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AQUATIC ENVIRONMENTS

Features

AQUATIC environments are as numerous as the very waters themselves. Rising in snowcapped mountains small streams collect the snow melt and transport it to the plains. As these streams meander through the countryside they take from the lands that which is released to them. Small streams soon form larger ones that eventually join to form the great rivers and these in turn terminate in coastal estuaries. Each change in size and shape forms a habitat that becomes unique and supports an assemblage of organisms that is adapted to life in that particular environment. Reservoirs, built by man on rivers, in turn form a particular habitat that is influenced greatly by the reservoir's morphometric features. The reservoir in turn may influence the downstream environement because of the depth of the penstock that releases water of lower temperature, or of less dissolved oxygen, or of higher mineral quality, than the waters that receive it. The landscape is dotted with ponds and with many larger lakes of varying sizes and shapes. Each, as Professor Forbes pointed out many years ago, is a microcosm that supports its own organism community. The Great Lakes are at the pinnacle of lake environments within the United States, and because of their vast size, depths, and currents they offer many environments within their confines.

Organisms that may be found in great numbers in the stream environments are often not adapted to life within the lake or reservoir environments and vice versa. There are many features that tend to make a particular aquatic environement suitable or unsuitable, completely or to some degree, to a particular organism or group of closely associated organism.

Common to all aquatic environments would be the changes brought about by differences among the water habitats. For the pond and lake group these may include:

Altitude	Area
Latitude	Mean depth

Maximum depth
Area of different depth zones
Volume of different depth strata
Length of shoreline
Littoral slope
Drainage area
Runoff rate
Average inflow
Average outflow
Detention time
Water level fluctuation
Number of islands
Island areas
Island shoreline length
Penstock depth (reservoirs).

Features that create particular aquatic environments in flowing water may include:

Altitude
Latitude
Relative extent of pools and riffles
Depth at collection site
Width at collection site
Velocity of flow
Drainage area to collection site
Runoff rate
Physical composition of stream bed
Physical nature of surrounding terrain
Area geology.

The estuarine environment is influenced by morphometric features that are common to both the flowing water and static environments. In addition it is influenced by tidal cycles and their fluctuations.

Life in waters is influenced also by water temperatures, dissolved oxygen, pH, color, turbidities, total dissolved solids, total alkalinity, nutrients and mineral composition. Maximum values, and in some cases minimal values also, of these constituents often create an environment that becomes intolerable to particular organisms and will limit their production or interfere subtly with physiological processes that in turn reduce their ability to compete with others within the environment.

Pollutional Effects

Effects of pollution assume many characteristics and an infinitesimal variaton in degree when pollution enters the aquatic environment. The specific environmental and ecological responses to a pollutant will depend largely on the volume and strength of the waste and the volume of water receiving it. As a basic introduction, five types of responses will be described in subsequent paragraphs, and within each of these response types there can be many changes in magnitude and degree.

The classic response that has often been described in the literature is the effects of organic wastes that may be discharged from sewage treatment plants and certain industries. As these wastes enter the water they create turbidity, decrease light penetration, and may settle to the bottom in substantial quantity to form sludge beds. The wastes are attacked immediately by bacteria and this process of decomposition consumes oxygen from the water and liberates essential nutrients that in turn stimulate the production of some forms of aquatic life.

Pollutional Zones

Upstream from the introduction of organic wastes, classic description details a clean water zone or one that is not affected by pollutants. At the point of waste discharge and for a short distance downstream there is formed a zone of degradation where wastes become mixed with the receiving waters, and where the initial attack is made on the waste by bacteria and other organisms in the process of decomposition.

Following the zone of degradation there is a zone of active decomposition that may extend for miles, or days of stream flow, depending in large measure on the volume of dilution that is afforded the waste by the stream, and the temperature of the water. The biological processes that occur within this zone are similar in many respects to those that occur in a "typical" sewage treatment plant. Within this zone, waste products are decomposed and those products that are not settled as sludge are assimilated by organisms in life processes.

