for most limnological studies. The method should be useful in the sorting of samples of more varied species composition and in the sorting of Cyclopidae from Diaptomidae. This appears rather important, since the latter are filter feeders, while the Cyclopidae, according to recent observations by Fryer (1957*a*, *b*) Monakov and Sorokin (1958), and Monakov (1959) are pure predators.

MILAN STRAŠKRABA
*Hydrobiological Laboratory,
Czechoslovak Academy of Sciences,
Praha 5, Vltavská 17,
Czechoslovakia.*

REFERENCES

FRYER, G. 1957*a*. The feeding mechanism of some freshwater cyclopoid copepods. Proc. Zool. Soc. London, **129**: 1–25.

———. 1957*b*. The food of some freshwater cyclopoid copepods and its ecological significance. J. Animal Ecol., **26**: 263–286.

MONAKOV, A. V. 1959. Predatory feeding of *Acanthocyclops viridis*. [In Russian] Tr. Inst. Biol. Vodokhranilishch Akad. Nauk SSSR, **2**: 117–127.

———, AND J. I. SOROKIN. 1959. Study of the predatory feeding of cyclopids by means of the radioactive isotope technique. [In Russian] Dokl. Akad. Nauk SSSR, **125**: 201–204.

———, AND ———. 1960. The application of the isotope-method to study the feeding of cyclopids and their naupliused stages by bacterial forage. [In Russian] Izv. Akad. Nauk SSSR Ser. Biol., **1960** (**6**): 917–922.

NAUMANN, E. 1923. Spezielle Untersuchungen über die Ernährungsbiologie des tierischen Limnoplanktons. II. Copepoden, Rotatorien. Lunds Univ. Arsskr. Avd. 2, **19**: 1–17.

———. 1924. Über die Narkose von Mesoplankton für mikroskopische Zwecke. Z. Mikroskop. Mikroskop. Tech., **41**: 343–349.

RAVERA, O. 1951. Emploi de la paraldehyde acétique pour la narkose du petits organismes d'eau douce. Trav. Assoc. Limnol. Theoret., **11**: 316–317.

AN INTEGRATED APPLICATION OF THREE KINDS OF SAMPLING TECHNIQUES TO STREAM LIMNOLOGY[1,2]

Studies of variations in physicochemical features of streams may be separated into three general categories: First, those based on grab samples as taken as a matter of course in many studies. These are of but little value except where large numbers of samples are processed over a long period of time. Second, the 24-hr or longer-term sampling programs that give estimates of variations at a given station. These have become easier with the advent of automation. Third, time-of-flow studies, made by following dye markers or radioactive tracers, or by calculation from cross-sectional profiles of the time required for a mass of water to pass through a stream segment. Various modifications of time-of-flow techniques have been used with success, not only in streams but in other flowing-water situations (Odum and Odum 1955; Odum 1956*a*, *b*, 1957; Edwards and Owens 1962).

Data given here were collected from Doe Run, Meade County, Kentucky, in a 26-hr period on 20–21 October 1961 and are a compilation of results from all three kinds of sampling. Doe Run is a spring stream about 56 km southwest of Louisville, Kentucky, and is a direct tributary of the Ohio River. The stream has been described in detail by Minckley (1963), and may briefly be characterized by its modal discharges between 20 and 40 ft^3/sec (0.56 and 1.13 m^3/sec), by relatively chemo- and thermostatic conditions at its source in periods of modal discharge, and by hard water. The upstream area of Doe Run flows over smooth bottoms with little turbulence and supports large stands of aquatic vegetation. The creek is heavily shaded by riparian trees and was relatively undisturbed by man in our period of study (October 1959 through August 1962).

Time of passage of water through the

[1] This work was supported in part by U.S. Atomic Energy Commission Contract No. AT-(40-1)-2595, with the University of Louisville, and in part by National Science Foundation Grant G-19449.

[2] Contribution No. 69 (New Series) from the Department of Biology, University of Louisville, Louisville, Kentucky.

upstream 1,100 m of Doe Run was 2 hr, as determined by movement of flourescein dye. Therefore, the five time-of-flow studies done in the 2-day period were each 2 hr long and involved sampling the same water

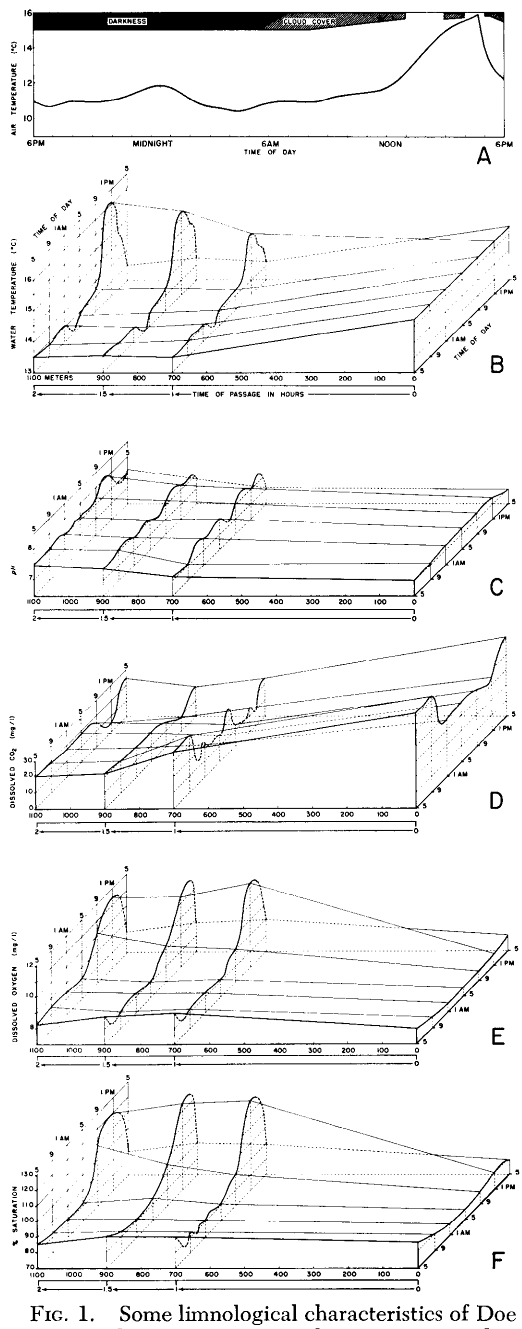

FIG. 1. Some limnological characteristics of Doe Run, Meade County, Kentucky, 20–21 October 1961.

