2d

Analysis of Aquatic Habitats

1. Introduction

Limnology is the study of fresh waters, including both their physical and biological aspects; **oceanography** considers the physical and biotic properties of marine and estuarine environments. Many of the basic principles and concepts concerning terrestrial habitats have parallels in aquatic habitats, although numerous details and patterns are unique to the latter. The aquatic habitat can be divided into certain basic dimensions such as time, space, and physical and chemical components. Unlike the terrestrial ecologist, the aquatic ecologist generally emphasizes physical and chemical factors instead of biological factors when describing the habitat. In aquatic systems these factors are often more complex than in terrestrial environments, and vegetation has a relatively minor role in modifying the physical characteristics of the habitat. This section will deal with methods for analyzing physical factors such as light, temperature, current, and conductivity. Section 2E presents techniques for analyzing chemical factors.

There are two basic types of freshwater habitats: **lentic** (calm) waters and **lotic** (running) waters. **Lakes** and **ponds** are lentic habitats. Lakes are deep and generally stratified with respect to temperature, oxygen, and nutrients; ponds are shallow bodies of water without seasonal stratification and whose waters mix regularly from top to bottom. A common system of classifying lakes refers to relatively young, deep, cold, and nonproductive lakes as **oligotrophic;** relatively shallow, warm, and productive lakes as **eutrophic;** and lakes having intermediate characteristics as **mesotrophic.** Ponds may be **temporary,** especially in dry climates; **vernal** ponds are those that fill in the spring and dry up in the summer.

Lentic habitats shallow enough to be inhabited by much vegetation are often called **wetlands,** although there is no agreement on their nomenclature (Mitsch 1993). Common North American terminology emphasizes the following wetland types: A **bog** is characterized by having no significant inward or outward water flow (*i.e.*, no source of water other than precipitation), an accumulation of partly decayed organic matter as peat, a low (acidic) *p*H, and mosses such as sphagnum. Other wetlands have relatively neutral *p*H and typically do not accumulate peat. A **marsh** has emergent (and, sometimes, floating) herbaceous vegetation (and may be saline in coastal regions); a **fen** is a peat-accumulating marsh; and a **swamp** has trees or shrubs as the predominant vegetation. Some additional regional terms are found: Shallow marsh-like ponds may be called **potholes** (or **playas)** in the southwest United States; a **muskeg** is a peat-forming wetland in Canada and Alaska, a periodically flooded forest area is a **bottomland,** a **wet meadow** is a grassland with waterlogged soils but without permanent standing water, and a **slough** is a term variously applied to swamps, marshes, or ponds in different parts of the United States. In Europe, a **swamp** is dominated by reed grass, and peatlands may be called **moors** or **mires.** Wetland areas have been greatly reduced in extent by human activities.

A lentic body of water often may be deep enough to exhibit distinct zonation. The **littoral** zone is the shallow portion along the shore, where light penetrates with sufficient intensity to sustain a significant photosynthetic rate down to the bottom. Rooted vegetation is commonly found in this region. In the open water beyond the littoral zone, a depth exists—the **compensation** depth—at which light penetration is so poor that the photosynthetic rate is just equal to the respiratory rate. Above the compensation depth is the **limnetic** region of the lake; below, the **profundal** zone. The littoral and limnetic waters often are collectively termed the **euphotic** zone, that portion of the lake where photosynthetic rate exceeds respiratory rate.

Streams are lotic, being flowing bodies of water. **Creeks** are small streams that are narrow, shallow, and may consist of relatively still areas (**pools**), areas of rapid shallow flow over gravel or rock (**riffles**), and areas of deeper flows (**channels**). **Rivers** are wide and deep streams, and may have more violent **rapids,** instead of riffles. Some small streams flow only seasonally or intermittently during periods of rainfall. The terrestrial borders of a stream are said to be the **riparian** habitat, and the **floodplain** is land that is periodically subject to flooding.

2. Temporal and Spatial Information

When studying an aquatic habitat, record the date, the time of day, and the names of the observers. Recorded

spatial information (noted in Section 2A.4) should include specific locality, topography, and drainage characteristics.

