

9-1-1990

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Recommended Citation

Austin, H. M. (1990) Marine Pollution Impacts on Living Marine Resources. Marine Resource Report No. 90-5. Virginia Institute of Marine Science, College of William and Mary. <https://dx.doi.org/doi:10.25773/v5-ztrc-2140>

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**Marine Pollution Impacts
on Living Marine Resources**

by

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Prepared for the

**Virginia Hazardous Materials Conference
HAZMAT 90
Virginia Beach, Virginia
27-29 September, 1990**

The Chesapeake Bay

The Chesapeake Bay is an estuary, a place where the river meets the sea. Richmond, Washington, Baltimore: all major sea ports since Colonial times. Located on the "fall line", Richmond, Fredricksburg and Washington have been the meeting point for inland products (tobacco, furs, corn) brought down river by canoe and barge, and sea borne commerce from Europe arriving up river in large ships. When the railroad economically supplanted barge and canal transportation from the interior to the coast, cities like Norfolk, Newport News and Baltimore became the major seaports. Today over 10,000 sailings occur annually in the Bay, 25-30 each day. Further, the military presence in Hampton Roads has, since World War II, become a significant economic cornerstone. Today Norfolk is the home base for the Atlantic fleet, with over 107,700 active duty military personnel and their families and 41,400 civilian employees living in the Tidewater area. In addition, the Navy pays out some $\$4.56 \times 10^9$ in salaries, and $\$3.27 \times 10^9$ in goods and services to the local economy. The Norfolk Shipyards, Newport News Shipbuilding and Drydock and Norfolk Naval Shipyard employ over 43,000 employees. Salaries from the shipyards, local goods and services bring over $\$1.34 \times 10^9$ into the local economy. Between marine transportation, the naval bases, and shipbuilding there are some $\$9.17 \times 10^9$ that the Chesapeake Bay provides the local economy. Coexistent on the Bay with this maritime military-industrial complex is another cryptic, hidden, quiet Chesapeake Bay.

The Chesapeake Bay is the largest estuary in the United States. Its image of abundant bluecrabs, oysters, striped bass, herons and ducks, sailboats

and warm beaches brings thousands of visitors each year, and has motivated thousands more to move into the area in search of "the good life." This quiet side of the Bay supports a \$ $x10^6$ tourist industry and $\$442 \times 10^6$ seafood industry. The "quiet" Bay is almost 10,000 miles of tidal shoreline (MD 4,000 miles, VA 5,000 miles), much of it marshy, forested and inhabited by various forms of protected wildlife. This side of the Bay is endangered by the former. During 1978-1983 the USEPA spent over $\$27 \times 10^6$ to document the extent of the pollution problem in the Bay.

A Physical Description

In layman's terms, The Chesapeake Bay is an estuary, where rivers meet the sea. To the oceanographer the explanation is somewhat more detailed. It is also where there is a measureable dilution of sea water with fresh, and the circulation pattern is unique. The most striking feature of estuarine circulation is the "salt wedge". Fresh water comes down river and flows out over the denser salt water. The salt water wedges itself up river under the fresh river water, hence the term "salt wedge." This means that the net surface flow is out to sea, but the net bottom water flow is up river.

The point furthest up river that the wedge penetrates is generally an area of high biological productivity; many estuarine species are spawned or spend the first year of life here. This major nursery ground is also known as the "turbidity maximum." As sediment comes down river the heavier fraction settles out first. The lighter fractions, often silt and clay, pass far down river, settling out in the lower Bay. Near the bottom they encounter the salt wedge and are transported back up river.

At the furthest up river points, just below the fall line, the water is always fresh, although there is still a daily tidal influence. Open ocean water is pure salt water, or about 35.00ppt (3.5%) by weight. The surface salt content at the mouth of most rivers in the Chesapeake Bay ranges around 10ppt (1.0%)

Above the fall line, river flow is entirely dependent upon rain (run off); below the fall line the tide begins to play an increasingly important role. As one moves down river the tide becomes stronger and wind begins to have an effect on circulation. In the Bay the tide and wind are most vital. followed by river run off. Outside the Bay, circulation is more dependent upon wind, with the tide losing strength. Further out, on the continental shelf wind and oceanic circulation are most important.

