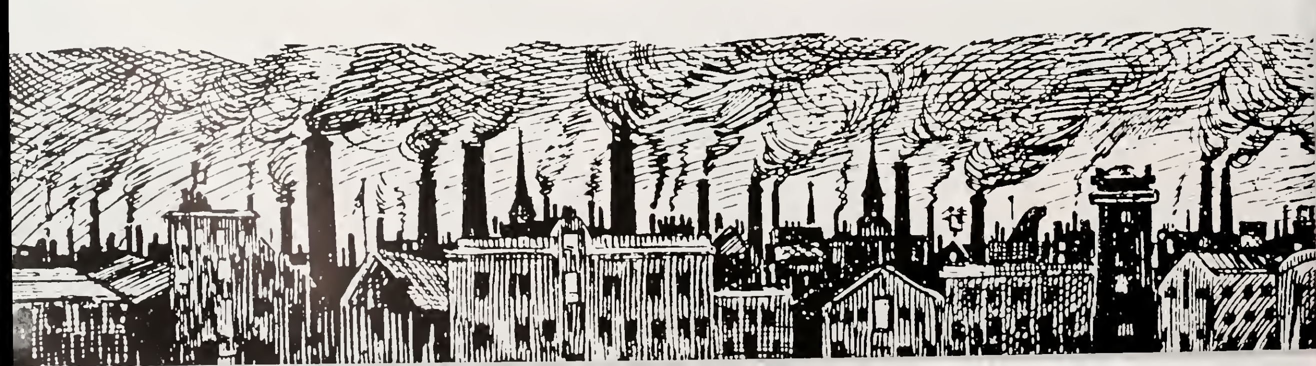
*See: "Sun, Sea and Air" by R. Revelle, Oceanus, Vol. V, Nos. 3 & 4, 1957.

Having criticized the producers of some of our environmental problems, I will also criticize the ecologists. Ecology is a young and developing science. The answers to some environmental questions often are not readily available. Some ecologists may be included in a group that I will call the "old fashioned conservationists" who hope to retain all the qualities of nature and preserve all species that exist on earth. This clearly is not possible. Unfortunately only a few ecologists are willing to examine the total ecosystem and to recommend the hard decision, even when information is available concerning the "right" or "wrong" way to solve the problems. Thus, while I complain that ecologists are not consulted early in the development of a new enterprise, I am forced to confess that if this were universally practiced, there would not be enough competent ecologist around to provide advice, and this diversion of their time would result in delaying or terminating further advances in the study of ecology. Obviously, the solution is to develop the ecological point of view among the industrialists, engineers, and civil authorities responsible for planning.

Some examples

The ecologist does have a real contribution to make to the management of our environment. I would like to demonstrate his approach by a few examples. Many others could have been used.

Two environmental problems illustrate the customary viewpoint, and the modification which would be made by incorporating the ecological viewpoint. The first table illustrates the problems created by our extensive use of persistent general