As most fresh water drains from or into some other body of water, the major drainage system (the **watershed**) should be identified, along with the name of the water body. The watershed is the total land area that drains into the waterway; it incorporates the energy and material exchanges of the terrestrial and aquatic ecosystems within it and is named by the major river system that eventually collects the water from it. The major watersheds are of the rivers that eventually enter the ocean, such as the Mississippi, St. Lawrence, Columbia, Colorado, and Hudson rivers. The **drainage density** for a watershed is

$$\frac{\text{total stream length}}{\text{total area drained}}. \qquad (1)$$

A topographic description of the study area (see Section 2A.4) should include the type of water body, such as creek, river, pond, lake, or reservoir. A map or aerial photograph of the water is desirable. If none is available, the mapping methods described by Lind (1985) or Wetzel and Likens (1993) may be employed. Record surface features such as the slope and form of the surrounding terrain and shoreline, the form of stream channel, and formations such as riffles, rapids, falls, and islands. Record the size of the water body and its approximate center depth. If water, substrate, or biological samples are taken, the distance from shore and the depth of the sampling should be noted.

For lakes, the surface area may be estimated from a topographic map or aerial photograph (see Section 2A.4). An important variable in limnological studies, particularly those dealing with lakes, is the ratio of the surface area to the volume of the lake. The larger the surface area relative to its volume, the greater will be the amount of gas exchange and mixing due to winds. If the volume and surface area are known, then we can define

$$\text{mean depth} = \text{volume/surface area}. \qquad (2)$$

But the surface area and especially the volume of lakes are usually difficult to measure, so a simple ratio of the width of the water body divided by the center depth can be used as a rough index of the surface area-volume ratio. In elongated lakes, the length of the lake may be considered instead of the surface area, particularly if the long axis is parallel to the direction of the prevailing winds.

It may be of interest, especially in deep lakes, to express the pressure at particular depths. This may be done as

$$P = 1 + 0.0967d \qquad (3)$$

(Wetzel, 1983:159), where P is the combined atmospheric and hydrostatic pressure, in atmospheres (1 atm = 760 mm Hg), at a water depth of d meters.

3. Physical Environment

A description of the physical factors affecting the aquatic environment includes information on atmospheric conditions and substrate, as well as water. Atmospheric conditions control the climate, season, and daily weather conditions, which of course affect the amount of incipient light at the surface, volume of water, temperature, water currents, and, subsequently, the distribution of organisms in the body of water. As biotic sampling results may vary with short-term changes in weather conditions, record the following atmospheric information: climatic zone, air temperature, wind velocity and direction, cloud conditions, and type and intensity of precipitation (see Section 2B).

The substrate of the water body provides habitat for a distinctive animal aggregation called the **benthos** (see Section 3E.1). Therefore, one should record the type of bottom materials: clay, silt, sand, gravel, or rock. Methods for physical analysis of the sediment are given in Section 2D. Streams with swift currents may lack sediment, having a bottom of bedrock or large rocks and boulders. Such rock may be recorded as sandstone, shale, limestone, granite, or other specific type. The slope of the bottom, the depth of any silt, and the occurrence of riffles, rapids, channels, and pools should also be recorded. Samples of substrate, other than rock, and the benthos therein may be obtained by the methods of Section 3E.2.

For a general analysis of an aquatic habitat, record in the field the following basic water measurements: surface water temperature, current velocity, turbidity, and conductivity. For a general chemical survey (see Section 2E), hardness, dissolved oxygen, alkalinity, and *p*H are properties measurable in the field and often included in a general habitat description. The Kemmerer water sampler (Figure 2D.1) can collect a known volume of water (as well as the organisms suspended therein). The sampler is lowered to the desired water depth and closed by dropping a "messenger" (a metal weight) down the

