

FACTORS INFLUENCING THE ECOLOGICAL
DISTRIBUTION OF TENDIPES DECORUS (JOH.)
IN COLDWATER LAKE,
ISABELLA COUNTY, MICHIGAN

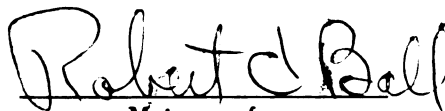
Thesis for the Degree of Ph. D.
MICHIGAN STATE UNIVERSITY
Gale R. Gleason, Jr.
1961

This is to certify that the

thesis entitled
Factors Influencing the Ecological Distribution
of Tendipes decorus (Joh.) in Coldwater Lake
Isabella County, Michigan
presented by
Gale R. Gleason, Jr.

has been accepted towards fulfillment
of the requirements for

Ph. D. **degree in** Fisheries & Wildlife


Major professor

Date April 21, 1961

Q-169



FACTORS INFLUENCING THE ECOLOGICAL DISTRIBUTION
OF TENDIPES DECORUS (JOH.) IN COLDWATER LAKE,
ISABELLA COUNTY, MICHIGAN

By
GALE R. GLEASON, JR.

A THESIS

Submitted to the School for Advanced Graduate Studies
of Michigan State University in partial
fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Fisheries and Wildlife

1961

1. 11111
11111

ABSTRACT

The profundal concentration-zone effect exhibited by the larvae of the Midge Tendipes decorus was investigated in Coldwater Lake, Isabella County, Michigan, for a period of two years (1956-1957).

Standard limnological methods were employed to determine the events that occurred above the benthic population. New methods were devised to collect the fresh sediment as it accumulated.

In the study it was found that the distribution of organic sediments and the time that the sediments reached the bottom were important factors in the survival of the first larval instar of this species. The nutritional value of the sediment appeared to determine both the density of the population and the bathymetric width of the concentration zone.

The test of other factors such as depth, temperature, bottom type, oxygen-carbon dioxide relationships, light, and pH indicated that they were not the major factors in establishing the limits of the concentration zone.

Contributions to the interrelationships of the life cycle of T. decorus with limnological events occurring in this typical eutrophic lake are presented in the text.

ACKNOWLEDGMENTS

This investigation was conducted under the direction of Dr. Robert C. Ball of Michigan State University, who continuously guided and evaluated the study and added positive direction in the analysis of the results. The financing of the research program was made possible by the continuous and enthusiastic endeavors of Dr. LaVerne L. Curry. His interest in research made it possible for the investigator to initiate this study with Central Michigan University, under Atomic Energy Commission Research Contract No. AT (11-1-350). Sincere gratitude is extended to the members of the various science departments of Central Michigan University for the numerous academic contributions which, related to their field of study, aided in the many ramifications of this investigation.

Gratitude is extended to Mr. and Mrs. L. Nichols of Coldwater Lake, who provided a boat and many other conveniences during the investigation. Their observations of the lake and weather changes between the surveys were valuable to many aspects of the program.

Valuable assistance was given in the preparation of graphs, charts, and photographs by Mr. Byron Clendening of Central Michigan University.

I owe much to my family who endured many inconveniences so that I might finish this work.

TABLE OF CONTENTS

	Page
ABSTRACT	ii
ACKNOWLEDGMENTS	iii
LIST OF TABLES	vii
LIST OF FIGURES	viii
INTRODUCTION	1
Concentration Zone Effect	5
Change in nomenclature	8
Problem	9
Parameters of the Problem	10
Life cycle of <u>Tendipes decorus</u>	12
Sediments and sedimentation	17
PHYSIOGRAPHY AND MORPHOMETRY OF COLDWATER LAKE	20
Physical and Chemical Limnology	24
Aquatic Vegetation	26
Bottom Types	26
EQUIPMENT AND METHODOLOGY	30
Previous Field Studies	30
Equipment	30
Preliminary Survey	31
Establishment of Stations	32
Samples	33
Winter sampling	33
Summer sampling	37
Sediment sampling	39

	Page
Analysis of Samples	45
Sediment	45
Larvae	46
THE PROFUNDAL CHIRONOMID COMMUNITY	50
Chemical and Physical Factors Influencing	
Distribution of Larvae	56
Oviposition and dissemination	56
Larval migration	57
Light	58
Temperature	59
Bottom muds	60
Oxygen	62
pH	63
Biological Factors Affecting Distribution	
of Larvae	64
Nutrients used by larvae	64
Feeding habits of larvae	65
Sediment composition	71
Organic sediments	71
Sediment composition and distribution of	
larvae	75
Per cent organic matter and growth of	
larvae	78
Sedimentation and pupation	82
Pupation and emergence	94
CONCLUSION	96
LITERATURE CITED	99

LIST OF TABLES

TABLE	Page
I. The Variations in Limnological Events Occurring on the Bottom at Stations 3 through 9, 1956-1957	16
II. Areas and Per Cent Surface at Various Levels, Coldwater Lake	23
III. Aquatic Plants Inhabiting the Littoral Zone at Coldwater Lake	27
IV. Volume of Particulate Matter with Diameter Greater than .025 Millimeter per Ekman Dredge Sample as Measured in Cubic Centimeters by Displacement	28
V. Dry Weight Comparisons of Sediments for Elevated and Countersunk Position in Sediment Chambers	44
VI. Sediment Analysis	47
VII. Number of Larvae per Sample, Late Winter, 1956	52
VIII. Larval Distribution as Related to Analysis of Sediments, June, 1956, through De- cember, 1957	77
IX. Data for Correlation Coefficient	79
X. Summarization of F. Distribution of Larval Measurements	81

LIST OF FIGURES

FIGURE	Page
1. Diagram of Concentration Zone in East Half of Coldwater Lake	11
2. Coldwater Lake (hydrographic map)	21
3. Comparison of Particulate Matter Greater than .025 Millimeters at Each Station	29
4. Gytija as Found in Coldwater Lake	34
5. Nylon Net Used in Separating Larvae from Muck	35
6. Bolus Formed after Sample Separation	36
7. Profile of Transect and Cable Location	38
8. Sediment Chamber as Removed from Lake	40
9. Open Chamber	41
10. Sediment Filled Liner	42
11. Distribution of Larvae on Transect	53
12. Aluminum Particles in Larval Gut	61
13. Sediment from Gut of <u>Tendipes decorus</u>	66
14. Sediment from Sampler at Station Six	67
15. Larval Case Construction at Various Temperatures	69

FIGURE	Page
16. Distribution of Sediment on Transect	72
17. Sediment Accumulation (1956–1957) as Related to Larval Population at Station 3	83
18. Sediment Accumulation (1956–1957) as Related to Larval Population at Station 4	84
19. Sediment Accumulation (1956–1957) as Related to Larval Population at Station 5	85
20. Sediment Accumulation (1956–1957) as Related to Larval Population at Station 6	86
21. Sediment Accumulation (1956–1957) as Related to Larval Population at Station 7	87
22. Sediment Accumulation (1956–1957) as Related to Larval Population at Station 8	88
23. Sediment Accumulation (1956–1957) as Related to Larval Population at Station 9	89
24. Chronology of Limnological Events as They Occurred in Coldwater Lake	91



There probably has never been an animal that so intrigued the minds of the ecologist as the "Bloodworms" inhabiting the ooze of our aquatic habitats.

INTRODUCTION

Entomologists generally conclude that the invasion of aquatic habitats by insects is a recent event and that most aquatic insects have their origin in terrestrial ancestors. About 4 per cent of one million species of insects live in or on the water. Of these, only a fraction of 1 per cent live or inhabit areas beyond the plant zone for both lentic and lotic habitats.

The greatest problem of the terrestrial to aquatic transition apparently is in the respiratory adaptations necessary for aquatic life. Many adult aquatic insects are not independent of atmospheric oxygen for respiration and, as a result, must make frequent returns to the air-water interface to effect gas exchange. The evolutionary plasticity of the immature forms, particularly those which undergo complete metamorphosis, has resulted in special structures adapted to oxygen absorption from the water. Gills and other body modifications have made it possible for insects to invade all types of aquatic habitats. Invasion, however, would be accomplished more easily in areas of high oxygen content, particularly in the plant zones. In lakes, almost all of the aquatic insects are confined to

the littoral zone. A very few highly specialized insect larvae exist beyond this zone.

The immature forms of insects capable of entering the oxygen-poor regions of lakes are found in the orders Diptera (true flies) and Ephemeroptera (Mayflies). Members of the latter order are seldom found at depths below 15 meters (Pennak 1953), whereas members of the dipteran family Tendipedidae (Chironomidae) have been found in the profundal region of lakes at depths greater than 100 meters (Miller 1941). The profundal regions of eutrophic lakes are commonly low in oxygen during certain periods of the year. The evolutionary migration from the heavily populated, oxygen-rich littoral zone to the profundal region indicates that these larvae are highly specialized and are virtually independent of all restrictions exerted on their littoral and terrestrial ancestors.

The degree of evolutionary specificity for the oxygen-poor regions of certain aquatic habitats is exemplified by the small number of larval types indigenous to these areas. So universal is their occurrence and abundance in these habitats that for many years limnologists have tried to use this group of benthic organisms as a possible means of typing aquatic habitats. This method was investigated in Europe early in the century by Thienemann (1920). Later, Brundin (1950) described major ecological habitats in Swedish

lakes. Deevey (1941) introduced the concept into the United States.

The appearance of certain species in similar, widely separated habitats led these men to believe that a single organism or an association of species would indicate the limnological characteristics of that particular habitat. Deevey found in his work with lake typology of Connecticut and New York a definite relationship between chironomid populations and lake types. The classification is based upon the oxygen and nutrient measurements as indicated by the redox-potentials and associated with the chironomid bottom fauna. Although his grouping of chironomids is not on the species level, he has lumped them into anatomically similar groups which, generally speaking, stand up under the taxonomic dismemberment that this family of insects is presently undergoing. Deevey's typology follows close to the old-world application of organisms to lake types proposed by Thienemann (1920) and many of his students. Until the synonymy of names has been resolved, it will not be known whether or not more recent work in this country will substantiate the findings of the early associations of bottom fauna to lake types.

Briefly, Deevey summarizes (1) Chironomus lakes as having eutrophic-type oxygen curves and Chironomus (bathophilus) larvae with two pairs of ventral blood gills; (2) Mesotrophic Chironomus

lakes with mesotrophic-type oxygen curves and chironomus larvae lacking ventral blood gills; (3) Tanytarsus lakes with mesotrophic-type oxygen curves; (4) Trissocladius lakes stratified as in shallow highland lakes whose typological position is uncertain; and (5) unstratified, faunistically and limnologically diverse lakes. At best, his summary is general and inconclusive in regard to the relationship of chironomid associations to specific lake types.

Tendipes decorus and T. plumosus are common examples of the bathophilic "indicator organisms," primarily because they are cosmopolitan forms of the chironomids and dominate the bottom fauna of most of the world's mature eutrophic lakes. These larvae have been found in habitats ranging from horse troughs (Leathers 1922) to oligotrophic lakes, and from small sluggish streams to the Mississippi River (Richardson 1928). Their occurrence is so universal that many limnologists use these organisms to express the bottom fauna characteristics of their study areas. As an example, Brundin (1956) refers to the Grosse Plöner Lake of Europe as having a C. plumosus (Tendipes plumosus) characteristic type bottom fauna. Lundbeck (1926) and Thienemann (1920) use the term "plumosus see" for those lakes which are inhabited by T. plumosus, T. decorus, and T. anthracinus. The larvae of these insects are grouped as the "plumosus type" because of the similarity in

anatomical features and ecological distribution. In addition, the importance of this group as food for higher aquatic vertebrates is well established.

Concentration Zone Effect

The tendency of certain midge larvae to form concentration zones around the basin of lakes has been reported by Eggleton, 1931; Deevey, 1941; Miller, 1941; and Curry, 1952. Bottom fauna surveys of lakes (personal observations) throughout Michigan have revealed many such zones. Concentration zones were found in Lake Medora, Keweenaw County, where the larvae T. tentans existed in several small bands; and in Pickerel Lake, Otsego County, T. anthracinus was found in a narrow band. T. decorus was found in a zone of varying widths around the basin of Coldwater Lake in Isabella County. Many other concentration zones of chironomid larvae have been reported in the literature.

The bands, or concentration zones, studied in Michigan have ranged from five feet to one thousand feet in width, and from several hundred feet in length to the complete circumference of a basin.

Welch (1952) uses the term "concentration zone" to describe a situation thought to be common to most eutrophic lakes in Michigan. The zone as defined by Eggleton (1931) is said to exist when a

species exhibits, during the summer, a high population within narrow limits of the lower sublittoral and the upper profundal regions of the lake.

It is suggested here that the concentration zone be considered as that limited area of the profundal region in which the perennial occurrence of a given species remains greater than in any other part of the lake. This application of the term "concentration zone" to a profundal population of chironomic larvae is believed to be more restrictive than that proposed by Eggleton and Welch for all benthic populations.

The lack of clearly defined species concentrations in other regions of the lake, such as the littoral zone, where high populations of invertebrate groups occur, has made the significance of the single species concentration zone even more important to limnologists.

The concentration of a single species in a small area has offered an excellent opportunity for population studies on growth, predation, and natural mortality (Curry 1952). The existence of these chironomid populations in the profundal zone greatly reduces the variables exerted against it, as compared to the more exposed terrestrial and littoral populations. The profundal region offers

less variations in such factors as light, temperature, oxygen, and many other physical-chemical influences.

Deevey (1941) postulates that concentration zones are the result of two major processes: (1) upward migration of "typical profundal species," which is associated with the reversal of bathymetric distribution of Chaoborus, and results in a concentration of larvae at the junction of the sublittoral and profundal zone; and (2) reproduction of chironomids, especially Tendipes, in the shallower parts of the lake.

Although these suppositions may be true for certain species of the chironomids and for Chaoborus, little evidence exists to show that this is also true of the "plumosus-type" larvae. The plumosus-type larvae beyond the first instar do not possess anatomical features conducive to coordinated directional movement; and, also, there is no evidence to indicate that this type of larva is capable of reacting to environmental changes occurring at the slow rates characteristic of the profundal regions. The presence of dead larvae during stagnation indicates that the larvae are unable to react to the slow progression of oxygen depletion as it moves from the deeper to the more shallow water. In many instances larvae, to avoid the effects of stagnation, would have had to move only a few feet. It also should be pointed out that the gradient of physical and chemical factors

thought to act as stimuli for the plumosus-type larvae can not be determined over the entire breadth of the concentration zone by existing sampling methods. This is particularly true in concentration zones which exist entirely below the lower limits of the thermocline and in uniform bottom deposits. The usage of the term "typical profundal species" also is misleading when an examination is made of the cosmopolitan distribution of these larvae.

Reproduction of chironomids in the shallow portion of lakes, as mentioned in Deevey's second reason for concentration zones, is generally true; however, that midges emerge from the profundal region to deposit their eggs by choice in the shallow regions of the lake is highly unlikely. The adult midge is a weak flier and is affected greatly by air currents. Emergences which take place during the night, when the water-created air currents set up offshore breezes tend to drive the adults toward the center of the lake rather than shoreward against the wind. This investigator has observed adult Tendipes plumosus and T. decorus depositing eggs on the surface of the water over the profundal region several thousand feet from the shore and well beyond the shallow regions of the lake.

Change in nomenclature

Note: Dr. Henry Townes (1959) discovered on his visit to London in June 1959 that Walker in 1848 had

classified a female midge as Chironomus attenuatus which Dr. Townes identified as a dark colored female of Tendipes decorus (Joh. 1905). Inasmuch as Walker's identification has been substantiated by Townes the scientific name of this species of Tendipedidae (Chironomidae) is now accepted as Tendipes attenuatus (Walker).

Observations of several chironomid concentration zones in Michigan and studies of chironomid life histories suggest that the factors establishing the limits of these zones could be presented in four general hypotheses.

1. The reason for concentration zones lies in the ability of the adult females to select the ideal location for the next generation.
2. Deposited eggs travel with water currents and finally sink to form concentration zones.
3. Eggs are deposited universally over the surface of the lake and survive only at a certain depth or in a certain type of bottom deposit.
4. The food supply (sediment) accumulates in sufficient quantities to support a high population of larvae only in limited regions of the lake.

Problem

This investigation was designed to test which of the above hypotheses is most nearly correct and whether any or all were applicable. A concentration zone of chironomids was found in profundal regions of Coldwater Lake, Isabella County, Michigan. This

benthic zone was composed almost entirely of a single species T. decorus. Some T. plumosus larvae were collected at the shoreward margin of this zone. The location of the zone presented an ideal opportunity to determine what factors influenced the ecological distribution of this insect in Coldwater Lake (Fig. 1). The preliminary survey was conducted in December, 1955. Sampling of seven stations continued for the next two years except when weather conditions made it too hazardous to get on the lake.

The investigation involved sampling at approximately fourteen-day intervals. The samples included biological, chemical, and physical analyses of the environment. Standard methods were used for obtaining chemical-physical data. New methods were devised for obtaining measurements of sediment distribution and the rate of growth for T. decorus.

Parameters of the Problem

Before proceeding into the analysis of data, certain aspects of the published material on the life history of Tendipes decorus and contributions made by this investigation should be presented to aid in establishing the ecological limits for this species within the concentration zone.