The Bay's Environmental Problems

The major focus of the EPA study mentioned above was to document the decline in submerged aquatic vegetation (SAV's), delineate the extent of low oxygen in the bottom waters, define the extent of the nutrient loading problem, and map the pollutants in the sediments. While what is termed "point source" pollutants (e.g. a sewage discharge pipe) were documented, a major finding was the magnitude of the "non-point source" pollutants (e.g. over fertilized fields in general runoff from agriculture). These results prompted, in 1984, the governors of Virginia, Maryland and Pennsylvania to sign an agreement initiating a Bay cleanup. It is against this documented background of over 400 years of misuse that we must gauge the impact of today's accidental releases, spills, and control efforts following

transportation and fixed facility emergencies. If a gasoline or sulfuric acid spill occurs on a roadway and we simply flush it into the already polluted Elizabeth River, what difference does it make and why should we care? Our first priorities are the protection of peoples' lives and property. How can we justify the protection of a few oysters or crabs when the real value of the Bay lies in the construction of an aircraft carrier, providing a home for National defense and a major transportation corridor? Obviously, if a human life is at stake our priority is its protection. However, most hazardous materials emergencies involve isolation and containment, giving us time, therefore, to weigh the environmental considerations.

After the immediate concerns for life and property are met, it is time to consider the impact of the spill and mitigation measures for the marine environment. Can we contain the product without undue risk to firefighters? The day of flushing a few gallons of gas, spilled at a 7-11, down the storm drain, are over. Most environmental impacts are not from the major high visibility tanker oil or gas spill. They are from the chronic smaller releases. A 7-11 here, a 7-11 there, here an Exxon, there an Exxon, everywhere a gallon at a time. Every storm drain eventually discharges into the Chesapeake Bay.

What are the major existing pollutants and hazardous materials in the marine environment and how do they interact in the marine environment to form a problem? The impacts of these pollutants on the biota are similar to those of terrestrial animals in many ways, unique in others. Let us consider the impacts starting at the base of the food chain.

Primary Producers

The primary producers in the Bay are the emergent grasses or marshes; submerged aquatic vegetation (SAV), such as eel grass and phytoplankton, the microscopic single-celled or colonial plants. Herbicides from agricultural runoff are a significant source of mortality, particularly since over 25% of the Bay's shoreline is farmland. Only 15% of the Bay is bordered by urban areas.

Because of their location, marshes are particularly susceptible to oil spills which has been shown to cause death and reduce the rates of growth. Marsh plants also concentrate metals which, when ingested by animals, are passed up the food chain. Interestingly enough, no evidence of direct effect by toxic metals on plants has been shown. The SAV's are most effected by nutrient loading and siltation although short term reductions in photosynthetic ability have been produced by herbicide concentrations of 1-5 ug/L (about one shot glass in a million gallon swimming pool); and 0.05mg/L of chlorine can lead to chlorophyll-a loss and death (Sanders 1987).

Phytoplankton are among the most sensitive of Bay life forms to contaminants. Chlorine, pesticides, and of course, herbicides and heavy metals all cause death or reduce photosynthetic ability. Concentrations of less than 1ug/L of Cadmium have been shown to reduce growth by more than 50%.

Although most toxic organics impact the higher trophic levels, little evidence exists to support an impact on phytoplankton at concentrations

normally found in the environment. Nevertheless it is possible that phytoplankton, at the base of the food web, is a bio-accumulator of dissolved compounds in the water which then find their way into the higher trophic levels.

Zooplankton

Zooplankton, the microscopic animal life in the water composed of fish eggs and larvae, crab and oyster larvae, copepods, mysids and a hundred other small shrimp, worms and jellyfish are the first animal step in the food chain. Most zooplankton studies have dealt with heavy metals, pesticides and oxidizers (chlorine).