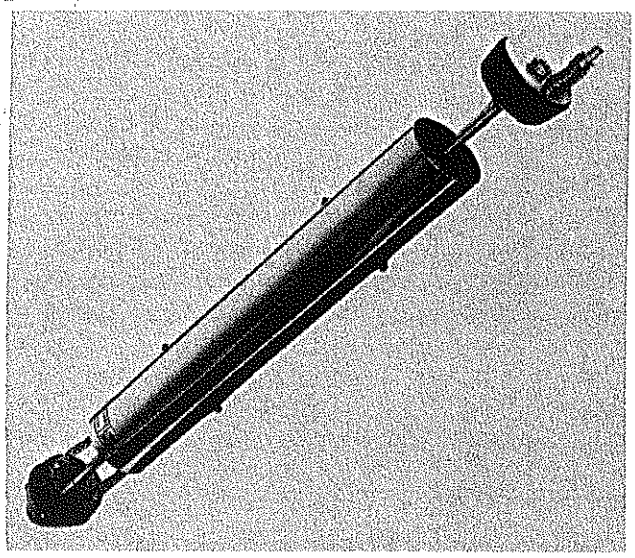

Figure 2D.1 The Kemmerer sampler, with which water and Plankton samples may be obtained. The sampler pictured has a capacity of 1.2 liters. (Photograph courtesy of the Wildlife Supply Company, Saginaw, Michigan.)

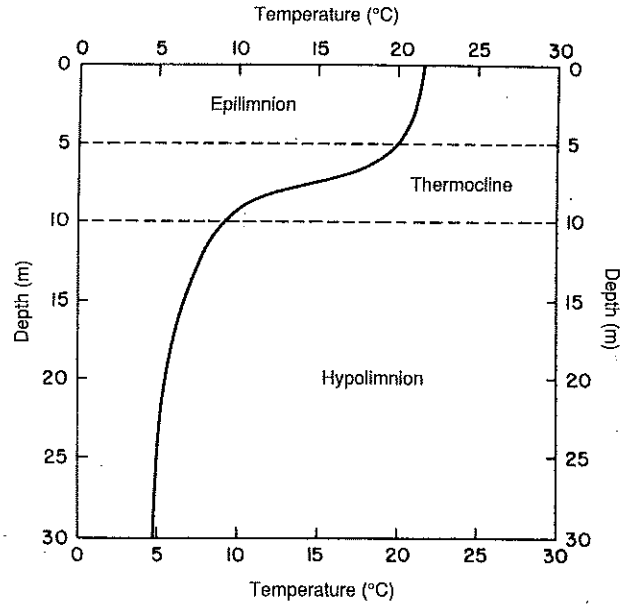

Figure 2D.2 The temperature profile of a lake.

supporting line. In lentic habitats, also record water temperature, dissolved oxygen, and *p*H measurements taken from just above the bottom.

3.1 Temperature In lakes and ponds, water temperature varies with depth and location. It affects not only the distribution of organisms but the density of the water and the solubility of minerals and gases. For a general analysis of the habitat, measure the water temperature a few centimeters below the surface and just above the bottom, record this from a number of locations, and calculate the mean surface and bottom temperatures. For a more detailed study of a lake, take temperatures at 1-m intervals at a number of different depths to make a **temperature profile** of the pond or lake. For this purpose, a maximum-minimum thermometer or a thermistor with a long extension is useful. Temperatures of water samples from different depths can be measured immediately after the sample is taken, but this will be accurate only if a large volume of water is collected and measured very rapidly. Some commercial water samplers contain a thermometer readable through a plastic window in the sampler. To graph a temperature profile, it is customary to place water temperature on the horizontal axis and depth on the vertical axis, with the water surface (zero depth) at the top (Figure 2D.2). A lake may be **stratified** thermally, having layers of water at distinctly different temperatures. If it is, there is often a short range of depths—the **thermocline**—in which the water temperature changes very abruptly. The water above the thermocline is the **epilimnion;** that below it is the **hypolimnion.** Some authors use the term **metalimnion** for the transitional layer between the epilimnion and hypolimnion and restrict the term **thermocline** to that portion of the metalimnion where the temperature change is most abrupt.

3.2 Current Use a current flow meter to measure the current velocity in streams at a number of locations. If such a meter is unavailable, the velocity can be approximated through use of a Pitot tube, an L-shaped glass tube marked off in linear units. The base of the L is placed in the stream with the tube's opening facing the current and its upper arm perpendicular to the surface. Pressure created by the current will cause water to rise in the tube. The height of the water column above the water surface is related to the stream velocity, which can be estimated using the following equation:

$$v = 0.977\sqrt{2gh} \qquad (4)$$

(Welch, 1948), where v is the velocity of the water (in centimeters per second), g is the gravitational constant (981 cm/sec^2), and h is the height of the water (in centimeters) in the tube.