Physiographic Cross-section of East Half of Coldwater Lake

Showing Larval Concentration

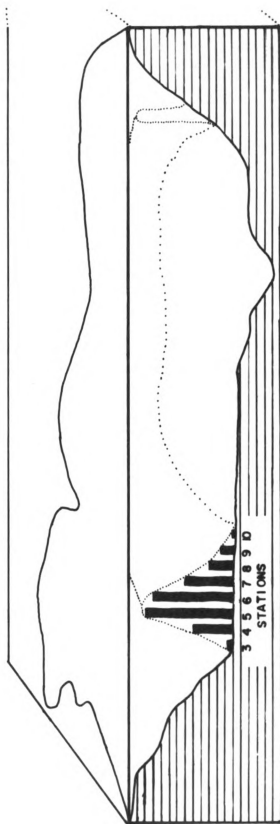


Figure 1

Most of the work previously published on this species has been confined to taxonomic and physiological investigations. Notes on its ecology appear in the literature only as miscellaneous observations during such studies.

Life cycle of *Tendipes decorus*

The eggs are deposited on the surface of the water as spherical masses three to five millimeters in diameter. Each mass is covered with a clear gelatinous matrix and has a denser involuted stalk. Jamnback (1941) states that "the several egg masses were found to be about .35 millimeters long and .10 millimeters wide, with two to three hundred eggs to the mass."

At average temperatures, the egg mass has a specific gravity slightly greater than that of water, and sinks very slowly. This may account for the even distribution of larvae on the bottom of certain lakes. The egg mass, sinking to a layer of water dense enough to slow down the descent may be carried from there across the surface of the dense strata by currents and internal wave action, and finally settle to the bottom. It is questionable that the eggs sink to the bottom directly below the point of oviposition.

When the eggs hatch, the newly-emerged larvae are about .6 millimeters in length, colorless (lacking at this time the

characteristic hemoglobin coloring common to third- and fourth-instar larvae), and very active.

During the first instar, which lasts about 2-1/2 weeks, the larvae remain active in the hydrosol and do not, as far as is known, construct tubes or cases. Case-building has been observed by Branch (1931) to start early during the second instar and, under most situations, continues until pupation. The length of time between hatching and case-building is not constant within the species and is apparently dependent on several factors not too clearly understood.

Factors which appear to influence case or tube construction are availability of food and oxygen supply. This species is an ooze feeder and obtains its food from the mud-water interface by ingesting the fresh sediments. When both oxygen and food are available, the case-building activity of the larvae is sporadic or absent. Cases built under these conditions are usually used only as temporary shelters.

When oxygen is abundant the maturing larva spends most of its time feeding. During stagnation much of the larval activity is spent in respiratory movements (Walshe 1947a). Larvae of Tendipes decorus are capable of filling their intestinal tracts three times every twenty-four hours. The food of the larvae includes all components of sediment which make up the bottom muds. The size of

the particles of sediment appears to be the only limiting factor in the process of ingestion. Laboratory experiments have shown that such inert substances as chalk, aluminum powder, and lampblack are ingested at a rate less than that of bottom muds. The larvae pass through four instars and are ready to pupate when they reach a length of 15 to 17 millimeters. Pupation occurs throughout the ice-free months. Emergence is usually in the late evening or early morning. The length of adult life is estimated at 9-1/2 days (adults do not feed) (Branch 1931). In Coldwater Lake there are two emergences a year: one in early June and another in late October.

In Coldwater Lake there are two generations a year. The summer generation lasts about 110 days; the overwintering generation, 170 days. There is overlapping of both generations, and only in November does there appear to be a brief loss in numbers from the population within the concentration zone. If this population is preyed upon by other insects and fish, the loss appears to be made up by the recruitment of young larvae into the population. The recruitment of larvae is understandable during the ice-free months, but the appearance of five- and six-millimeter larvae during the late winter months in the population of Coldwater Lake is a mystery. It is possible that cold temperatures delay the hatching of eggs

deposited in November and also inhibit the growth of young larvae so that they do not reach a size retained by the sampling equipment until late February or early March. Growth rates of larger larvae did not indicate that temperature had a noticeable influence.

At the end of the first six months of sampling (January, 1956, to June, 1956), preliminary analyses of chemical, physical, and biological samples indicated that data collected from the concentration zone were not significantly different from those of areas beyond the zone which could enable one to establish the reasons for the zone's existence in this particular location. It has been anticipated that differences in depth, bottom type and composition, temperature, and oxygen-carbon dioxide relationships would be intrinsic to the existence of the concentration zone (Table I). Observations and analyses of bottom deposits within the zone indicated that a slight difference existed between stations 3 and 4, and the other stations; but beyond station 4, differences were not appreciable. Correlations between growth and bottom types at each station showed that the larvae, although fewer in number at the extreme limits of the zone, grew and matured at the same rate and emerged at the same time. As a result of the above analyses, it was decided that a more specific study would be made to establish the nutritional relationships between sediment accumulations and larval concentrations.

TABLE I

THE VARIATIONS IN LIMNOLOGICAL EVENTS OCCURRING ON THE BOTTOM
AT STATIONS 3 THROUGH 9
1956-1957

Station	3	4	5	6	7	8	9
Depth in meters	9	10	12.5	13	13	13	13
Bottom Characteristics							
Type	pulpy peat	fibrous peat	muck	muck	muck	muck	muck
Percent .025 mm in diameter or larger	.027	.006	.005	.005	.004	.003	.002
Temperature							
Range °							
1956	3.5 - 14.5	3.5 - 13.2	3.5 - 12.8	3.5 - 9.6	3.5 - 9.6	3.5 - 9.6	3.5 - 9.1
1957	3.0 - 12.5	3.0 - 12.2	3.0 - 9.1	3.0 - 9.2	3.0 - 9.0	3.0 - 9.0	3.0 - 9.0
Oxygen Range							
1956 ppm	3.35 - .22	3.35 - .01	4.2 - .01	4.4 - 0	4.4 - 0	4.4 - 0	4.4 - 0
1957 ppm	4.2 - 1.2	4.2 - 1.2	4.1 - 0	3.9 - 0	3.8 - 0	3.8 - 0	3.8 - 0
Days without oxygen							
1956	none	none	none	21	24	25	25
1957	none	none	none	28-	28-	28-	28-

Sediments and sedimentation

To insure the clarification of the basic problem in this research, it is necessary to define sediment. Sediment as used in this study is the total organic and inorganic solid material, permanent or temporary, accumulating at the water-mud interface.

In the literature, there is no accepted limnological definition given to sediment. Geologists have defined it as the particulate material transported by water and air which accumulated in protected depressions or basins. The derivation of the word is confusing. The word was apparently derived from the French sedere, which means "to sit" and from the Latin sedimentum, meaning "a settling." The modern interpretation is a composite of the terms "to settle" and "to rest." This definition is appropriate from the geological standpoint, but does not take into consideration the interchange effected by the biological decomposition and subsequent return of many decomposition products to the lake water or atmosphere.

The mud-water interface represents one of the most dynamic regions within a lake. Thienemann (1955) refers to it as the zone of "reincarnation." Its complicated chemistry, its interrelated complex bacterial communities, and the physical transitions at its deeper depths provide a fertile field for analysis. Many theories as to the fate of the accumulating sediments are summarized by Ruttner (1953).

From this study it was found that a large part of the sediment is composed of diatoms which contain several to many oil droplets. The production of oil in diatoms is stimulated when the organism approaches the tropholytic zone. Barge (1943) states:

Fat production is more marked in "unsuitable" environment. Pinnularia viridis and Nitzschia putrida may fill two-thirds of their available volume with oil droplets. During rapid fat formation no accumulation of other cell constituents occurs. . . . In plastid-bearing diatoms fat is formed mainly within the plastids. In Pinnularia sp. and Synedra sp., extra fat plastids are formed.

Efforts to extract these fats with a Soxhlet extractor failed because of their low melting points (some less than 90° F). It is believed that these lipids are vital to the chironomid metabolism especially during periods of low oxygen.

Walshe (1947b) and Harnisch (1936) have suggested that these fats ingested during anaerobic conditions or fats ingested prior to anaerobiosis were fermented to points which required no oxygen and then excreted or stored, depending upon the species. Harnisch interprets the absence of an oxygen debt after anaerobiosis as an indication that even when oxygen is present these larvae respire anaerobically. Walshe interprets the lack of a substantial oxygen debt as being due to the ability of these euroxybiotic species to eliminate rapidly metabolic waste products or to store them and effect their release during aerobiosis at a very slow rate. There

is a possibility that these partially metabolized fats persist as the accumulations observed in pupal and adult stages where feeding does not take place.

As T. decorus is a benthic burrowing form, it would appear that its foods would fall upon the mud surface from the waters above. Analysis of the stomach contents of larvae indicates that particles of the fresh sediment make up their diet rather than the older mineralized deposits. Further work revealed that the algal cells found in the gut contained fresh pigments and numerous oil droplets.

Microscopic studies of mineralized deeper bottom deposits indicated that these organic components of the cells, especially in the diatoms, were absent or sparsely distributed. Cooper, Murray, and Kleerekoper (1950) and Cole (1953) all show that bacterial decomposition is rapid in the upper strata of bottom deposits. Kleerekoper (1953) points out in his studies of sedimentation that bacterial mineralization of settling plankton starts before they reach the bottom. It can be assumed from these studies that freshly accumulating sediments would have higher nutritional value for T. decorus and other profundal organisms than those mineralized in the bottom muds. On the basis of these data, a method of collecting biweekly sediment accumulations for correlation with nutritional values was devised and collection was initiated.

PHYSIOGRAPHY AND MORPHOMETRY OF COLDWATER LAKE

Coldwater Lake (Fig. 2), in the northwest corner of Isabella County, is located about 17 miles northwest of Mt. Pleasant, Michigan. The area around the lake is mostly poor farmland or partially wooded pasture. The soils along the east, south, and west shores are of sandy loam. The north shore is composed of muck and peat, with an underlying bed of marl. The ice has formed a four-foot bank along the north end. The bank separates the lake from a marshy meadow.

Geologically, Coldwater Lake was formed from a pit along a terminal moraine about a mile long and a half-mile wide (Scott 1921). Except for a small bay in the northwest corner, the basin is nearly rectangular in shape. The lake is fed by the Coldwater River, which flows into it from the north and continues to the south where it joins the Chippewa River. The latter is a part of the Tittabawassee River drainage system.

The inlet, Coldwater River, is located at the northeast end of the lake. It is about 35 feet wide and about 1-1/2 feet deep for most of the year. A large portion of the inlet water is from

COLDWATER LAKE
ISABELLA CO.
MICHIGAN

Sec. 29, 30, 31, T15N, R5W.
Contour Interval - 5 meters
Area - 294 acres

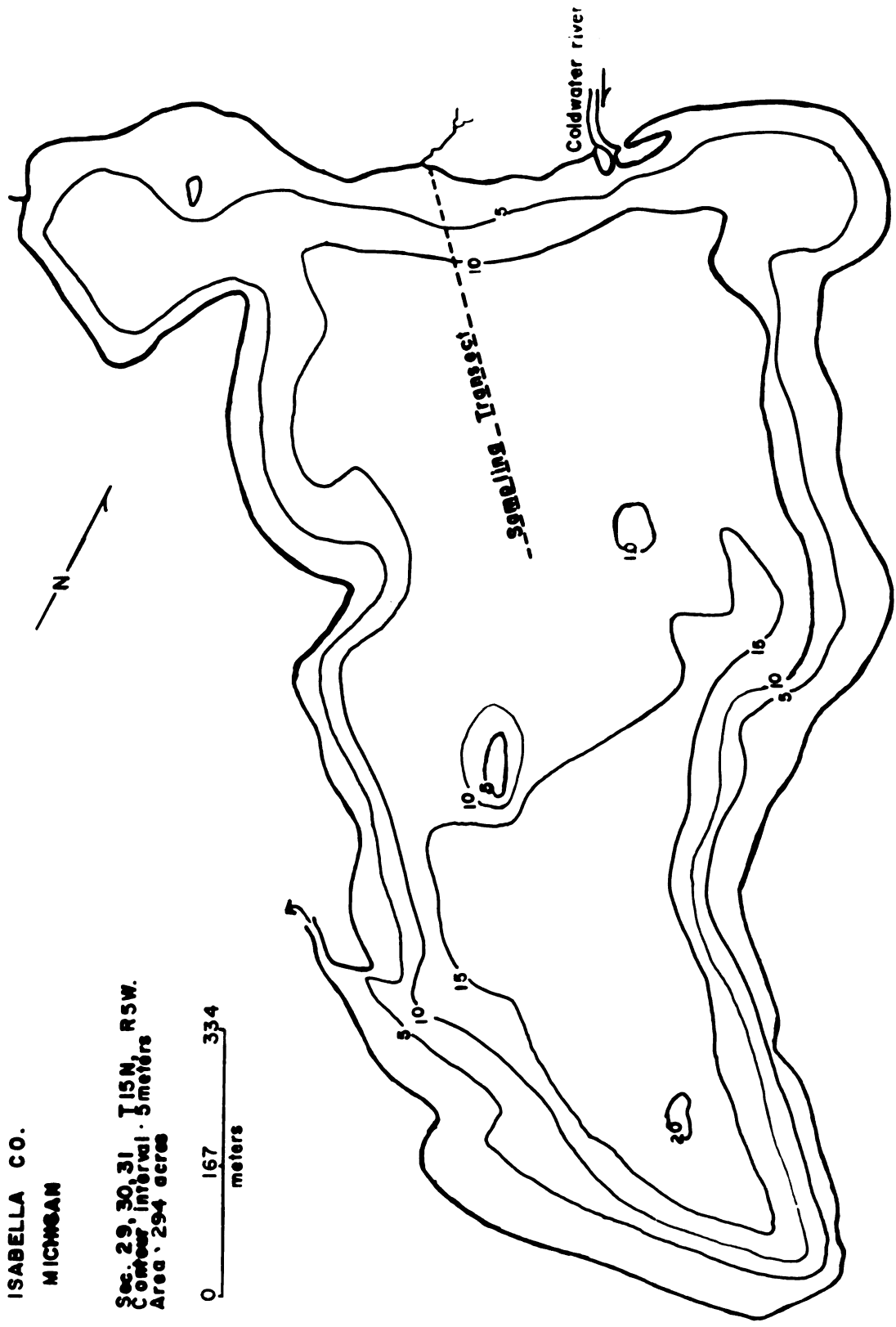
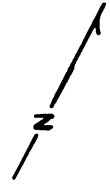


Figure 2

agricultural drainage ditches; the balance is supplied from Littlefield Lake drainage, seven miles to the north. Nearly 70 square miles of land are drained by this system.

The lake's maximum depth of 65 feet is found in a small depression at the southeast end. The average depth over the limnetic portion of the lake is about 45 feet. The sides of the basin are steep, dropping to an average of 30 feet in depth about 70 feet from shore.

Coldwater Lake has an area of 294 acres and a shoreline development of 1.53. The concentration zone in Coldwater Lake lies almost entirely between the 10- and 15-meter isobaths. The area delimited by these depths makes up 40.6 per cent of the surface area of the lake (Table II). The concentration zone occupies only a small per cent of this area. The bottom types vary around the margin of the basin. In depths less than 30 feet, marl deposits are evident. Along the east, south, and west margins, sand and marl form the edge of the basin. Most of the marl is deposited in and just below the heavy vegetation zone along the north half of the lake. The north margin of the sublittoral zone, crossed by the transect, is muck mixed with pulpy peat. At depths below 20 feet, the bottom is predominantly muck with patches of pulpy peat along the northwest edge.

TABLE II
AREAS AND PER CENT SURFACE AT VARIOUS
LEVELS, COLDWATER LAKE

Depth (meters)	Area		Pct. of Surface Area
	Square Feet	Acres	
0	12,807,640	294.0	100.0
0-5	2,857,500	65.6	22.4
5-10	2,728,800	62.6	21.4
10-15	5,176,800	118.8	40.6
15-20	1,960,200	45.0	15.3
20 and over	25,200	0.6	0.1
Totals		292.6	99.8

Physical and Chemical Limnology

Temperature and chemical samples (Table I) indicate that Coldwater Lake is a second-order lake, having a well-developed thermocline with spring and fall overturns. According to Deevey's classification of harmonic lakes (1941), Coldwater is a mature eutrophic lake.

The light penetration measured with a Secchi disc varied from four to seven feet during the two-year sampling period. In the plant zone, the water was often clearer than in the limnetic zone. Descents made with an "aqua lung" showed plants to extend to a depth of 18 to 20 feet. At this depth, the visibility was at least five feet. Water below the thermocline was clear and free from turbidity.

Chemical and physical analyses extended from December, 1955, to December, 1958. Although samples were taken periodically at the seven stations, most of the biweekly chemical-physical measurements were made at the deepest station.

It should be mentioned that this investigation was confined to limnology of the concentration zone. The chemical and physical limnology of Coldwater Lake has been under investigation since 1948, and the basic patterns of the lake are reported by Curry (1952).

As a result, samples over the small area of the concentration zone were intensified in order to relate as many factors as possible to the distribution of larvae within this benthic community.

Chemical analyses for oxygen showed that Coldwater Lake had two stagnation periods a year: one during August and early September, and another in late March and early April.

The water can be classified as "hard" (Welch 1948). Analyses indicated the seasonal variations in methyl orange alkalinity to be between 147 and 194 ppm. Seasonal variations in pH ranged from 6.3 to 7.7. The acid readings were only evident at depths over 13 meters during stagnation. During the balance of the year, the range was 7.0 to 7.7 in top-to-bottom sampling over the concentration zone.

