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POLLUTION ASSESSMENT: A TRAINING MANUAL

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Arthur L. Buikema, Jr.

Karl E. Schwaab

John Cairns, Jr.

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Arthur L. Buikema, Jr., Karl E. Schwaab,

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Abstract. This manual provides a self-instructional method for assessing effects of pollution upon species diversity in water ecosystems. No formal taxonomic training is necessary. The method has been used successfully all over the world for both aquatic and terrestrial ecosystems. It is a useful first exercise to acquaint students with natural and stressed communities. Detailed instructions and ample illustrations have been provided.

INTRODUCTION

The elimination of organisms, animals or plants, from a given locale is often the result of introduced, human-generated pollution. More often than not, societal concern with pollution is stimulated only as a result of the effects of pollution on resident organisms, especially fishes and birds.

Examination of plant and animal life within an area can result in significant data concerning the presence of pollutants. The type of organisms disturbed and the extent of that disturbance are factors directly related to the type and quantity of the pollutant. However, assessment of the magnitude and impact of pollution on organisms has been a complex problem requiring methodologies not readily usable by all those desiring to make such assessments.

The purpose of this manual is to provide a self-instructional means by which individuals desiring to monitor aquatic or terrestrial systems can learn to assess those systems by observing the organisms present. The method employed, the Sequential Comparison Index (SCI), allows individuals ranging from members of the general public to scientists to establish a diversity index without taxonomically identifying the organisms. Comparison of a series of indices will allow the system to be assessed.

1/Arthur L. Buikema, Jr. is Associate Professor of Zoology and Assistant Director of the University Center for Environmental Studies; Karl E. Schwaab is Assistant Professor of Biology and Education; and John Cairns, Jr. is University Distinguished Professor and Director of the University Center for Environmental Studies: Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061.

ECOLOGICAL CONCEPTS

The validity of the Sequential Comparison Index is based on several ecological concepts. Although the use of the SCI does not require a complete understanding of the concepts, it is desirable for the user to be at least familiar with them.

The environment can be cataloged into somewhat distinct and recognizable units called ecosystems. Examples of ecosystems include lakes, ponds, forests, aquariums, terrariums, and hot houses. By definition an ecosystem is an assemblage of different kinds of organisms that interact with each other and with the nonliving or abiotic components of their environment. The nonliving components include chemical and physical parameters such as minerals, elements, water, temperature, light, and wind. The living component of ecosystems includes organisms that produce the food, organisms that consume the food, and organisms that degrade organic materials so that these materials may be reused. The most important aspect to remember about an ecosystem is that all of its functional and structural parts are interrelated.

There are many different ways to characterize an ecosystem, among which are the food chain (fig. 1) and the food web (fig. 2). The food chain and web represent the means by which energy for life (i.e., food) is passed from one organism to the next. At the base of all food chains and webs are green plants, the producers, which capture light energy and convert it into chemical energy. The chemical energy is stored by plants and is ultimately used by other organisms. Producers may be the plants that are growing in your yard or they may be the green scum that you find in various types of ponds. Producers are in turn eaten by organisms referred to as primary consumers or herbivores. Primary consumers are in turn eaten by other organisms called secondary

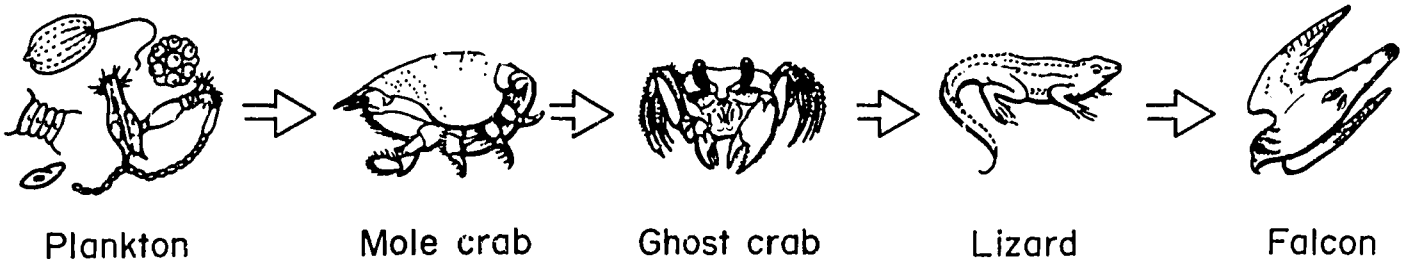


Figure 1. A simplistic sand-beach food chain.

consumers. Secondary consumers may be carnivores (meat eaters) or omnivores (plant and meat eaters). The secondary consumer may be eaten by a tertiary consumer, which in turn may be eaten by a quartenary consumer and so on until a top carnivore, an organism which has no predator, is reached. An example of a top carnivore is man. There are also detritivore organisms that feed on dead and decaying matter known as detritus. Detritivores include crayfish, turtles, and many beetles and worms. Ultimately many of the materials incorporated into the bodies of the producer and subsequently into the bodies of the consumer that fed upon the producers would be exhausted from the environment, and in all likelihood life would terminate unless these materials were recycled for reuse.

The organisms that are important in recycling these materials are called the decomposers. They degrade the detritus, body waste, dead bodies, etc., and release many of the raw materials that are then reused by the producers. These decomposer organisms include bacteria and fungi, and the materials that they release for reuse include carbon, hydrogen, nitrogen, phosphorous, and sulfur.

The life forms of the ecosystem are linked together in a series of predator-prey relationships, which are classified into two types: simple food chains and complex food webs. An example of a simple food chain is a producer which is eaten by a primary consumer, which is in turn fed upon by a secondary consumer, which is in turn fed upon by a tertiary consumer. Notice that in this food chain there is a linear relationship of one organism feeding on the next organism; thus the secondary consumer does not have an alternative food source.

A food web, on the other hand, is made up of many different types of producers and many different types of carnivores and herbivores. In this type of system no one organism is dependent upon only one source of food, but it can usually rely on many different types of food. Thus the relationships are branched, and most organisms have more than one alternative food source.

Ecosystems with complex food webs might have 25 to 50 different species of organisms that could be readily identified, and if a complete analysis were made of the particular environment, hundreds of species would be found.

In ecosystems complex food webs are the rule rather than the exception. Food chains usually exist only in experimental situations or in highly polluted situations where there has been considerable stress on the environment. In ple, less diverse, and less complex ecosystems find simpler food webs or in fact may actually find food chain relationships among the organisms. These ecosystems have a very low diversity, and they are more susceptible to natural and unnatural, or man-made, stress.