One may also determine surface velocity by measuring the time it takes for a floating object to travel a known distance downstream (but care must be taken to use an object that does not project much above the water's surface and is thus influenced by wind). This procedure is not recommended when turbulence is great or current is slow. Velocity varies with distance from the shore and depth of the stream.

An estimate of the **average water column velocity** is conventionally obtained by measuring the water velocity at a distance $0.6d$ below the water's surface, where d is the depth of the stream; for deep streams, it is better to use the average of the velocities of $0.2d$ and $0.8d$ (Gordon, McMahon, and Finlayson, 1992: 161; Rahn, 1986: 256). A current flow meter may be attached to a graduated "wading rod" with a sliding mechanism that allows for depth adjustment. In wide streams, mean velocity should be estimated at several points along a transect across the stream.

Discharge, another measurement, is the volume of water flowing past a given section of a stream per unit time. It may be calculated as the mean velocity of the stream times its mean cross-sectional area. The mean cross-sectional area is approximated from the mean width of the stream multiplied by the mean depth.

3.3 Turbidity An optical property of water, **turbidity** causes light to be scattered or absorbed in the water, resulting in a decrease in water transparency. It is a function of at least three variables: (1) dissolved chemicals, such as tannins, acids, and salts, (2) suspended particles, such as silt, clay, and organic matter, and (3) the density of microbiological organisms.

Turbidity should be measured because the depth of light penetration affects the distribution and intensity of photosynthesis in the body of water. (See Section 2D.1 for a description of the compensation depth and the euphotic zone.) One scale of turbidity measurement employs the **Jackson turbidity unit** (JTU). This unit, on a logarithmic scale, considers the height of a column of water that extinguishes the light emitted by a standard "candle."[1] (A height of 2.30 cm that extinguishes the candle image represents 1000 JTU.) Difficult to interpret ecologically, this scale of turbidity measurement is useful mainly in comparing different sites or times.

A common and sounder measurement of turbidity is the **extinction coefficient:**

$$E = 2.30 \log(I_0/I_d)/d, \qquad (5)$$

[1] This refers to luminous intensity as described in Section 2B.4.1.

where E is the extinction coefficient, d is the depth at which the measurement is taken, I_d is the light intensity at that depth, and I_0 is the light intensity at zero depth, or just below the surface. (Use Table D.2 in Appendix D to obtain logarithms.) This coefficient may be measured with a waterproof light meter lowered to the desired depths. Ideally, these measurements should be taken at about the same time of day and under fairly clear skies. The extinction coefficient is a measure of the amount of light absorbed per unit depth of the water, and it can therefore be related to the photosynthetic potential of that body of water.

Another method for measuring turbidity uses a colorimeter or a spectrophotometer. A water sample is shaken well to avoid settling and is placed in a colorimeter tube to its marked level. The percent transmittance (T) is compared to that of distilled water. The wavelength of the spectrophotometer is set at 450 nm, for this blue-green wavelength is an optimal one for photosynthesis. (Most of the light at the other photosynthetically optimal wavelength of 650 nm in the red-orange region is rapidly absorbed by water and thus has little role in photosynthesis below the first meter of depth.) Since the percent transmittance is $100(I_d/I_0)$, an extinction coefficient may be estimated by substituting $100/T$ for (I_0/I_d) in Equation 5; the value of d represents the inside diameter or light path distance of the colorimeter tube. Because artificial white light or a specific wavelength is being used, the extinction coefficient will not be identical to that of a direct field measurement given above, which employs sunlight. A nephelometer is an instrument that measures light scattering in water, higher turbidity causing greater scattering. Nephelometer turbidity units are not the same as Jackson turbidity units; they are useful as comparative measures among various water samples.