A zone of recovery follows the zone of active decomposition. The recovery zone is essentially a stream reach in which water quality is grad-

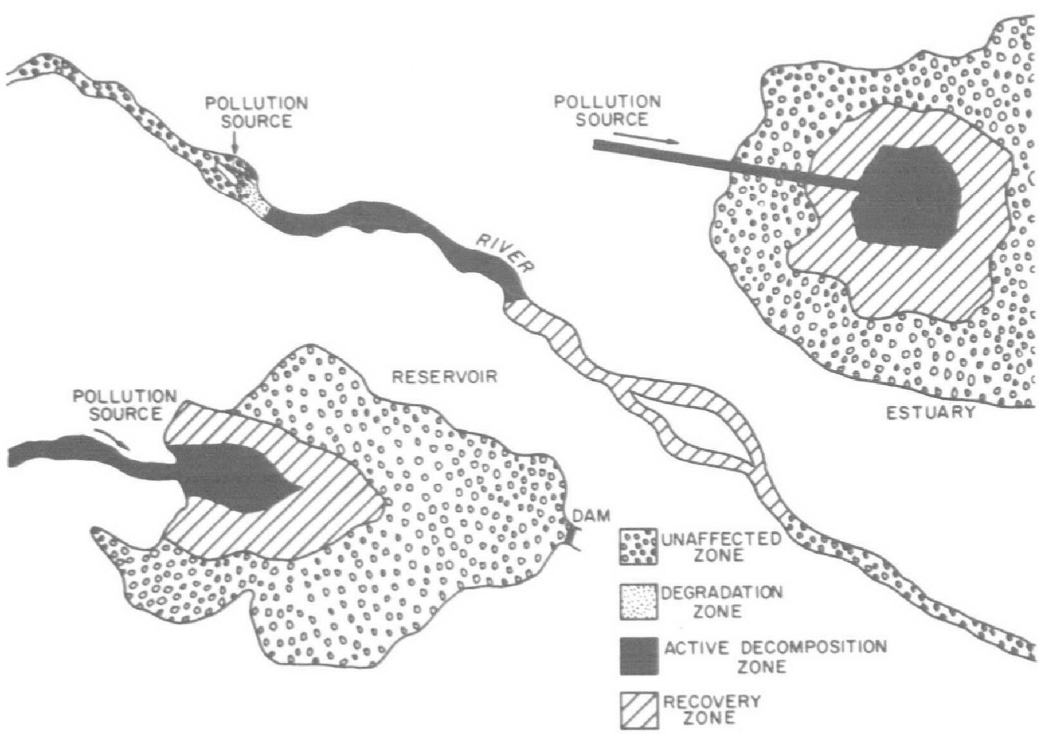

Figure 2. Pollutional Zones

ually returned to that which existed prior to the entrance of pollutants. Water quality recovery is accomplished through physical, chemical, and biological interactions within the aquatic environment. The zone of recovery may extend also for many miles and its extent will depend principally upon morphometric features of the waterway.

Finally the zone of recovery will terminate in another zone of clean water or area unaffected by pollution that is similar in physical, chemical, and biological features to that which existed upstream from the pollution source.

Organic Wastes

The classic description of the effects of organic wastes on the receiving stream often becomes confused in a specific stream investigation, because additional sources of pollution may enter the environment before the receiving water has been able to assimilate the entire effects of an initial source. When this occurs the effects of subsequent introductions become superimposed on those of the initial source and the total effect may confine large reaches of stream to a particular zonal classification.

Effects of organic wastes in the static water environment, as opposed to the flowing water environment, are modified principally by the morphometric features of the receiving water. Zonal changes that have been described for flowing water do exist but may be compressed in great measure either laterally or vertically when the discharge is to a lake or estuary. Such compression may tend to decrease the severity of pollution that is often observed in the flowing water environment and, on the other hand, may increase substantially the development of biotic nuisances such as algae or rooted aquatic plants that may develop from the nutrients released with and decomposed from the introduced organic materials.

Organism communities that may be related to pollution principally are those that are by nature associated with the bed or bottom of the waterway; those that attach themselves to objects such as rocks, aquatic plants, brush or debris submerged within the water; those that are essentially free floating and are transported by currents and wind, such as plankton and other microscopic forms; and those motile free swimming organisms such as fish. Considering each of these common organism groups, a number of observations can be made on their reaction to the introduction of organic wastes to a flowing stream.

Upstream from the waste source such limiting factors as food and intense competition among organisms and among organism groups, predation, and available habitat for a particular species will limit organism populations to those that can be sustained by the particular environment. Most often the limiting factor will be available food. Within this population, however, there will exist a great number of organism species. Thus, the old biological axiom for an environment unaffected by pollution is one that supports a great number of species with the total population delimited largely by food supply.

Following the introduction of organic wastes, conditions of existence for many organisms become substantially degraded. Increased turbidity in the water will reduce light penetration that in turn will reduce the volume of water capable of supporting photosynthesizing plants. Particulate matter in settling will flocculate small floating animals and plants from the water. As the material settles, sludge beds are formed on the stream bed and many of the areas that formerly could have been inhabited by bottom associated organisms become covered and uninhabitable.

