THE VALUE AND USE OF MACRO-INVERTEBRATES[1] IN EVALUATING STREAM POLLUTION CONDITIONS

by

Billy J. Grantham, Biologist
Mississippi Game and Fish Commission Laboratory
Biology Department, University of Southern Mississippi
Hattiesburg, Mississippi

Protection and conservation of aquatic resources is not a simple assignment for any regulatory agency. Perhaps, the most urgent and pressing problem faced is how to assess the damage of pollution to the aquatic environment. There has been a tendency in the past to underestimate values arising from a fisheries, wildlife, and recreational aspects of aquatic habitats and to take a rather short range view. Fortunately, this type of thinking is gradually changing due to an ever-growing concern by the general public regarding the aquatic environment. In the past the only group to raise any violent protests were a few dedicated conservationists. The trend is now, however, undergoing radical change as more leisure hours are enjoyed by Americans in all walks of life. The growing populace nationwide is demanding that criteria be developed to insure clean water conditions and for abatement programs to become operative and given high priority in areas that have long received the brunt of damaging pollutants.

Most Mississippians are aware that one function of the Mississippi Game and Fish Commission is that of a pollution regulatory agency. The Commission's legal authority in this field is in the realm of industrial pollutants. However, any type of waste discharge into a stream, be it municipal or industrial, is of vital concern. Historically, the Commission acted merely as a regulatory agency, but in 1959, the fact was recognized that additional background data on the actual condition of streams were badly needed. As a result of this, a cooperative project known as the Pollution Studies Program was initiated between the Mississippi Game and Fish Commission and the U. S. Fish and Wildlife Service. This program is primarily to determine the effects of pollutants on Mississippi streams. The three objectives are: (1) to determine the effects of pollutants on water quality, (2) fish populations; (3) and aquatic invertebrates (Macro-invertebrates). Three studies have been completed and a fourth is currently underway.

The aquatic environment in its primitive state supports a delicately-balanced population, and this balance exists as a result of the inherent characteristics of the particular stream. Certain events can happen that tend to upset it and may produce biological changes resulting in an entirely different animal population. All three parameters

---

1. Contribution from Dingell-Johnson Project F-9-R.

as listed above must be conducted if a stream is to be properly assayed, since all three tend to supplement each other rather than reveal the entire story individually. One of the main drawbacks to a program consisting of collection of water quality data alone is that the individual collections reveal only those conditions existing at the precise time the sample was collected. They give no indication of conditions that might have existed at any time in the past. In like manner, fish populations give no real indication of prior conditions of water quality other than at the time of sample collection. This is due to the well-developed means of locomotion exhibited by fishes. This allows them to escape damaging pollutants in many cases especially if the level of pollutants gradually increases.

Macro-invertebrates, however, are more or less at the mercy of their environment, due to their rather feeble means of locomotion. In other words, they are able to tolerate the adverse conditions or they are killed. This fact has prompted many aquatic biologists to refer to macro-invertebrates as "Nature's built-in monitoring system." On this premise, then, the ability to determine whether or not a stream has received damaging pollutants depends on the ability of the biologist to analyze the animals present and to have some idea of their life history. Many animals inhabiting streams have rather long and complicated life cycles and once this cycle is upset and the animals destroyed, several years are necessary for them to re-establish after the stream returns to the unpolluted state. If the discharge is an intermittant one, say once a year, the condition can never return to normal.

The term macro-invertebrate as used here refers to quite an assemblage of animals that are found inhabiting the fresh water environment. Animals such as annelids, aquatic insects, crustaceans, molluscians, and several other groups that are sporadic in their occurrence comprise the macro-invertebrates. Their use to evaluate environmental conditions was first used by Kolkwitz and Marsson in 1908. Since this time, they have been used by a number of American biologists. Some of the better-known works were done by Gaufin and Tarzwell (1952), Patrick (1953), Surber (1953), Beck (1955), and many others which are just as significant, but too numerous to mention here. Beck (1955) has worked out a unique method known as a biotic index. In this method a numerical value is assigned, based on the forms found at a particular station. This type of treatment is very useful in explaining interpretations to non-biologists.