The greater the intricacies and interrelationships of the food web, the more complex the ecosystem would be. Many ecologists have speculated that complex ecosystems are more resistant to change than simple ecosystems, possibly because they are more mature and are not undergoing a process of natural change. They happen to be in balance with their chemical and physical environment. Complex ecosystems also tend to have a high diversity; that is, they have many different kinds of organisms.

Another concept that has been used in literature to refer to complex systems is "healthiness." The more complex the ecosystem, the greater its diversity, and thus the healthier it is. Conversely, if we find an ecosystem that is not very complex, we tend to think of it as an unhealthy community. This again is related to the system's susceptibility to further stress.

Species diversity, complexity and healthiness are basic ecological concepts. The relationship between healthiness and diversity and complexity can be illustrated by the ability of a complex community to resist change on the one hand and the inability of a simple community to resist change on the other. Let's take the simple food chain where we have the producer, a primary consumer, a secondary consumer and a top carnivore. The availability of food follows a simple, straight-line path. If some sort of perturbation were to occur that disrupted the top carnivore, the impact on the rest of that food chain would be nominal. However, if we were to perturb the base of that food chain, i.e., the producer, then the impact would be quite noticeable in the sense that

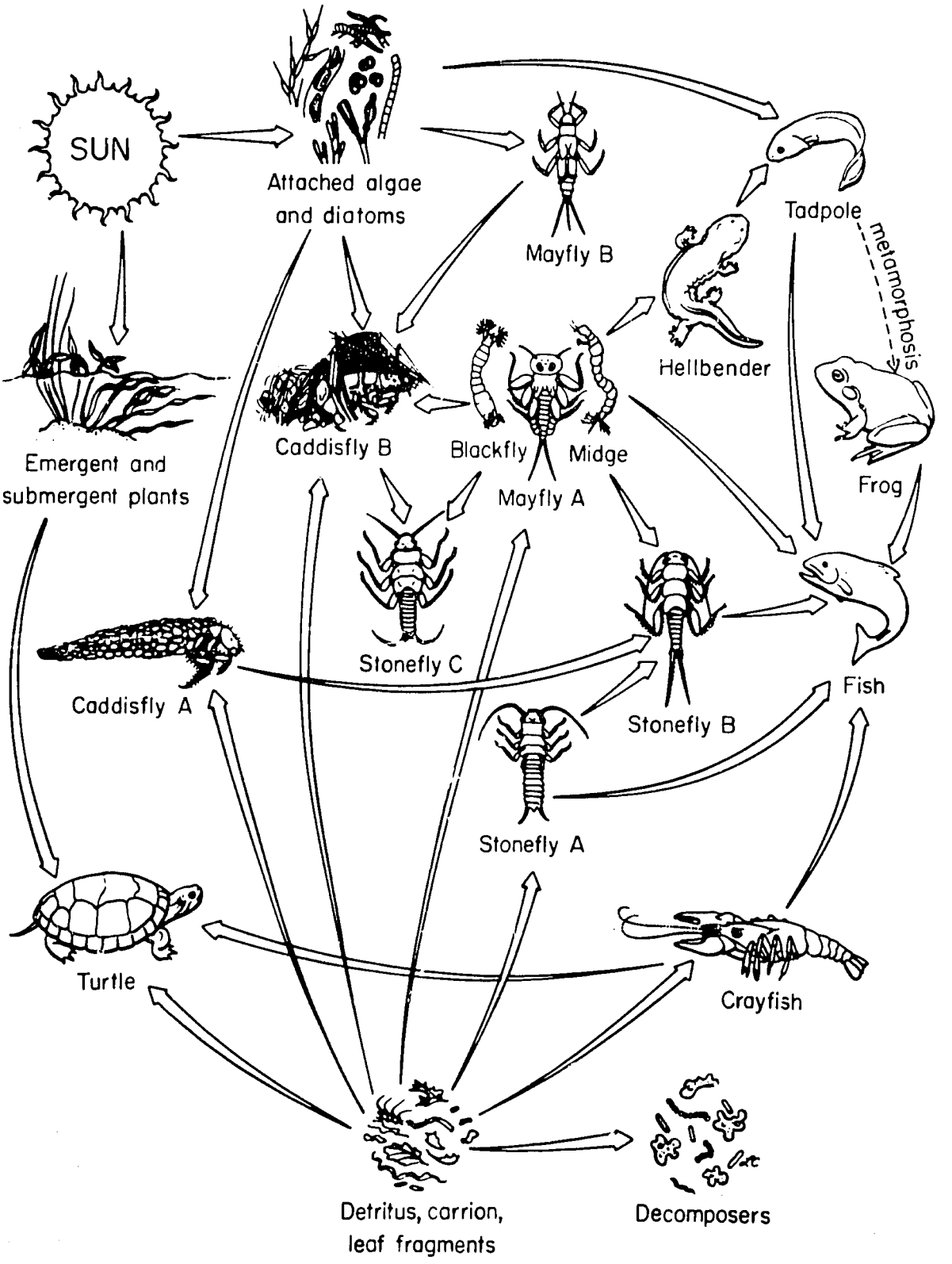


Figure 2. A simplified stream food web.

if the producer were not there, you would not have any other organisms. In this example, the food chain would be very unstable. If we take a food web in which we have many different types of producers and many different types of consumers, and we perturb that system so that only one producer at the base were moved, the impact on the complexity of that community would not be very great because other foods would be available to the secondary and tertiary organisms. Complex communities can tolerate quite a change in their population structures before there are any significant effects on the overall integrity of their systems. The reason for this is that there are many different sources of food available to the consumer organisms. Under extreme cases of pollution or other types of perturbation lasting a long time, it is possible to take a complex food web and basically reduce it to a simple system approximating a food chain. Once we have done this to a particular community, we have a system that is even more susceptible to change should any type of perturbation occur.

The emphasis of the preceding discussion has been to illustrate that complexity, healthiness and species diversity are interrelated. Thus, a healthy ecosystem has a very diverse community in which the energy flow is of the type known as a food web and which we refer to as a complex ecosystem. Because a complex community has a high diversity of organisms and many types of populations, its ability to respond to perturbations is quite great. Consequently, we say that system is healthy. Conversely, if we have a system which is not very complex with very few populations comprising the community and we have a perturbation, that system is less healthy because the removal of any member of a simple food web or food chain will have a relatively greater effect on the rest of the community. This is particularly significant when the perturbation occurs at the base of the food chain.

HISTORICAL DEVELOPMENT OF ASSESSMENT METHODOLOGIES

Until recently people interested in documenting whether a particular environment was healthy conducted simple surveys of the organisms present in that particular environment. The data they used to describe the healthiness of the situation were based on the number of organisms found and the number of taxa identified. However, evaluating systems with this methodology has its pitfalls. First of all, the technique is subjective and is somewhat dependent on the skill and experience of the person who makes the collections. Secondly, the presence or absence of a particular taxon may depend on the characteristics of the environment rather than on the impact of a perturbant on that particular environment. Thirdly, the evaluations made from these collections are based on the mere presence or absence of many organisms, and in these instances a single specimen would have as much weight as a large population.