ECOLOGY AND THE ENVIRONMENT

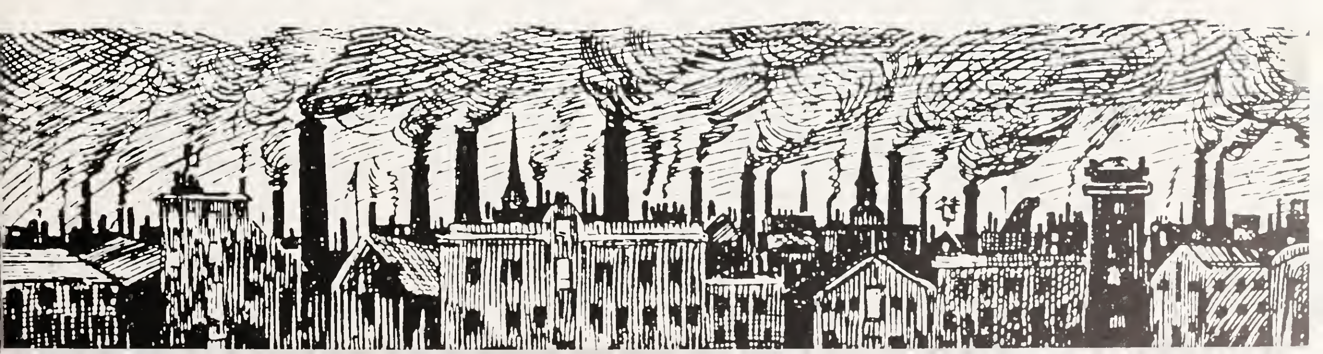
TABLE I

THE PROBLEM:	PERSISTENT, GENERAL INSECTICIDES
BENEFITS:	DISEASE CONTROL (E.G. MALARIA)
	IMPROVED CROP YIELDS
	EASY TO APPLY AND EFFECTIVE
	ECONOMIC GAINS EXCEED COSTS
	LARGE INDUSTRY
HIDDEN COSTS:	KILLS BENEFICIAL INSECTS (E.G. POLLINATORS AND PREDATORS)
	KILLS PREDACEOUS BIRDS
	SELECTS FOR RESISTANT MUTANTS OR STRAINS
	ACCUMULATES TO UNSAFE LEVELS IN PLANTS, LIVESTOCK AND FISH
	ACCUMULATES IN HUMAN FATTY TISSUES (EFFECTS UNKNOWN)
ALTERNATIVES:	STOP USAGE — BUT INTOLERABLE LOSS OF FOOD
	RIGOROUS CONTROL OF AMOUNT AND AREA OF APPLICATION
	DEVELOP METHODS OF BIOLOGICAL CONTROL: INTRODUCE NATURAL PREDATORS ARTIFICIAL STERILIZATION SPECIFIC DISEASE VECTORS
	DEVELOP BIODEGRADABLE AND SPECIFIC PESTICIDES
	INTERRUPT LIFE CYCLE OF PEST
	MIXED SPECIES AGRICULTURE

insecticides. As is shown, the benefits from the use of insecticides are great. We have controlled disease and increased the productivity of agriculture enormously as a result of the discovery of DDT and other insecticides. The industry which produces pesticides, including the herbicides, has been estimated at a value of $1.7 billion for 1968. It is obvious that an ecologist who criticizes their use is challenging a veritable Goliath of industrial might.

However, Table 1 also shows the hidden costs; so called because they are borne by the population as a whole and not by the producer or the user of the pesticides. The contamination of our environment by these pesticides or their persistent residues is world wide.

Well publicized were the recent condemnations of tons of coho salmon which were harvested from the Great Lakes in the U.S. because the pesticide content exceeded levels fit for human consumption. Tons of milk have been condemned and the U.S. federal government has reimbursed the farmer for his losses. Perhaps a more important ecological effect is the destruction of beneficial insects and birds which served as the natural enemies of the insect pests in earlier days, or which, like the bees, are important in pollinating some essential products of agriculture. Also, the widespread use of insecticides has resulted in the appearance of mutants or strains of the same insects which are resistant to the pesticide. We are all aware of Darwin's theory of natural selection which, stated simply, is that those organisms which live on earth today are those which are best fitted to the environment; the weak and the unfit have died off and disappeared. Unfortunately, the pesticides act rapidly in a similar way, and the survivors require heavier and heavier doses of pesticides in order to achieve the same level of control. Many examples could be given. DDT-resistant house flies and mosquitoes are appearing everywhere. It is reported that the incidence of malaria in India is on the increase again because of pesticide resistant strains of the Anopheles mosquito. These hidden costs are real and important, but it is difficult to place an economic value on them because the real extent is still unknown and because economists have not considered these factors in their evaluations.



The ecologists would be remiss in applying his science if he merely deplored the situation; he also must offer alternative ways to achieve the same results. Some of these are shown in Table 1. There are legal battles underway in the states of Michigan and Wisconsin, as a result of petitions, to make the use of persistent insecticides illegal in these states. When banned, substitution of other effective methods of insect pest control will be essential to avoid an intolerable loss of food. Rigorous control of the use of pesticides would merely delay the solution of the problem although it might have some immediate beneficial effects.

Biological control

Some excellent results have been obtained by methods of biological control and other non-chemical systems. These include light traps, pest resistant crops, attractors, radition, sterilization, etc. However, fundamental information in this field is inadequate. If 10% of the funds now being spent on pesticide research were diverted to support studies of biological control, research in this field could increase about tenfold. The artificial sterilization and release of males of the screw worm fly has effectively reduced the population of this pest. We know little about insect disease, another promising method of control. Probably the most promising solution to these problems is the development of specific pesticides which are active only against the undesirable species. Such pesticides should be decomposed by soil and water bacteria so that they would disappear quickly from the environment and their effects would be short range rather than persistent. There are many ways to interrupt the life cycle of insects since many of them require specific plants for one stage of their cycle. Removal of these plants from the area where control of the harmful insect is desirable has been shown to reduce the pest population.