In an attempt to illustrate the use of macro-invertebrates on studies that have been conducted by the Game and Fish Commission, data are used from the Pearl River Study. This study was conducted during 1959 and 1960. The data presented here is from stations above and below the Jackson area. The uppermost station is at mile 349 in Leake County, immediately below the confluence of the Yockanookany and the Pearl Rivers. The lower station is at mile 184 near Monticello. Eleven sampling stations were located in this section of the river, a distance of 165 miles (Figure 1). Benthic samples were collected at each of the eleven stations on a quarterly basis. Three stations were located below the Jackson area to better depict the polluted conditions. At the

time of the study, the river was receiving wastes from a population in excess of 150,000 as well as wastes from slaughter houses, poultry processing, and other types of industrial wastes.

A generalization that is often used in reference to macro-invertebrates in the aquatic environment is that in areas that receive organic wastes the number of forms or variety per unit area is reduced, but those surviving increase in large numbers. The factors that result in this increase are increased nutrients and a reduction in predatory forms.

The generalization referred to above is quite evident when the data collected at the various stations is compared (Figure 2). The total number of different forms (genera or kind) at river miles 349, 314, and 305, which are above any pollutants from the Jackson area, were 30, 31, and 29 organisms, respectively. This number was reduced to a low of three at mile 275, an increase to six at mile 268, and thirteen at mile 262. The gradual increase continued at downstream sampling points until the diversity of that at stations above pollution was reached.

It can also be noted in Figure 2 that the forms that were able to survive in the grossly-polluted area increased in exceptionally large numbers. Annelids were the only forms that occurred at all stations on all sampling dates. Their concentrations, however, increased in large numbers below the polluted section near Jackson. The Annelid plot in Figure 2 is the mean concentration for the four benthic collections, which were made at different times of the year. The mean number at the upstream stations, river miles 349, 314, and 305 was less than 50 per square foot, but increased to 23,600 at the first station below some of the Jackson outfalls (mile 275). It is of interest to note that this increase is approximately 600 fold over stations immediately above. This large build-up in annelids produced a distinct red border along each edge of the stream for several miles below the outfalls. A reduction is noted in annelids at mile 268, 262, and 251, a distance of 79 river miles. Levels with concentrations similar to those above the Jackson area occurred at the other downstream stations. The annelid population at the upstream stations was composed entirely of oligochaets, with Limnodrilus as the predominant form.

At stations immediately below the first outfalls, river miles 275, 268, and 262, three genera of leeches occurred. These organisms were devouring organic matter and the large numbers of sewage worms that were present. The heaviest leech concentration was at mile 275, where 348 per square foot was recorded for Helobdella. Larger concentrations, however, were undoubtedly present because large numbers were observed drifting downstream with the current.

In Figure 3 the macro-invertebrates are broken down into three groups: annelids, insects, and Unionidae.

The genus Limnodrilus of the annelids was the only form that occurred at all stations, and the form that contributed to the large build-up at the heavily-polluted stations below Jackson.

Insects were found at all stations (Figure 3), but their diversity was drastically reduced at miles 275, 268, and 262. Their variation at upstream stations ranged from fifteen to twenty different forms. Included were such clean water forms as dragon flies, mayflies, caddis flies, stone flies, riffle beetles, and several species of midges. Insects were completely missing on three sampling occasions at mile 275, and only one aquatic moth was recorded during the other. The only representative of the group Insecta at mile 268 was one tabanid larva, and it was recorded on only one sampling date. Two midge larvae were found at mile 262 on one occasion and insects were missing on all other sampling dates. The number of insect forms increased to seven at mile 251 and a gradual increase is noted at downstream stations, with the exception of miles 222 and 186. The most logical reason for the drop in forms at mile 222 is that it is located immediately below the mouth of Strong River, and the scouring and silting effect in all probability brought about this reduction. The reduction of forms at mile 186 is probably due to a localized habitat difference since the stream at this point has a slow, sluggish current most of the year, and the bottom deposits are composed of silt and deposited matter.

