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STAGE SETTING

WATER:

A necessity for life
A transporter of disease
A sustainer of navigation
A coolant, cleanser, diluent
A medium for recreational pursuits
A resource with food for populations
A power source to harness and control
A source of tranquil, aesthetic enjoyment
A refuge for biological pests and nuisances
A defiled purveyor of civilization's wastes

Water means different things to different people. A particular definition depends in large measure on the personal uses to which water is put by the definer. In this book the concern is not so much with specific water uses as it is with water quality and aquatic life, and the investigation of it.

A section in the National Technical Advisory Committee on Water Quality publication (Anon., 1968) states that, "It is not surprising that water has occupied an important position in the concerns of man. The fate of tribes and nations, cities and civilizations has been determined by drought and flood, by abundance or scarcity of water since the earliest days of mankind."

From the days of the earliest investigator it has been known that each water supports its particular life forms. As early as 1918 Henry Baldwin Ward wrote:

> "From the tiniest rivulet to the mightiest river one may find every possible intermediate stage, and between the swiftest mountain torrent and the most sluggish lowland stream there exists every intermediate gradation. Biologically considered, the torrent imposes on the development of life within its waters evident mechanical limitations which are not present in the slow-flowing streams. Ordinarily the

biological wealth of a stream varies inversely with its rate of flow, and anything which stops or checks the flow makes conditions more favorable for the development of life. Flowing waters are thinly inhabited and also present considerable difficulties to the student; hence they are relatively unexplored territory.

"Taken together lakes compose one-half the fresh water on the surface of the globe. They present an infinite variety of physical features in rocky, sandy, swampy margins, in steep and shallow shores, in regular and broken contours with no islands or many, with shallow water or depth that carry the bottom far below the level of the sea.

"They vary in the chemical character of the soil in the lake basin as well as in their banks and bed, in the degree of exposure to wind and sunshine, in the relative inflow and outflow in ratio to their volume, in their altitude as well as in geographic location. All of these and many other factors modify and control the types of living things and their abundance in the waters." (Ward and Whipple, 1918).

To continue the description of water quality in embellished terms, Mark Twain many years ago eulogized Lake Tahoe in this everlasting prose: [1]

"In the early morning one watches the silent battle of dawn and darkness on the waters of Tahoe with a placid interest but when the shadows skulk away and one by one the hidden beauties of the shore unfold themselves in the full splendor of noon: When the smooth surface is belted like a rainbow with broad bars of blue and green and white, half the distance from circumference to center, when in the lazy summer afternoon, he lies in a boat far out to where the dead blue of the deep water begins and smokes the pipe of peace and idly winks at the distant crags and patches of snow from under his cap brim: When the boat drifts shoreward to the white water, and he lolls over the gunwale and gazes by the hour down through the crystal depths and notes the color of the pebbles and reviews the finny armies gliding in procession a hundred feet below: When at night he sees moon and stars, mountain ridges feathered with pines, jutting white capes, bold promontories, grand sweeps of rugged scenery topped with bald glimmering peaks, all magnificiently pictured in the polished mirror of the lake, in richest, softest detail the tranquil interest that was born with the morning deepens and deepens by sure degrees, till it culminates at last in resistless fascination."

Water quality affects man in his direct use of the water; it affects also the aquatic life that the water contains. Considering the latter, Shelford

[1] From "Lake Tahoe Water Quality Control Policy," June 1966, prepared by State of California, The Resources Agency, Lahontan Regional Water Quality Control Board.

(1918) chose to phrase these aspects as "conditions of existence." He stated that conditions of existence are of importance only insofar as they affect the life and death processes of organisms. Earlier, Forbes (1887) noted the complexity and interrelationship of organism community studies in water quality explorations with the words, "If one chooses to become acquainted with the black bass . . . he will learn but little if he limits himself to that species." Forbes further called attention to the close community of interest that exists among species with the reasoning that to exist a species birth rate must at least equal its death rate and that when a species is preyed upon by another it must produce regularly an excess of individuals for this destruction. Forbes went on to say that on the other hand the dependent species must not appropriate, on the average, any more than the excess of individuals upon which it preys. He argued that the common interest among species was promoted by the process of natural selection.

Figure 1. Lake Tahoe: A Jewel of the West

Aquatic biology, the subject of this discussion, is only one of many disciplines involved in water quality investigations. Other disciplines include chemistry, microbiology, engineering, hydrology, and geology.

The early chronicle of published biological effort began with Hassall in 1850 (1850, 1856) who noted the value of microscopic examination of water for the understanding of water problems. Sedgwick (1888) applied biological methods to water supply problems. Under his leadership the Massachusetts State Board of Health was the first agency in the United States to establish a systematic biological examination of water supplies. In 1889, Sedgwick collaborated with George W. Rafter to develop the Sedgwick-Rafter method of counting plankton. Whipple (1899) produced a treatise that, in 1948, was in its fourth edition and fifth printing; it has served through the years as an often-used reference in the water supply and water pollution field.

One of the first practical applications of biological data to the biological definition of water pollution was contained in the "saprobien system" of Kolkwitz and Marsson (1908, 1909). This system, based on a check list detailing the responses of many plants and animals to organic wastes, has been used extensively to indicate the degree of pollution at a given site. That the sound basic judgment of these early investigators has withstood the passage of time is shown by the frequent references currently made to their works.