The nitrogen content was high, as indicated by the frequent blooms of blue-green algae, Oscillatoria sp. and Gleotrichia sp.

Previous limnological surveys and observations by lake residents indicated that this type of bloom is recent (within the last ten years) and is becoming more pronounced each season. This condition is probably due to the increase of year-around residence at the lake and the intensification of the dairy industry in the drainage area. These blooms may have contributed to the partial depletion of oxygen resulting in stagnation in late August.

Aquatic Vegetation

The aquatic vegetation found in the lake in 1952-1958 (Table III) was not significantly different from that reported by Ball (1943) and Curry (1952). Two species of pond weeds, Potamogeton Richardsonii and P. zosteriformis, have become common in the 16-year interval since the first survey.

Bottom Types

The composition of the bottom muds changed gradually across the width of the concentration zone. The particulate matter gradually changed from a pulpy peat at station 3 to a fine fibrous peat at station 9. The quantity relationship of the particulate matter to the muck bottom is shown in Table IV and Figure 3. The volumes for these samples were obtained by taking the average of three Ekman samples and washing all particles less than .025 millimeter in diameter through an 80-mesh nylon net (an example of the quantity from one Ekman sample can be seen in Fig. 6). The samples were then placed in a graduate, partially filled with water, and their volume computed by displacement.

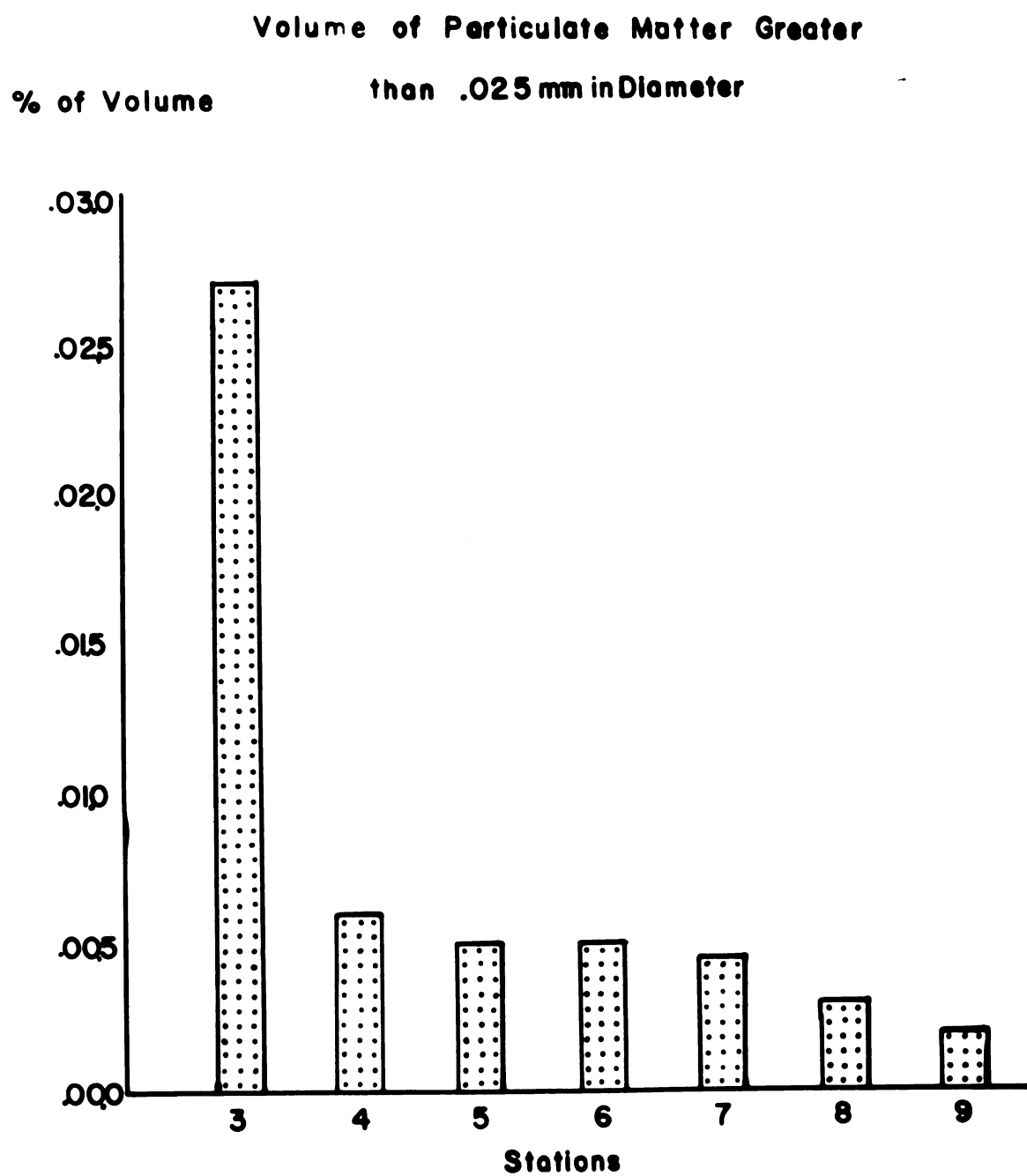
TABLE III
AQUATIC PLANTS INHABITING THE LITTORAL ZONE
AT COLDWATER LAKE^a

Species	Abundance
Coon tail (<u>Ceratophyllum demersum</u>)	common
Musk grass (<u>Chara sp.</u>)	abundant
Lesser duck weed (<u>Lemna minor</u>)	sparse
Water milfoil (<u>Myriophyllum sp.</u>)	common
Bushy pond weed (<u>Najas flexilis</u>)	abundant
White water lily (<u>Nymphaea odorata</u>)	sparse
Pondweed (<u>Potamogeton angustifolius</u>)	abundant
Pondweed (<u>Potamogeton Friesii</u>)	common
Sago pondweed (<u>Potamogeton pectinatus</u>)	common
Clasping leaf pondweed (<u>Potamogeton Richardsonii</u>) .	1941 rare, 1957 common
Flat stemmed pondweed (<u>Potamogeton zosteriformis</u>) .	1941 sparse, 1957 common
Wild celery (<u>Vallisneria americana</u>)	common

^aInstitute for Fisheries Research, Report No. 872, 1943
(slightly modified).

TABLE IV
VOLUME OF PARTICULATE MATTER WITH DIAMETER
GREATER THAN .025 MILLIMETER PER EKMAN
DREDGE SAMPLE AS MEASURED IN
CUBIC CENTIMETERS BY
DISPLACEMENT

Station	Ekman Sample			Avg.
	1	2	3	
3	72.5	83.7	127.2	94.5
4	21.8	18.5	16.7	19.0
5	19.1	19.2	19.9	19.4
6	14.0	12.8	11.5	12.8
7	17.0	17.5	17.1	17.2
8	12.7	12.2	12.5	12.5
9	9.5	10.5	8.8	9.6

**Figure 3**

EQUIPMENT AND METHODOLOGY

Previous Field Studies

The ecological history and morphological data for Coldwater Lake were based upon reports and maps supplied by the Institute of Fisheries Research (Ball 1943).

Valuable information for correlation with this field study was supplied by Curry (1952), who investigated the ecology of several genera of midges from Coldwater and Campau lakes, Isabella County. Additional observations have been recorded since 1954 by the Central Michigan University research staff.

Observations of weather were made at the time of each survey. These include wind direction, relative velocity, sky conditions, visibility, air temperature, and relative humidity. Records of extreme climatic changes between sampling dates were obtained from lake residents. These observations included temperature extremes, dates of first ice cover, and ice breakup dates.

Equipment

Water temperatures were taken with a Negretti-Zambra reversing thermometer. Light penetration was determined with a

Secchi disc. Water samples were taken with a modified Kemmerer water bottle, and bottom samples with a 6 x 6 inch Ekman dredge. Sedimentation quantities and rates were obtained by an instrument designed by the investigator (Fig. 8).

Preliminary Survey

On December 15, 1955, a transect along the longitudinal axis of Coldwater Lake was established on the ice (Fig. 2). Three dredge samples were taken at each 100-foot interval, starting at the north shore and working lakeward. This interval was used until the transect had passed through the concentration zone. The zone at this point was 700 feet wide and started 300 feet offshore at a depth of nine meters. The zone terminated at 1,000 feet from shore at a depth of 13-1/2 meters. This transect was sampled at two-week intervals.

During the winters of 1955 and 1957, the transect was extended across the lake. Samples of the profundal mud were taken 300 feet apart across the lake to the southeast shore. At a depth of about 30 feet, another "concentration zone" of T. decorus was found. This zone extended 14 feet shoreward to a depth of 15 feet. This population was reported by Curry (1952) within his station eight and had a greater population density than that of the zone at

the northwest end of the lake. This band was about 800 feet from the south shore. A winter survey again in 1957 showed the bands to have about the same limits. Larvae were found all the way across the lake, but in numbers too small to be considered as a portion of the concentration zone. Usually not more than eight larvae per sample were found.

Due to the difference in the width of the concentration zones at opposite ends of the lake, it was decided that the wider band at the northwest end would be used to investigate the ecological factors influencing the distribution of the larvae in this zone. The 700-foot expanse provided a greater area for investigation of the biological, chemical, and physical factors affecting the distribution of the larvae.

Establishment of Stations

As a result of the winter survey in 1955, sampling stations were established along a 1,000-foot transect on the lake bottom and were 100 feet apart (Fig. 7). Station 0 was located at the north shore on the transect. Stations 1 through 10 were located at 100-foot intervals along the transect. Samples taken from stations 0, 1, 2, and 10 did not contribute data related to the concentration zone and were thus omitted from later sampling periods. As a result of this finding, all subsequent samples were taken from stations 3 to 9.

Each station was considered to be that area of the bottom directly below the surface which could be reached by standard methods of sampling. Lateral extensions of 150 feet at each station were initiated to get a relatively unbiased sample. The vertical limits of the station were considered to extend approximately one foot above the surface of the hydrosol.

Samples

Winter sampling

When samples were taken through the ice, the 100-foot intervals were measured along the transect on the ice. At each station, a three-foot hole was cut. Chemical and physical samples were taken before larval samples. Three dredge samples were taken from each hole. Each sample was washed through an 80-mesh nylon net (Figs. 4, 5, 6), and placed in a jar with a small amount of lake water (Fig. 6). The nylon net was used during the winter because it could be kept in the hole and would not freeze while the next sample was being taken. Early attempts to use the standard wire screen failed because the screen, when left on the ice, froze between samples. The bottom fauna samples were placed in an insulated box, transported to the laboratory alive, and kept under refrigeration until they could be sorted from the net residue.



Figure 4

The gelatinous consistency of the bottom mud is clearly shown as it is emptied into the net. This bottom type is very close to *gyttja*, described for aerated Scandinavian Oligotrophic Lakes. The main difference is a higher concentration of organic matter (3 to 4 percent higher in Coldwater Lake).



Figure 5

The use of the net to remove the larvae from the mud was found more expedient than the use of standard screens. Comparison of samples strained through the net and screen indicated that fewer second instar larvae escaped through the net than the screen.



Figure 6

The bolus formed from centrifugal movements of the net in the air is easily transferred to labeled sample jars. (Note that the net is clean and free from enmeshed larvae, a condition seldom true for the wire screen).

When temperatures dropped below 0° C, oxygen samples were fixed in the field and analyses were made in the laboratory. Free carbon dioxide and pH determinations were always made in the field.

Subsequent sampling was made on a transect parallel to the original, but 25 feet to the right or left of the previous sampling. To insure that the sampling was not from the same area, three different positions were selected in the three-foot hole. These samples were treated in the same manner as those along the study transect.

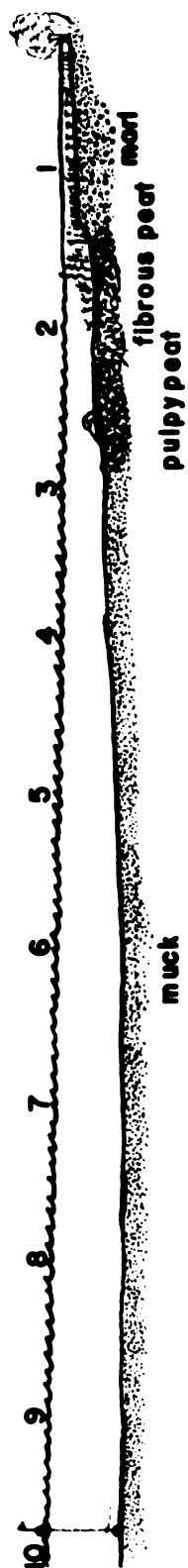
Summer sampling

During the ice-free period, a wire was placed along the transect. The shoreward end was anchored to the bottom by cement blocks, and the lakeward end was attached to a draw line anchored to a bouy (Fig. 7). When not in use, the wire was on the bottom. When samples were to be taken, the wire was drawn to the water surface, making it possible to pull the boat shoreward along the wire. Each station was marked on the wire with an aluminum tag and a hook. While the hook held the boat, samples were taken. The wire allowed ample freedom perpendicular to the transect, but held the boat within a narrow radius along the line (Figs. 2, 7).

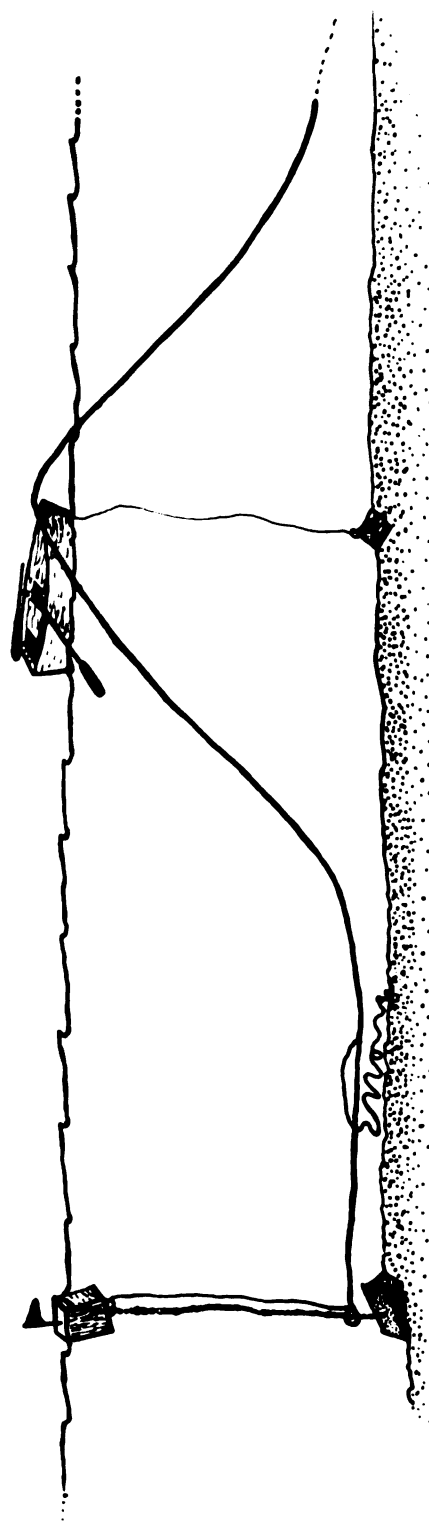
Profile of Sampling Transect

Stations 1-10 100 ft. apart

NW 



Cable Anchorage & Sampling Method



10

9

8

Figure 7

Sediment sampling

A review of the literature revealed that such a device for this type of measurement was not commercially available. The apparatus described by Kleerekoper (1952a) and Jarnöfelt (1955) was not suitable for the type of measurements needed in this investigation.

Several experimental devices were employed before consistent results were obtained by the sediment chamber shown in Figure 8. This device made it possible to collect sediments that moved horizontally as well as vertically. The simplicity and economy of construction made it possible to make many chambers and to repair any malfunctions discovered in the field without replacing the chamber. The disposable liners (baby food jars) were small and easily transported to and from the lake.

The chambers consisted of two baby food jars, housed in US No. 2 cans attached to a weighted plywood base. The two cans were attached to the base so that they would collect sediments moving across the bottom and sediments that were deposited vertically. The lower chamber would collect both horizontal and vertical sediment accumulations (Fig. 10), while the upper chamber would collect only vertically deposited sediments. Both levels were covered with an automatic closing and opening lid. The lid opened when tension

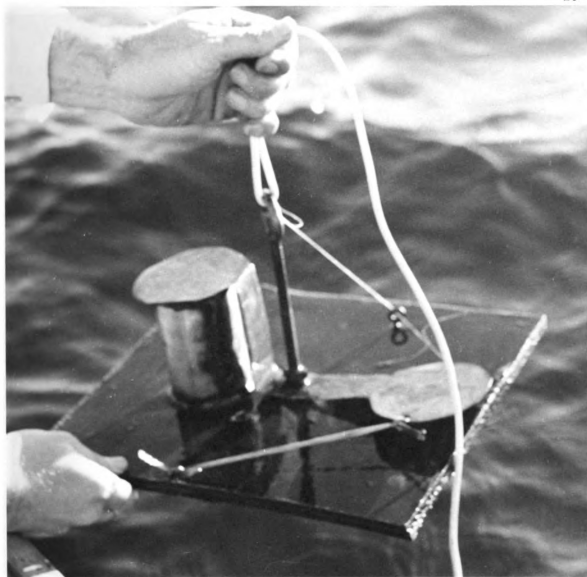


Figure 8

The sediment chambers, when recovered from the bottom, are closed by the tension on the plastic line. Plastic was used because cotton lines rotted under the anaerobic conditions of the bottom.