Unionids (mussels) are not able to exist in polluted waters, and this fact is very evident from the plot in Figure 3. A diverse unionid fauna is found at stations above the polluted zones (miles 349, 314, and 305), but all representatives are missing at miles 275, 268, and 262. Only one form was found on one sampling occasion at mile 251, and two forms at 226 and 222. This plot points out that unionids were virtually missing in the Pearl River below Jackson for approximately 50 miles and that the population did not reach the upstream diversity for approximately 90 miles.

Molluscians, other than unionids, were encountered at a number of stations. The small gastropod, Physa, which has the ability to utilize atmospheric oxygen, thereby enabling it to live in polluted water, occurred in large numbers near the water's edge in the heavily-polluted zone. These organisms were also devouring annelids. Fingernail clams are also forms that can tolerate and thrive under polluted conditions. They were recorded in large numbers at mile 262, a point in the stream where recovery has started.

Figure 4 compares the dissolved oxygen present as percent saturation to the genera or kind of organism found under summer, winter, spring, and fall conditions. It is noted that the stations in this figure are referred to by number rather than river mile. Station 1 is at river mile 349, Station 2 river mile 314, etc. (Figure 1).

During the summer dissolved oxygen values ranged from a supersaturated condition of 107 at upstream stations to a low of 18 at the low point in the curve. It is also of interest to note that the genera or kind of organisms present followed a similar pattern during this particular time of the year. During the winter conditions, however, the dissolved oxygen plot was practically a straight line, although the macroinvertebrates maintained a characteristic pattern very similar to that during summer conditions. The D. O. values during the spring indicate a slight drop from that of the winter, but values are such that a

healthy benthic population could exist if conditions did not worsen. The macro-invertebrate plot still indicates that adverse water quality conditions have occurred at some time in the past. The conditions that exist in the fall are more pronounced from a dissolved oxygen standpoint, that is, the drop is more drastic. The macro-invertebrate population still exhibits the characteristic dip below the heavily-polluted zone.

Although oxygen data alone do not determine the presence or absence of individual animal forms in a population, the comparisons made in this figure point out the need for biological data to supplement any water quality surveys that have as their objective to depict environmental conditions in aquatic habitats.

In conclusion, it should be pointed out that no single organism or group of organisms should be used exclusively as indicator species, but that the entire population of forms living in the community should be considered to make an accurate evaluation. In the same fashion, pollution surveys should not be made to include only water quality data. The need for biological data and its usefulness in supplementing water quality data will always be invaluable in pollution surveys.

BIBLIOGRAPHY

Beck, William M., Jr.
1954. A Simplified Ecological Classification of Organisms. Quart. J. Florida Aca. Sci. 17: 211 - 227.

Gaufin, Arden R., and Clarence M. Tarzwell
1952. Aquatic Invertebrates as Indicators of Stream Pollution. Public Health Rep., 67: 57 - 64.

Kolkwitz, R., and Marsson
1909. Oekologie der Tierischen Saprobien. Int. Rev. d. ges. Hydrobiologie u. Hydrographie 2: 126 - 152.

Patrick, Ruth
1953. Aquatic Organisms as an Aid in Solving Waste Disposal Problems. Sewage and Ind. Wastes, 25: 210 - 217.

Surber, Eugene
1953. Biological Effects of Pollution in Michigan Waters. Sewage and Industrial Wastes, 25: 79 - 86.