The survey of the Illinois River by the Illinois Natural History Survey was one of the first studies that demonstrated clearly the biological effects of organic pollution; these studies were presented in a series of papers that provided much impetus and professional status to biological stream investigations in the United States (Forbes and Richardson, 1913, 1919; Forbes, 1928). Richardson (1921) described changes that had occurred in the bottom fauna of the Illinois River since 1913 resulting from increased movement of sewage pollution southward. Later, Richardson (1928) noted that ". . . the number of small bottom-dwelling species of the fresh waters of our distribution area that can be safely regarded as having even a fairly dependable individual index value in the present connection is surprisingly small; and even those few have been found in Illinois to be reliable as index species only when used with the greatest caution and when checking with other indicators."

Purdy (1916) demonstrated the value of certain organisms to indicate areas of pollution in the Potomac River receiving sewage discharges. The shallow flats of the Potomac River were found to be of great importance in the natural purification of organic wastes; sunlight and turbidity were observed to be prominent factors in the determination of oxygen levels and in waste purification processes. Weston and Turner (1917), Butterfield (1929), and Butterfield and Purdy (1931) reported other studies that demonstrated the effects of organic enrichment on streams, the sudden change in the biota after the introduction of the waste, and the progressive recovery of the biota downstream as the wastes were utilized.

Butcher (1932, 1940) studied the algae of rivers in England and noted that attached algal forms gave the most reliable indication of the suitability of the environment of an area for the support of aquatic life. In the United States, Lackey (1939, 1941a, 1942) investigated planktonic algae and noted their response to various pollutants. The work of Ellis (1937) on the detection and measurement of stream pollution, the effects of various wastes on stream environments, and the toxicity of various materials to fishes has served as a reference handbook and toxicity guide through many years.

Cognizance has been taken of the biotic community and the effect of pollution on the ecological relationships of aquatic organisms (Brinley, 1942; Bartsch, 1948). Bartsch and Churchill (1949) depicted the biotic response to stream pollution and related stream biota to zones of degradation, active decomposition, recovery, and clean water. Patrick (1949) described a healthy stream reach as one in which " . . . the biodynamic cycle is such that conditions are maintained which are capable of supporting a great variety of organisms," a semihealthy reach as one in which the ecology is somewhat disrupted but not destroyed, a polluted reach as one in which the balamce of life is upset, and a very polluted reach as one that is definitely toxic to plant and animal life. Patrick separated the biota into seven groups and illustrated specific group response to stream conditions with bar graphs. The number of species was used rather than the number of individuals. Fjerdingstad (1950) published an extensive list placing various algae and diatoms in zones or in ranges of stream zones similar to those of Kolkwitz and Marsson.

Epoch making water quality legislation in the Water Quality Act of 1965 that amended the Federal Water Pollution Control Act provided for the establishment of water quality standards for interstate (including coastal) waters.

Paragraph 3, section 10, of the Act reads as follows:

> "Standards of quality established pursuant to this subsection shall be such as to protect the public health or welfare, enhance the quality of water and serve the purposes of this Act. In establishing such standards the Secretary, the Hearing Board, or the appropraite state authority shall take into consideration their use and value for public water supplies, propagation of fish and wildlife, recreational purposes, and agricultural, industrial, and other legitimate uses."

Subsequent to this legislation the Federal Water Pollution Control Administration issued guidelines for establishing water quality standards for interstate waters. These policy guidelines included such statements as "Water quality standards should be designed to 'enhance the quality of water.' . . . No standards of water quality will be approved which provide for the use of any stream or portion thereof for the sole or principal purpose of transporting wastes . . . Numerical values should be stated for such quality characteristics where such values are available and applicable. Where appropriate, biological bioassay parameters may be used. In the absence of appropriate numerical values or biological parameters, criteria should consist of verbal descriptions in sufficient detail as to show clearly the quality of water intended."

On February 27, 1967, the Secretary of the Interior established the first National Technical Advisory Committee on Water Quality Criteria to the Federal Water Pollution Control Administration. The Committee's principal function was to collect in one volume a basic foundation of water quality criteria. A smaller but equally important function was to develop a report on research needs. In its published report the Committee recognized that there is an urgent need for data collection from systematic surveillance of waters and waste sources and for an expanded research effort (Anon., 1968). Systematic surveillance was defined as ". . . traditional sanitary surveys broadened to include aesthetic qualities . . .". The Committee's Report also underscored the relative value assigned to recreational use by the Act with statements that ". . . recreational uses of waters in the United States have historically occupied an inferior position in practice and law relative to other uses," but that today there is a growing realization that recreation is a full partner in water use; one that, with associated services, represents a multimillion dollar industry with substantial prospects for future growth, as well as an important source of psychic and physical relaxation. Water quality research needs including those assigned to fish, other aquatic life, and wildlife have been defined in a 1968 report of the National Technical Advisory Committee.

What, then, is a defined role of the field investigative water pollution biologist? Basically it seems apparent that the role of individuals working in this discipline is to:

1. Determine water quality compliance with established standards, and, determine the effectiveness of established standards to meet the needs of an enhanced water quality.
2. Identify, define, and interpret the effects on aquatic organisms of water quality changes that result from pollution.
3. Project these effects on man and man's use of the water.
4. Predict environmental conditions that might prevail, and beneficial water uses that would result, when pollution that can now be controlled is abated or alleviated, wholly or in some degree.
5. Determine impact of water quality on those important biotic community segments that are either harvestable directly by man or are essential to support more advanced levels of life within the aquatic environment.
6. Contribute to existing knowledge of the cause and control of pest and other nuisance aquatic organism populations.