A third but more subjective method of turbidity measurement uses the **Secchi disc.** For limnological studies, this disc typically is 20 cm in diameter, having four quadrants, two opposing ones painted black and the other two either white or unpainted. The disc is suspended from the center by a calibrated cord or chain and is usually lowered from a boat into the water. It is lowered slowly until no longer visible; the depth at this point is recorded. This disc is lowered further and then slowly raised until it just becomes visible from directly above; then the depth at this point is recorded. Calculate the mean of these two determinations and repeat the procedure at a few other locations. This is a quick and easy method for relative comparisons of degrees of light penetration, but exercise care when interpreting the results as the method is difficult to standardize between individual observers and between different overhead light conditions.

3.4 Conductivity The inverse of electrical resistance, **conductivity,** is another useful physical measurement in aquatic habitats. The greater the conductivity, the greater the amount of ions in the water. Thus conductivity is an indirect measure of salinity, which reflects the osmotic concentration of solutes. And osmotic concentration is an important physical property of water related to the water and salt balance of organisms. Since polluted waters have a higher conductivity than natural waters, this measure is often used as an index of pollution. The unit of conductivity is mhos per centimeter and represents the amount of current that can be conducted between two electrodes 1 cm apart. Commercial conductivity meters are convenient, but you may also use a standard resistance test meter with platinum electrodes spaced 1 cm apart. Because conductivity is dependent on temperature, a correction for this variable must be made. See Section 2E.5 for details on measuring conductivity.

4. Biological Components

Biological components in aquatic environments are not as important as physical and chemical factors for rapid habitat descriptions in the field. Unlike terrestrial habitats, where plants dominate the community and strongly influence the physical environment (see Section 2A), aquatic habitats are less conspicuously affected by organisms. Their effect is largely on the concentrations of dissolved nutrients and gases. Here, the task of the ecologist is to sample and tabulate quantitatively the more common plant and animal forms (see Section 3E). Except in ponds, marshes, and swamps, most aquatic plants are suspended algae and make up the part of the community termed **phytoplankton.** Enumeration of certain "indicator" species is common practice in water pollution studies (see Section 2D.5.1).

In the littoral zone of most ponds and marshes and often along river edges, a well-developed pattern of vegetation occurs, described as free-floating plants (e.g., duck-weeds), rooted floating plants (e.g., pond lilies), submerged plants (e.g., stoneworts, hornworts), and emergent plants (e.g., arrowhead, sedges, rushes, and cattails).

5. Water Pollution

Few bodies of water remain free of human contamination. Contaminants, or pollutants, have drastically altered the ecology of many lakes and streams. Therefore some measure of the degree of pollution should be included in an aquatic habitat description.

Some pollution involves introduction of excess amounts of naturally present substrates (e.g., organic matter, nitrates, and phosphates). Other pollutants (e.g., most pesticides) are substances foreign to natural habitats. The major sources of pollution are **industrial** (chemical, organic, and thermal wastes), **municipal** (largely sewage consisting of human wastes, other organic wastes, and detergents), and **agricultural** (animal wastes, pesticides, and fertilizers). Different sorts of pollution may have vastly different effects on an ecosystem. For example, some characteristics of organically polluted waters include low dissolved oxygen, high biochemical oxygen demand (BOD), high turbidity, and high concentrations of such nutrients as phosphates, nitrates, and ammonia. However, acid mine drainage may be associated with water that is rich in oxygen, clear, low in nutrients, and low in organic carbon, but if introduced into the above waters could have devastating ecological effects.

5.1 Biological Indicators Some organisms serve as indicators of organically or nutrient enriched waters, such as fecal coliform bacteria, "blooms" of blue-green algae, sludge worms (Tubificidae), and the so-called "rat-tailed maggots" of some syrphid flies. Organisms not present in such an environment are either intolerant of it or depend for food on organisms intolerant of it. Gaufin (1973), Goodnight (1973), Hart and Fuller (1974), Palmer (1962, 1969), and Patrick (1973) describe indicator organisms and discuss the use and misuse of indicator organisms in water pollution studies. Often the greater the density of these organisms, the greater the degree of organic pollution. Also, biological indicators can signal the occurrence of pollution even if the pollutant is temporarily absent at the time of measurement.