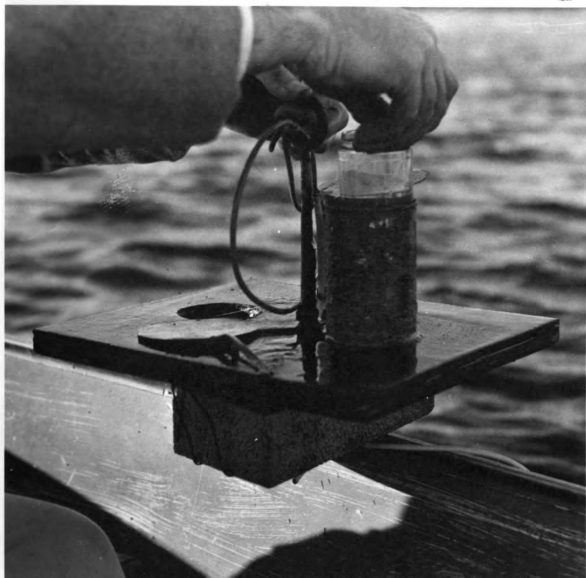


Figure 9

With the release of tension on the anchor line, the lids slide away from the can openings and the "baby food jar" liner can be removed.

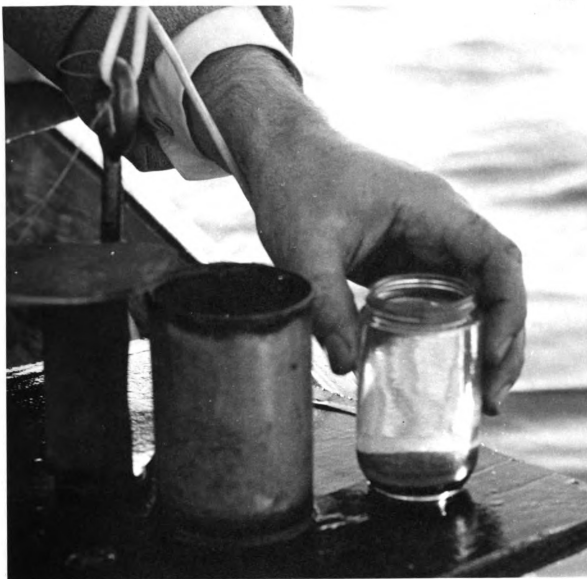


Figure 10

The liner is removed and a clean jar put back into the chamber. The jar above contains a two-week accumulation taken in October of 1957. The oven dry weight of this accumulation is just over three tenths of a gram.

was released on the anchor line and closed when made taut (Fig. 9). The chambers were attached to the transect cable at each station tag with a cord slightly greater in length than the depth of the station. Because of the sensitivity of this test, the sediment chambers were the first samples to be collected at each station. The samples were placed in a dark insulated box, and clean jars were sent down in their place. During the winter the chambers remained on the bottom, and parallel series of chambers were lowered through the ice. The duplicate sampler was supported with a rope attached to a two-foot piece of wire on a wooden float. The float supported the rope and wire until it froze in the hole. Removal of samples was made possible by chipping along the wire until it was free and then recovering the sample. The total accumulation from the samples submerged all winter was then compared with the total of the bi-weekly samples collected. The difference between the two totals was not significant.

The lack of a great difference in the parallel series plus sample comparisons between the two levels built into the device (Table V) indicated that the samples were consistent enough to use as a means of measuring sedimentation.

On June 3, 1956, three months after the first chambers were tried, it was found that neither time nor laboratory equipment was

TABLE V
 DRY WEIGHT COMPARISONS OF SEDIMENTS FOR
 ELEVATED AND COUNTERSUNK POSITION
 IN SEDIMENT CHAMBERS
 (grams)

Station	1956			
	March 30–April 30		May 20–June 3	
	Elevated	Counter-sunk	Elevated	Counter-sunk
3	.584	.605	.478	.472
4	.607	.600	.497	.479
5	.620	.595	.483	.481
6	.569	.615	.480	.502
7	contaminated		.475	.477
8	.640	.582	.476	.470
9	.568	.571	.506	.491

available to analyze sediments collected from both levels of the sediment chamber. Because of frequent contaminations of the countersunk level, due to angular recoveries from the bottom, it was decided that only the elevated chambers (five inches) would be used in the analysis.

Analysis of Samples

Sediment

The refrigerated samples of sediment were left in their original containers and allowed to reach room temperature. The analysis of these sediments was a modification from that of Theroux, Eldridge, and Mallmann (1943). The sample was agitated, and two 5-milliliter aliquots were drawn off the agitated sample. These aliquots were saved for lipid and organic phosphate determinations. One drop of the lipid aliquot was placed on a microscope slide and allowed to dry. When dry, the slides were made permanent in a Diaphane mount. These slides were used to compare the biological composition of the sediments between stations and between collection dates. The balance was filtered through an asbestos-lined gooch crucible which had been reduced to a constant weight. The crucible and sediment were oven-dried at 100° C to constant weight. Percent organic matter was determined by igniting at 550° C for 12

minutes, cooling, and weighing. To determine the per cent silica and carbonates, the remaining sediment was washed with concentrated HCl and ignited at 1,000° C, cooled, and then weighed. The results of these analyses are presented in Table VI.

Larvae

The small amount of detritus left with each screened sample (Fig. 6) made it possible to sort out the larvae from the samples in a living condition. The value of this type of sorting over sorting of preserved material cannot be overemphasized. Treated in this manner, the larvae retained their bright red color and became active when brought from refrigeration. Many larvae built cases at temperatures close to freezing. The cases were disintegrated with a strong jet of water. The turbulence created by the jet brought most larvae to the surface where the surface tension kept them afloat until they were removed. After all apparent larvae had been removed in the above manner, a small amount of formaldehyde was added. All inactive larvae then became active and were easily removed from the sample. The larvae were preserved in shell vials with 10 per cent formaldehyde and glycerin.

When chironomid larvae were preserved, they became turgid and assumed a curved position. The curvature made it very difficult

to make accurate measurements. If the larvae as they were removed from the preservative could be measured without stretching or puncturing, a more accurate length could be obtained.

The content of each vial was poured onto a 5 x 11 inch square of white blotter paper, and the label was placed in the upper-right corner. The larvae were then spread out and the blotter was placed in a frame directly below a 35-millimeter Recordographic camera. The frame contained a metal millimeter rule accurate to .2 millimeter. The rule was visible along the left margin of the photograph. Exposures were made on high-contrast 35-millimeter film. After the film was developed, the length of each larva was read directly from the scale in the photograph. A piece of flexible lead wire was used for measuring the enlarged projected negative of the larvae. The wire was placed along the contour of the larvae and the length was read directly from the extended wire. Lengths as small as .01 millimeter could be made accurately in this manner. This method eliminated the tedious work with the binocular microscope and preserved material. The use of film also provided a permanent record of the samples and their dates. The importance of this record is apparent in case of lost samples through breakage or dehydration.

The taxonomic characteristics for the larval forms of most midges are minute and often confusing. To be certain of the identification of the larval forms of T. decorus, mature larvae were reared to adults, and positive identification was made of adults, male and female. Results were compared by Dr. LaVerne Curry with specimens checked by the National Museum.

THE PROFUNDAL CHIRONOMID COMMUNITY

Studying a population which in its native habitat cannot be actually observed poses many problems. One must hypothesize conditions on the lake bottom as they exist on the basis of measurements made from the surface. From samples taken for this investigation, it can be assumed that the larvae of Tendipes decorus in Coldwater Lake exist on a muck plain having very little change in topography. The days are marked by changes between total darkness of night and dim translucence of day. There is a continuous rain of planktonic particles day and night. Currents are rare and slow. The temperature changes are scarcely noticeable from day to day, and seasons are reduced to two, both of which are marked by a continuous decrease in oxygen concentration and a progressive increase in soluble carbonates.

It can be said that T. decorus is the dominant benthic organism of the profundal region in Coldwater Lake (Chaoborus are considered to be nektonic). This species represents the only significant primary benthic consumer at depths below 10 meters. The population of T. decorus probably extends over the entire profundal region.

The larvae are "normally" distributed along the transect in the concentration zone with the greatest numbers at station 6. From the comparison of three samples for each station at any one date, it appears that the larvae are also uniformly distributed at any one station. Presented in Table VII are the actual numbers of larvae occurring in each sample for all of the stations from December, 1955, through March, 1956. Data from this period are presented because they were taken when the lake was covered with ice, a time when additions and deletion from the population by oviposition and pupation would not be factors. Another reason for presenting data for these months is because more accurate measurements could be made from the surface of the ice than during the open-water months. Station locations marked on the ice insured that samples would not be taken from the same position on the bottom. This degree of accuracy for station location and sample distribution could not be guaranteed for samples taken from the boat.

Although uniformly distributed populations are rare in nature, Odum (1959) points out in his text that such populations do exist in environments that are very uniform. Further evidence of uniformity was found in the frequency of larvae per square inch of bottom in the concentration zone (Fig. 11). This pattern did not vary throughout the five generations of larvae studies; thus it is possible to

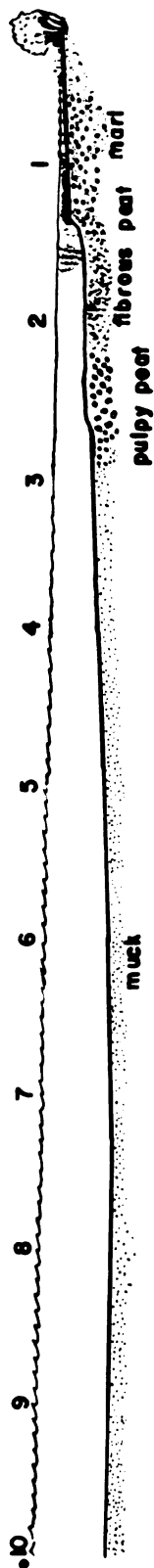
TABLE VII
NUMBER OF LARVAE PER SAMPLE,
LATE WINTER, 1956

Sta- tion	Sam- ple	Dec. 19	Dec. 31	Jan. 14	Jan. 31	Feb. 14	Mar. 13	Mar. 25
3	1	2	4	7	2	5	6	rotten ice
	2	3	6	8	6	4	8	
	3	1	4	6	6	4	2	
4	1	32	17	50	43	25	37	25
	2	18	29	48	41	24	25	19
	3	8	19	42	41	14	16	29
5	1	32	41	53	33	28	37	37
	2	34	50	47	43	44	38	39
	3	39	38	55	37	47	47	39
6	1	47	40	50	50	40	53	44
	2	39	41	66	49	58	52	37
	3	41	43	49	36	50	47	50
7	1	36	31	32	34	35	21	23
	2	30	31	40	40	31	35	32
	3	34	26	26	25	34	34	15
8	1	22	11	13	20	16	13	13
	2	18	14	15	15	13	27	7
	3	11	6	12	16	6	19	12
9	1	7	6	10	7	5	7	4
	2	5	4	11	6	6	6	5
	3	3	4	10	2	5	8	8

PROFILE OF SAMPLING TRANSECT

Stations 1-10 100ft.apart

— NW —>



LARVAL DISTRIBUTION ON TRANSECT

1956-1957

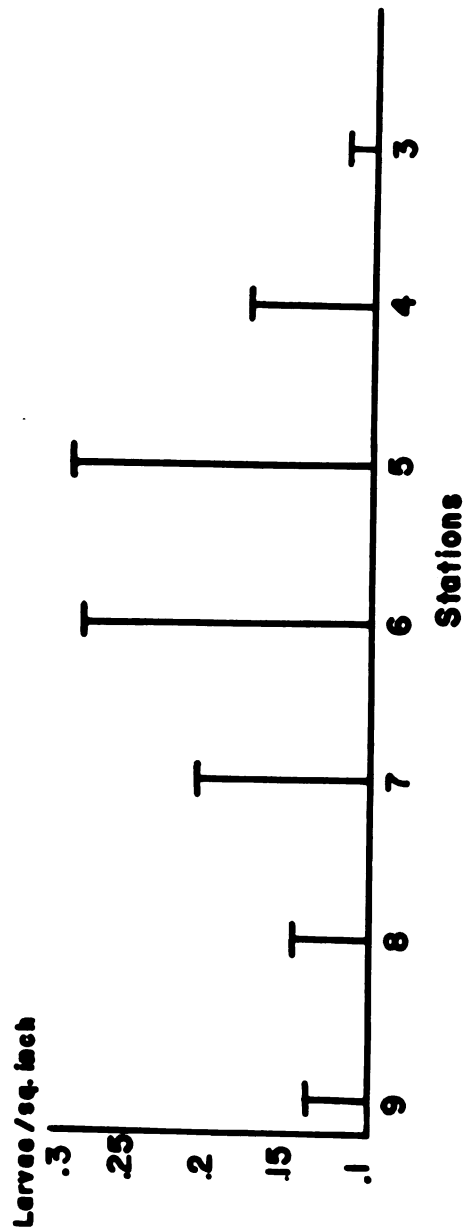


Figure 11

hypothesize that uniformity in distribution exists for this population.

It should also be considered that the populations are re-established from a point which must of necessity be at least equal to the depth of the water above the concentration zone. The egg masses which contain 200 to 300 eggs may or may not disintegrate before they reach the bottom, depending on currents and other factors which slow their descent. If the egg masses remain intact until they reach the bottom muds, the planktonic larvae will become dispersed with the aid of currents and their own random movements. As will be pointed out later, random distribution of the eggs does not mean that the larvae survive equally well over the profundal bottom, but rather that they tend to survive in areas that form concentration zones. If these larvae were capable of migration and could react to a nutritional tropism with any degree of success, then uniformity would be destroyed and give way to random clumps or some other population organization. From studies of number of larvae per sample for consecutive samples through one generation (Table VII), it was found that at each station there was not a significant difference from one sample to the next nor from the beginning to the end of one generation. The normal loss, due to predation and other factors, always seemed to be compensated for by

young larvae growing to adequate size to be collected by the apparatus used. From December 19, 1955, to March 25, 1956, the number of larvae remained relatively constant for all stations. This condition prevailed except during the short interval between generations. Samples within the concentration zone were never without some representatives of the population.

Interspecies competition does not appear to exist at the benthic level. Some organisms occupying the pelagic region of the hypolimnion prey upon the larvae. Intraspecific competition may exist at the nutritional level, but only among the first instar larvae which must have rich organic sediments in the immediate vicinity of their settling-out point.

Macroscopic endoparasites are rare in this species and were not found in any of the 2,000 larvae examined. Ectoparasitic protozoans were common on the head capsules of the larvae. Most of these were Vorticella sp. which were symbionts (0-0) according to Odum's (1959) classification of parasitism.

To summarize, it must be assumed that:

1. The larvae do not settle to the bottom confined to the egg mass; or, if they do, they are randomly distributed by their brief planktonic condition.
2. The larvae do not emigrate or immigrate during the 110 to 170 days of the generation once they are established in the concentration zone.

3. The distribution of larvae is probably affected by intra-specific competition within the concentration zone.
4. Larval density is limited by factors extrinsic to the population.
5. The concentration zone is, in effect, an ecotone dominated by one species which exists between the chironomid-rich littoral zone and the sparsely inhabited reaches of the profundal zone.
6. The specimens of T. decorus within the concentration zone would be considered in this instance as an "edge" species. Odum (1959) defines this concept as "organisms which occur primarily or most abundantly or spend the greatest amount of time in junctional communities are often called 'edge' species."

Chemical and Physical Factors Influencing Distribution of Larvae

Oviposition and dissemination

The density of the egg mass of this species is almost that of water. Coldwater Lake, during egg-laying time, is usually well stratified. The more dense layers constitute a shearing plane for the overlying waters, and any eggs dropping from one zone to another would be slowed to a point that currents would translocate the eggs before they finally settled to the bottom. The greatest concentration of larvae was found at depths of 40 feet or more. This distance alone allows for random distribution of the eggs. Air movements on the surface of the water also contribute to random oviposition,

because of the weakness of flight inherent in the adults of T. decorus.

Very little is known about the per cent emergence from eggs or survival through the first instar. Present sampling methods make it nearly impossible to recover larvae between hatching (0.6 mm) and the first instar (about 3.5 mm). During this instar the larvae are planktonic. Some were collected in sediment chambers which were 4-1/2 to 5 inches above the bottom muds. Observations of similar aquatic species during this critical stage have revealed that many larvae failed to emerge and that many more failed to establish themselves during the first hours of larval life. Rearing experiments carried on in the laboratory have shown that this age or size group died within hours under conditions in which larger larvae grew through to pupation. The two limiting factors appeared to be food type and particle size.

Larval migration

On the basis of results obtained from sampling, it appears that this species does not migrate, but rather follows a random movement pattern. Anatomically, these larvae are not fitted for coordinated continuous movement, except when the larvae emerge from the egg. At this time rapid undulations of the body cause the

larvae to swim for short distances. The direction is random, and only in the case of strong light are young larvae negatively phototropic.

Rearing experiments have shown that many larvae perish if food is not within a few centimeters of their case or tube. In the laboratory many mature larvae (10–20 mm) did not survive unless food was in suspension and deposited over their case or tube.