Perhaps the most controversial alternative is to return to mixed species agriculture. One reason why pests have developed so extensively is that man offers them thousands of acres of a single food species. The reason for these enormous areas planted with grain, corn, cotton, tobacco, etc. is economic; large machines can be used and thus reduce the cost of harvesting. This provides an ideal habitat for the organism which attacks that particular crop. Mixing other agricultural products interferes with the explosive growth of the pest population and also affords habitat protection for the predaceous birds and insects which help to control the pests.

DR. KETCHUM is Associate Director of our Institution. He has just returned from a year's leave of absence to serve as Section Head for ecology and systematic biology at the National Science Foundation.

A similar table shows the aquatic disposal of domestic sewage. This, too, has obvious benefits to the producer; the benefits are greater for untreated wastes than for treated wastes since it costs money to build and operate a sewage treatment plant. Sewage treatment does eliminate some of the problems which are created by the disposal of untreated wastes, and rapidly is becoming the accepted practice required by law in many areas.

The hidden costs are imposed upon the general public and frequently on populations downstream who have not been consulted and who have no responsibility for the activity. The water in many fresh water streams is used over and over again during its travel from the source to the sea. Each increase in pollution increases the cost of water purification for downstream locations. It is no secret that much of our water is unsuitable for bathing and recreation and large areas have been closed for shellfishing. Land values along polluted lakes and streams obviously have suffered.

Overfertilization

The great hazard in aquatic sewage disposal is the overfertilization of natural waters. This eliminates desirable species, encourages the growth of undesirable algae and depletes the oxygen content. The alternatives include development of better treatment plants, but these will be unsuccessful unless the mineral elements which cause plant growth are also removed. When these fertilizing elements are added to natural waters, the plant growth can produce as much organic material as was removed at great expense in the treatment plant. This merely moves the problem downstream and has been called secondary pollution.

ECOLOGY AND THE ENVIRONMENT

TABLE 2

THE PROBLEM:	DOMESTIC SEWAGE — AQUATIC DISPOSAL
BENEFITS:	UNTREATED WASTES — LOWEST COST DISPERSION AND TRANSPORT AWAY FROM THE SOURCE
	TREATED WASTES — REDUCTION OF ORGANIC MATERIAL AND SMELL REDUCTION OR ELIMINATION OF SLUDGE BANKS EASIER DISPERSION AND TRANSPORT
HIDDEN COSTS:	INCREASES WATER PURIFICATION REQUIREMENTS
	WATER UNSUITABLE FOR BATHING AND RECREATION
	LARGE AREAS CLOSED FOR SHELLFISHING
	DECREASED LAND VALUES
	EUTROPHICATION (OVERFERTILIZATION) OF NATURAL WATERS RESULTS IN: ELIMINATION OF DESIRABLE SPECIES GROWTH OF OBNOXIOUS ALGAE DEVELOPMENT OF ANOXIC CONDITIONS
ALTERNATIVES:	IMPROVED TREATMENT, INCLUDING REMOVAL OF MINERALS
	GREATER DILUTION (E.G. OCEAN DISPOSAL)
	RECYCLING: BALANCED AND CONTROLLED FERTILIZATION FOR AQUACULTURE, FOREST CULTURE OR AGRICULTURE
	"DRY" WASTE DISPOSAL METHODS

TABLE 3 HISTORICAL SUMMARY OF POLLUTION-CAUSED FISH KILLS JUNE 1960—DECEMBER 1968

	JUNE-DECEMBER 1960	1961	1962	1963	1964	1965	1966	1967	1968
Number of States reporting	36	45	37	38	40	44	46	40	42
Number of reports	286	411	381	436	485	531	436	375	438
Reports which state number of fish killed	149	263	233	300	385	446	372	303	379
Total estimated number of fish killed	6,379,000*	15,910,000*	7,118,000*	7,860,000	18,387,000	11,784,000	9,115,000	11,591,000	15,236,000**
Average size of kill***	2,925	6,535	5,710	7,775	5,490	4,310	5,620	6,460	6,015
Largest kill reported	5,000,000	5,387,000	3,180,000	2,000,000	7,887,000	3,000,000	1,000,000	6,549,000	4,029,000
Reports where extent of area affected was stated									
River									
Number of reports	189	240	259	271	339	292	251	219	264
Miles of stream	1,204	1,686	1,448	2,203	1,440	1,300	989	1,039	1,565
Lakes and reservoirs									
Number of reports	25	50	25	49	57	38	46	33	37
Acres affected	1,407	5,967	2,581	5,664	12,637	4,630	21,564	1,996	2,400
Average duration of kill in days	2.95	2.64	2.59	3.18	2.44	2.57	2.71	3.34	2.99