However, be cautious about conclusions drawn from the presence or absence of indicator organisms. The presence of a pollution-tolerant species is not always an indication of pollution as these species occur naturally under less disturbed conditions. Likewise, the absence of such clean-water forms as stonefly naiads, mayfly naiads, caddisfly larvae, or damselfly naiads may be due to habitat conditions other than pollution. Also, organisms that indicate specific types of pollution may differ in different geographic regions or different types of habitats. Differences between the species composition of two areas can be quantitatively described (see Section 5C).

5.2 Species Diversity Qualitative sampling procedures referred to as rapid-assessment approaches are designed to detect organic-pollution impact on macroinvertebrate communities in small, shallow streams. They are intended to reduce the effort in collecting macroinvertebrates and summarize the results of site surveys in a single index that varies over some range of values. The measures used can be grouped into five major categories:

taxonomic richness, taxonomic enumeration (abundance), taxonomic diversity indices and similarity indices, biotic indices, and functional feeding-group measures. Resh and Jackson (1993) review these approaches and provide guidelines for their use.

Taxonomic diversity has been one of the more popular measures of water pollution and other habitat disturbances (Wilhm, 1967; Wilhm and Dorris, 1968). In general, the more polluted a body of water the lower is the diversity index, but the use of such an index is difficult to standardize because a variety of factors other than pollution will affect it. The use of artificial substrate samplers (Section 3E.2.5) helps alleviate many standardization problems.

Section 5B summarizes several measures of species diversity, and such measures may be used to assess taxonomic diversity even when species identifications are not made. Here we describe a rapid and very simple method (Cairns et al., 1968) to obtain a relative measure of diversity without requiring any taxonomic knowledge. Mix thoroughly the collection of organisms by shaking them in a container of water or preservative, and then examine them, one at a time, *at random.* (A subsample from a suspension may be placed on a microscope slide and the slide examined systematically, from left to right, from top to bottom. Or, a well-mixed collection of macroinvertebrates may be placed in a shallow pan marked with lines or a grid for systematic examination.)

In examining each organism, decide only whether it looks like the previous organism examined (on the basis of shape, size, color, and other obvious characteristics). If so, it is a member of the same "run"; if not, it is said to belong to a new "run." For example, a series of organisms observed at random might look like this (where different letters depict taxa subjectively judged to be different):

A B B A C C C B A A B C C D

Here, a total of fourteen individuals appears in a sequence forming nine runs (a run indicated by an underline).

A **sequential comparison index** (SCI) may then be expressed as

$$\text{SCI} = \text{number of runs}/n, \qquad (6)$$

where n is the number of specimens examined. For the above example,

$$\text{SCI} = 9/14 = 0.64.$$

Obviously, the greater the variety (diversity) of organisms in the collection, the higher will be the computed SCI. The greatest possible diversity would be when each individual was unlike each preceding individual (SCI = 1.0); the lowest possible diversity would be indicated by all of the n specimens being judged identical (SCI = $1/n$). A disadvantage of this index is the variability with which different observers declare organisms to be the same or different.

If the collection contains a large number of organisms, a performance curve (Section 1A.3) may be used to determine how many individuals should be counted. Count 50 specimens and calculate the SCI; count another 50 and calculate the SCI for all 100; then proceed to the next 50, and so on. Each time a value of SCI is computed for the cumulative number of organisms, plot it. Counting may be terminated when the performance curve levels off.

The counted organisms should then be returned to the collection and the latter thoroughly mixed once again. A second SCI should be determined for that same collection in the same manner as the first. Calculate the mean of the two replicate determinations of SCI. Cairns and Dickson (1971) have found that a mean of two replicates is sufficient to analyze most ecological assemblages. For more precision, however, six to eight replicates should be obtained for each collection.

The SCI may be transformed into a somewhat more refined index of diversity with little additional effort. While determining the SCI one can also keep track of the total number of different taxa (four in the above example), and calculate a diversity index (DI) as

$$\text{DI} = \text{SCI} \times \text{number of taxa}. \qquad (7)$$

For the present hypothetical data,

$$\text{DI} = (0.64)(4) = 2.56.$$

Field experience has shown that "healthy" streams have DI values greater than 12.0, whereas communities in polluted habitats have DI values of 8.0 or less (Cairns and Dickson, 1971).