On the basis of sediment accumulation and the concentration of organic matter in the sediment, it was found that the larvae did not perceptibly migrate to those areas which received higher concentrations of organic matter. The area of highest concentration of organic matter (food for the larvae) was about 200 feet from both the shoreward margin and the lakeward margin of the larval concentration zone. If the larvae of this species could react to a food gradient with any degree of success, the distance of 200 feet would not be too great for the immature larvae to traverse before they had completed their metamorphosis (110–170 days).

Light

Experiments in rearing have shown that larvae survived and pupated either with or without light. In the laboratory, it was observed that more larvae completed metamorphosis if light was

discontinued at the time of pupation. In Coldwater Lake, however, it is questionable that light penetrated in sufficient amounts to the larval habitat to be a limiting factor. A group of 10-millimeter larvae placed in a refrigerator in complete darkness for 72 days grew to mature (15–16 mm) larvae and pupated when brought out into the warm lighted room. In this case, light did not inhibit pupation. This was possibly due to the physiological age of the organism at this stage of development.

Temperature

Temperature ranges on the bottom of the lake (Table I) did not exceed 10°C annually. These changes in temperature were slow and probably did not exceed 6° to 7°C for any one generation of larvae. It was found by laboratory experiments that larvae will grow and mature at a temperature held at 4°C. Low temperatures did not seem to hinder the rate of ingestion or other metabolic activities. In a feeding experiment designed to test the effects of temperature on the rate of ingestion, twenty (10–12 mm) larvae were placed in a 50-milliliter vial. One-tenth of a gram of aluminum powder thoroughly mixed with 10 milliliters of freshly collected sediment was poured over the larvae. The vial with the larvae was placed in a refrigerator at 4°C. At the end of each succeeding

hour, one larva was removed from the vial and the intestinal tract was dissected out. The aluminum particles mixed in the sediment were clearly visible through the intestinal wall (Fig. 12), and their progress through the gut could be measured in millimeters per hour. At 4°C the aluminum moved through the gut at the rate of about 2.5 millimeters per hour or through the 12-millimeter larvae in 8 to 12 hours. Previous experiments with such inert substances as chalk, fine sand, and powdered charcoal had set the time of passage close to 24 hours for this size larvae at the same temperature. The experiment was repeated one month later. At the end of each hour, three larvae were removed instead of one. A comparison of their average rates of ingestion indicated no differences existed between the first and second tests.

Larvae held at 11°C and 22°C did not feed continuously, and time for the rate of ingestion was inconclusive. Larvae in rearing trays at 22°C in many cases failed to mature; most of them died before pupation.

Bottom muds

The bottom within the concentration zone is muck, with little variation from one station to the next, except for the lower limits of station 3 and the upper 30 feet of station 4, where more fibrous



Figure 12

The light flecks apparent along the intestine are particles of aluminum as they appear through the gut wall.

peat and particulate material were found. This is shown in the per cent volume of residue left from bottom muds washed through an 80-mesh nylon net (Table IV; Fig. 3). Curry (1952) investigated Coldwater Lake in 1949–50 and showed that there was less than 4 per cent difference in both combustible and noncombustible matter at the same location as shown by this investigation. Analyses of sediments accumulating at the seven stations showed a progressive decrease of inorganic materials between stations 3 to 9. No significant correlation between bottom type and larval distribution could be drawn from the data obtained in the analyses. Because T. decorus larvae inhabit the bottom mud and are dependent upon it for food and cover, a closer consideration will be given to bottom composition under "Sediment Composition and Distribution of Larvae," with special attention to distribution of organic matter.

Oxygen

Walshe (1947b) showed that complete absence of free oxygen for short periods is not a limiting factor for the "plumosus type" larvae. Other workers (Harnisch 1936; Ewer 1942) have proposed that the hemoglobin-containing members of this group are capable of existing by anaerobic respiration. The population of T. decorus in Coldwater Lake survived through 28 days or more in the absence of

measurable oxygen as determined by the modified Winkler method (American Public Health Association 1955).

At the beginning of the stagnation period, oxygen disappeared from stations 5 through 9 at about the same time. Stations 3 and 4 came close to becoming stagnant, but were never completely devoid of measurable oxygen. The above investigators generally concluded that T. plumosus (a species closely related to T. decorus) does exist for considerable periods of time under anaerobic conditions. During these periods the larvae are able to maintain metabolic processes. Anaerobiosis is thought to be possible for extended periods without incurring an oxygen debt by excreting metabolic products such as lactic acid and other organic acids resulting from incomplete glycogen metabolism. With the return of oxygen, the larvae's hemoglobin does not seem to be functional as a transporting agent of oxygen during basal metabolic periods. However, Walshe believes it is important in storing oxygen for a limited time in order to decrease the time of respiratory undulation characteristic of "plumosus-type" larvae.

pH

The benthic pH range found at Coldwater Lake does not appear to be a limiting factor in the distribution of T. decorus. Again,

as with oxygen, the range from stations 3 through 9 does not exceed the limits that these larvae are known to tolerate. Walshe (1950) found that T. plumosus demonstrated normal activities within a pH range of 6.5 to 8.1. The production of hydrogen sulfide during the stagnation period may build up to a point where acid conditions within microhabitats may exceed the limits tolerated by these larvae. In August, 1954, prior to this research, a large number of dead T. decorus larvae were observed in samples taken from Coldwater Lake over the area covered by this investigation. It was noted at the time of sampling that a strong hydrogen sulfide odor prevailed over the sample screen.

In view of the cosmopolitan distribution of this insect, it can be assumed that the species is tolerant to a wide range of chemical and physical variations. It would appear that the limits for the factors mentioned above do not materially control the distribution of T. decorus in Coldwater Lake.

Biological Factors Affecting Distribution of Larvae

Nutrients used by larvae

A large portion of the bottom deposits is formed in many second-order lakes by plankton and plant detritus that settle out of

the littoral and trophogenic regions. These deposits are often supplemented with chemical precipitates, washed-in drift, and soil particles.

Examinations of the content of the intestinal tracts of T. decorus have shown that there is little or no difference in the comparisons of gut content with sediment samples (Figs. 13, 14). It has been concluded by this investigator that T. decorus is an indiscriminate feeder. The larvae are not physically able to separate the organic and inorganic components of sediment, and as a result they ingest the accumulating sediments and digest the organic portions.

Feeding habits of larvae

T. decorus is classified as one of the tube-building midges. The method of construction of the tube has been observed and follows a pattern similar to that described by Walshe (1947c) for T. plumosus. The U-shaped tube is constructed by grasping particles of sediment and by binding them into a tube around the body with the aid of a salivary-secreted thread. The tube is formed around the posterior end of the abdomen and continued up and over the head. Due to the flexibility of the larvae, it can turn around in the tube and add additional sediment to each end, to complete the

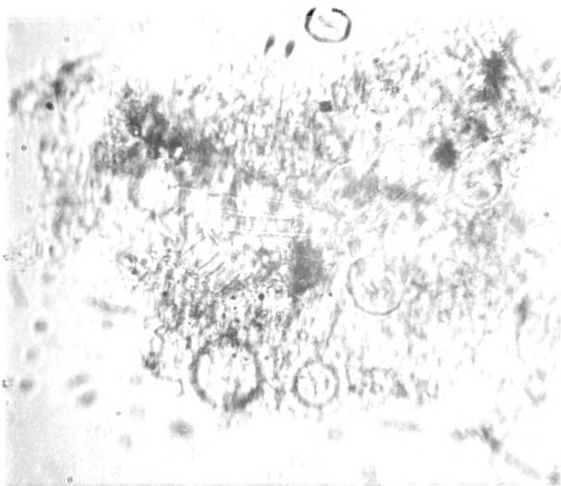


Figure 13

This sample was removed from the gut of a ten millimeter larvae.. It can be seen by the unbroken colony of Melosira sp (left center) that the larvae ingest the sediment in toto. The large discs are Stephanodiscus sp.

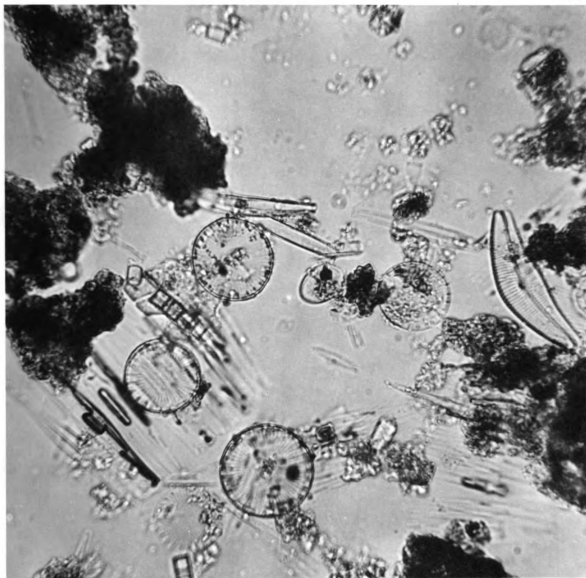


Figure 14

This sample of sediment was removed from the sediment sampler at Station 6 on November 3, 1957. Close examination of the diatoms will show oil droplets or plastids (light circular areas within the frustules) evident in many of the specimens.

tube. The openings of the U-shaped tube are at the interface of the mud and water. The tube is thought to have several functions. In T. plumosus, Walshe (1947c) points out that it offers protection, provides a constriction around the larvae for irrigation of body surface in respiration, and provides an anchorage for a salivary-secreted cone for filter feeding. Undulation of the body creates a current within the tube, drawing sediment-laden water through the cone filter. The cone and its contents are then ingested. Tendipes decorus larvae build a tube similar to T. plumosus but have never been observed building the cone by this investigator. Observations in the laboratory have shown that T. decorus will build a case only when there is a scarcity of both food and oxygen.

At temperatures from 4° to 6° C, 10-millimeter larvae, placed in freshly collected sediment, filled their intestinal tract before building a case. On numerous occasions, the larvae would spin only enough tube to anchor the posterior end so that they could feed on the surface of the sediment.

In an experiment designed to determine the effect of temperature on the rate of case construction, it was noted (Fig. 15) that, with the increase of temperature, case construction proceeded at a much faster rate than at lower temperatures. Case construction at temperatures from 1° to 10° C usually was not started until one to

LARVAL CASE CONSTRUCTION AT VARIOUS TEMPERATURES

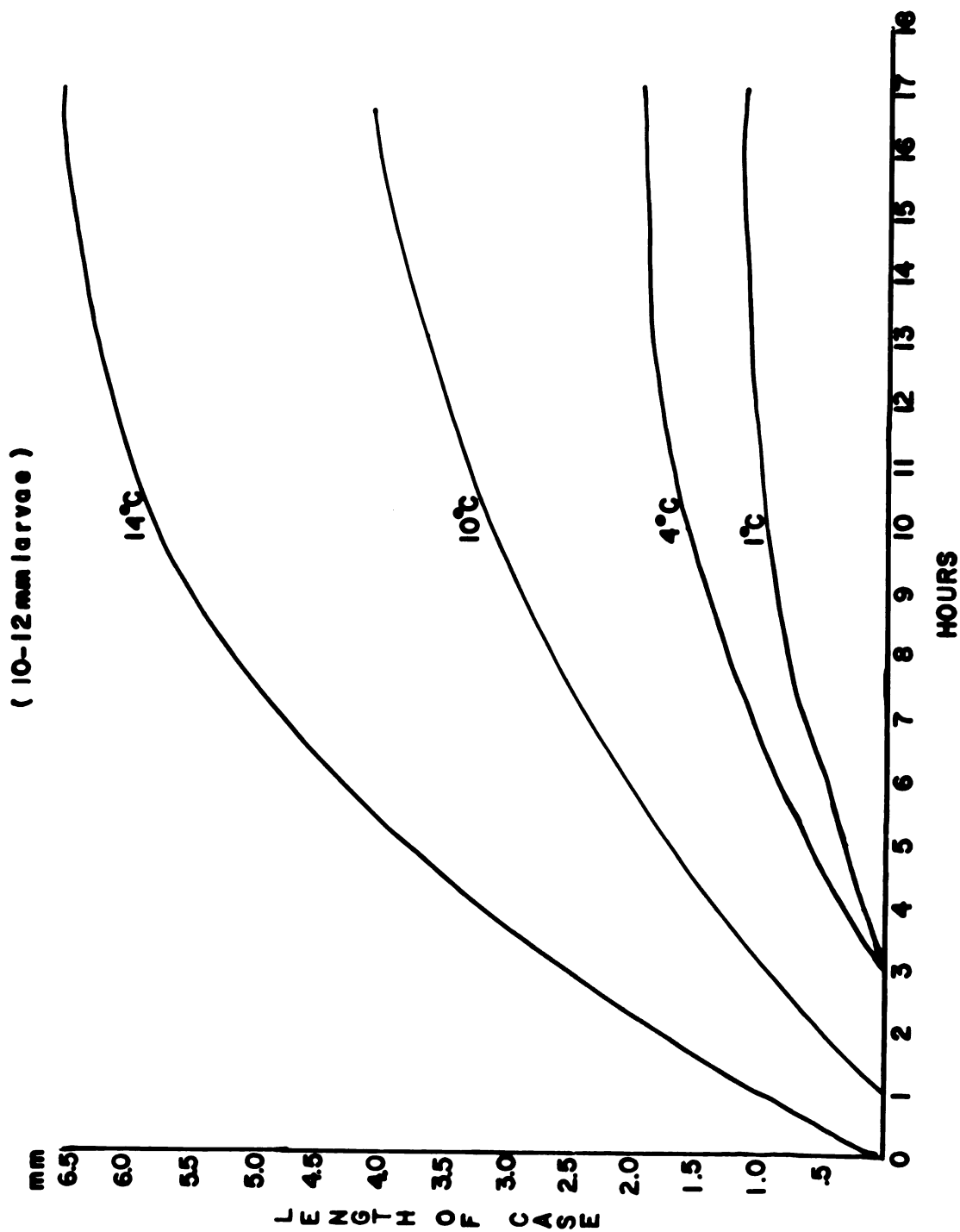


Figure 15

three hours after the naked larvae had been placed in the sediment. Even then, individual larvae varied greatly in their case-building activities. The rate of ingestion did not vary much when temperatures ranged from 4° to 14° C.

At temperatures higher than 14° C, case-building started immediately and continued until the larvae had enclosed itself within the tube. This is probably due to the lower oxygen content which would be the case at these higher temperatures and would necessitate tube construction for respiratory movements.

The methods of feeding for the profundal chironomids can be reduced to three basic categories with modification for different species: (1) construction of a cone net in the tube to trap plankton and ingestion of the net; (2) scraping of the walls of the tube and the ingestion of trapped particles; (3) feeding on the surface around the entrance to the tube. These methods are listed in the order of food and oxygen availability. The first and second methods are used when food is scarce; the third is used when food is plentiful and oxygen is abundant. T. decorus appears to favor fresh sediments over mineralized sediments. When in fresh sediment and at cold temperatures, the larvae would go 12 to 72 hours before building a complete tube. When placed in mineralized bottom muds at the same temperature, larvae usually completed tubes within eight hours.

Sediment composition

The measure of sediment was the amount in oven-dry weight accumulating on a two-inch-square surface for a two-week period. Figure 16 shows the accumulations of organic and inorganic sediments from June, 1956, to December, 1957. It will be noted that there is a steady decrease in total accumulation from stations 3 through 9. This distribution does not correspond to the distribution of larvae along the transect. In the quantitative analysis of sediment, it was found that the per cent organic matter was not proportional to the total sediment accumulation. The per cent organic matter increased from station 4 to station 6, and then gradually decreased from station 6 to station 9.

Organic sediments

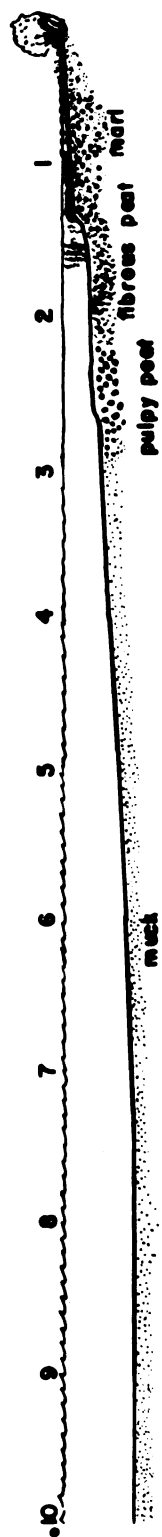
There are two main sources of sediment. One is in the trophogenic layer within the limnetic zone and the other is the littoral zone.