Another methodology was based on the belief that one could characterize the impact of a perturbant on a natural system by looking for indicator species (fig. 3). Indicator species are organisms that are generally considered to be intolerant to stress. If the indicator species were found in a particular environment, the environment was judged to be healthy. The idea of the indicator species is not generally accepted today although it is possible to classify the organisms in an ecosystem as tolerant, facultative, or intolerant species. Tolerant organisms are those that can live in a polluted environment; intolerant organisms are those that cannot live in a polluted environment. Facultative organisms have a wide range of tolerance and are usually found in areas where there is a moderate level of perturbation.

The problem with studies based on indicator species is much the same as that of the earlier studies, which relied on a description of the environment based on numbers of taxa and numbers of organisms. Because of different life cycles of organisms, environmental impacts and minor environmental factors influencing the growth and reproduction of an organsim, the mere absence of an organism may not necessarily indicate that the organism has been perturbed in any way. To try to correct for some of the shortcomings of these earlier studies, methods have been proposed by which these data, number of taxa and numbers of organisms, could be integrated into an index. Many types of diversity indices have been proposed by biologists and ecologists. Unfortunately, there are some problems. First, the diversity index cannot be compared from drainage system to drainage system; therefore, the index itself has limited value except when compared within a particular system. Secondly, the diversity values which are calculated require that the organism be classified by species and that all organisms be so classified. Thirdly, the calculations are very difficult without the aid of a computer. In response to these problems another type of diversity index has been proposed.

In 1971 a paper by Cairns and Dickson was published on the diversity sequential comparison index. The Sequential Comparison Index (SCI) is a statistically valid method which does not require the investigator to know the specific name of the organism in question. The SCI only requires the investigator to have the ability to distinguish two organisms as different species or different life stages of the same species. Further, the calculation and analysis of an SCI index does not require calculators or computers. This manual discusses the Sequential Comparison Index (SCI) and its utility in evaluating ecosystems and perturbation in ecosystems. Parenthetically, we want to mention that the SCI method is so simple that even young students, as young as fifth and sixth graders, have

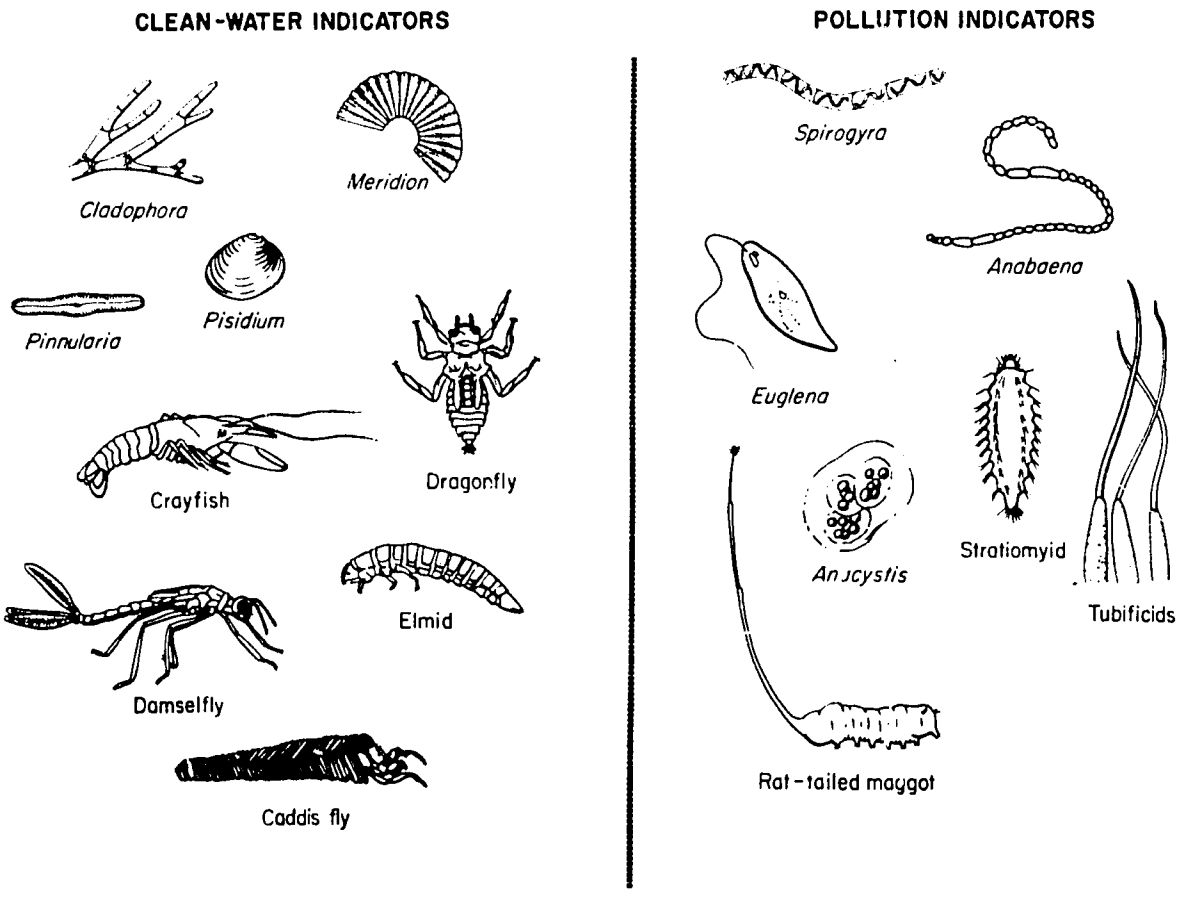


Figure 3. Examples of indicator organisms.

been able to utilize the method and to establish scientifically defensible information about a particular habitat or environment. The method is, therefore, designed to be used by people with very little biological background.

METHODOLOGY

The example below uses an aquatic ecosystem to present most of the SCI's assumptions and requirements. The SCI can be used to study other ecosystems as well. For example, streams, ponds, lakes, fields and forests are ecosystems. Most of the basic assumptions and requirements discussed below also must be met when studying other ecosystems.

The SCI is designed for comparative purposes and, therefore, an individual index value generally has little significance. Application of the SCI method has shown that a low SCI indicates less complexity and stability than a high SCI value. Proper use of the SCI requires calculating a series of separate SCI values. This series may represent points along a transect, within a study area, or over time at a given place in the ecosystem. Comparisons between the SCI values within a series will then indicate healthiness or complexity of the ecosystem being assessed. Changes occurring with regard to healthiness will also be evident.