* After adjustment for reports giving two or more causes.
** Includes all fish killed as reported plus an allowance computed for reports which do not indicate the number of fish that died
*** Excludes 31 reports of 100,000 kills or more as being unrepresentative

TABLE 4 FISH KILL SUMMARY BY SOURCE OF POLLUTION FOR CALENDAR YEAR 1968

SOURCE OF POLLUTION	TOTAL REPORTS	REPORTED FISH KILLED No. of Reports	No. of Fish	AVERAGE KILL	ESTIMATED FISH KILLED** Total	Game	Nongame	Commercial
Agricultural operations	77	66	375,548	4,240	422,000	152,000	270,000	277,000
Industrial operations	177	152	6,255,713	5,675	6,398,000	415,000	5,983,000	2,349,000
Municipal operations	122	108	6,791,464	7,585	6,952,000	320,000	6,632,000	6,558,000
Transporation operations	39	33	825,365	9,155	880,000	430,000	450,000	244,000
Other operations	23	20	578,124	1,995	584,000	19,000	565,000	575,000
Total	*438*	*379*	*14,826,214*	*6,015*	*15,236,000*	*1,336,000*	*13,900,000*	*10,003,000*

* Excludes 31 reports of 10,000 kills or more as being unrepresentative.
** Includes all fish killed as reported plus an allowance computed for reports which do not indicate the number of fish that died.

Elegant euphemisms sometimes are used to camouflage unpleasant facts . . .

This article was adapted from a speech: "An ecological view of environmental management" given by Dr. Ketchum at a National Science Foundation symposium on Systems Analysis for Social Problems, May 28, 1969.

Fertilization is good if not carried too far. There are ways by which we can dilute the pollution to a level where natural growth is encouraged without over fertilization. This could be done by greater dilution, such as ocean disposal with a good dispersion system. Alternatively, the sewage wastes can be dried, fortified with essential elements, (since the wastes are not balanced) and used as fertilizers for agriculture, forest culture, or aquaculture.

Evaluate hidden costs

The alternatives may be more expensive than the methods now in use, and they certainly will continue to be so if we look only at the direct costs and benefits of our present procedures. The economists must learn to evaluate the hidden costs. If a realistic value can be placed upon these costs, it may prove advantageous to require a method which appears more expensive. The popularity and demand for a clean environment makes it clear that we must modify the present methods.

In case anyone believes that the hidden costs are negligible and unimportant, I present the extent of fish kills in the United States as reported by the Federal Water Pollution Control Administration. Table 3 shows that fish kills have occurred in thousands of miles of streams and in thousands of acres of ponds throughout the country each year over the last several years. Annually, many millions of fish are killed by pollution. Probably the numbers are a minimum estimate since only rather massive fish kills are reported and it is probable that smaller kills are ignored. The tremendous piles of alewives on the shores of Lake Erie a few years ago indicate how drastic these effects may be. The dead fish were buried at great cost to alleviate the stench which was making human life intolerable on the shores. There are also massive fish kills associated with "Red Tide" outbursts in the ocean. It is not known how many of the Red Tides are natural phenomena or how many occur because of pollution resulting from human activities.

The causes of fish kills are shown in Table 4, which makes it obvious that a number of other problems could be discussed in the same way as pesticides and domestic pollution. We could consider, for example, industrial water pollution, thermal pollution, atmospheric pollution, solid wastes, and abuses of our landscape. All have benefits, hidden costs, and alternative solutions.

What then should be the role of ecologists in total environmental management? I would like to provide one example, the multiple uses of an estuary, with which I have some personal experience. (See the colored graphs on page 23).

