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Methods for Measuring Ecosystem Stress

R. J. Huggett and M. E. Bender

If one looks back over the past twenty-five years, at the pollution crises which have made the headlines and influenced our decision making policies on both local and national levels, one may note a very interesting aspect. That is, the crises are often associated with the development of new and more sensitive types of analytical instrumentation. Several examples of this readily come to mind: for example, it wasn't until the development of electron capture detection for gas chromatography that DDT really became a crisis. The reason is quite simple: the concentrations which were being accumulated by the organisms were below detection limits of most available instrumentation. Another example is mercury. The advent of atomic absorption spectrophotometry and the refinement of the the flameless method for mercury allowed the mercury problem to be investigated. New instrumentation doesn't *cause* the crisis, it merely finds it.

Measuring Stresses

After detecting a potential pollutant, scientists, usually biologists, determine whether or not the levels found are detrimental to organisms. This is not an easy task. The methods used usually involve both field sampling and laboratory bioassays. In the case of field sampling, the biologist collects samples in suspect areas as defined by the chemical analyses and in unaffected areas. The data are compared station by station to determine whether the differences may be attributable to the pollutant in question.

York River, Va.

As an example of a field survey, I would like to briefly mention a minor oil spill which occurred near the mouth of the York River, Virginia in 1971. It involved approximately 800 barrels (bbls) of #6 oil which was actually a cracking residue which had been cut with a lighter oil to the consistency of #6 oil. It came ashore at Station 2 as indicated in Figure 1. Stations 1 and 3 were established as controls since no oil hit these areas. The oil coated the intertidal areas as evidenced by sight and feel but after several days, the evidence was not apparent except for residues left on marsh grasses. After a month or so, all visual evidence was gone. To

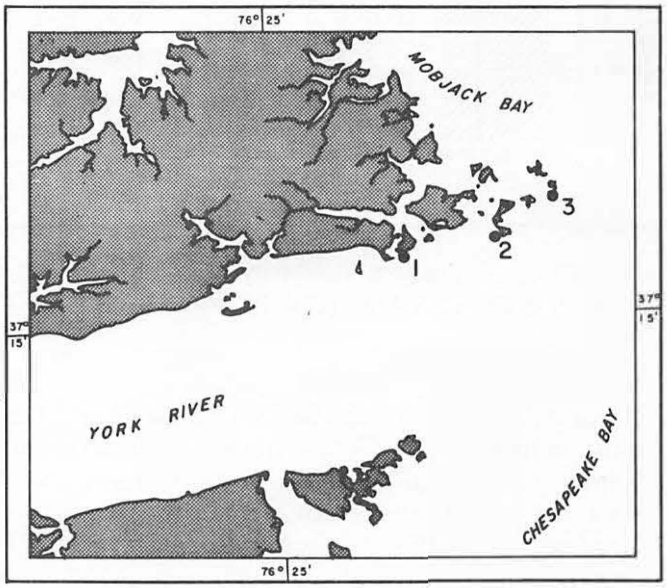

FIGURE 1. Map of the Lower York River with Sampling Stations Indicated

the eye there was no lasting effect of the oil spill. However, biologists sampled the area and the controls and found that indeed the system had been stressed. The species richness in the spill area (Station 2) was calculated for benthic organisms and compared to those of the controls. Subsequent samplings showed the area to be affected until 1973 — almost two years after the spill (Figure 2). The

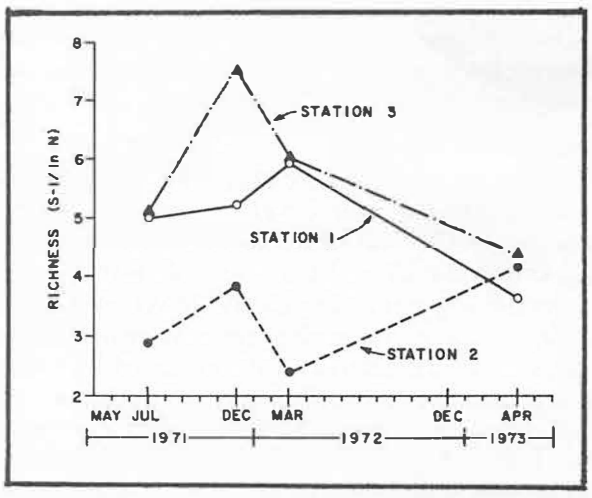

FIGURE 2. Species Richness at Control Stations and Oil Spill Station (Sta. 2) from 1971 to 1973

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Sorenson's Similarity Quotient calculations showed that the three stations were different after the spill, and were dissimilar for approximately two years (Figure 3).

