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The Ohio State University, Ph.D., 1965
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THE DYNAMICS OF THE BENTHIC FAUNA OF ACTON LAKE
IN HUESTON WOODS STATE PARK
OHIO

DISSERTATION
Presented in Partial Fulfillment of the Requirements for the
Degree Doctor of Philosophy in the Graduate School of
The Ohio State University

by
Paul Mason Daniel, B.S.in Ed., M.S.

The Ohio State University
1965

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PUBLICATIONS


## CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>Survey of the Literature</td>
<td>3</td>
</tr>
<tr>
<td>A Description of the Study Area</td>
<td>16</td>
</tr>
<tr>
<td>Deposition in the Lake</td>
<td>17</td>
</tr>
<tr>
<td>Geological Development</td>
<td>23</td>
</tr>
<tr>
<td>Physical Characteristics</td>
<td>26</td>
</tr>
<tr>
<td>Temperature</td>
<td>26</td>
</tr>
<tr>
<td>Oxygen</td>
<td>32</td>
</tr>
<tr>
<td>Other Chemical Factors</td>
<td>36</td>
</tr>
<tr>
<td>Biological Factors</td>
<td>36</td>
</tr>
<tr>
<td>Description and Location of the Stations</td>
<td>38</td>
</tr>
<tr>
<td>Methods and Materials</td>
<td>42</td>
</tr>
<tr>
<td>The Results Obtained</td>
<td>50</td>
</tr>
<tr>
<td>Analysis of Samples Obtained by Dredging</td>
<td>50</td>
</tr>
<tr>
<td>Analysis of Emerged Insects</td>
<td>64</td>
</tr>
<tr>
<td>Emergence of Selected Species and Groups</td>
<td>80</td>
</tr>
<tr>
<td>Analysis of Sampling Techniques</td>
<td>89</td>
</tr>
<tr>
<td>Daily Sampling vs. Semi-Weekly Sampling</td>
<td>89</td>
</tr>
<tr>
<td>Comparison of Traps Placed on the Bottom and Below the Surface</td>
<td>89</td>
</tr>
<tr>
<td>Midlake Stations Compared with Shoreward Stations</td>
<td>94</td>
</tr>
<tr>
<td>Discussion</td>
<td>96</td>
</tr>
<tr>
<td>Productivity</td>
<td>96</td>
</tr>
<tr>
<td>Temperature and Emergence</td>
<td>99</td>
</tr>
<tr>
<td>Page</td>
<td></td>
</tr>
<tr>
<td>------</td>
<td></td>
</tr>
<tr>
<td>Trophic Levels ................................ 101</td>
<td></td>
</tr>
<tr>
<td>Drawdown ........................................ 102</td>
<td></td>
</tr>
<tr>
<td>Summary and Conclusions .......................... 104</td>
<td></td>
</tr>
<tr>
<td>Literature Cited .................................. 108</td>
<td></td>
</tr>
</tbody>
</table>
## ILLUSTRATIONS

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Selected Ranges for Sediment Study.</td>
<td>19</td>
</tr>
<tr>
<td>2</td>
<td>Selected Sediment Profiles.</td>
<td>20</td>
</tr>
<tr>
<td>3</td>
<td>Surface and Bottom Temperatures.</td>
<td>29</td>
</tr>
<tr>
<td>4</td>
<td>Temperature Profiles.</td>
<td>30</td>
</tr>
<tr>
<td>5</td>
<td>Monthly Mean Air Temperatures.</td>
<td>31</td>
</tr>
<tr>
<td>6</td>
<td>Day Degrees at Station 30.</td>
<td>33</td>
</tr>
<tr>
<td>7</td>
<td>Oxygen Profiles.</td>
<td>34</td>
</tr>
<tr>
<td>8</td>
<td>Oxygen at the Nine Meter Depth</td>
<td>35</td>
</tr>
<tr>
<td>9</td>
<td>Location of Stations.</td>
<td>39</td>
</tr>
<tr>
<td>10</td>
<td>Trap Handle.</td>
<td>44</td>
</tr>
<tr>
<td>11</td>
<td>Standing Crop.</td>
<td>51</td>
</tr>
<tr>
<td>12</td>
<td>Wet Weights Stations 20 and 30.</td>
<td>52</td>
</tr>
<tr>
<td>13</td>
<td>Wet Weights Station R.</td>
<td>53</td>
</tr>
<tr>
<td>14</td>
<td>Wet Weights Stations 10 and I.</td>
<td>53</td>
</tr>
<tr>
<td>15</td>
<td>Generalized Macroinvertebrate Standing Crop.</td>
<td>56</td>
</tr>
<tr>
<td>16</td>
<td>Standing Crop Station 30.</td>
<td>58</td>
</tr>
<tr>
<td>17</td>
<td>Standing Crop Station 20.</td>
<td>59</td>
</tr>
<tr>
<td>18</td>
<td>Standing Crop Station R.</td>
<td>60</td>
</tr>
<tr>
<td>19</td>
<td>Standing Crop Station 10.</td>
<td>60</td>
</tr>
<tr>
<td>20</td>
<td>Standing Crop Station I.</td>
<td>61</td>
</tr>
<tr>
<td>Figure</td>
<td>Description</td>
<td>Page</td>
</tr>
<tr>
<td>--------</td>
<td>-------------</td>
<td>------</td>
</tr>
<tr>
<td>21</td>
<td>Emergence of Tendipedini Station I</td>
<td>66</td>
</tr>
<tr>
<td>22</td>
<td>Emergence of Tendipedini Stations 10, R, 20, and 30</td>
<td>67</td>
</tr>
<tr>
<td>23</td>
<td>Emergence of Pelopinae All Stations</td>
<td>68</td>
</tr>
<tr>
<td>24</td>
<td>Emergence of Hydrobaeninae All Stations</td>
<td>69</td>
</tr>
<tr>
<td>25</td>
<td>Emergence of Chaoboridae All Stations</td>
<td>70</td>
</tr>
<tr>
<td>26</td>
<td>Emergence of Trichoptera All Stations</td>
<td>70</td>
</tr>
<tr>
<td>27</td>
<td>Emergence in Organisms per Square Meter from Station I</td>
<td>72</td>
</tr>
<tr>
<td>28</td>
<td>Emergence in Organisms per Square Meter 10, R, 20, and 30</td>
<td>73</td>
</tr>
<tr>
<td>29</td>
<td>Emergence in Organisms per Square Meter of <em>Procladius bellus</em></td>
<td>82</td>
</tr>
<tr>
<td>30</td>
<td>Emergence in Organisms per Square Meter of <em>Pentaneura</em></td>
<td>84</td>
</tr>
<tr>
<td>31</td>
<td>Emergence in Organisms per Square Meter of <em>Cricetopus</em></td>
<td>85</td>
</tr>
<tr>
<td>Plate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>Emergence Trap</td>
<td>45</td>
</tr>
</tbody>
</table>