Phytoplankton makes up the bulk of sediment from the limnetic zone. In Coldwater Lake, most of these were diatoms (Chrysophyta). Some of the more common diatoms were represented in the following genera: Tabellaria, Orthosira, Synedra, Stephanodiscus, and Fragillaria. Less common were Encyonema, Denticula, Cyclotella,

PROFILE OF SAMPLING TRANSECT

Stations 1-10 100ft. apart

— NW —



SEDIMENT DISTRIBUTION ON TRANSECT

Bi-monthly average of total sediment accumulation

June 15, 1956 - Dec. 3, 1957

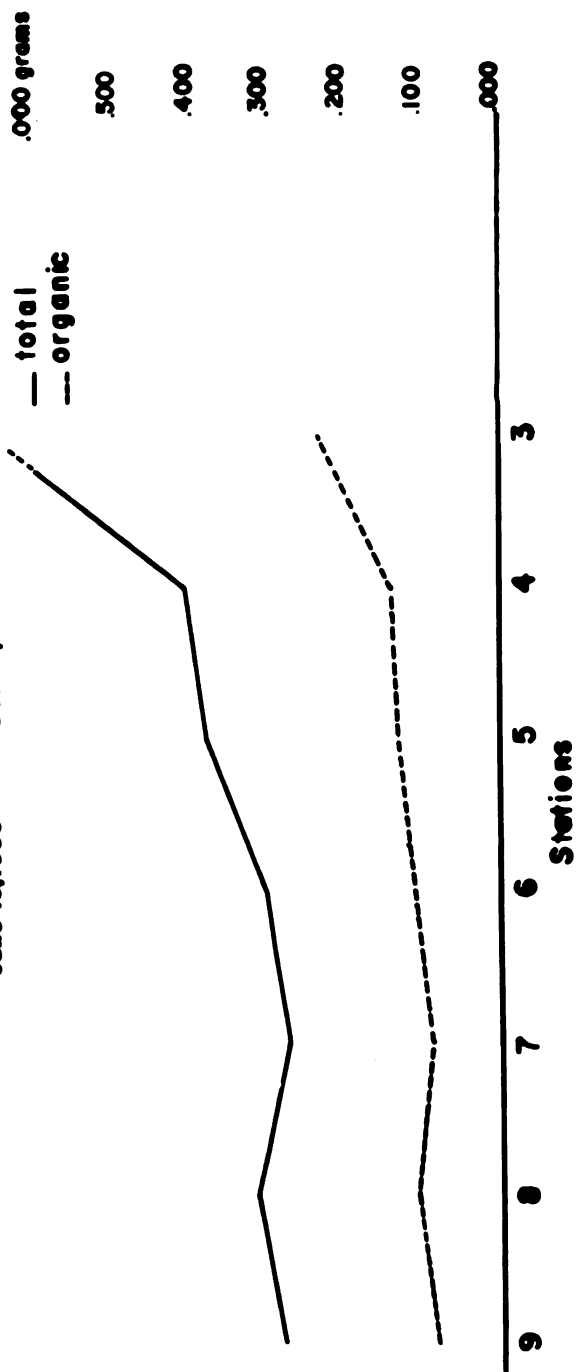


Figure 16

and Amphora. The blue-green algae (Cyanophyta) were represented with occasional filaments of Oscillatoria and fragments of colonies of Gleotrichia sp. The green algae (Chlorophyta) were lacking in most of the samples.

Periodic blooms that appeared in the upper strata in water samples lost their identity as blooms by the time they had settled into the lower hypolimnion. Examinations of the sediment collected in the chambers showed that there was not a discernible qualitative difference from one sample to the next. When comparisons of seasonal composition of sediments were made, it was difficult to define the difference. The winter samples were dominated by diatoms with few green and blue-green algae. The colonial blue-green algae, which were evident in mid and late summer, were absent in the winter samples. This inability to establish periodicity for successive samples suggests that both time and mixing enter into the homogeneity of each sample.

Grim (1950) found, in Schleinsee, Germany, a similar condition when he recovered species of diatoms eight to ten times more abundant in accumulating sediments than were found in the highest concentrations of the particular species beneath a unit surface area.

Stations 3 and 4, which were closest to the littoral zone, received considerable quantities of plant detritus and periphyton

from this region. Examinations of sediments from these stations showed that much of the plant detritus and periphyton was encrusted with marl. Chemical analyses also indicated that these sediments were high in carbonates.

A large portion of sediment from stations 3, 4, and part of 5 was from the littoral zone, while stations 6 through 9 received most of their sediment from the limnetic zone. This is indicated by the percentage of carbonates in the sediments when we observe the difference between total accumulation and per cent organic matter. Accumulations at stations close to the shore were heavier, but had a lower percentage of organic matter than stations farther out in the profundal regions.

It can be theorized that the littoral contributions to the profundal muds are produced by two limnological phenomena: (1) the subsurface seiche movements of the lake water tend to move the sediment with a specific gravity greater than one gradually down the basin slope to a point where the gradient gives way to the profundal plain; and (2) the wind-influenced mixing of surface waters with those of the hypolimnion which takes place in Coldwater Lake at the juncture of the thermocline and the sublittoral portion of the basin. Many current-dependent organisms would drop into the more dense strata and would accumulate below these junctures. There

are undoubtedly other physical conditions and related phenomena that contributed to the greater accumulations occurring just below the sublittoral zone.

The factors influencing limnetic sedimentation are poorly understood, and little work has been done in the field of interrelationships between chemical-physical limnology and the biochemical aspects of plankton sedimentation. Welch (1952) mentions no less than twenty factors which contribute to sedimentation. It can only be stated here that the accumulations of sediment from stations 3 to 9 showed a steady decrease in amount while the organic accumulation within the total sediment followed a distribution similar to that of the larvae at the same stations. The sediments in the concentration zone undoubtedly received contributions from both the littoral and limnetic production of plankters.

Sediment composition and distribution of larvae

The organic part of the sediment accounted for an average of 31.1 per cent of the total accumulation for all stations. There was less than 6 per cent range from the lowest of 29 to the maximum of 35 per cent. The range for organic distribution plus the variation in biweekly accumulations of sediment superimposed on the life cycle of T. decorus appeared to be sufficient in establishing the benthic



limits of the concentration zone. The range in amount of silica (a good indicator for diatom content) was less than 5 per cent. The silica content averaged 30 per cent of the inorganic portion of the sediment. Birge and Juday (1922) found an average of 30.78 per cent silicates in Lake Mendota sediments. Kleerekoper (1952b) reports sediments as having 28 to 36 per cent silicates in samples taken just below the thermocline by his one-meter-square samples in Lake Lauzon.

The fall overturn produces the maximum sediment accumulation for the year due to the loss of stratification and aggressive carbon dioxide. After the fall overturn the sediment accumulation is relatively constant. This condition remains through the formation of ice and continues until ice breakup in spring. A large accumulation of sediment occurs during the first week immediately following the spring overturn. The sediment averaged 50 per cent or more of carbonates for this two-week sample.

When the average biweekly accumulation of organic matter for each station during the 18-month sampling period was compared to the number of the larvae per unit area at each station, a definite correlation was evident (Table VIII).

In order to make a correlation coefficient analysis it was necessary to convert per cent organic matter to grams of organic

TABLE VIII

LARVAL DISTRIBUTION AS RELATED TO ANALYSIS OF
SEDIMENTS, JUNE, 1956, THROUGH DECEMBER, 1957^a

Station	No. of Larvae per Sq. In.	Grams of Sed- iment per Sq. In.	Grams of Or- ganic Matter per Sq. In.	Per Cent Or- ganic Matter
3	.123	.3290	.1147	34.85
4	.188	.2062	.0698	33.77
5	.297	.1912	.0667	34.89
6	.281	.1549	.0514	33.14
7	.217	.1390	.0449	32.28
8	.158	.1620	.0482	29.74
9	.141	.1412	.0418	29.60

^aThese data represent averages of seventy-six Ekman dredge samples from each station and twenty-eight sediment samples from each station.

matter per 10 grams of sediment. These conversions and the average number of larvae are compared in Table IX.

Because station 3 is next to the littoral zone and was receiving a major portion of its sediment from there, and because the particulate matter greater than .025 millimeter in diameter settling in this region contributed considerably to the organic sediment, it was decided that this station should not be included in the correlation. It was found that the larval densities at stations 4 through 9, when compared with organic accumulations, had a correlation coefficient of .83 and that this was significantly different from zero at the 5 per cent level of confidence.

If the amount of organic matter is the critical factor in the distribution of T. decorus, as it appears to be in this lake, then there must be a direct correlation of organic matter with a particular period of the larval life history. The amount of organic matter accumulating at any station must affect either the growth of the larvae or the survival of the larvae, at one station as compared to another.

Per cent organic matter
and growth of larvae

An analysis of variance was made on the mean growth in larvae lengths for one generation (December, 1955, to July, 1956).



TABLE IX
DATA FOR CORRELATION COEFFICIENT

Station	No. of Larvae per Sq. In.	Grams of Organic Matter per 10 Grams of Sediment
3	.123	3.4850
4	.188	3.3770
5	.297	3.4888
6	.281	3.3137
7	.217	3.2275
8	.158	2.9735
9	.141	2.9597

This was done by comparing mean lengths of larvae for each station with larvae from each sampling period between the above dates. The estimate of the population variance of combined sample mean lengths was computed from the F distribution of the "within-group variance" (S_w^2) divided into the "between-groups variance" (S_b^2) with a K (n-1) and K-1 degrees of freedom, respectively.

A summarization of the calculations is presented in Table X. In three of the nine comparisons, no significant difference exists in the estimated value of F from that found for F_{95} . These means would thus be homogeneous. In the other six, at least one station for a given date was different from the others. On January 31 and July 2, 1956, there was unity at the 1 per cent level. It must be concluded that there is a tendency for the population to grow at the same rate even though it was indicated in only three of the nine samples. This conclusion is drawn from the fact that the population N ranged from 320 to 646 and the sample n from 6 to 155, increasing the probability that one station would be different from all the rest.

It has been shown that there is a positive correlation between the number of larvae per unit area and the distribution of organic matter over the concentration zone. From the analysis of the larval growth rates, it may be assumed that the larvae grow at about the

Table X

SUMMARIZATION OF P. DISTRIBUTION OF LARVAL MEASUREMENTS

Date	Station 3		Station 4		Station 5		Station 6		Station 7		Station 8		Station 9		Population Variance		
	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	$\bar{P} = \frac{\sum x^2}{n}$	$\bar{P} = \frac{\sum x^2}{n}$	$\bar{P} = \frac{\sum x^2}{n}$
Dec. 19	6	10.70	58	11.66	105	10.91	127	10.50	90	10.60	51	9.12	15	8.95	425	14.32	2.12 2.85
Jan. 1	9	9.24	68	10.53	130	10.35	135	11.75	88	11.25	31	12.51	14	11.54	475	6.98	2.12 2.85
Jan. 14	21	10.13	138	11.05	155	10.60	163	11.46	98	11.79	40	12.45	31	11.10	646	4.25	2.12 2.85
Jan. 31	13	11.06	83	11.99	103	10.92	134	11.67	105	12.05	51	11.59	16	11.48	505	1.58	2.12 2.85
Feb. 15	13	12.89	63	12.61	120	11.91	135	13.31	101	12.30	35	11.90	11	12.40	478	5.74	2.12 2.85
Mar. 10	16	12.48	78	12.61	123	11.37	152	11.92	80	11.40	55	10.61	21	10.47	525	3.14	2.12 2.85
Mar. 25	13	11.66	73	10.45	115	10.62	133	11.44	70	11.35	33	10.40	13	11.66	437	2.58	2.12 2.85
June 2	6	12.57	31	12.79	30	13.19	60	13.03	60	13.66	25	14.22	18	12.75	230	3.29	2.12 2.85
July 2	25	13.13	48	13.45	86	13.36	103	13.60	81	14.20	32	14.25	24	14.45	399	1.98	2.12 2.85

same rate at all stations and the larvae at one station do not show a consistent difference in relation to the others.

The limiting factor, then, must be effective between the time the larvae emerge from the egg and when they reach a size which can be collected (0.6 millimeter and 3.5 millimeters) with existing apparatus.

Therefore, the per cent organic matter and its composition may be one of the most critical factors in the survival of the minute forms of T. decorus.

Sedimentation and pupation

When the time of appearance of new larvae is compared with the total sediment accumulation for that sampling period, a close relationship appears at all stations. Each peak accumulation of sediment for the season occurred at the same time as the maturation and pupation of T. decorus larvae, followed by the subsequent appearance of new larvae. The coinciding dates for these phenomena were the weeks of July 2 and November 10 in 1956, and July 1 and November 18 in 1957 (Figs. 17-23).

The occurrence of these two apparently unrelated events at the same time suggests that a third factor stimulates the larvae to pupate and emerge at the same time that materials of which sediments