Selecting Study Sites

The number and spacing of sampling sites is a critical decision and is dependent on each given situation. If a general survey of a stream ecosystem were being conducted, samples would be taken at intervals where the interval distance would be determined by the environment, and by time, money and labor constraints. If, on the other hand, a particular manufacturer was suspected of discharging pollutants into a stream, sample sites would be much closer, beginning above the plant and continuing for some distance downstream below the plant.

A single methodology for selecting stations cannot be given. Valid surveys will be obtained if the following points are adhered to when determining the effects of a given factory discharge on the aquatic ecosystem.

1. A baseline level of community or ecosystem healthiness must be established. Therefore, there must always be a minimum of two sampling stations above the suspected site of disturbance; one must be far above the point of discharge and one directly above the point of discharge, but not influenced by it. At least two stations are needed to determine the variability in the community and to determine if any changes occur immediately upstream from the discharge source (fig. 4).

2. A sampling station immediately downstream from the point of discharge and on the same side of the stream is required.

3. It must be determined if the discharge has an irregular pattern of entrance into the ecosystem. For example, in most streams industrial discharges often channel to one side of the stream. In such cases it is necessary to subdivide station samples into left bank, mid-channel and right bank. All data thus collected are kept separate by substations. If the industrial discharge does not channel, it may not be necessary to subdivide station samples.

4. The extent of disturbance to the ecosystem is assessed by having sample stations at various distances downstream from the point of discharge. For long-term studies of a community, such stations should be sampled a minimum of once during each annual season or during low, mid and high flow conditions.

Specific site selection also must be carefully controlled. It is important, especially where trying to determine possible pollutant effects, that each station sampled be as ecologically similar to other stations as possible. For example, aquatic stations must be similar with regard to substrate (soil, gravel, rock, etc.), depth, presence of riffles and pools, stream width, flow velocity and bank cover. In fact, it is recommended for stream studies that each site be sampled at three points: across the streams, along both banks, and in the center.

In a forest habitat it would be inappropriate to compare samples within the woods, along the edge, and near a stream cutting through the woods because these are in effect three different community types. Sample stations should be located in areas not influenced by an atypical habitat, such as that created by bridges or roads. Terrestrial habitats must be similar with regard to slope, moisture, soil type, trace metal content, direction of the sun's path and stage of succession.

Succession is important to consider, especially in terrestrial systems, because it affects the number, kind and diversity of organisms present in a particular ecosystem. Succession is defined as the process of change that occurs in communities over time. In other words, communities are subsequently replaced by other communities over a long

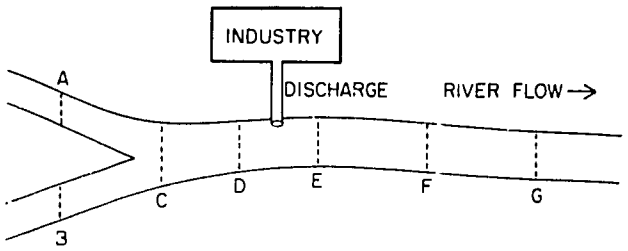


Figure 4. Example of sampling locations for evaluating the impact of industrial dischrage.

period of time until a final or mature community comes into balance with the physical and chemical aspects of its environment.

All sites should be sampled at approximately the same time for valid comparisons to be made. No more than two weeks should lapse between the first and last sampling periods.

Sampling Techniques

Once study sites have been identified, then sampling of organisms may begin. Samples for each site should be obtained by standard collection procedures specific for that ecosystem. Standard collection methods for various habitats are widely published and will not be discussed in this manual.*

Whatever organisms are chosen for collection and whatever collection method is selected, the following points should be remembered: 1) emphasis should be given to random sample collection; and 2) most reliable indices are obtained when samples contain 250 or more organisms.

An advantage of the SCI is its applicability to delicate systems that may be disrupted by removal of organisms. Each organism observed can be assigned a name, code number or letter which is recorded on an individual square of paper. A separate code must be used for each "type" of organism collected. Also, a separate record must be kept for each individual of a given type that is collected. The squares from each sample may then be placed in a container, mixed and randomly drawn from the container. Following the recording, the organisms may be returned to their habitat if it was necessary to collect them.

Data Gathering

Once samples have been obtained, they may be processed immediately in the field or upon return to the laboratory, or stored until a later date.

*See for example, Phillips, E. \. 1959. Methods of Vegetation Study. Holt, Rinehart, and Winston, Inc. N.Y.; Southwood, T.R.E. 1978. Ecological Methods. J. Wiley & Sons, Inc. N.Y.

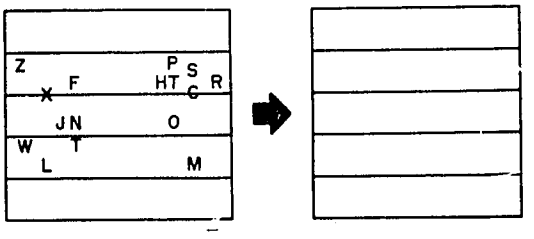
The initial step in processing the samples is to thoroughly mix each sample. It is important that organisms be randomly distributed within the sample. In the example of a stream community this may be accomplished by vigorously shaking the bottle in which each sample is stored.

The mixed sample is then poured into a container, such as a porcelain pan, which has a series of parallel lines drawn on the bottom. Clumps of organisms must be physically dispersed without any effort of placement. This may be accomplished by pouring water over them. Figure 5 illustrates possible results.

If slips of paper are used to represent the organisms, the slips may be placed in a bowl, mixed, and randomly drawn out of the bowl one at a time. Do not replace the slips once they have been drawn. As the slips of paper are removed from the bowl, the code on each paper slip should be recorded in sequence. This procedure will produce a random, linear array needed for further analysis. An alternative is to spread the slips on some type of grid system just as is done with the organism samples.

After the organisms are dispersed in the pan they must be lined up on the parallel lines (fig. 6). This is accomplished by moving each organism up or down to the closest line and maintaining the left to right sequence of organisms. This procedure should be done quickly without any conscious effort to place individual organisms. With practice the experienced investigator may be able to do this operation mentally, thus saving time.

Self Check 1: What would be the linear order of the organisms on the following grid?



After the organisms have been properly aligned, the investigator is ready to examine them individually. Starting with the upper left organism, the investigator records an "X" for this first organism. The investigator must now determine whether the second organism is the same as, or different than, the first which is its immediate predecessor. If it is the same, a second "X" is recorded; if it is different, an "O" is recorded. The third organism is then compared with the second. If it is the same, the code (X or O) of the second is repeated, and if it is different, then the code is changed. This sequential comparison is continued line by line until the last organism has been compared to the second to the last organism.