FIGURE 1

SAMPLING STATIONS PEARL RIVER

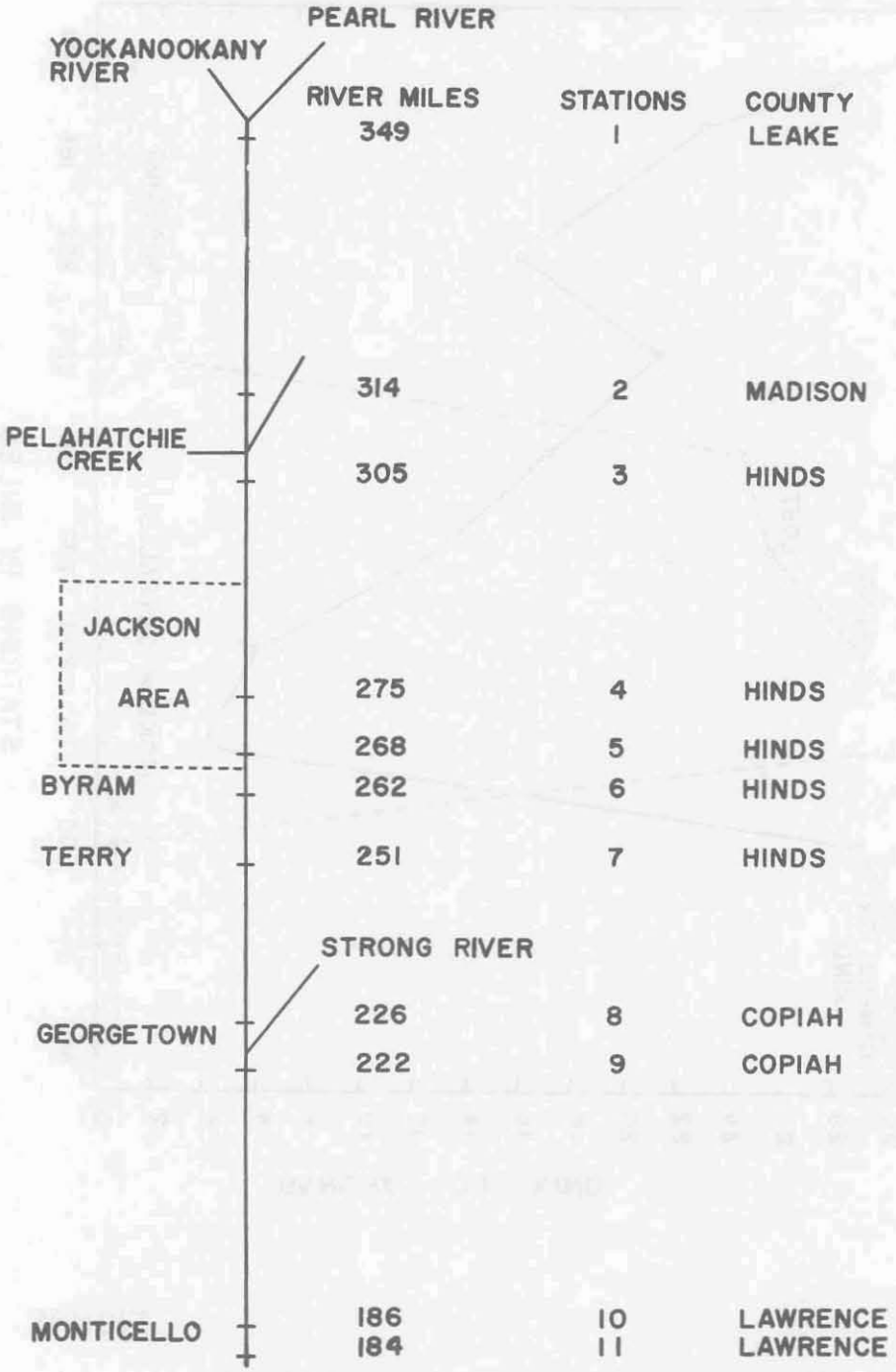