The zone of degradation is a transition area between the clean water unaffected reach and a zone of decomposition of organic wastes. In such, the dissolved oxygen may be diminished but not completely removed. Sludge deposits may be initiated but are not formed in maximum magnitude or extent. Conditions of existence become impaired and typically there is a reduction in both the organism population and the number of species that can tolerate this environment.

Within the zone of active decomposition conditions of existence for aquatic life are at their worst. The breakdown of organic products by bacteria may have consumed available dissolved oxygen. Sludge deposits may have covered the stream bed thus eliminating dwelling areas for the majority of bottom associated organisms that could be found on an unaffected area. Fish spawning areas have been eliminated, but perhaps fish are no longer present because of diminished dissolved oxygen and substantially reduced available food. Here, aquatic plants will not be found in large numbers because they cannot survive on the soft shifting blanket of sludge. Turbidity may be high and floating plants and animals destroyed. Water color may be substantially affected. When organic materials are decomposed a seemingly inexhaustible food supply is liberated for those particular organisms that are adapted to use this food source. Thus, bacterial and certain protozoan populations may increase to extremely high levels. Those bottom associated organisms such as sludgeworms, bloodworms, and other worm-like animals may also increase to tremendous numbers because they are adapted to burrowing within the sludge, deriving their food therefrom, and existing on sources and amounts of oxygen that may be essentially nondetectable by conventional field investigative methods. Within the zone of active decomposition the organism species that can tolerate the environment are reduced to extremely low levels. Under some conditions those bottom associated animals that are visible to the unaided eye may be completely eliminated. Because of the tremendous quantity of food that is available to those organisms that are adapted to use it, the numbers of individuals of the surviving species may, indeed, be great. For example, it may be possible to find 50,000 sludgeworms or more living within each square foot of bottom area with the above-described conditions.