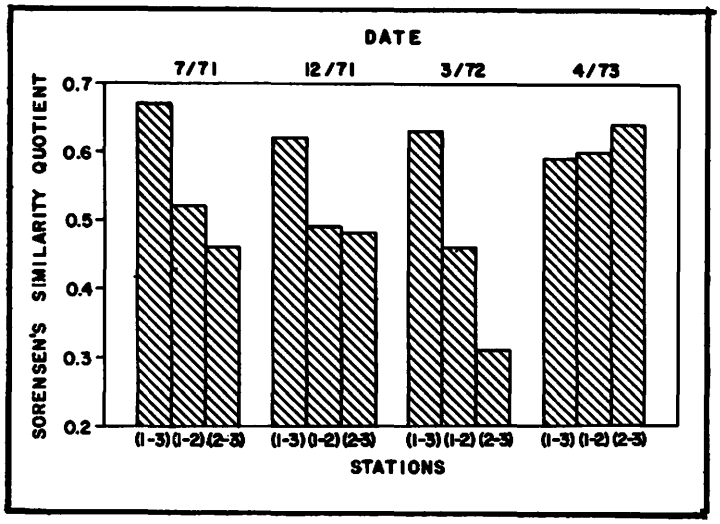

FIGURE 3. Sorensen's Similarity Quotient of Control Areas and Oil Spill Area (Sta. 2) from 1971 to 1973

From this survey, it was obvious that the oil spill had a lasting influence on the biota — not evident to the eye after cleanup. Yet, we didn't know how much oil produced an effect, nor did we know which compounds in the oil were responsible. For this, we performed bioassays in the laboratory.

Pollution bioassays (toxicity tests) are tests which determine how much of a substance it takes to affect a given percent of a population of animals in a given amount of time. In most cases, the acute bioassay test is used. Acute bioassays tell how much of a substance it takes to kill test animals (usually 50% of them) in a given amount of time usually 48 or 96 hours. Chronic bioassays that last longer than four days are used infrequently because they are difficult to set up and expensive. However, chronic bioassays yield information on sublethal effects of substances and tell how much of a substance it takes to make the animal sterile, to swim slower, etc.

Once bioassay data are in hand, the scientist can, theoretically predict whether or not there has been biological impairment through field measurements of the instance.

James River, Va.

The necessity to be able to predict biological stress from a component in the estuarine environment is exemplified in the chlorine (Cl_2) problems of the James River, Virginia. It is well known that Cl_2 and its ammonia derivatives are toxic to freshwater organisms (Brungs, 1973); yet toxicity levels for marine and estuarine species are unknown. Recently, Cl_2 inputs in the James River have increased with increasing sewage load from population expansion (Figure 4). In May and June of 1973 between 5 and 10 million fish were killed in the lower James River. The species included spot, *Leiostomus xanthurus*; croaker, *Micropogon undulatus*; bluefish, *Pomatomus saltatrix*; weakfish, *Cynoscion regalis*; and menhaden, *Brevoortia tyrannus*. After several weeks of

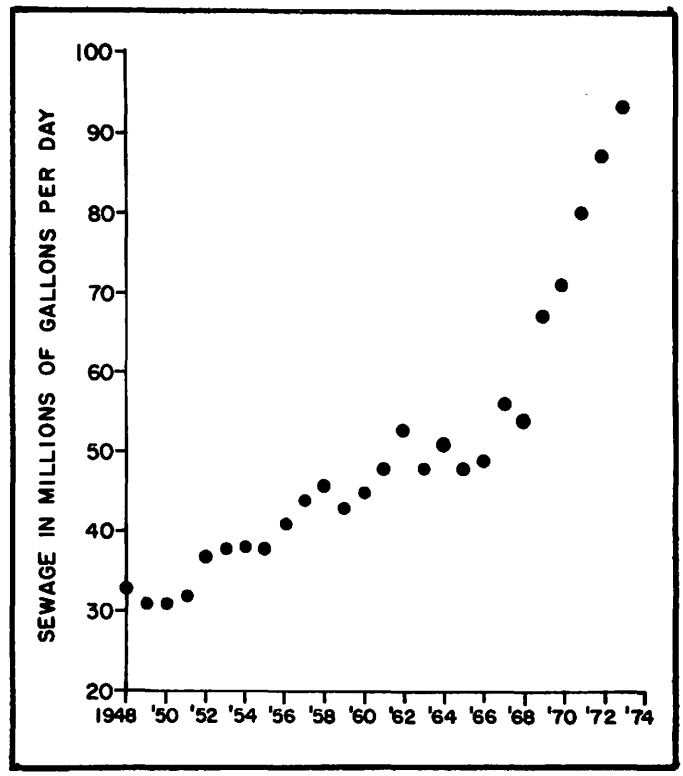

FIGURE 4. Sewage Flows into the Lower James River from 1948 to 1973

intensive chemical and biological sampling and analyses, it was determined that the cause was Cl_2 residuals from sewage treatment plants; the river had reached its ability to assimilate inputs and fish began dying.