5.3 Biochemical Oxygen Demand **Biochemical oxygen demand** (BOD) is a bioassay of the amount of biodegradable organic carbon in water. Two samples of water are taken in glass-stoppered bottles. Then the amount of dissolved oxygen is determined in one of them, as described in Section 2E.6. The second sample is stored for five days at 20°C, after which its dissolved oxygen is determined. The difference in the concentration of oxygen between the original sample and the stored sample represents the amount of oxygen (in milligrams

per liter or parts per million) consumed by microorganisms while decomposing organic material:

$$\text{BOD} = (C_1 - C_2)/c, \qquad (8)$$

where C_1 and C_2 are the original and final dissolved oxygen concentrations, respectively, and c is the dilution factor. For polluted water, the sample should be diluted 1:10 or 5:10 (resulting in c values of 0.1 and 0.5, respectively), depending on the expected concentration of organic matter.

BOD represents a laboratory measurement, so extrapolation of this value to the actual oxygen demand of a body of water is questionable. However, it has become standard procedure for comparing the relative amounts of organic enrichment of streams, lakes, or waste waters. In nature, BOD may range from a trace to 5 ppm oxygen consumed over a five-day period. Ten to 20 ppm oxygen would indicate a high level of organic pollution, and some waste waters may have BOD values greater than 100 ppm.

Measurement of BOD can be biased by free chlorine in the water, supersaturation of oxygen, large concentrations of acids or bases, reduced inorganic compounds in the water (sulfite, ammonia, or nitrite), and reduced iron. The types of available microorganisms can also affect the results.

3.4 Physical and Chemical Factors Biological indicators, diversity indices, and bioassays do not reveal the exact identity of pollutants. For this, a chemical and physical analysis of the water should be made. The chemical analyses of Section 2E can determine quantities of some pollutants.

In habitats where nutrient enrichment is suspected of causing algal blooms, phosphate and nitrate concentrations should be determined. However, if the algal bloom is far advanced, most of the soluble nutrients would be in the algal biomass and an analysis of soluble phosphate and nitrate may reveal low concentrations. Salt contamination, if suspected, is determined from measurement of conductivity and an analysis of chlorides. And acid mine drainage results in a low *p*H and high amounts of sulfates.

Low values of dissolved oxygen when accompanied by a high BOD will often result in greater concentrations of ammonia. High values of BOD are also accompanied by high turbidity and conductivity. However, high turbidity and conductivity are also associated with siltation, the major contaminant in many streams, lakes, and reservoirs. But siltation will not necessarily be associated with a high BOD or low dissolved oxygen.

Thermal pollution is easily detected by measuring the temperature of various parts of a lake or stream. This m of habitat alteration, unlike that caused by siltation or organic wastes, is less visible and may have more subtle effects on the diversity, productivity, and species composition of a body of water. Slight increases in the temperature of a water body may increase the rate of nutrient cycling, alter the reproductive efficiency of certain fishes, and even encourage algal blooms.

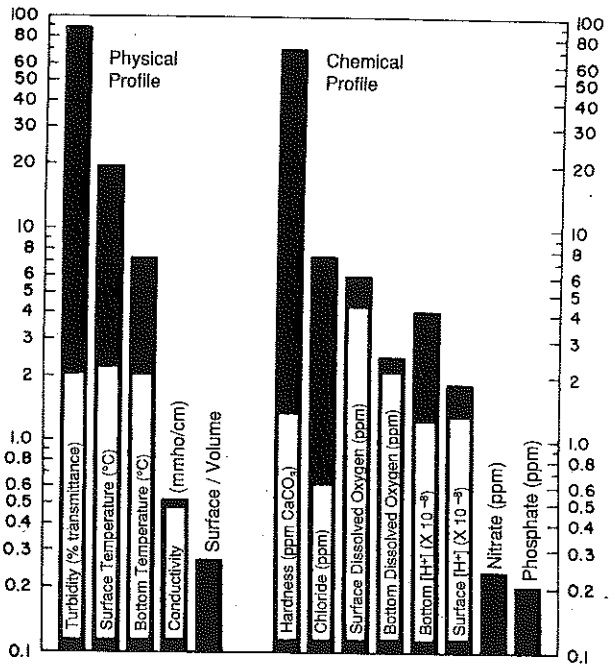

Figure 2D.3 A habitat profile of a pond.