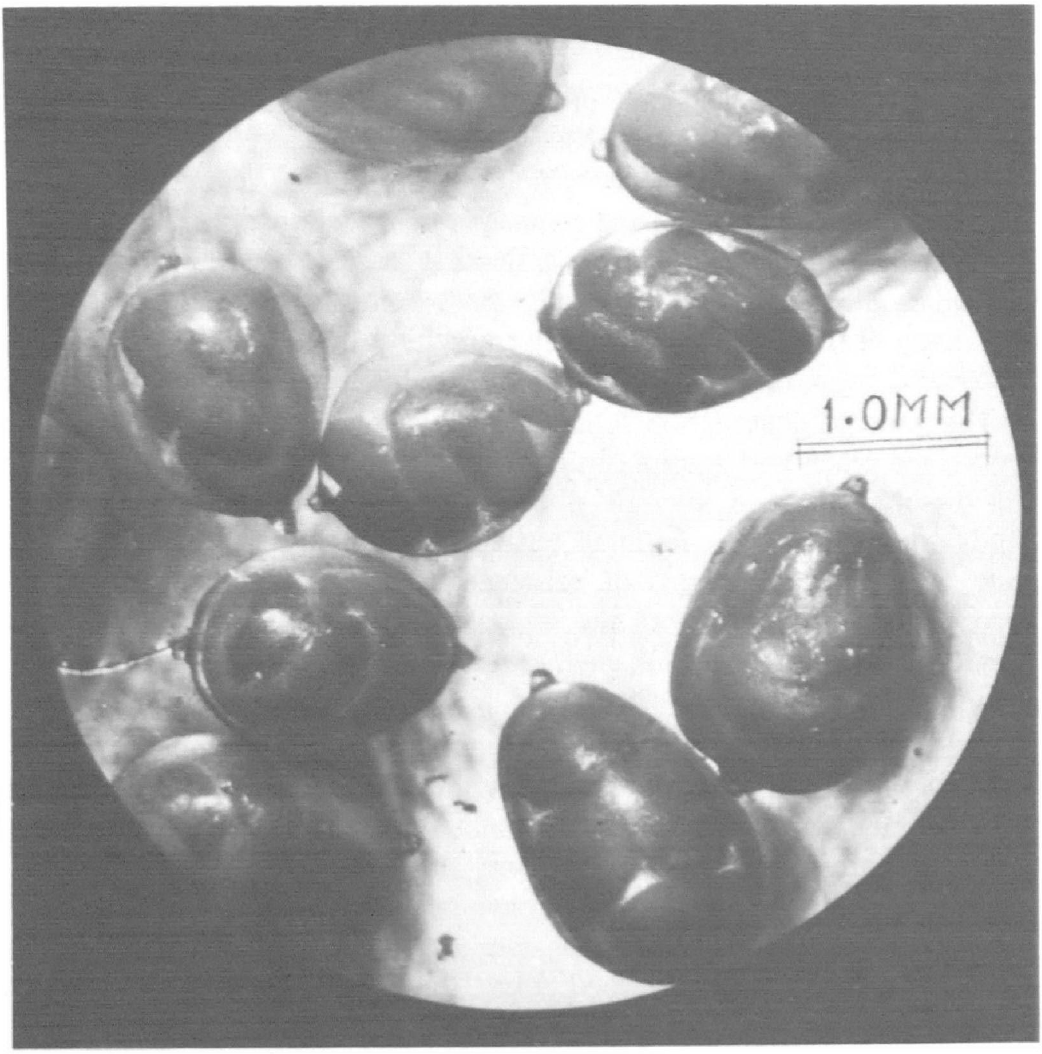

Figure 3. Sludgeworm eggs with embryos.

The zone of recovery is essentially the downstream transition zone between the zone of active decomposition and an environment that is unaffected by pollution. This zone features a gradual cleaning up of the environment, a reduction in those features that form adverse conditions for aquatic life, an increase in organism species, and a gradual decrease in organism population because of decreased food supply and the presence of some of the predators that are less sensitive individually to pollutional affects.

Because of some variation in response among species to conditions of existance within the environment, and because of inherent difficulties in aquatic invertebrate taxonomy, the ecological evaluation of the total organism community is the acceptable approach in water pollution control investigations. At the present time, investigators tend to place organism in broad groups according to the general group response to pollutants in the environment. As we are able to advance our knowledge and determine more specifically the water quality requirements of identifiable species, the use of specific organism indicators may become more prevalent in biological interpretation. The general group known as "sludge-worms," for example, is found in both the unpolluted, as well as the organically polluted environment. Its value as a group lies in the fact that the numbers of individuals within the group is exceedingly low in unpolluted water, whereas in the organically polluted environment its numbers may be very high. Examples of organisms that may inhabit both the unpolluted and polluted environments are presented in table 1.

The converse of the effects of pollution on organisms is the effects of organisms on pollutants. Organic wastes, especially, supply food which in turn produces an abundance of a few types of organisms greater than that produced in an unpolluted environment. In consuming organic wastes, the organisms stabilize the waste in a given number of feet or miles of horizontal stream in a manner similar to that in a vertical trickling filter that is designed especially for maximum stabilizing efficiency by the organisms.

Purdy (1930) found long ago that sludgeworms eat continuously. Observations during 21 out of 24 hours showed no perceptible decrease in the foraging activity. Evacuation of a string of fecal pellets about 68 inches in length in a 24-hour period was recorded for each worm. An incubation of 24 hours showed an oxygen demand of 2.8 mg./l. by these pellets, whereas the original mud beneath the surface showed a demand of 6.7 mg./l. Purdy's conclusion was that the large surface area of fecal pellets exposed to the flowing water possessed a far greater purification

Table 1. Organism Associations

Clean water association		Polluted water association	
Algae	*Cladophora* (green) *Ulothrix* (green) *Navicula* (diatom)	Iron Bacteria	*Sphaerotilus*
Protozoa	*Trachelomonas*	Fungi	*Leptomitus*
Insects	Plecoptera (stoneflies in general) Negaloptera (hellgrammites, alderflies, and fishflies in general) Trichoptera (caddisflies in general) Ephemeroptera (mayflies in general) Elmidae (riffle beetles in general)	Algae	*Chlorella* (green) *Chlamydomonas* (green) *Oscillatoria* (blue- green) *Phormidium* (bluegreen) *Stigeoclonium* (green)
Clams	Unionidae (pearl button)	Protozoa	*Carchesium* (stalked colonial ciliate) *Colpidium* (non-colonial ciliate)
Fish*	*Etheostoma* (darter) *Notropis* (shiner) *Chrosomus* (dace)	Segmented Worms	*Tubifex* (sludgeworms) *Limnodrilus* (sludge-worms)
		Leeches	*Helobdella stagnalis*
		Insects	*Culex pipiens* (mosquito) *Chironomus* (*-Tendipes*) *plumosus* (bloodworms) *Tubifera* (*Eristalis tenax*) (rat-tailed maggot)
		Snail	*Physa integra*
		Clam	*Sphaerium* (fingernail)
		Fish*	*Cyprinus carpio* (carp)

* Names from: American Fisheries Society Special Publication No. 2, "A List of Common and Scientific Names of Fishes from the United States and Canada" (Second Edition) Ann Arbor, Mich. (1960), 102 pp.