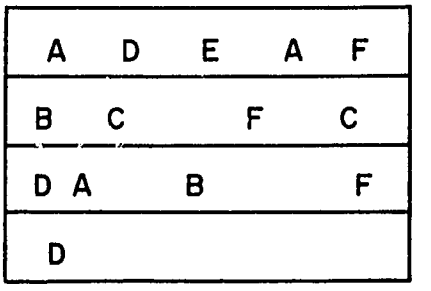


Figure 5. Initial dispersion of sample.

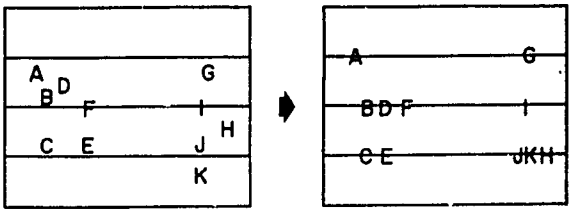
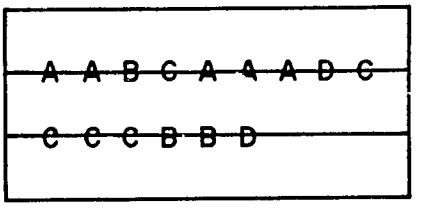


Figure 6. Method of sample adjustment for further analysis.

In each instance when an organism is the same as the previous organism, the current X or O code is repeated. When an organism is different from the previous organism, the current code, X or O, is changed and an O or X is respectively recorded. The X and O information must be recorded in a linear sequence so that the exact order in which the organisms were observed is maintained. This procedure results in data having a sequence of this type depicted in figure 7.



XXOXOOOXOOOOXXO

Figure 7. Transformation of individual organism designations to sequential comparison code.

The next step in this procedure is to determine the number of different species in the sample. This may be accomplished by segregating like organisms into distinct groups and recording the number of groups established. This number represents the "equivalent species" present in each sample. The example in figure 7 has four "equivalent species."

Calculating the SCI

The formula for calculating the SCI value is:

Sequential Comparison Index (SCI) =

$$\frac{\text{Number of runs}}{\text{No. of organisms}} \quad \text{(No. of equivalent species)}$$

The number of runs is determined by counting the groups of X's and O's. The first run begins with the first X and ends with the first O. The second run begins with the first O and ends with the next X that appears. In other words, every time the X-O code is changed, a new run is initiated. In the following example from figure 7 the individual runs are underlined and counted.

Number of runs =

$$\underset{1}{\underline{XX}}\ \underset{2}{\underline{O}}\ \underset{3}{\underline{X}}\ \underset{4}{\underline{OOO}}\ \underset{5}{\underline{X}}\ \underset{6}{\underline{OOOO}}\ \underset{7}{\underline{XX}}\ \underset{8}{\underline{O}} = 8$$

Self Check 2: How many runs are in the following example?

Number of runs =
XOXXOOOXXOXXXOOOXXXXXOOXO = ____

The next piece of data required is the total number of organisms, which is equivalent to the total numbers of X's and O's recorded. In figure 7 the total number of organisms is 15 and in Self Check 2 the total is 25.

The number of equivalent species has been determined previously. You will recall that this is the number of distinct groups of organisms found in the sample. The number of equivalent species for figure 7 is 4.

The SCI value for figure 7 can now be calculated:

$$\text{SCI} = \frac{8 \text{ runs}}{15 \text{ organisms}} \text{ (4 "equivalent species")} = 2.13$$

Self Check 3: What is the SCI value for the data in Self Check 2 if there are six different "equivalent species?"

Self Check 4: The following SCI values were obtained by two workers studying the same sample. How can you account for this variation in SCI values?

AAAAABBBCCCCCDD SCI = 1
ABACADCACACBCBD SCI = 4

The example in Self Check 4 emphasizes two important concepts. First, samples of organisms must be randomly distributed. If not, wide variations in the SCI value may be obtained and the ecological significance of the SCI value may be misinterpreted. Secondly, the smaller the sample size the greater chance that wide variation in SCI values will be obtained. Therefore, adequate sample size is important in conducting ecological assessments.

Adequate Sample Size

The number of times the above procedure is performed on each sample is dependent on the number of organisms in the sample and the confidence levels the investigator elects to achieve.

Samples containing more than 250 organisms are recommended. In this situation the SCI may be determined without examining all of the organisms. The following procedure should be used:

1. Determine the number of runs for the first 50 specimens.
2. Calculate SCI values where
   $\text{SCI} = \frac{\text{No. of runs}}{50}$ (No. of "species")
3. Plot SCI against the number of specimens examined (fig. 8).

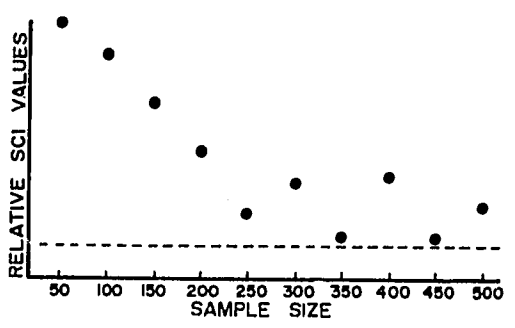


Figure 8. Relative SCI values vs. sample size.

4. Continue the analysis for the next 50 specimens.
5. Determine the total number of runs for the 100 specimens examined.
6. Calculate a new SCI value for 100 specimens (No. of runs/100)(No. of "species") as in Step 2 and plot the value obtained on the graph made in Step 3.
7. Repeat this procedure with increments of 50 specimens until the curve obtained becomes asymptotic (fig. 8). When the curve becomes asymptotic, then enough specimens have been examined and additional work will produce an insignificant change in the final SCI value.
8. Calculate a final SCI value based on the decision made at Step 7.

When less than 250 organisms are contained in the sample, the SCI is determined from the total sample.

For each sample, the SCI should be determined 2 or 3 times. The investigator may then be 95 percent confident that the mean index is within 20 percent of its true value. This level of accuracy should be sufficient for most studies. If 95 percent confidence of detecting a 10 percent difference in means is desired, the SCI will need to be determined 7 or 8 times for each sample.

Following these procedures, the sample is no longer needed and it may be returned to the community, stored for future reference, or discarded.