We have since performed bioassays on some of the animals indigenous to the area and have analyzed the river water for Cl_2 residuals. This was possible only after a new, more precise instrument was developed by the National Bureau of Standards and the Virginia Institute of Marine Science to measure minute amounts of Cl_2 (Marinenko, Huggett, and Friend, 1975). The concentrations found in the river as compared to those found toxic to the biota through bioassay tests are shown in Figure 5.

From these data we are aware of the levels that kill, and based on these findings, Virginia reduced its state requirements for Cl_2 residuals in sewage effluent during the 1974 oyster spawning season. Although the results are circumstantial, the James River had a better oyster set last year than it had in the past 10 years, while other sets in Virginia were about the same as during the previous year.

These examples show that environmental measurements by new analytical instrumentation coupled with bioassay tests provide estimates of damage to the marine life when toxic substances are discharged into the ecosystem.

The monitoring techniques described here are applicable to studies being conducted in the Potomac estuary by various agencies and institutions. With careful planning and surveillance, repetition of the problems in the York and James Rivers can be prevented.

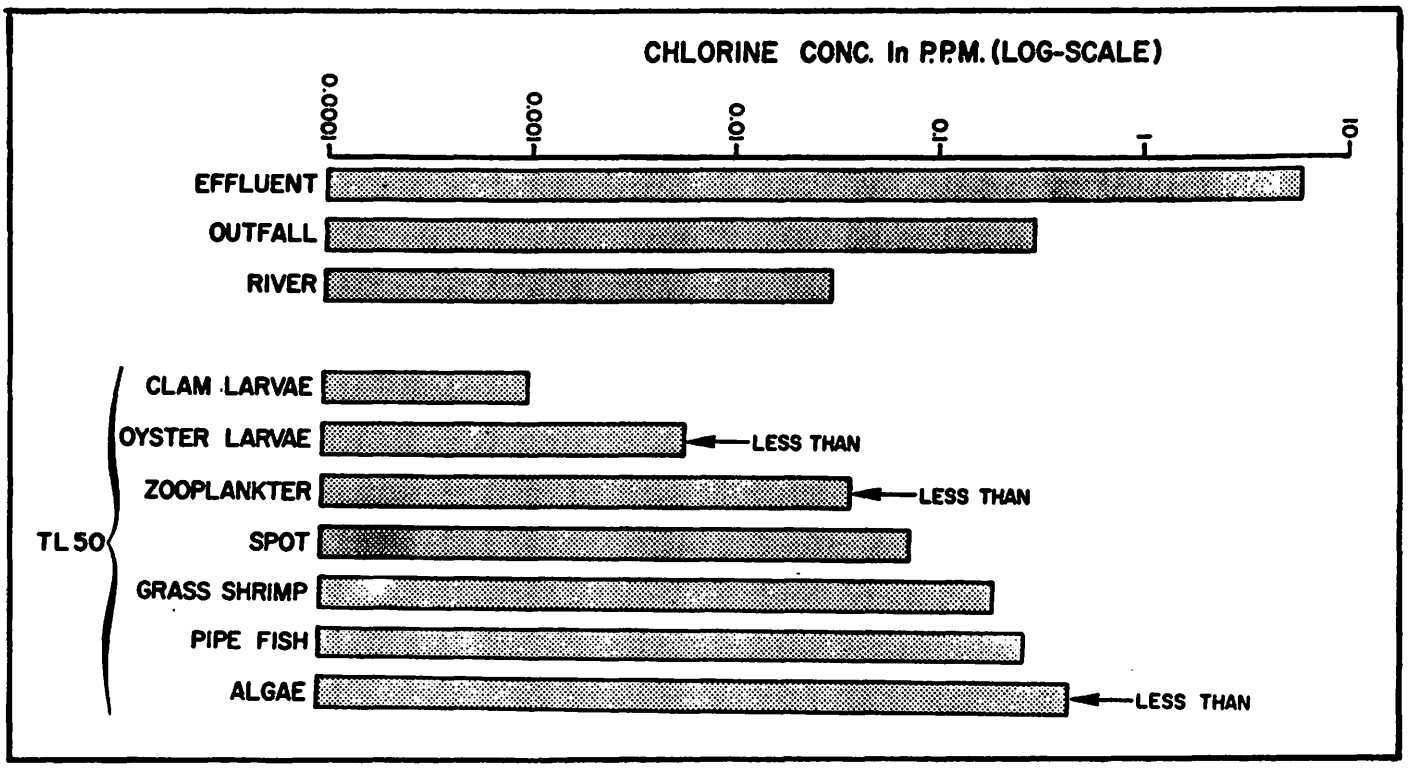

FIGURE 5. Total Residual Chlorine (TRC) Measured in the Lower James River and TL50 Bioassays for TRC

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