Heavy metal toxicity has been of special concern to researchers. Compounds carrying mercury, copper, silver and cadmium have been shown to be the most toxic. An organism's body, for example (including humans), mistakenly recognizes cadmium for calcium and uses it in shell or bone formation. There is an inverse relationship to salinity, and it has been suggested that the metal ions compete with the chlorine ions, making them less bioavailable (Sunda et al 78, as seen in Bradley and Roberts 1987).

Crustacean larvae are more sensitive to pesticides than bivalve larvae.

Oil spill effects on copepods seem short-term although swimming behavior and reproduction have been depressed. Larval forms have the added stress of metamorphosis and settlement. Early studies with DDT during the 1950's documented the pesticide's blocking of the crustaceans' ability to shed or

initiate metamorphosis. Oyster larvae are particularly susceptible to depressed settlement rates ("striking") after exposure to chlorinated sewage.

Resource Species (finfish, shellfish, crustaceans)

Concentrations of Heavy metals (e.g. mercury, copper, cadmium) in the sediments are generally considered to delineate industrial contaminated areas. Heavy metals are quickly bound in the estuarine sediments on clay particles or precipitated in anoxic (deoxygenated water) environments. Here they are often covered by clean sediments and become less of a problem. Dredging or flooding often resuspend the toxic sediments into the water column (e.g. Baltimore, Norfolk Harbors, or the James River ship channel). Heavy metals do not generally impact adult finfish except in large spill volume concentrations. Chronic exposure to metals, however, have resulted in deformed skeletal development in fish larvae (Klauda and Bender 1987). The effects of metals on finfish is greatest in freshwater, decreasing with increased salinity. Reduced pH (increased acidity), caused by natural humic acid runoff or acid rain, can release metals from their chemically bound state in sediments (e.g. aluminum) and make them biologically available.

Shellfish are notorious for their ability to concentrate metals in their flesh. Oysters living in the cooling ponds of heated water from power plants have concentrated so much copper from the cooling pipes that they have turned green.

The presence of organics, which is a wider spread problem, is less well documented. Organics are compounds derived from once living sources. They are hydro-carbon compounds. The oil spill is the most "famous", yet generally not worst case actor. Over the years different compounds have been on the "most wanted" list by government agencies. Pesticides, primarily DDT (1950-1960's), then PCB's, polychlorinated biphenals (1970's), polynuclear aromatic hydrocarbons (PAH's) (1980's), and now the organotins (e.g. TBT) (1990's). Tomorrow's most wanted may depend upon advances in analytical techniques. Best documented of the organic pollutants is Kepone, a pesticide released into the James River prior to 1976.

Kepone, although toxic in higher concentrations, is a good example of the indirect impact pollutants exert on marine resources. Concentrations observed in the tissue of finfish, oysters and bluecrabs were such that no discernable effects could be noticed in the organisms; but, the entire crab and oyster industry in the James River was closed for a decade, resulting in an economic loss of over \$50,000 a year for oyster and \$65,000 for crab harvest. During the period of the closure bluefish caught above the James River Bridge could not be retained.

Organotins (TBT) are quite toxic, even in low concentrations, but few studies have been completed (Klauda and Bender 1987). The PAH's, on the other hand, generally produced from combustion of hydrocarbons (automobile exhaust emissions), have been shown to cause fin rot, lesions, cataracts and reduce the immune response in Chesapeake Bay spot, Leiostomus xanthurus, croaker Micropogonius undulatus, weakfish, Cynoscion regalis and hogchoker, Trinectes maculatus (Weeks and Warinner 1984).

Shellfish concentrate organic compounds as well as metals, and it has been suggested that they are good "indicators" of pollution (Bender and Huggett 1987), and can serve as a monitoring tool. This is further supported by the fact that unlike finfish, shellfish cannot depart unfavorable areas.

Evanescient contaminants leave no record. These include chlorine and other halogenated organic compounds, mostly solvents. Chlorine is a primary disinfectant in sewage outfalls, and the solvents can include industrial degreasers or laundry cleaning solvents. Although the more mobile juvenile and adult life stages can detect and avoid chlorine the egg and larval stages cannot, and chlorine is very toxic to them in concentrations less than 100ug/L. This is equal to a "pinch of salt" in a 1000gal booster tank.