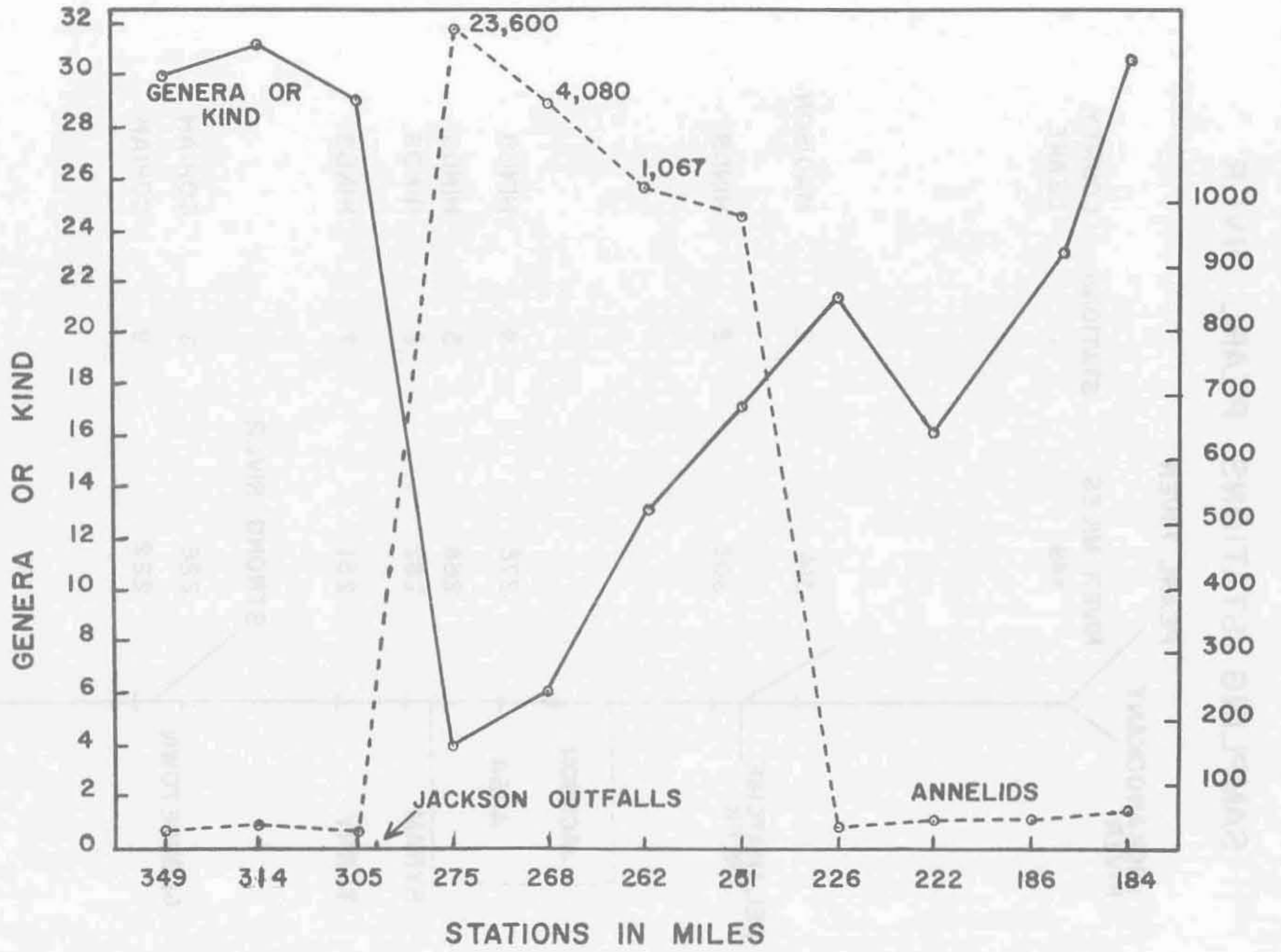