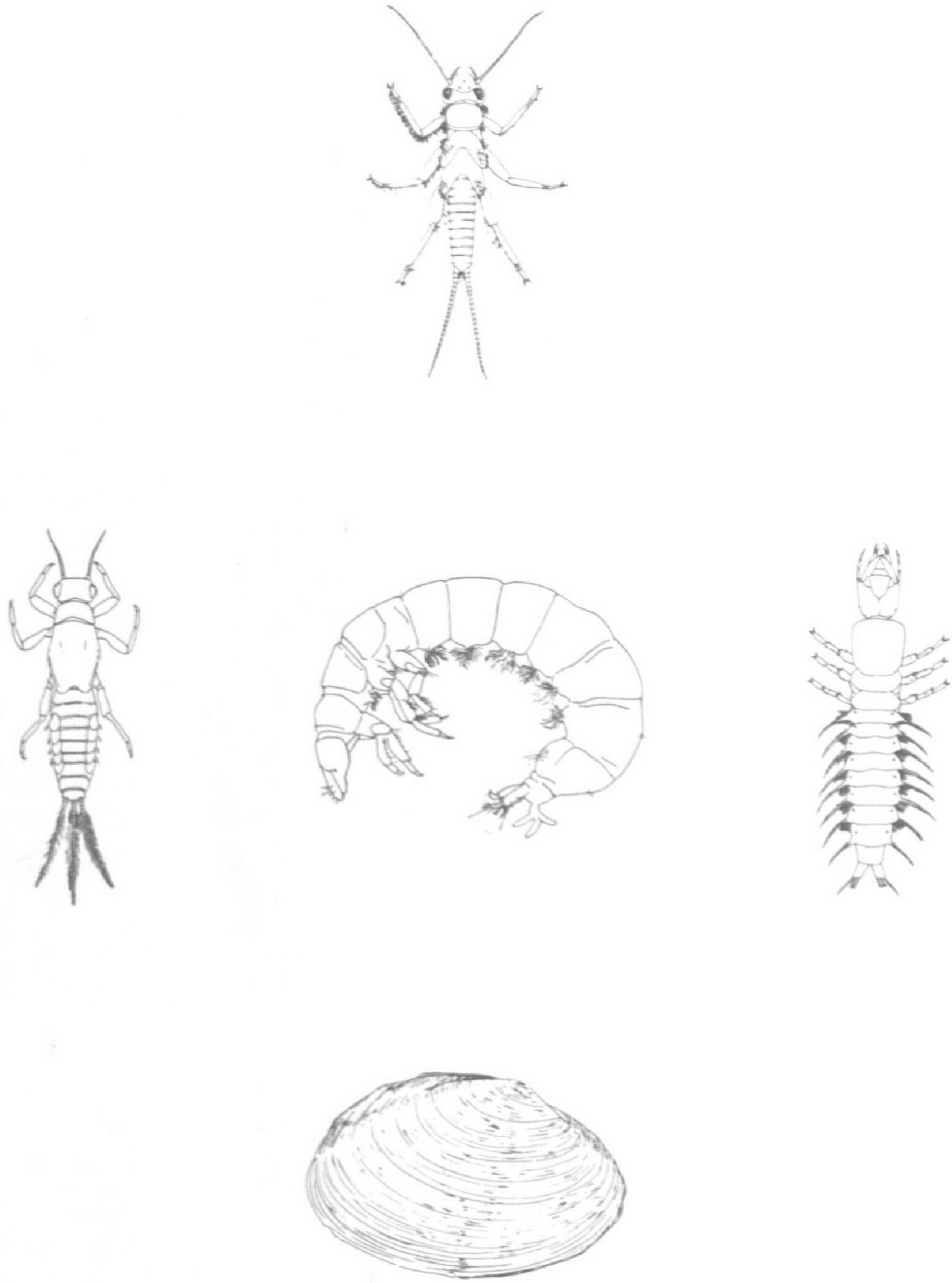

Figure 4. Representatives of stream bed associated animals (The clean water (sensitive) group).

From left:

Stonefly nymph
Mayfly naiad; Caddisfly larvae; Hellgrammite
Unionid Clam

potential than did the same mass of material an inch or more beneath the sludge-water interface.