INTERPRETING RESULTS

The SCI results in two general types of data series. One type is a series of similar SCI values, for example, 14.5, 15.3, 13.7, 15.0, 14.1 and 14.8. This series is representative of an ecosystem that is healthy over a transect or time span sampled. The second series type is one which contains one or more significantly different SCI values, for example, 15.4, 13.5, 14.6, 6.8, 8.7, 11.5, 14.1, 13.9 and 15.1. Here we have a healthy ecosystem which becomes less healthy at or about the 6.8 sample site or time. If these data were for a stream, then the series would indicate that there is recovery of the ecosystem by the third site (14.1) following the disturbance at the site with the 6.8 value. In this second case, we have identified a potential problem. The decreased diversity or healthiness may be caused by a pollution source or by a change in the quality or quantity of factors normally present in the community (discussed in previous paragraphs). In a stream, this could be a substrate change; in a terrestrial ecosystem, it could be a nutrient deficiency. More specific investigations will then be required to determine the exact cause for the lowered diversity.

Application to Terrestrial Ecosystems

The above discussion has been on pollution stress in aquatic ecosystems. The principles that are described for the SCI when stress is monitored in an aquatic environment are also applicable to a terrestrial ecosystem. Stress due to air pollution on a terrestrial ecosystem is a good example. The SCI also can be used to study the effects of stress on microhabitats. For example, the discharges from air conditioners and heat exchangers can affect microhabitats or create new microhabitats.

Some of the problems that we had in studying aquatic environments are very similar to the problems encountered in studying the terrestrial environments. For example, similarity of habitat must be controlled as much as possible. If you are studying an area which is exposed to the sun and you are going to compare it to another area, make sure that the new area also is exposed to the sun in the same way. In selection of the habitat, you want to use as many physically common features as you can. If in your analysis you find that there are differences among your indices, you will want to go back and determine why the differences occurred. In a terrestrial habitat there may be differences in moisture content, soil type changes, succession stage, etc. The other major consideration in studying a terrestrial environment at any particular site is that the selection of the study area within that site must be chosen at random. This can be accomplished simply in a terrestrial environment by throwing sticks into an area and using these as one corner of your quadrat or as the basis for starting your transects.

Fragile terrestrial habitats may be more susceptible to damage than many aquatic habitats. Because you would not want to disrupt the environment, you might consider using numbers or slips of paper with names on them to represent the organisms that you encounter. These will then be placed into a bowl or a hat, and randomly drawn for calculation of the SCI.

In conducting studies on terrestrial habitats the methods required especially the size and number of quadrats, will vary with the type of community that is being investigated. Quadrat size must be sufficient to assure that the number of organisms will exceed 250 so that the SCI can be calculated properly. If you are looking at the weed community of a field, you will have to set up a number of one-meter square quadrats. Within these quadrats you will have to accurately count the different types of plants. In analyzing the data from these types of quadrat studies one might be interested in the species of plants; however, if this is not possible, the analysis can be done just as easily by referring to the plants as species A, B, C, etc. based on differences in external morphology. This technique is very similar to that proposed for aquatic organisms.

Within these quadrats one also may want to determine the percent of the area that the various types of organisms cover. It may also be advantageous to divide plants into annuals, perennials, shrubs and trees.

When evaluating a terrestrial community that is in the shrub stage (where you have short, woody-stemmed plants), the number and size of quadrats will have to be increased since a quadrat one meter square will contain few shrubs. It may be necessary to set up quadrats that are from 5 to 10 meters square. Again the analysis of the vegetation data would be similar to the analysis discussed for other data.

If later successional stages contain intermediate tree communities, or even possibly a climax forest, one might consider having quadrats which are minimally 10 meters square. In forest work, particularly when we are studying a climax type forest, transects are often used instead of quadrats. In a transect a very narrow, straight line is set up with a compass extending through the community. All plants in that strip or along that line will be enumerated for some fixed distance. In transect studies, signs of animals should be observed carefully in order to gain an index of the types of species present.

If you are interested in obtaining information on the various types of mammals present in terrestrial habitats, it is recommended that at least 50 live traps be used. These will need to be examined for small mammals before you leave the area and early the next day if the traps are left overnight. Many vertebrates will not be actually seen or collected, but other indications of their presence may be used in assessing the diversity of that particular habitat. Indicators, such as tracks, droppings, calls, nests, and so forth may be used. Collections of insects may be made by sweep netting.

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QUESTIONS

1. What is an ecosystem?

2. Compare and contrast a food chain and a food web.

3. Are complex communities healthy? Are they stable?

4. In conducting research on ecosystems, is it necessary to sample all types of organisms? Why?

5. An investigator conducted a survey for a one-mile section of a river. An effluent entered in the middle of this section. After calculating the SCI the investigator noted the following sequence of values as he went downstream: 4.5, 4.6, 4.0, 4.3, 1.1, 1.7, 2.3, 4.5, 4.0. What conclusions can be reached from these data?

6. After completing a study on two separate terrestrial areas in two different drainage systems, an investigator concluded that because the diversity of organisms in Area A was significantly lower than that in Area B, Area A was affected by pollution. Is this conclusion valid?

7. Assume that you had just finished surveying a river at five transects with three samples taken per transect. After calculating the SCI values, you obtained the following data:

Transect A	4.1	3.9	4.4
Transect B	4.3	3.8	4.0
Transect C	3.9	3.0	2.1
Transect D	4.0	2.4	2.6
Transect E	4.6	3.6	5.0

Discharge

River Flow

   a) What do these data tell you about impact of the waste discharge on the river biota?
   b) Why do you think that the SCI values generally are lower in the middle of the river?

8. Figure 9 represents a part of a small river basin which has several industrial discharges.

a) If you were to fully assess the impact of these discharges on the riverine biota, where would you locate your sampling stations? Why?

b) If all SCI values varied from 10 to 12 irrespective of location, what conclusions would you reach about the impact of these industries on the river?

9. If you are asked to conduct a survey on a system that has several species designated as rare or endangered, could you still use the SCI? If so, how?

10. The following questions are based on the quadrat maps (fig. 10) representing terrestrial vegetation on which the SCI will be determined. Each symbol represents a different species of plant. Assume your sample size is large enough to calculate a SCI value.

a) Calculate a SCI for each quadrat.
b) Which quadrat has the greatest density? Why?
c) Could the results be different if you conduct a transect rather than a quadrat type of survey?

11. If you compared a very early and immature or man-influenced ecosystem with a mature, natural ecosystem would you expect a relatively high or low SCI value for each of the items below?