Sediment Accumulations as related to Larval Populations of Tendipes descurvi

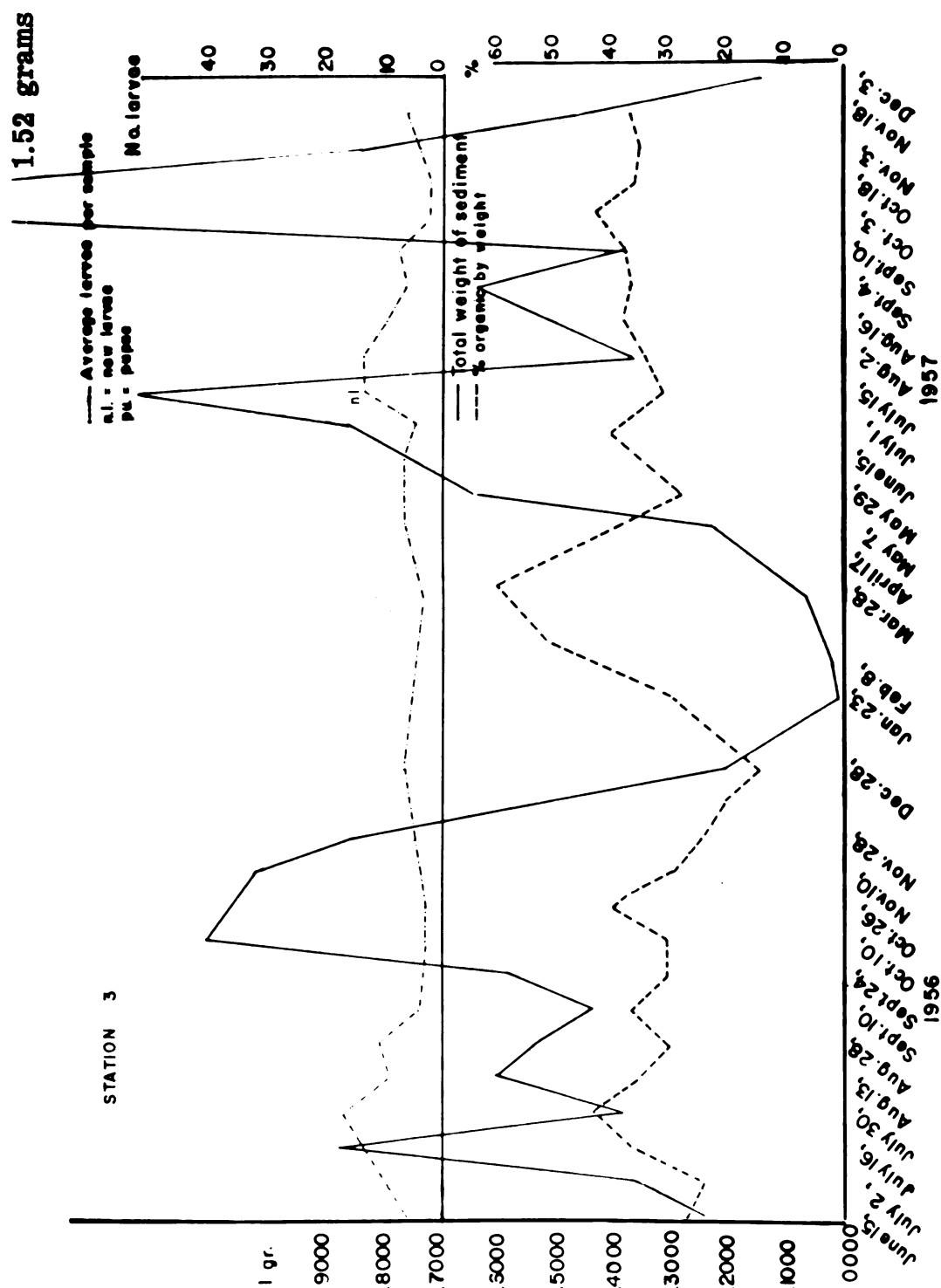


Figure 17

Sediment Accumulations as related to Larval Populations of *Leandineae decorus*

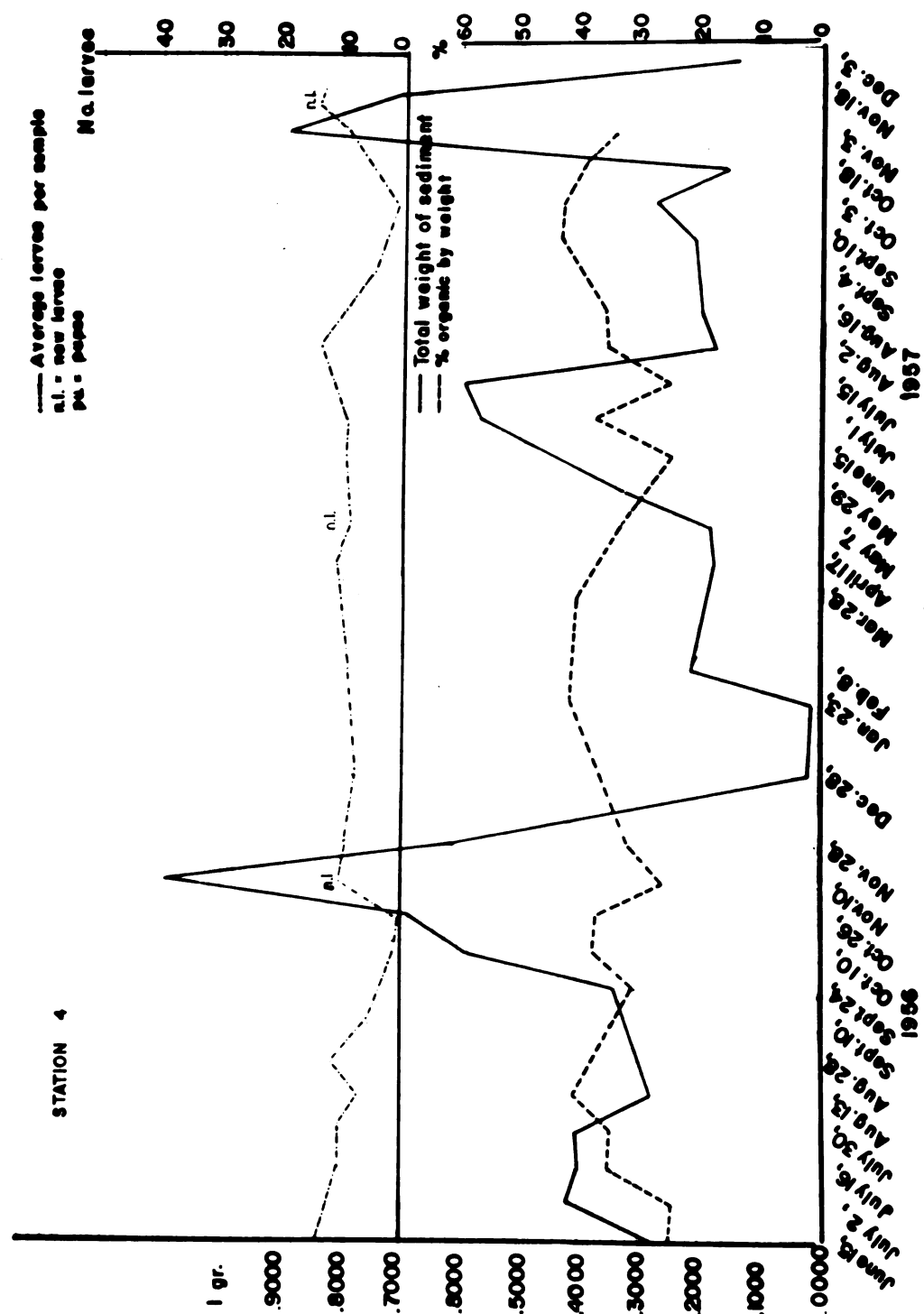


Figure 18

Sediment Accumulations as related to Larval Populations of Leaenae decurre

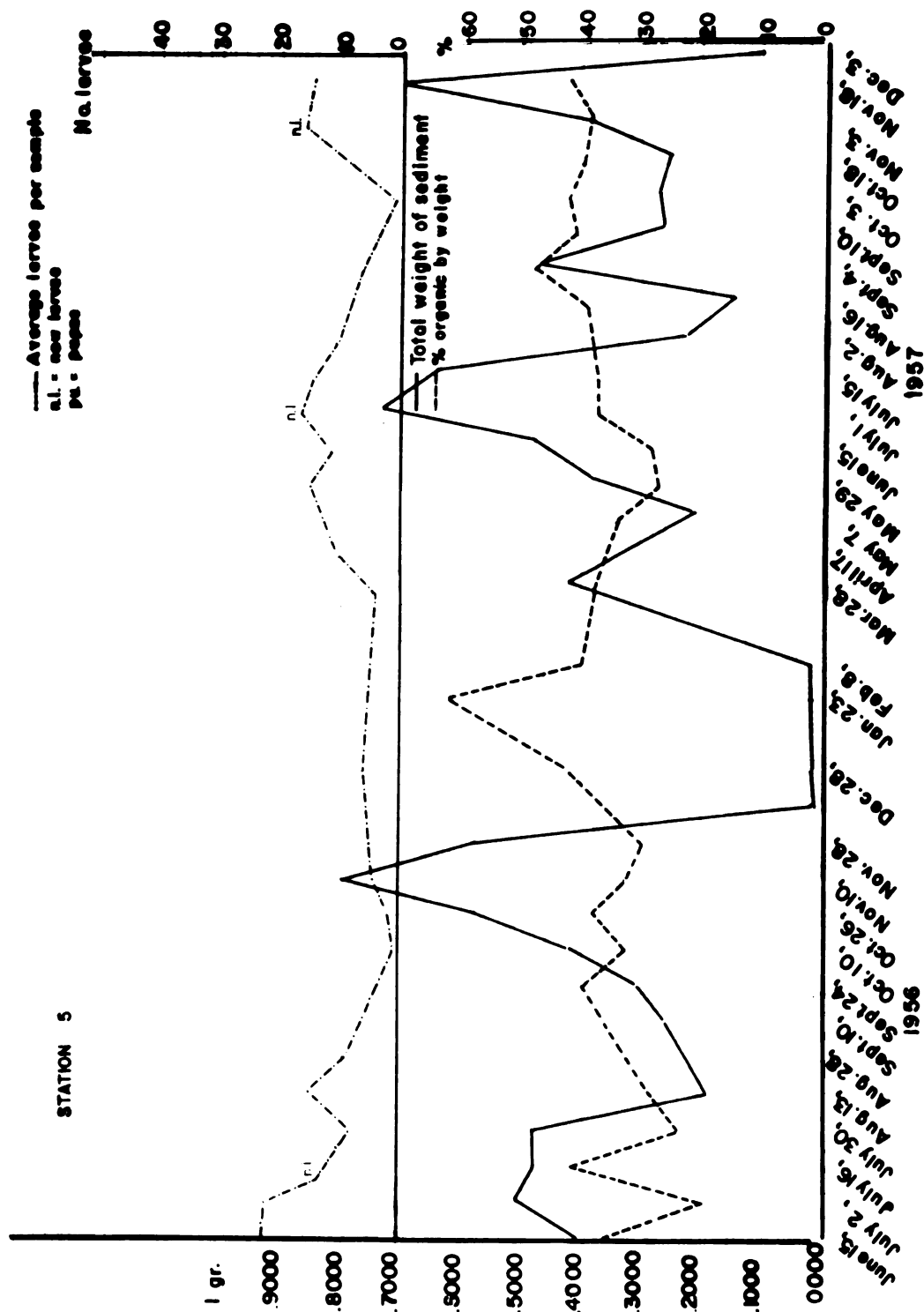


Figure 19

Sediment Accumulations as related to Larval Populations of Tendipes descurvi

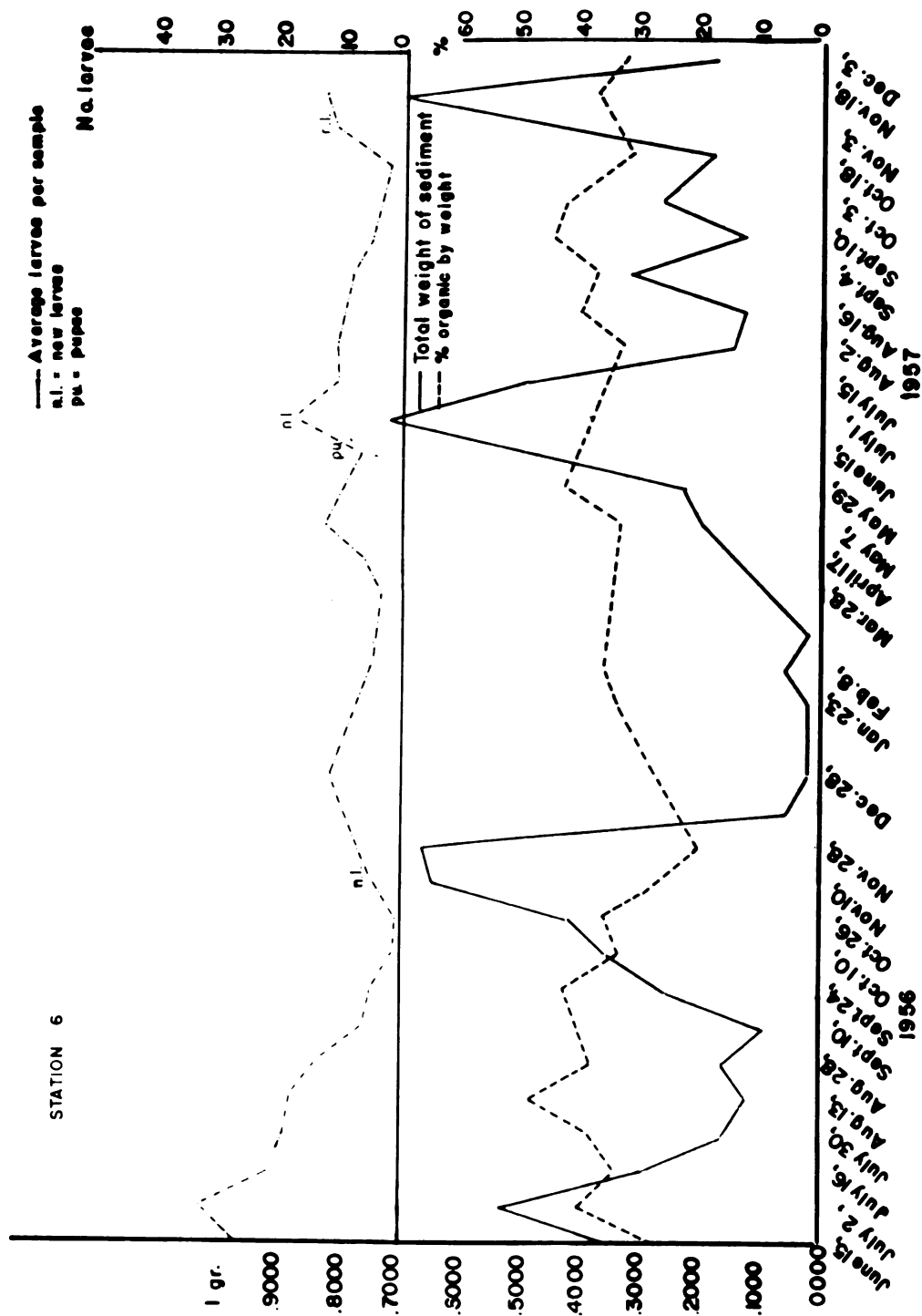


Figure 20

Sediment Accumulations as related to Larval Populations of Tendipes decorus

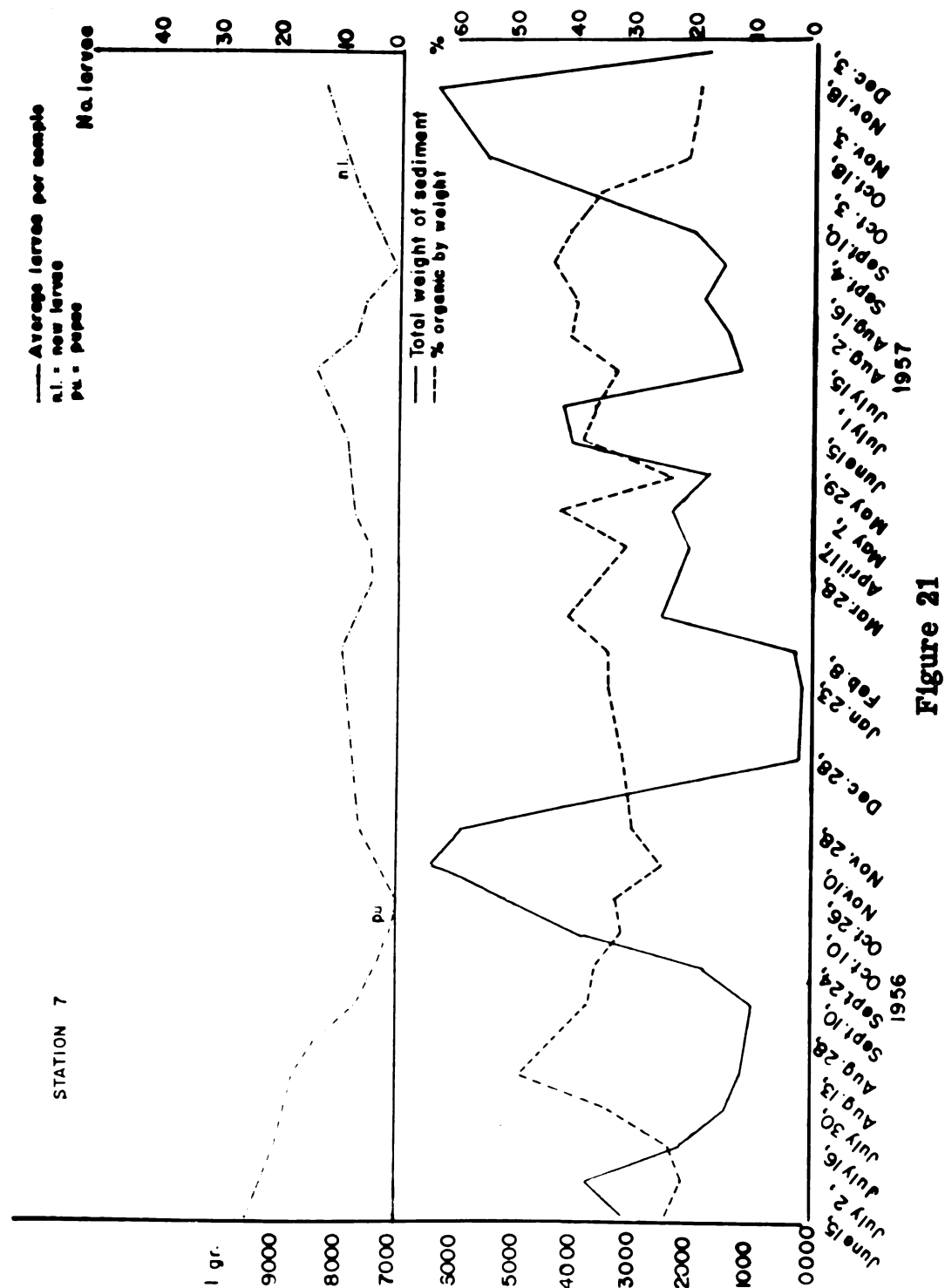


Figure 21

Sediment Accumulations as related to Larval Populations of Tendipes descurvi

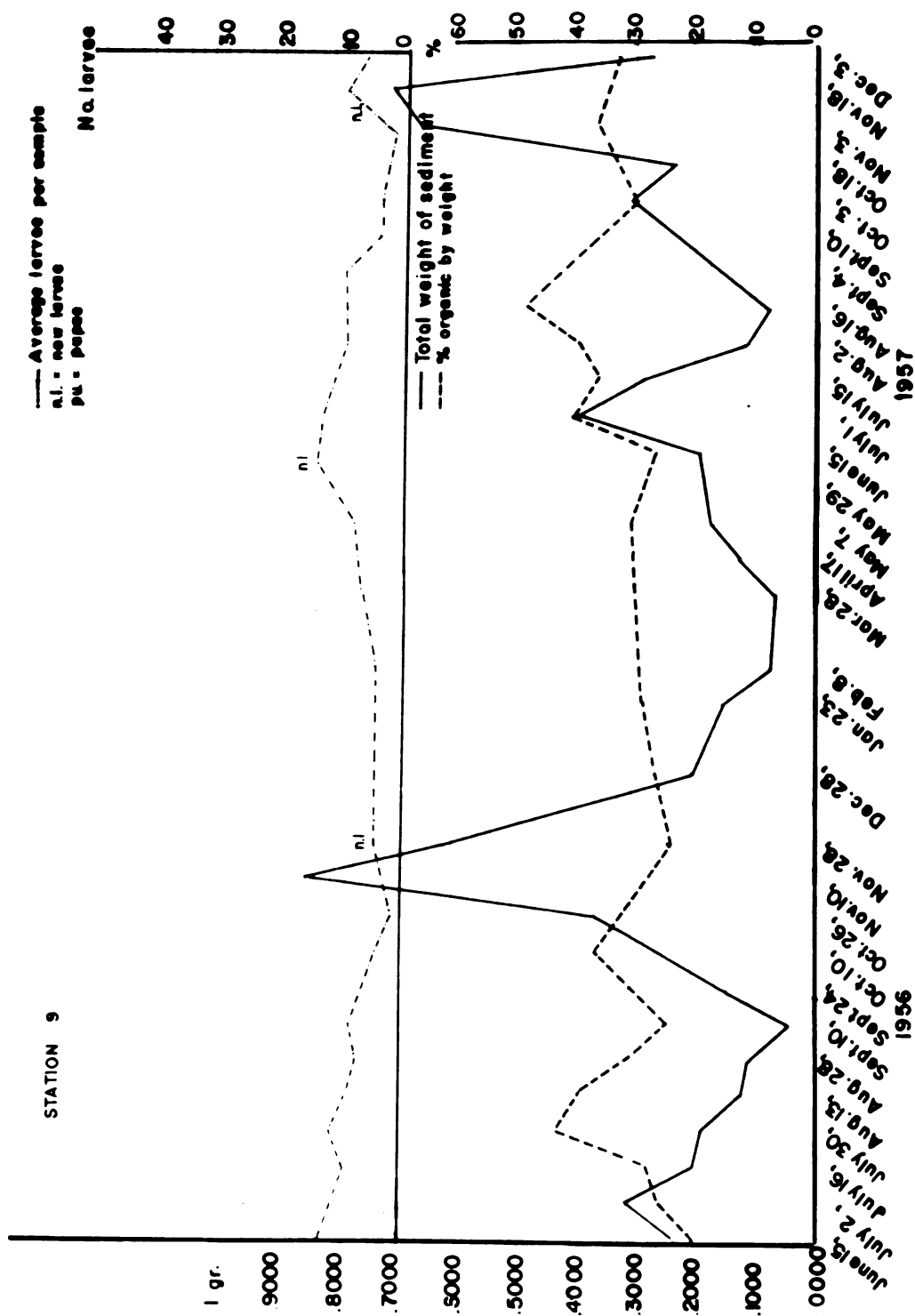


Figure 23

are composed are building up for their heaviest accumulation (Fig. 24). The maturing larvae may possess an inherent ability to anticipate the heavy accumulation of sediment and initiate pupation prior to this period or are inhibited from emerging due to adverse conditions prior to the heavy sedimentation.