In planning for total environmental management, hard decisions must be made which will eliminate some uses in favor of others. These decisions should be based on all the factors involved, not upon short term expediency. Before the environment is changed, the public should be fully informed about the potential effects and the reasons for the choice made. If a decision is made, for example, to use a particular estuary for industrial purposes, including waste disposal, the public should realize that this is being done at *their expense* since this use will not be compatible with personal uses of the estuary (boating, swimming, fishing), and the results of the decision often may be irreversible.

Improvements demanded

Many of the streams and estuaries have reached a state of deterioration where the personal uses are reduced to a minimum or have been entirely eliminated. The public has been slow to realize its loss, but now is aware that deterioration has progressed too far and the people are demanding improvements for the benefit of better living conditions.

We may return now to an evaluation of the hidden costs of our activities. Due to public demand, many communities are being forced to improve the quality of air and water, and they are discovering, to their regret, that the cost of restoring quality greatly exceeds the cost that would have been incurred to maintain quality in the first place. Some of the damage we have done to our environment through irresponsible activities may be irreversible. We cannot know until more basic studies are completed which environments can be improved and which are lost beyond repair.

The protection of the public against the hidden costs of human endeavors should be borne, in part at least, by the public since they benefit from the improvement. Contributions of public funds, federal, state, and local, is a reasonable expectation. Industries and municipalities must, however, also bear part of the financial burden because it is unjust to give them the privilege of destroying that which belongs to all of us without our agreement and consent.

This, then, is an ecological view of environmental management. Only when serious consideration is given by industrialists, engineers, city planners and other representatives of the public to the total effect of an operation, including not only the immediate benefits but also the hidden costs and alternative methods, can we hope to develop a policy which is equitable and fair to the population as a whole.

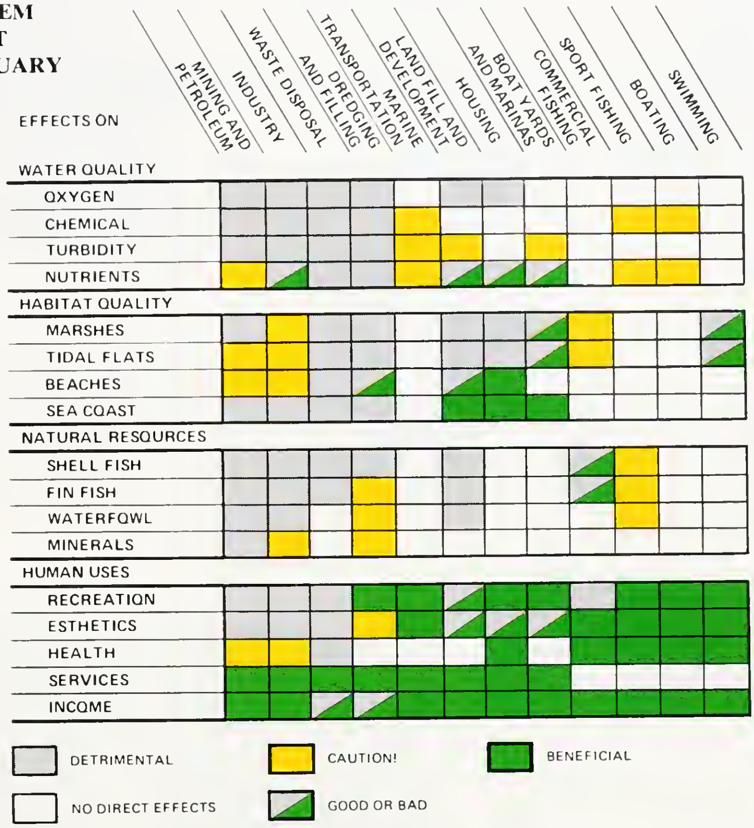
A clean environment is man's greatest joy

The hidden costs of pollution often are difficult to estimate.

Compatible use—A navigational lighttower (Brenton Reef) which replaced a former lightship, is used as a turning marker in a New York Yacht Club Race.