As organic wastes become more stabilized, other organism types predominate within the aquatic animal community. Midge larvae have been

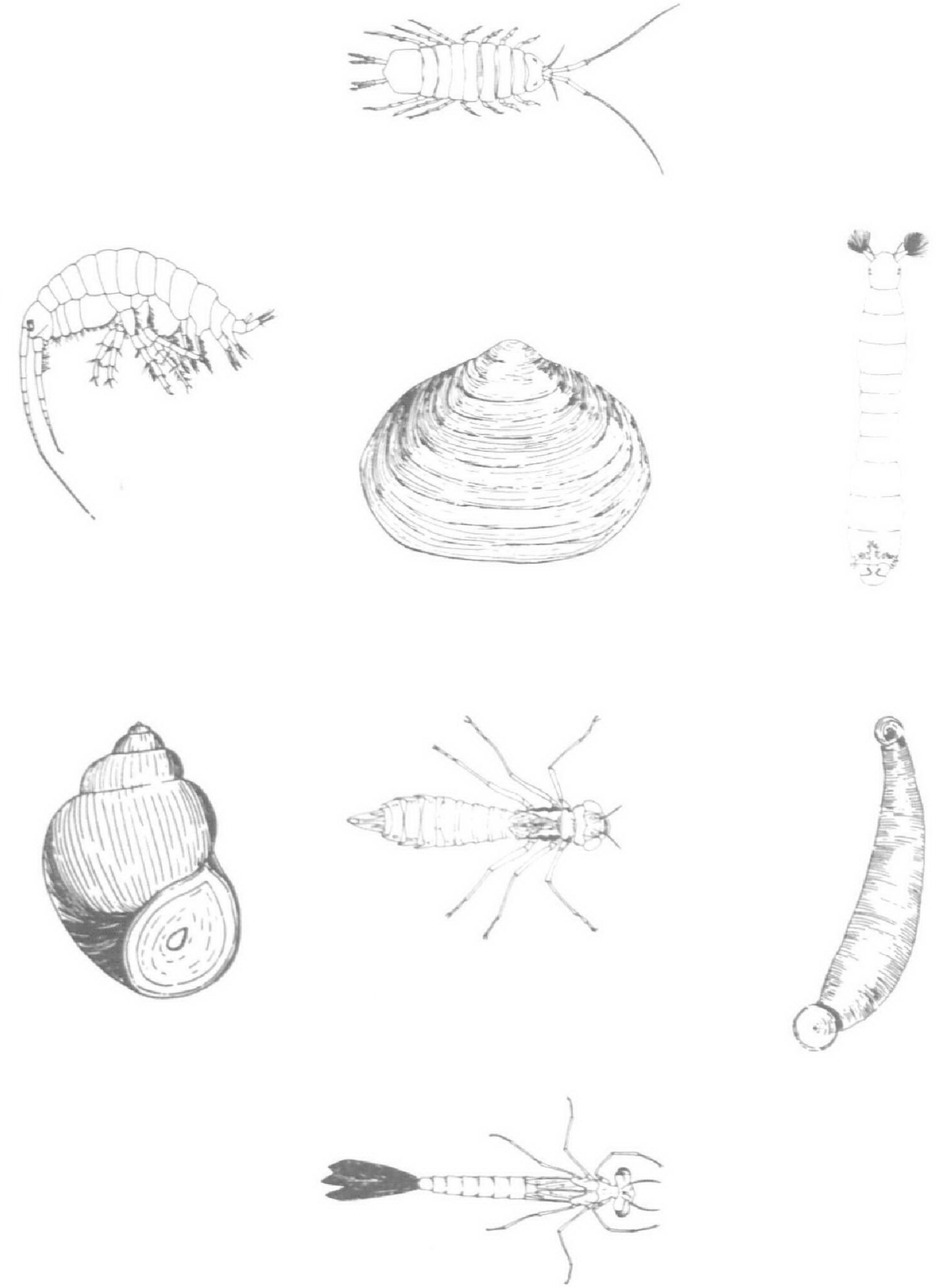

Figure 5. Representatives of stream bed associated animals (The intermediately tolerant group).

From left:

Scud; Sowbug; Blackfly larvae
Fingernail Clam
Snail; Dragonfly nymph; Leech
Damselfly nymph

found to "paint" the stream bed a brilliant red with their undulating bodies. Caddisfly larval populations greater than 1,000 per square foot of stream bed or mayfly nymphs numbering more than 300 per square foot have been found on several occasions.