Water Fowl

Several pollutants have, over the years, been shown to be toxic to water fowl. In fact, DDT residue in pelican, osprey and eagles were, in the 1950's, felt to be the cause of the thin egg shells which lead to high juvenile mortalities. Public concern was such that restrictions on the use of DDT were initiated. Lead poisoning in ducks, from non-fatal lead shot and their feeding on shot used by hunters, has lead to legislation requiring the use of steel shot. Currently (mid-1960's through mid-1980's), both organochlorine pesticides and PCB's are at relatively low concentrations. Heavy metals (Hg, Ca and Cu and Zn) are highest in ducks that feed on animals (e.g. old squaw) and lowest in herbivores, although some herbivores are high in lead.

Perhaps the best documented impact on water fowl, as well as other wildlife, has been in reduction of habitat. This is due both to pollutants (e.g. the loss of aquatic vegetation) and "land reclamation" by dredge and fill operations. It is estimated (Silberhorn, pers comm) that prior to the 1972 Wetlands Act some 400-600 A of wetland were filled annually, and that without the Act, some 600-700 A would be filled annually today.

Response Perspectives

Marine spills or releases of a non-chronic nature are generally from transportation accidents. Fixed facility, road and rail releases are logistically easier to handle than those from marine accidents. During 1988 there were 561 oil spills reported. Two thirds (370) found their way into state waters. Most were 25 gallons or less, but their combined total was 259,015 gallons reaching state waters. Oil spills (including gasoline) were ten times more prevalent than other hazardous materials.

A spill or release from a vessel in navigable waters will bring a response by the Coast Guard, State Water Control Board, Virginia Marine Resources Commission and the Virginia Institute of Marine Science. Unless the release endangers waterfront property (e.g. a flammable liquid or toxic airborne release), the local emergency response agencies are not likely to be contacted. Nevertheless, the above figures point to the fact that several hundred spills occur each year on land to which local fire departments are likely to be called, and from which a significant volume of material finds its way into the Chesapeake Bay. In many respects the shoreline, or

intertidal zone, is the most environmentally fragile, and the area most likely to receive the products of a spill from either sea or land.

A normal terrestrial emergency response includes the initial pumper, and depending upon the magnitude of the release and information given the dispatcher, additional fire units and/or specialized hazardous materials teams. Objective priorities must always be life, followed by property; then, we sometimes remember the environmental concerns.

We must make every effort to retain spills and keep them from entering the Chesapeake Bay or its tributaries. While the hundred thousand gallon oil or gasoline spill is the most dramatic, it is the smaller, but constant daily spill of a few gallons, that like a pack of cigarettes a day, does the real damage. Certainly it is hard to justify, on a cost-benefit ratio, all the effort to contain then pick up the small spill. Especially when we constantly see large spills from fuel loading platforms, barge lightering, ship building industries, and the military. Further, the background level is already so high that there is no way to measure our success or failure. In effect, we receive no feedback for our efforts.

Efforts to control spills need not start with emergency responses. Local Emergency Planning Committees (LEPC) can include in their plans specific directions to cover spill response and recovery in intertidal and local navigable waters. Knowledge of terrain and likely spill movement to creeks and marshes should be considered. Environmentally sensitive sections of highway, where a spill may end up in a creek, should be mapped in local plans.

Following the Alaskan spill in 1989 the Virginia Secretary of Natural Resources formed a Virginia Joint Committee on Spill Prevention and Response Readiness. This Committee produced, in November, 1989, a report entitled, "Protecting Virginia Waterways: Oil Spill Prevention and Response," The report contains, in addition to recommendations on how to protect the marine environment, a listing of resources available in the event of a spill. This report is available from the Virginia Secretary of Natural Resources.

The Chesapeake Bay as a natural resource, cannot be ignored because it is already polluted or because the value of the marine resources do not equal the dollar value of ship building, marine transportation or national defense. The Bay is part of the world we live in and we cannot continue to foul even a small corner of it.