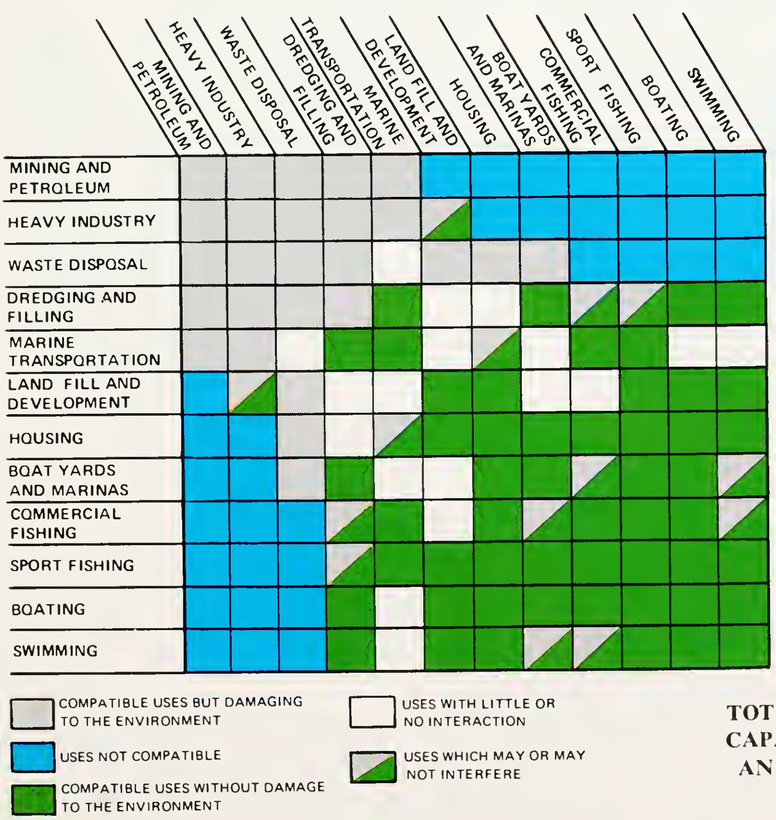
Federal, State and Local authorities, as well as the public, ought to begin cleaning their own front yards.

TOTAL ECOSYSTEM MANAGEMENT EXAMPLE: AN ESTUARY

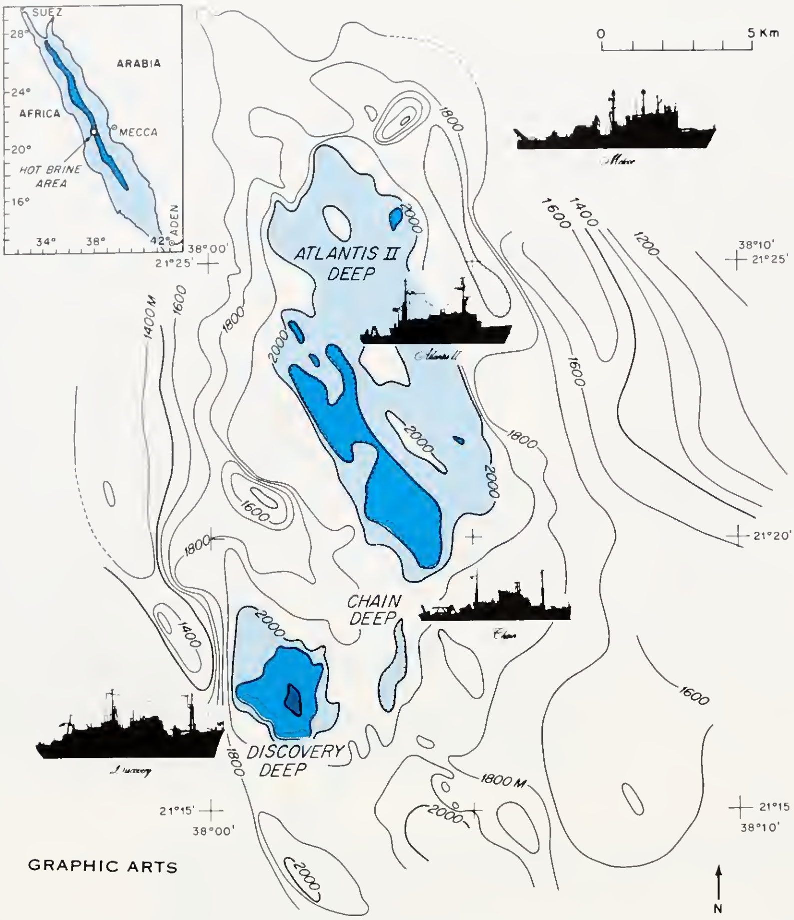


THE effects of various uses on the quality of the environment of an estuary are shown in the first graph. The uses are ranged across the top of the table from industrial uses at the left to the more personal uses on the right. The effects of each use on the water quality, on the resources and on the human uses are shown in blocks. The highly industrial use of an estuary is generally detrimental to quality, as shown by the areas in gray. The areas colored yellow indicate caution, in such cases it is uncertain as to whether the quality would be reduced drastically. Beneficial uses are shown in green. When the effect may be good or bad, depending upon how the operation is performed, the area is colored half gray and half green. The open white spaces indicate the many activities which have no direct effect on the quality or use of the estuary. It is obvious that some uses are not compatible with others.