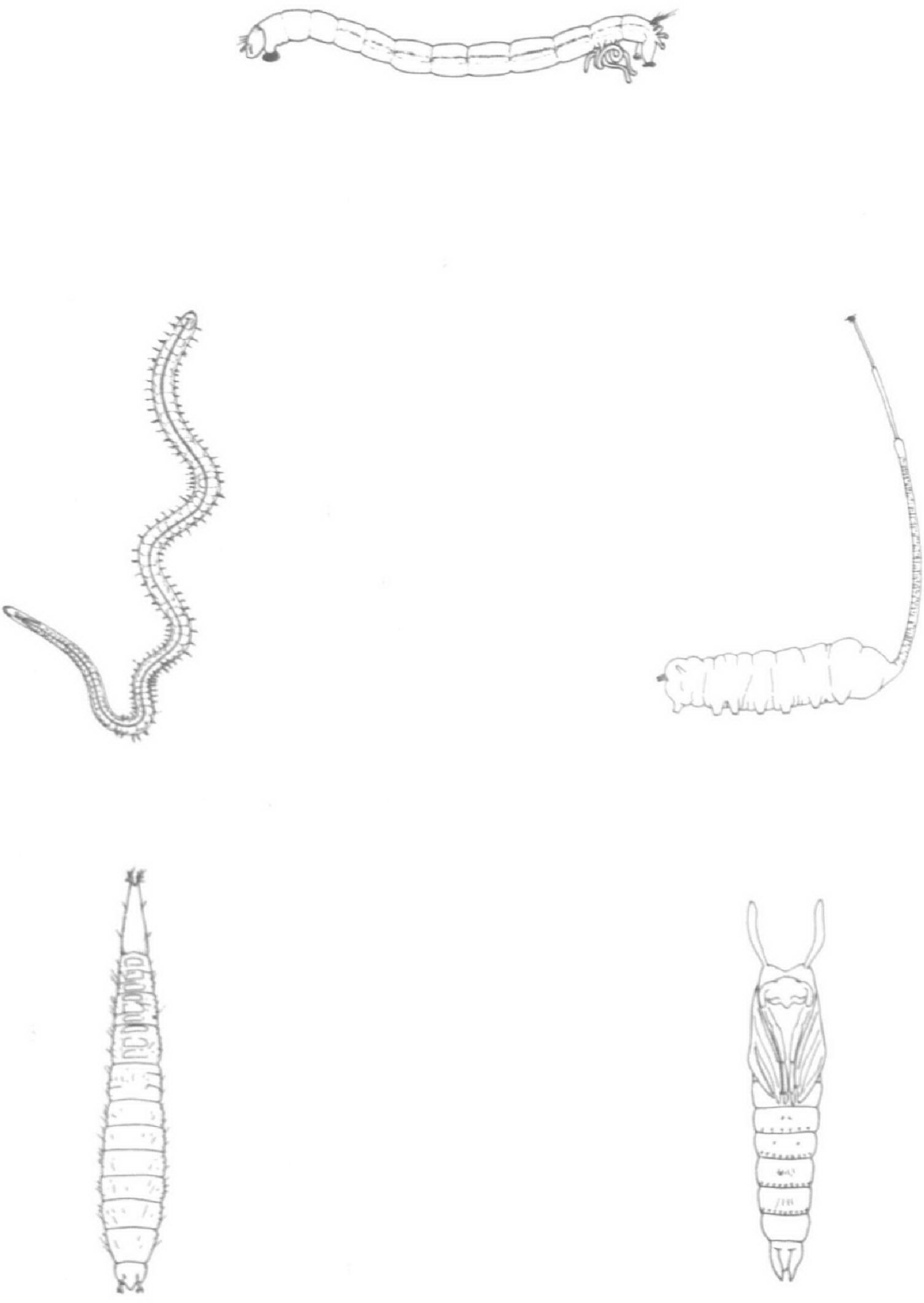

Figure 6. Representatives of stream bed associated animals (The very tolerant group).

From left:

Bloodworm or midge larvae
Sludgeworm; Rat-tailed maggot
Sewage fly larvae; Sewage fly pupae

The estuarine and marine environments have not been studied as extensively as the fresh-water habitats. Reish (1960) cited Wilhelm (1916) to the effect that the polychaete *Capitella capitata* (Fabricius) plays a role in marine waters similar to that of the oligochaete, *Tubifex,* in fresh water.

Filice (1954) and Reish (1960) found three benthic zones surrounding a major pollutional discharge: one essentially lacking in animals, an intermediate zone having a diminished fauna, and an outer zone unaffected by the discharge. Filice (1959) found the crab *Rhithropanopeus harrisii* (Gould) present more abundantly than expected near industrial outfalls: this crab and *Capitella capitata* (Fabricius) were present in large numbers near domestic outfalls. Hedgpeth (1957) reviewed the biological aspects of the estuarine and marine environments.