mass at four places along the reach. Samples were obtained at the spring source, at a point 700 m downstream, at 900 m, and at 1,100 m. Time-of-flow studies were begun on 20 October at 5:00 PM (E.S.T.); 11:00 PM; 6:30 AM (21 October); 11:40 AM; and 3:25 PM. A 24-hr sampling program was conducted concurrently, with hourly sampling at the 700-m station. Grab samples were obtained throughout the area to corroborate other results. Methods of physical and chemical analyses are given by Minckley (1963).

Fig. 1 illustrates some specific aspects of the limnology of the upper part of Doe Run and is based on all samples taken by all methods. In each diagram (excepting Fig. 1A), the factor of time is included both horizontally (as the time-of-flow between consecutive points of sampling) and on the 45° axis (as time of day). Therefore, an estimate of variations in a given mass of water as it passes through the stream segment may be obtained by consulting the horizontal axis of the diagram, with time of day (right side) as the beginning reference point. Also, by reading from left to right on the 45° axis (and displacing the grid given on the left side toward the right), the magnitude of change in a given factor over a 24-hr period may be ascertained, with any point on the horizontal axis used as the beginning reference.

Presentation of data in this manner allows rapid comparison of a number of limnnological factors. For example, the period of minimum water temperature correlates with the period of minimum air temperature throughout the reach, and maximal heating of the reach occurred at the same time as did the period of greatest intensity and duration of insolation (Figs. 1A–B). Fluctuations in dissolved oxygen appear for the most part to have resulted from photosynthetic activity of benthic micro- and macrophytes, and changes in oxygen concentrations, following changes in temperature observed at the same times (Figs. 1B, E, F), emphasize the close relationship of both factors to the incoming solar radiation. As the duration of insolation increased, the point in the stream at which supersaturation with dissolved oxygen was attained moved progressively upstream. This occurred with increasing light intensity (in part), with increasing duration of time with light in contact with the water, and also with thermal changes in the water that made it less capable of holding oxygen. With cessation of photosynthetic activity and heating of the water at night, the reverse situation occurred simply as a result of water's being replaced from the spring. Pronounced increases in pH in daytime coincided with greatest oxygen production and temperature increases; however, variations in pH (and dissolved carbon dioxide) at night showed similar trends and are unexplained.

We are currently involved with estimates of production in Doe Run and have a number of problems requiring consideration. It must be noted that many of these have been mentioned by other workers and are undoubtedly under study. A major problem, for example, is the difficulty involved in measurement of insolation in areas of differential shading by trees, banks, or other objects. A solution ideally lies in study of the stream itself rather than in use of extraneous information, and such a solution is suggested by the data given here. Since heating of the stream and production of oxygen by plants therein are intimately linked in that both are functions of insolation, it would seem that measurement of heating might be a direct, more precise means of estimating incoming energy (after incorporation of factors for transparency of the water, cooling by evaporation, low air temperatures, etc.) than would any instrument above or below the surface of the water.

Diagrammatic matrices of the physicochemical conditions in Doe Run based on data obtained by diverse techniques have helped us to visualize some of the problems, and, along with recent reevaluations of concepts relating to streams (e.g., Leopold 1962), may give us means for precise definitions of stream dynamics. Biological work in streams must be preceded by accumulation of such data, since extreme conditions affect the well-being of organisms directly; averages are rarely encountered in nature.

Donald R. Tindall
Department of Biology,
University of Louisville,
Louisville, Kentucky.

W. L. Minckley
Department of Zoology,
Arizona State University,
Tempe.

REFERENCES

Edwards, R. W., and M. Owens. 1962. The effects of plants on river conditions. IV. The oxygen balance of a chalk stream. J. Ecol., **50**: 207–220.

Leopold, L. B. 1962. Rivers. Am. Scientist, **50**: 511–537.

Minckley, W. L. 1963. Ecology of a spring stream, Doe Run, Meade County, Kentucky. Wildlife Monographs No. 11. 124 p.

Odum, H. T. 1956*a*. Primary production in flowing waters. Limnol. Oceanog., **1**: 102–117.

———. 1956*b*. Primary production measurements in eleven Florida Springs and a marine turtle-grass community. Limnol. Oceanog., **2**: 85–97.

———. 1957. Trophic structure and productivity of Silver Springs, Florida. Ecol. Monographs, **27**: 87–112.

———, and E. P. Odum. 1955. Trophic structure and productivity of a windward coral reef community on Eniwetok Atoll. Ecol. Monographs, **25**: 291–320.

Ferrous Iron in Water

Colored surface water in Norway usually contains 0.01–1.0 mg iron/liter. It is generally accepted that this iron originates partly from vegetation and partly from minerals in the soil and rocks. It is believed that most of the iron in Norwegian surface waters occurs as soluble organic complexes and that these are responsible for the brownish yellow color of the waters. Bloomfield (1952, 1953, 1954) showed that ferric oxides are dissolved through the action of aqueous extracts of plant residues and that the dis-