The lower graph illustrates the compatibility of use. The gray areas show compatible uses which are damaging to the environment. The green blocks identify compatible uses which do little or no damage to the environment. The divided blocks again show ambiguous cases where there may or may not be interference with other uses or may or may not be damage to the environment.



TOTAL ECOSYSTEM MANAGEMENT CAPABILITY OF MULTIPLE USE OF AN ESTUARY AND THE EFFECTS ON THE ENVIRONMENT



GRAPHIC ARTS

New Book

The Red Sea Waters

A remarkable book on a remarkable subject, published in a remarkably short time is: **"Hot Brines and Recent Heavy Metal Deposits in the Red Sea." Edited by E. T. Degens and D. A. Ross. Springer-Verlag, N.Y. 1969. 600 pp. Illus. Index. $32.00.***

The book is a perfect example how international and interdisciplinary cooperation can accomplish a great task in a relatively short time. The Red Sea deposits are so extra-ordinary that their discovery and particularly the results of the intensive effort to examine and report so many aspects of the narrow holes ought to be as widely known as the moon explorations. In our age it is not easily understood that an entirely new environment can be found on earth.

The 76 contributors came from 7 different countries (Great Britain, Germany, Canada, Australia, New Zealand, Egypt and the U.S.A.) and from many different universities and other organizations. They include: geophysicists, geologists, chemists, biologists, paleontologists, physical oceanographers, lawyers and economists. Twenty of the authors, including the editors, are from our Institution. Support for the studies came chiefly, but not exclusively from the National Science Foundation, from the Office of Naval Research, from the Atomic Energy Commission and from the American Chemical Society; also from the British Admiralty and from the Deutsche Forschungs Gemeinschaft.

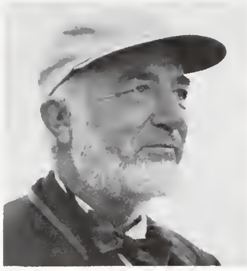
One interesting sidelight is that many of the investigations were made during short periods of time while various ships were on their way to take part in the International Indian Ocean Expedition.

*See: "A major discovery", by P. M. Fye. Oceanus, Vol. XI, No. 3, April 1965. "Hot Brines and Heavy Metals in the Red Sea", by E. T. Degens and D. A. Ross. Oceanus, Vol. XIII, Nos. 2 and 3, June 1967.

Other reading — Pollution Problems:

The subversive science, edited by P. Sheppard and D. McKinley, Houghton Mifflin Co., 1969. 453 pp., illus. $8.95.

America the raped: The engineering mentality and the devastion of a continent, by G. Marine. Simon and Schuster, 1969. 312 pp. $5.95.



J. Seward Johnson

W. Van Alan Clark

Miscellaneous Notes

A Splendid Gift

ASSOCIATES and the general public no doubt have heard of the two generous gifts, totalling 13 million dollars, for the support of the Institution's graduate program and related research. The donors: Mr. J. Seward Johnson and Mr. and Mrs. W. Van Alan Clark, are long-term Associates of the Institution. Their generosity is deeply appreciated.

U.S.-U.S.S.R. Co-operation

Soviet lady scientists at our clambake

MEDEIROS

Dr. Edgerton led the singing

IT was quite a year for the exchange of amenities and information. In the spring, the R.V. 'Atlantis II' (Captain E. H. Hiller) visited the Soviet ports of Novorossiysk and Yalta where visits were exchanged between the ship and the Soviet laboratories. Three Soviet scientists joined the Black Sea cruise between ports.