Phenomenon	Ecosystem Immature	Man-Perturbed	Mature
species diversity	____	____	____
healthiness	____	____	____
number of kinds or species	____	____	____
fluctuation in population numbers	____	____	____

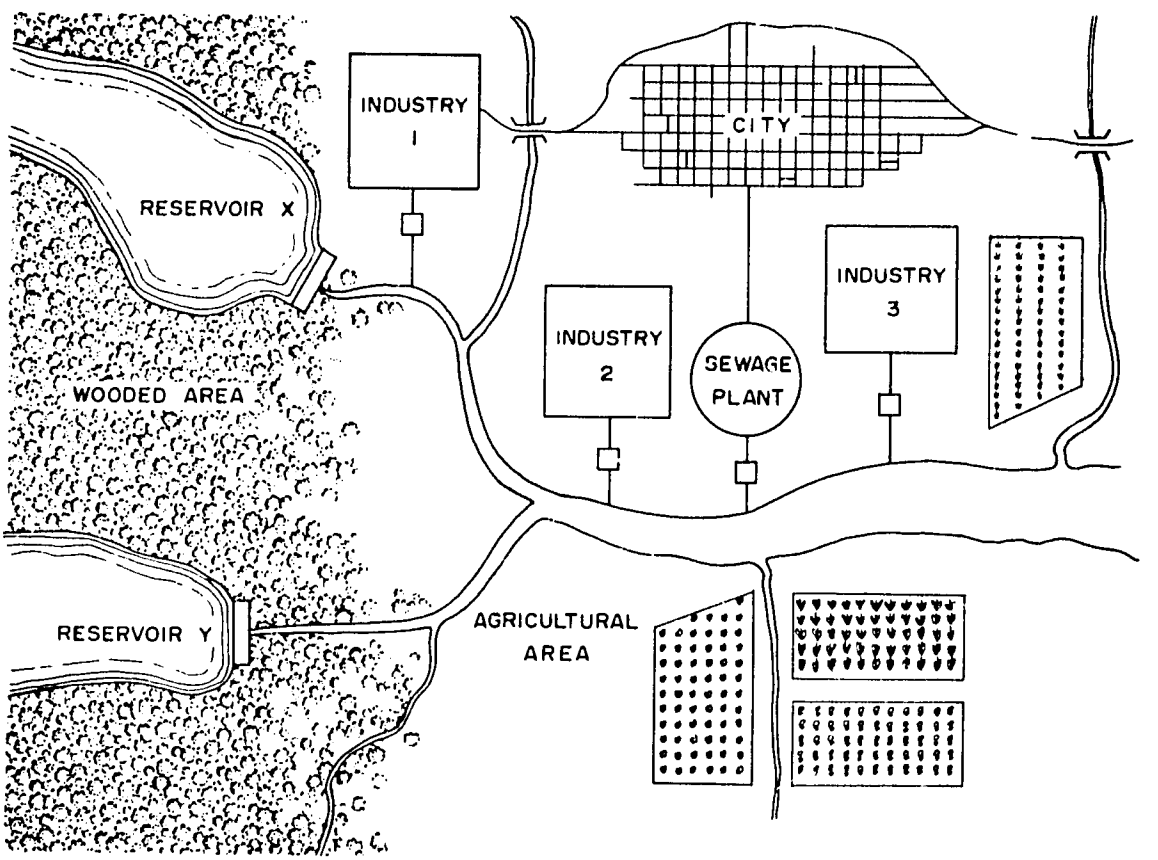


Figure 9. Example of a small river basin receiving industrial discharges.

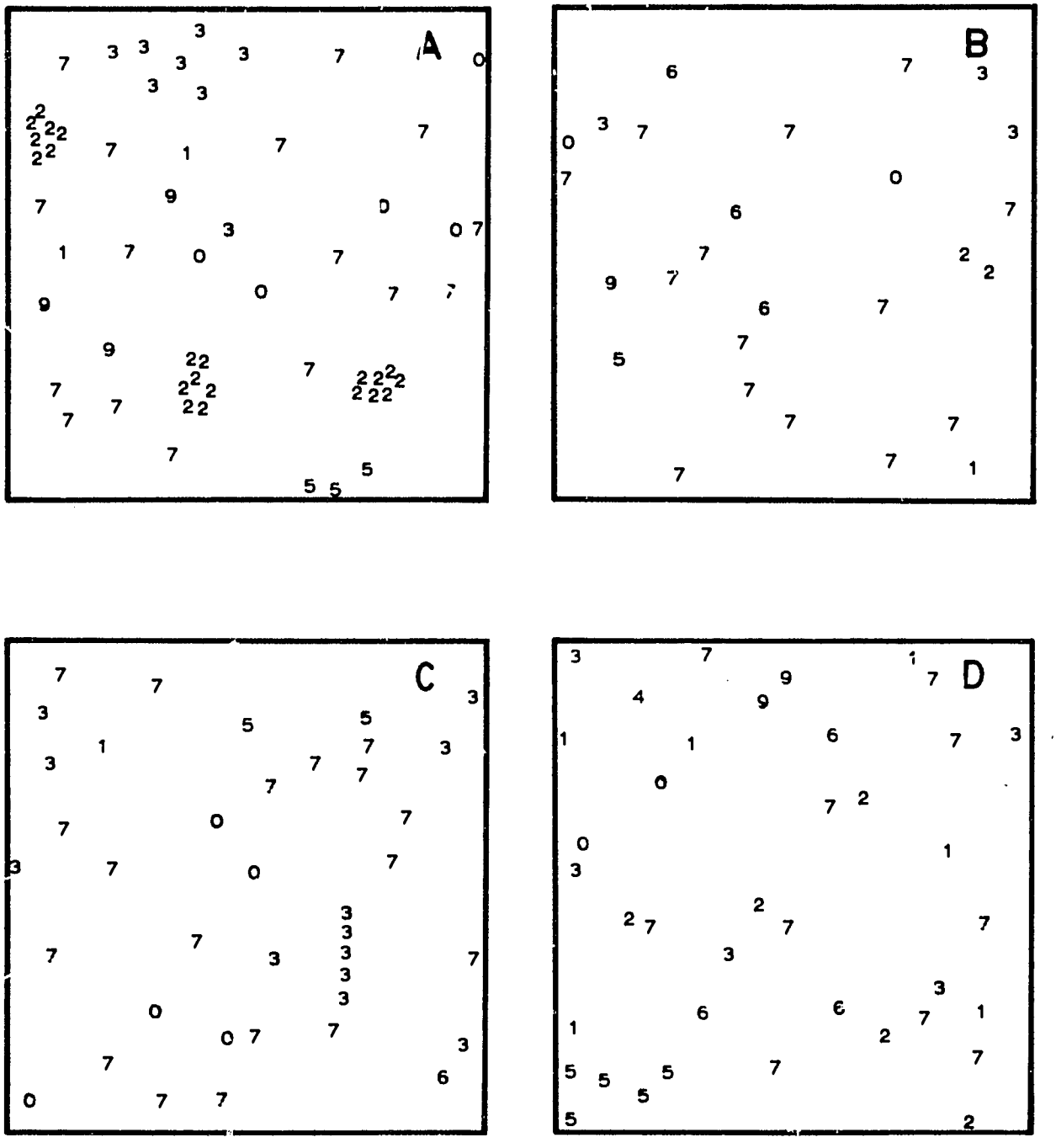


Figure 10. Sample of quadrat maps of terrestrial vegetation.