FIGURE 2



MACRO - INVERTEBRATE DISTRIBUTION - PEARL RIVER

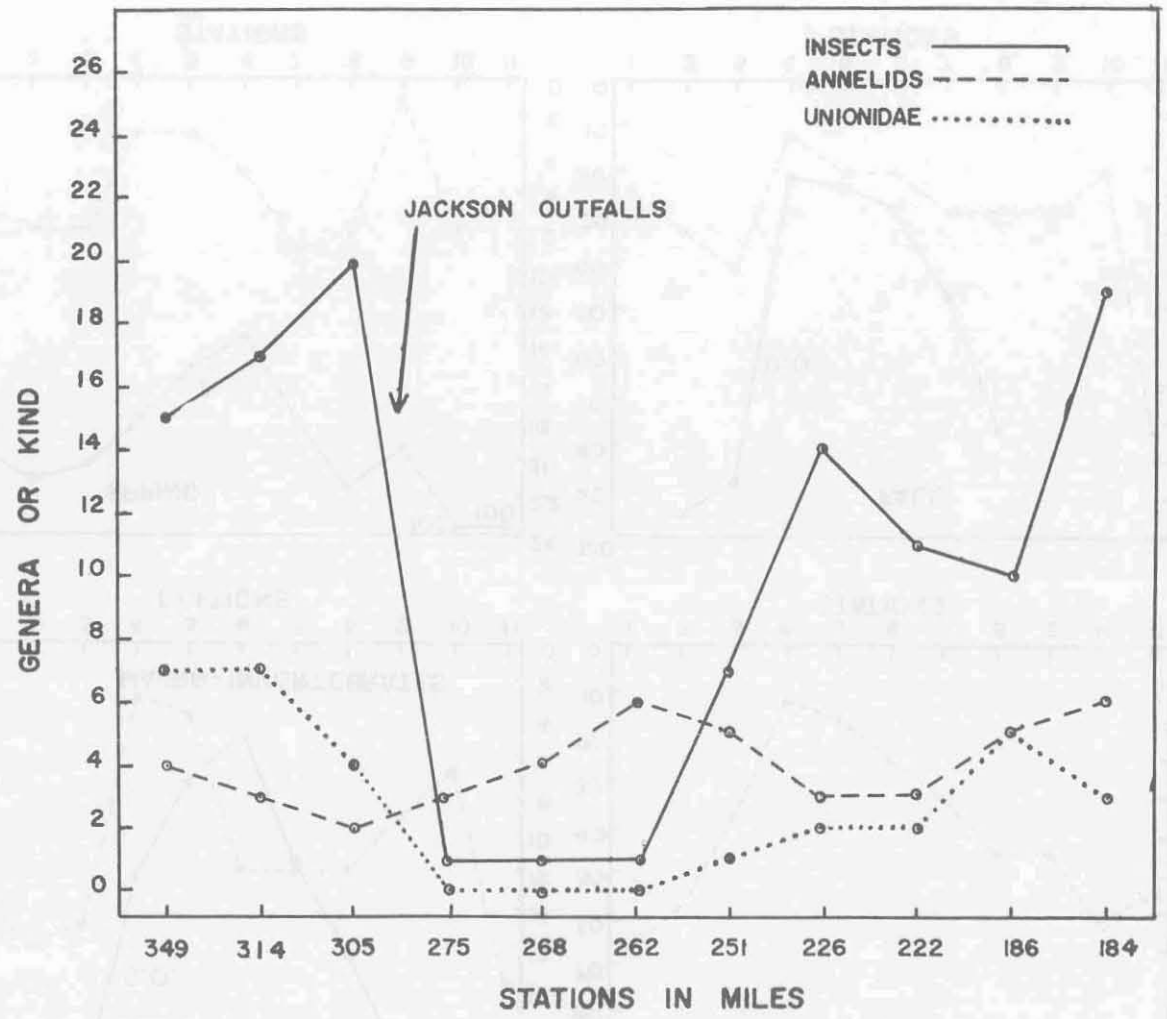


FIGURE 3

MACRO - INVERTEBRATE DISTRIBUTION - PEARL RIVER

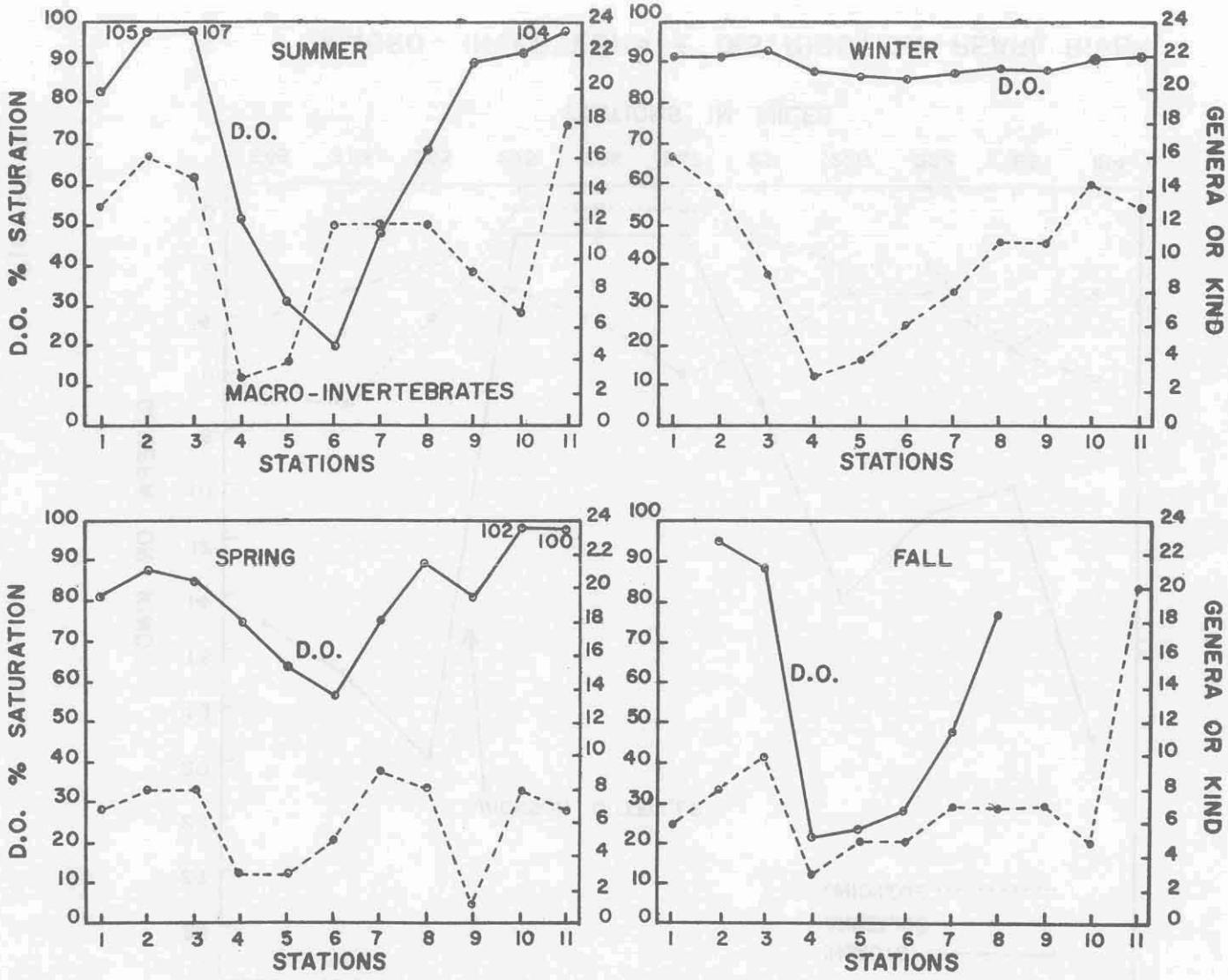

SUMMER
105
107
104
D.O.
MACRO-INVERTEBRATES
WINTER
D.O.
SPRING
102
100
D.O.
FALL
D.O.
D.O. % SATURATION
GENERA OR KIND
STATIONS
1 2 3 4 5 6 7 8 9 10 11
0 10 20 30 40 50 60 70 80 90 100
0 2 4 6 8 10 12 14 16 18 20 22 24

FIGURE 4