6. Aquatic Habitat Profile

How does one use all of these seemingly disjunct pieces of data from a habitat? One can simply but confusingly graph each of the physical and chemical variables as a function of space or time, as in a temperature profile of a lake in relation to depth. Such illustrations are useful for evaluation of individual physical and chemical variables, but it is desirable to have a holistic impression of the habitat. Kaill and Frey (1973) have attempted to summarize habitat data into an environmental profile, based on measurements taken at dawn and dusk. The following procedure, while using a lake as the example, may also be applied to streams and terrestrial habitats. In the latter case, use physical and chemical soil data and atmospheric measurements.

To prepare an environmental profile, construct a histogram of the measured variables for each ecological situation (location or time) being studied (Figure 2D.3). In these histograms, the logarithm of the value is plotted on the vertical axis, and the environmental factors are sequenced along the horizontal axis. (Commercially available 3- or 4-cycle semilogarithmic graph paper is very convenient for this purpose.) The logarithmic scale is used so that very small and very large numbers may be placed on the same graph. The order of the environmen-

tal variables is arbitrary but should be consistent from one profile to another. For convenience, physical measurements may be placed together and chemical determinations grouped together. (Biotic measures, such as abundance and species diversity, are not included in the habitat profile.)

Since the extinction coefficient is a logarithm, it is convenient to graph the percent transmittance instead. The plotting of *p*H presents a problem, for this variable normally falls in a very narrow range of 6.5 to 8.5. Thus a small but important difference would appear insignificant on the graph, so it is recommended that *p*H be converted to hydrogen ion concentration $[H^+]$:

$$pH = \log(1/[H^+]); \tag{9}$$

therefore,

$$[H^+] = 1/(\text{antilog } pH). \tag{10}$$

Logarithms and antilogarithms may be obtained from Table D.1 in Appendix D. For example, if the *p*H of a water sample is 7.62, we would use Equation 10 to compute:

$$\begin{aligned}[H^+] &= 1/(\text{antilog } 7.62)\\ &= 1/(4.17 \times 10^7)\\ &= 0.240 \times 10^{-7} \text{ or } 2.40 \times 10^{-8}.\end{aligned}$$

The selection of units of measurement is done to allow the bars in the graph to fall within easily plotted limits. For example, conductivity values less than 0.1 mmho/cm may be plotted as μmho/cm; hardness values exceeding 100 ppm $CaCO_3$ may be plotted as ppm $\times 10^{-2}$. Acidity is represented as $[H^+] \times 10^{-8}$ (so a *p*H of 8 would appear on the profile graph as 1, a *p*H of 7 would appear as 10, a *p*H of 6 as 100, and so on). If habitat profiles are to be compared, they should each employ the same unit of measurement. It is not reasonable to attempt to average all the measurements to arrive at some kind of habitat index.

Measurements such as temperature, turbidity, conductivity, dissolved oxygen, and *p*H should be made near the surface and near the bottom of a lake, and both surface and bottom values should be graphed. The measurement of these variables only near the surface can lead to a poor representation of the lake.

7. Suggested Exercises

1. Compare the habitat profiles of two different ponds, lakes, or streams. Explain the differences between the physical and chemical variables observed.
2. Compare the habitat profiles of a polluted and an unpolluted body of water.
3. Compare the habitat profile of a riffle and a pool in a stream.
4. Select environmental variables such as temperature, turbidity, and oxygen, and determine the profile of these as a function of depth in a lake or pond (see Figure 2D.2).
5. Sample a polluted stream, both upstream and downstream from the source of contamination, attempting to sample in habitats with similar currents, depths, and substrates. Identify the major taxa of algae or benthic invertebrates and note the relative abundances of typical clean-water or polluted-water taxa.
6. In a stream pollution study such as above, calculate a measure of taxonomic diversity at each sampling location. Determine how this changes with distance from the source of contamination.

8. Selected References

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