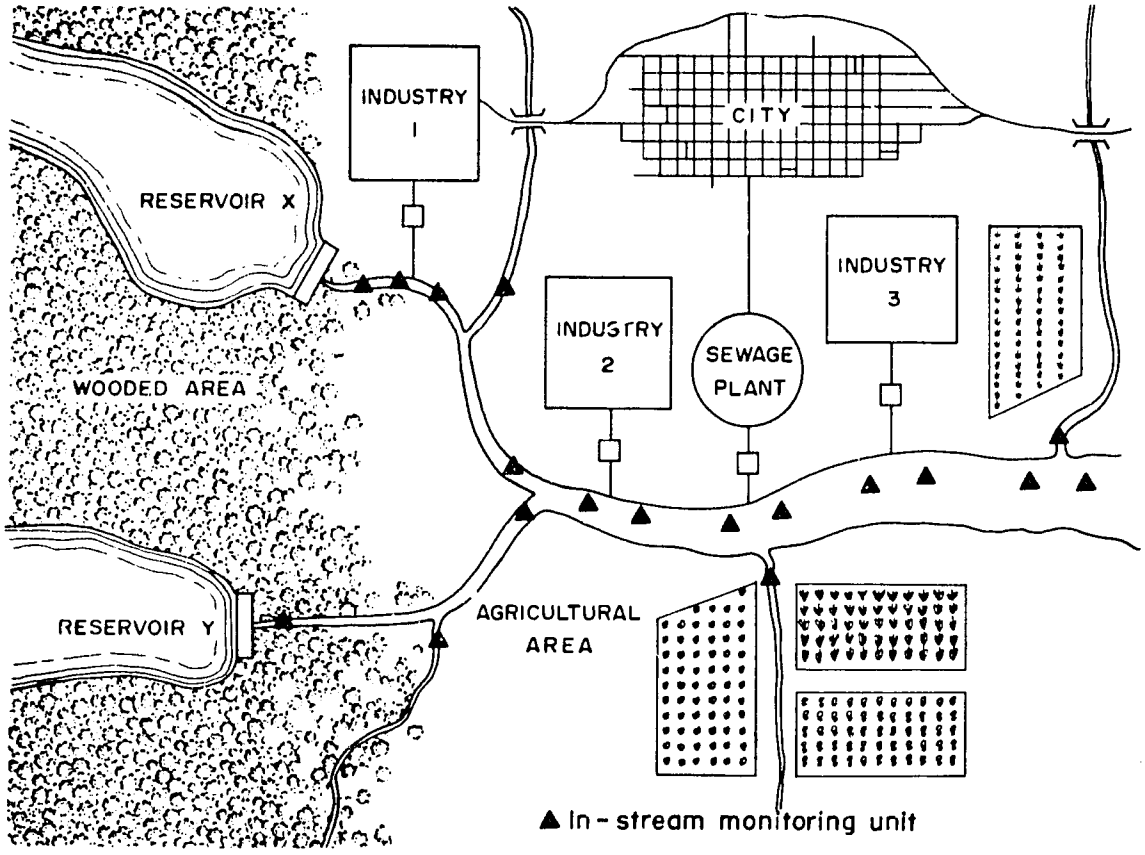


Figure 11. Suggested sampling stations for the river basin shown in figure 9.

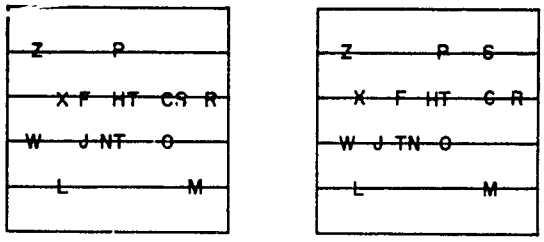
11.

Phenomenon	Ecosystem Immature	Man-Perturbed	Mature
species diversity	L	L	H
healthiness	L	L	H
number of kinds or species	H	H	L
fluctuation in population numbers	L	L	H

ANSWERS

Self Checks

1.



Slight variations are acceptable. Note the differences in the placement of S, N and T. These differences occurred because of the position of the specimen to the grid line or other specimens.

2. The number of runs is 12.

3. The SCI value for the data in Self Check 2 is 2.88.

4. The wide variation in SCI values occurred because the low SCI value was calculated for a nonrandom sample.

Questions

1. An ecosystem is an assemblage of different kinds of organisms that interact with each other and with the abiotic components of their environment.

2.

Food Chain	Food Web
simple system	complex system
one food source	alternative food sources
few species	many species
low diversity	high diversity
"unhealthy"	"healthy"

3. Complex communities are considered healthy because of the large number of interactions that occur among different organisms. The loss of one or two species usually will not disrupt a complex community.

4. It is not necessary to sample all kinds of organisms. A sample of the animals alone will give you a good indication of diversity and complexity because of their position in the food web.

5. Assuming that the investigator sampled similar types of habitats, i.e., riffle areas, these data indicate that the aquatic ecosystem was perturbed about midway. Because the values rose further downstream, the perturbed communities recovered from the stress.

6. The conclusion is not valid because the investigator only calculated one diversity value per area. More research is needed to document pollution, including more measurements of the SCI; chemical and physical parameters need to be measured to be sure that the habitats that were sampled were comparable.

7. a) These SCI values indicate that there was an effect on the biota below the discharge. The data also indicate that the discharge plume spread to mid-river at Transect D. Recovery occurred by Transect E.

   b) The SCI values are lower in the center of the river because the current velocity is faster in the middle of a river.

8. a) The needs of each sampling program must be evaluated before designing a study. The example given in Figure 11 is designed to assess potential water pollution. Note that sampling stations located on tributaries may contribute organisms to the main river, above and below each discharge pipe and some distance downstream from the last discharge.

   b) If all the SCI values vary from 10 to 12, chances are that the impact of industrial discharge on the diversity of the biota is negligible.

9. Yes, the SCI can be used in areas containing designated rare or endangered species. Symbols on slips of paper would be used for each species identified. When working with rare and endangered species, one must be careful not to disrupt critical habitats.

10. a) The approximate SCI values are:

    Quadrat A (2.9)
    Quadrat B (5.4)
    Quadrat C (3.2)
    Quadrat D (7.2).

    b) Quadrat D, because it had nine species randomly distributed.

    c) The results would be different if the transect were too short because the probability of finding different species would decrease. However, if the transect were long, the SCI value should approach the SCI value for the quadrat.