Inorganic Silts

The general effect on the aquatic environment of inorganic silts is to reduce severely both the kinds of organisms present and their populations. As particulate matter settles to the bottom it can blanket the substrate and form undesirable physical environments for organisms that would normally occupy such a habitat. Erosion silts alter aquatic environments chiefly by screening out light, by changing heat radiation, by blanketing the stream bottom and destroying living spaces, and by retaining organic materials and other substances that can create unfavorable conditions. Developing eggs of fish and other organisms may be smothered by deposits of silt; fish feeding may be hampered. Direct injury to fully developed fish, however, by nontoxic suspended matter occurs only when concentrations are higher than those commonly found in natural water or associated with pollution.

Toxic Metals

Wastes containing concentrations of heavy metals, either individually or in combination, may be toxic to aquatic organisms and, thus, have a severe impact on the water community. A severely toxic substance will eliminate aquatic biota until dilution, dissipation, or volatilization reduces the concentration below the toxic threshold. Less generally toxic materials will reduce the aquatic biota, except those species that are able to tolerate the observed concentration of the toxicant. Because toxic materials offer no increased food supply, such as has been discussed for organic wastes, there is no sharp increase in the population of those organisms that may tolerate a specific concentration. The bioassay is an important tool in the investigation of these wastes, because the results from such a study indicate the degree of hazard to aquatic life of particular discharges; interpretations and recommendations can be made from these studies concerning the level of discharge that can be tolerated by the receiving aquatic community.

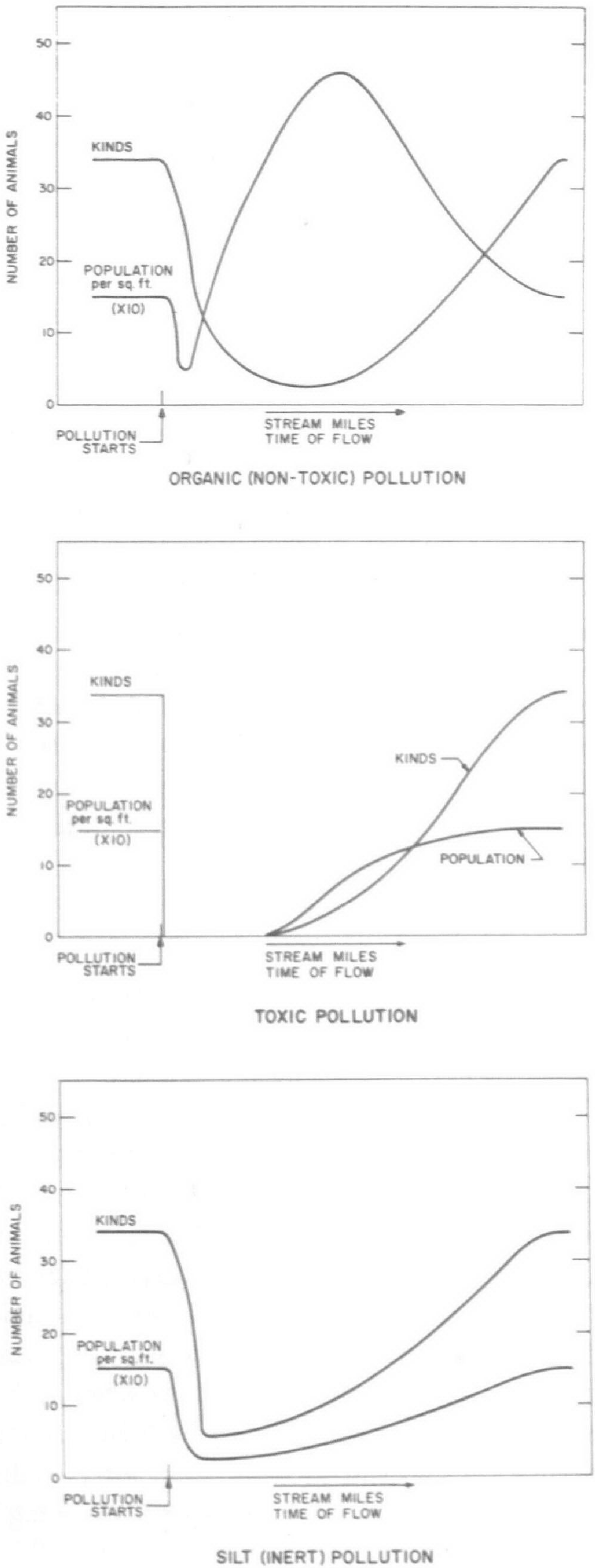

Figure 7. Pollutional Effects on Animals