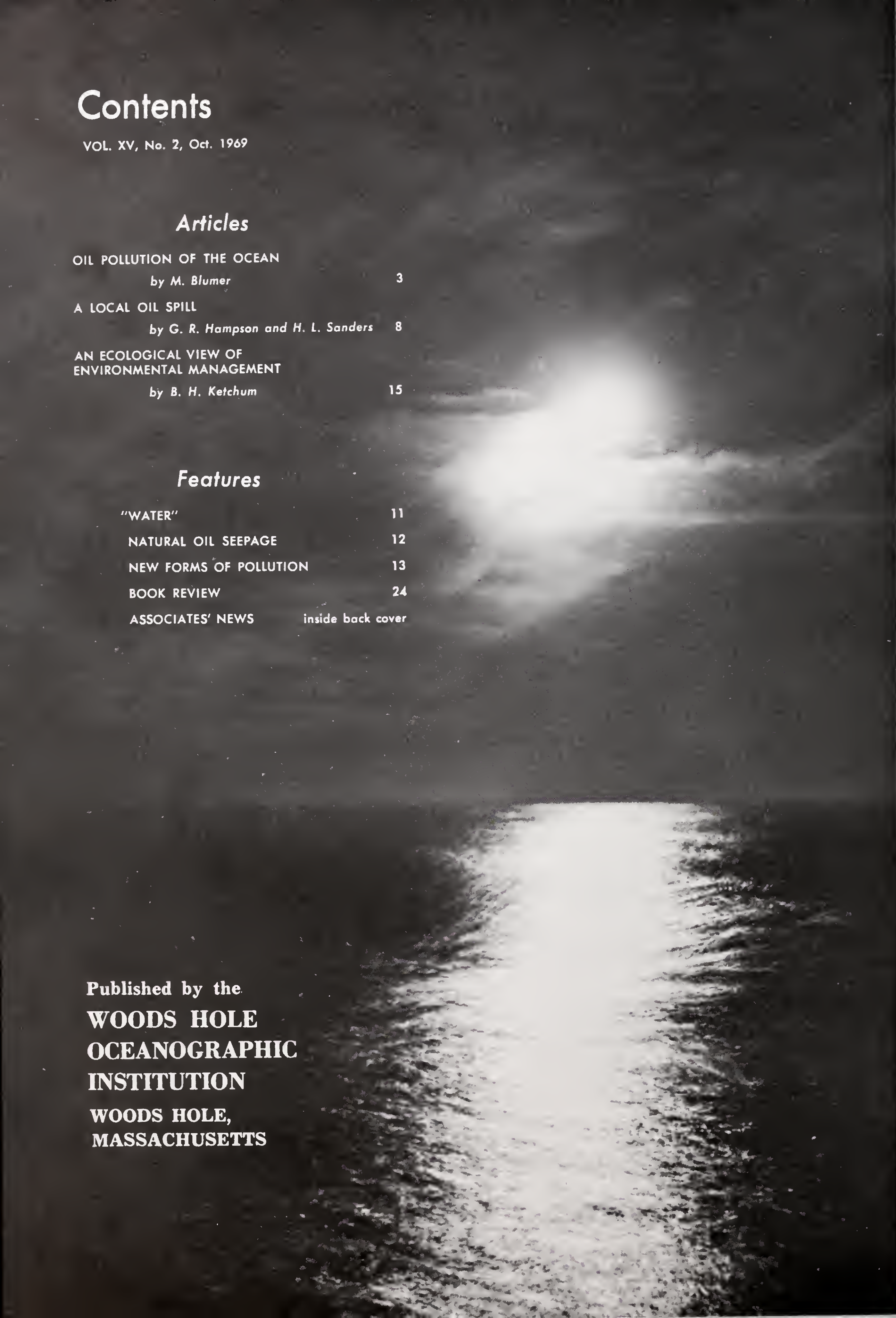
In September, the 'Akademik Kurchatov' (Captain E. Rebains), perhaps the largest research vessel in the world, visited Boston. Over one hundred scientists and crew members spent a day at Woods Hole, ending with a typical New England clambake and music and songs, led by Dr. Harold E. Edgerton (M.I.T.), who had participated in the ship's cruise together with several other U.S. scientists.

It should be noted also that for several years now Soviet fisheries' research vessels have spent considerable time each year at Woods Hole, co-operating in the program of the U.S. Bureau of Commercial Fisheries.

Associates of The Woods Hole Oceanographic Institution

President	TOWNSEND HORNOR
Executive Assistant	L. HOYT WATSON

MEMBERSHIP inquiries are invited. They should be addressed to Mr. L. Hoyt Watson, Woods Hole Oceanographic Institution, Woods Hole, Mass. 02543.



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