If the factor is one of inhibition, then it could be assumed that these larvae are capable of undergoing a temporary diapause. Diapause in insects is a type of physiological arrest and has been observed in many arthropods. Wigglesworth (1950) points out that the arrest may be in any stage of metamorphosis from egg to adult and is probably induced by both external and internal stimuli; these range from inborn cyclic factors to lack of nutrients for continued growth.

Diapause in aquatic insects is usually short in duration. The mosquito larvae of Aedes when not permitted to fill their tracheal system stop growing during the second instar due to the lack of oxygen. This type of temporary diapause is true for "homodynamic" insects in which a "continuous succession of generations occurs as long as conditions are favorable and in which growth is arrested only by the direct action of adverse circumstances" (Wigglesworth 1950). The factor that may initiate diapause prior to pupation in the profundal population of T. decorus could be stagnation.

Chronology of Limnological Events
as they occurred in Coldwater Lake
Station 6. 1957

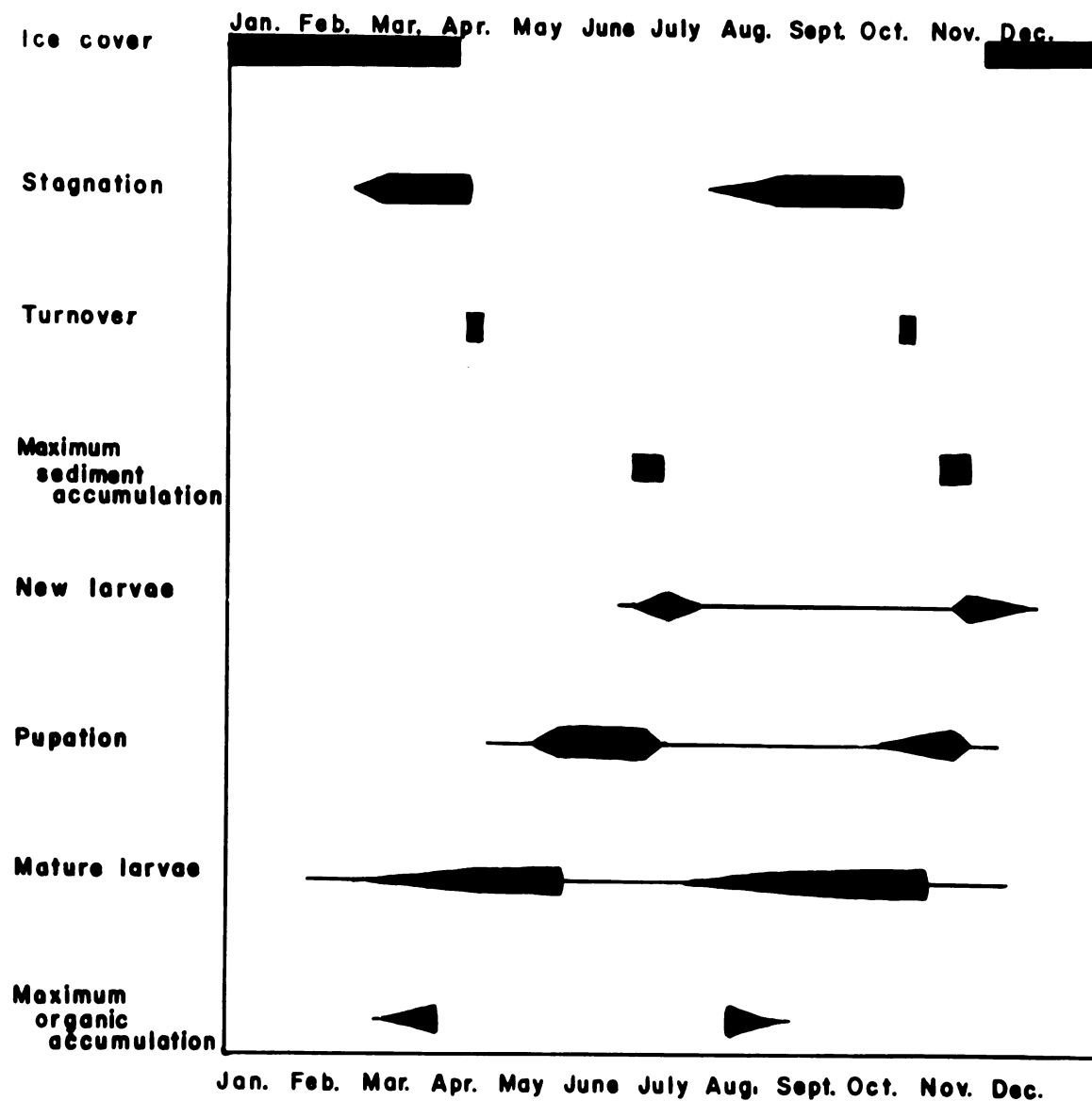


Figure 24

The absence of oxygen-transporting pigments in the first-instar larvae would virtually eliminate the possible survival of any young larvae emerging from eggs deposited at this time.

This investigation confirmed an observation of Curry (1952) that the larvae prior to pupation reached a growth "plateau." This plateau appears at about 16 millimeters and may last for 15 to 30 days prior to pupation. During this time the larvae continue to feed. The only noticeable difference in the larva during the plateau effect is an accumulation of fat in the region of the salivary glands which extends back into the prothoracic and mesothoracic segments of the larvae. This period of fat deposit coincides with a period when the per cent of organic matter is high in comparison to the total accumulation of sediment. At the time of the heaviest sediment accumulation, the eggs are deposited and the young larvae appear in the samples. In observing the similarity of dates for oviposition and maximum sediment accumulation for the two years, it would appear that the factor of coincidence is environmental and closely related to the physical events within the lake. These events are listed in the order of their occurrence:

1. The larvae have reached a growth plateau prior to summer and winter stagnation.

2. The sediments built up during stagnation are high in organic content.

3. The consumption of rich organic sediments during stagnation results in anaerobic respiration which contributes to the accumulation of partially metabolized fats.

4. Emergence occurs just prior to the accumulation of sediments low in organic matter.

5. The approaching spring and fall overturn guarantees a new supply of nutrients for the pelagic plankton which will settle out over the next generation of larvae.

In 1956, spring and fall overturns occurred on May 20 and October 26; in 1957, the dates were April 17 and October 22. In each case, the overturn preceded the heavy accumulation of sediment and the crest of larval pupation. Chronologically, these events were closely related to the morphological events of the T. decorus population. These events are summarized in Figure 24.

It is impossible to conclude that T. decorus has an inborn cyclic factor which controls emergence. Miller (1941), writing of Lake Costello, in Ontario, indicates that T. decorus has two generations in the summer (40–50 days each) and one during the winter. This lake lies at a latitude north of Coldwater Lake. In Coldwater

Lake there are two generations of T. decorus. The length of time for summer generations varied from 110 days in 1956 to 112 days in 1957. The overwintering generation took 150 days in 1956 and 170 days in 1957. These figures are based on dates when the number of larvae in the samples dropped considerably at all the stations. These data are similar to those found by Curry (1952) on the same lake.

In any case, whether it be a morphological arrest or an inherited cyclic rhythm, the larvae of T. decorus in the profundal region of Coldwater Lake undergo pupation and emerge prior to the heavy sediment accumulations; and the appearance of the young larvae coincides with that of the heavy fallout of sediments.

Pupation and emergence

As pointed out in the life history of this species, the direct relationship of pupation and emergence to the reintroduction of T. decorus into the same zone of concentration in the lake is highly unlikely.

Pupation follows normal distribution in occurrence. The pupa begins to form about 8 to 24 hours before emergence. Emergence in Coldwater Lake usually started just after dusk and continued until about 4:00 a.m., reaching a peak between 9:30 and 11:00 p.m.

The major portion of the population within the concentration zone emerged from the lake for about two weeks in spring and slightly longer during fall.

Ten to fifteen seconds after the pupal skin ruptures, the adult T. decorus is able to fly. The imagos spend a few seconds in extending the wings. Curry (1956) observed that adults gathered into swarms 10 to 15 feet above the water surface and moved en masse, horizontally, back and forth within a 15- to 20-foot radius. Mating occurs in flight. Oviposition may take place immediately or as late as 14 days after emergence.

CONCLUSION

Many eutrophic lakes have populations of chironomid larvae concentrated at the juncture of the sublittoral and upper profundal zones. Such areas have been termed "concentration zones." The factors contributing to the location of these population concentrations have not been determined.

The results of this investigation have shown that the larval concentration of the midge Tendipes decorus in Coldwater Lake was characterized by the following factors:

1. The concentration of T. decorus was at the shoreward margin of a population of larvae that extended throughout the profundal zone. The concentration zone was 12 to 700 feet in width, parallel to the sides of the basin. The frequency of larvae in a transect of the concentration zone approached a normal distribution curve.

2. Results of tests made for chemical-physical variations of the water above the concentration zone were the same as those immediately adjacent to the zone. There was no indication that

such factors as depth, bottom-type, oxygen supply, pH, and light independently influenced the limits of the concentration zone.

3. Oviposition takes place over the entire lake surface, and the young larvae tend to become randomly distributed over the profundal zone.

4. A positive relationship was found between the distribution of maturing larvae in the concentration zone and the amount of organic matter in the accumulating sediments.

5. All larvae that survived through the second instar grew at the same rate within the concentration zone irrespective of the distribution of the organic content of the accumulating sediments.

It was concluded from factors three, four, and five that distribution of larvae was dependent on the survival rate during the first larval instar, and that sediment distribution and composition were related to survival.

6. Evidence of a chronological relationship between the emergence of adults and the period of maximum sediment accumulation was found. Many larvae reached a "growth plateau" prior to pupation and did not pupate until the rate of sedimentation had increased to the maximum amount during a particular generation.

This apparently unrelated phenomena occurred for the four successive generations studied.

Observations were made concerning the larval habits of Tendipes decorus. These include data on the rate of ingestion and case-building under various laboratory conditions.

LITERATURE CITED

American Public Health Association

- 1955 Standard methods for the examination of water, sewage, and industrial waste. New York, Tenth Edition, 521 pp.

Ball, Robert C.

- 1943 A fisheries survey of Coldwater Lake, Isabella County, Mich. Rpt. No. 872, Inst. Fish. Res.

Barg, T.

- 1943 Fat content of Diatoms. Ber. deut. Botan. Ges., 61: 31-127.

Birge, E. A., and Juday, C.

- 1922 The inland lakes of Wisconsin: The plankton. I. Its quantity and chemical composition. Wisc. Geol. and Nat. Hist. Sur. Bull., 64:1-222.

Branch, Hazel

- 1931 Identification of chironomid egg masses. II. Trans. Kans. Acad. Sci., 33:151-57.

Brundin, L.

- 1950 Chironomiden und Andere Bodentiere der Sudschwedischen Urgebirgsssen. Inst. Freshwater Res., Dröttningholm. Fishery Board of Sweden, Rpt. 30, 915 pp.
- 1956 Die bodenfaunistischen Seetypen und ihre Anwendbarkeit auf die Sudhalbkugel. Inst. Freshwater Res., Dröttningholm. Fishery Board of Sweden, Rpt. 37: 186-235.

Cole, Gerald A.

- 1953 Notes on the vertical distribution of organisms in the profundal sediments of Douglas Lake, Mich. Amer. Midl. Nat., 49(1):252-56.

- Cooper, B. A., Murry, E. G. D., and Kleerekoper, H.
1950 The bottom sediments of Lake Lauzon, Montcalm County, Province of Quebec. II. Bacteriological investigations (M.S.).
- Curry, LaVerne L.
1952 An ecological study of the family Tendipedidae of two fresh-water lakes in Isabella County, Mich. Ph.D. Thesis, Mich. State Coll., E. Lansing, Mich., 252 pp.
1956 Notes on the ecology and taxonomy of the midge *Tendipes* (*Tendipes*) *staegeri* (Lundbeck)-*Chironomus staegeri* Lundbeck (Diptera) Ent. News, 67(9):225-36.
- Deevey, Edward S., Jr.
1941 Limnological studies in Connecticut. VI. The quantity and composition of the bottom fauna of thirty-six Connecticut and New York lakes. Ecol. Monogr., 11(4):413-55.
- Eggleton, Frank E.
1931 A limnological study of the profundal bottom fauna of certain fresh-water lakes. Ecol. Monogr., 1:231-331.
- Ewer, R. F.
1942 On the function of haemoglobin in *Chironomus*. J. Exp. Biol. 18:197.
- Grim, J.
1950 Versuche zur Ermittlung der Produktionskoeffizienten einiger Planktonphyten in einem flachen See. Biol. Zbl., 69:147.
- Harnish, Otto
1936 Primarie und sekundäre Oxybiose der Larven von *Chironomus thummi*. Z. Vergl. Physiol., 23:391.
- Jamnback, Hugo
1941 The biology and control of the midge *Tendipes decorus* (Joh.) in Moriches Bay. N.Y. State Science Service., Univ. of the State of N.Y., 12-13.

- Jarnėfelt, H.
1955 *Über die Sedimentation des Sestons. Verh. int. Ver. Limnol.*, 12:144–58.
- Johannsen, O. A.
1905 *Aquatic nematoceros Diptera. II. Chironomidea. N.Y. State Mus. Bull.*, 86:76–331, 37 plates.
- Kleerekoper, Herman
1952a A new apparatus for the study of sedimentation in lakes. *Can. J. Zool.*, 30:185–90.

1952b The bottom sediments of Lake Lauzon, Montcalm County, province of Quebec. I. Chemical and physical investigations. *Can. J. of Zool.*, 30:219–42.

1953 The mineralization of plankton. *J. Fish. Res. Bd. Can.*, 10(5).
- Leathers, Albert L.
1922 Ecological study of aquatic midges and some related insects with special reference to feeding habits. *Bull. U.S. Bur. Fisheries*, 38:1–61.
- Lundbeck, J.
1926 *Die Bodentierwelt norddeutscher Seen. Arch. Hydrobiol. Suppl.*, 7:1–473.
- Miller, R. B.
1941 A contribution to the ecology of the Chironomidae of Costello Lake, Algonquin Park, Ontario. *Univ. Toronto Studies, Biol. Serv.*, 49:1–63.
- Odum, Eugene P.
1959 *Fundamentals of ecology. Philadelphia: W. B. Saunders Co.*, 384 pp.
- Pennak, R. W.
1953 *Fresh-water invertebrates of the United States. New York: Ronald Press*, 769 pp.

- Richardson, R. E.
 1928 The bottom fauna of the middle Illinois River, 1913–25: Its distribution, abundance, valuation, and index value in the study of stream pollution. *Bull. III, Hist. Surv.* 17(12):387–475.
- Ruttner, Franz
 1953 *Fundamentals of Limnology.* Univ. of Toronto Press, 242 pp.
- Scott, I. D.
 1921 *Inland lakes of Michigan.* Mich. Geol. and Biol. Surv. I–XXI 383. Pub. 30, Geo. Series 25. 371 pp.
- Theroux, F. R., Eldridge, E. F., and Mallmann, W. L.
 1943 *Laboratory manual for chemical and bacterial analysis of water and sewage.* New York: McGraw-Hill Book Co., Third Edition, 228 pp.
- Thienemann, A.
 1920 *Biologische Seetypen und die Gründung einer hydrobiologischen Anstalt am Bodensee.* *Arch. Hydrobiol.* 13:347–70.
 1955 *Die Binnengewässer in Natur und Kultur.* Springer-Verlag, Berlin. Gottingen: Heidelberg, 145 pp.
- Townes, Henry K., Jr.
 1945 The Nearctic species of Tendipedini [Diptera, Tendipedidae (=Chironomidae)]. *Amer. Midl. Nat.* 34(1):1–266.
 1959 Notes on the types of Nearctic Tendipedinae in London-Copenhagen (Diptera, Tendipedidae). *Ent. Soc. Wash.*, 61(3):135–36.
- Walshe, Barbara M.
 1947a The function of Haemoglobin in *Tanytarsus* (Chironomidae). *J. of Exp. Biol.*, 24(3, 4):343–51.
 1947b On the function of haemoglobin in *Chironomus* after oxygen lack. *J. Exp. Biol.*, 24:329.

1947c Feeding mechanism of Chironomus larvae. Nature,
Lond., pp. 160—474.

Welch, Paul S.

1948 Limnological methods. Philadelphia, 379 pp.

1952 Limnology. 471 pp.

Wigglesworth, V. B.

1950 The principles of insect physiology. New York:
E. P. Dutton and Co., Fourth Edition, 544 pp.

11

ROOM USE

~~GEN 13 1964~~ USE

~~SEP 3 1964~~

MAY 20 1965

MICHIGAN STATE UNIVERSITY LIBRARIES



3 1293 03061 4709