viii
# TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Physical Characteristics of Acton Lake</td>
<td>16</td>
</tr>
<tr>
<td>2</td>
<td>Mean Summer Temperature for Acton Lake 1959 - 1963</td>
<td>26</td>
</tr>
<tr>
<td>3</td>
<td>Extreme Temperature for Acton Lake 1959 - 1963</td>
<td>27</td>
</tr>
<tr>
<td>4</td>
<td>Emergence of Heleidae, Ephemeroptera and Calopsectrinii</td>
<td>74</td>
</tr>
<tr>
<td>5</td>
<td>Total Emergence All Stations</td>
<td>79</td>
</tr>
<tr>
<td>6</td>
<td>A Comparison of Daily and Semi-Weekly Sampling</td>
<td>90</td>
</tr>
<tr>
<td>7</td>
<td>A Comparison of Bottom and Surface Traps Stations 10, 20, R, and 30</td>
<td>92</td>
</tr>
<tr>
<td>8</td>
<td>A Comparison of Bottom and Surface Traps Stations 21, 22, and 23</td>
<td>93</td>
</tr>
<tr>
<td>9</td>
<td>A Comparison of Midlake and Shoreward Stations</td>
<td>95</td>
</tr>
</tbody>
</table>
Introduction

The number of reservoirs resulting from the impoundment of surface waters is increasing at a rapid rate in the United States. Research in biological and hydrological problems in such reservoirs is thus an important phase of modern limnology. The benthic habitat has been investigated in several reservoirs and from several aspects. Most of these studies involve the study of dredge samples. Fewer studies have involved collecting benthic fauna as it leaves the benthic habitat. The present study involves a combination of regular dredge sampling from several stations in a 640 acre Ohio reservoir and the collection of emergent insects by the utilization of funnel traps placed on the bottom of the reservoir and just below the surface. These were placed at several stations. Acton Lake has two features which make it an ideal site to conduct such a study. It has been studied since its impoundment by several limnological investigators. A mass of data on its limnological properties is available. Information on the composition and dynamics of the benthic components is rather meager. The management of the reservoir has involved the lowering of the lake level by nine to ten feet in November and allowing it to refill in March. This has been done to protect the boat docks. The effect of this rather drastic action on the benthic fauna of
the shallowest contours of the lake is one of the unique aspects of the problem.

A listing of the components of the benthic fauna over several years formed an initial part of the problem. This was obtained from quantitative sampling. A regular and intensive dredge sampling in 1964 provided information on components and densities at various depths and in various parts of the lake during the entire year. Wet weights provided data on the amounts of biomass. The emergence of benthic insects was determined by placing funnel traps on or close to the bottom and checking the contents of the traps on a semi-weekly basis. A clearer identification of insects to the species level in some cases was possible by utilizing adult insects. This was made possible by using adult insects obtained in a funnel emergence trap. The emergence pattern of several of the more prominent members of the benthic fauna was determined from information from trap samples. The traps were in place from late March until mid-November 1964. Two of the stations sampled both by dredge and by emergence trap were in the contour of the lake which was exposed in the winter drawdown. Mud samples were checked from these areas during the winter period. This provided information on events associated with lowering the lake.

There has been confusion in the literature about the placement of emergence traps. Traps were placed on the bottom and just below the surface and comparisons made. Another question has been the validity of semi-weekly sampling.
Sampling was done on a daily basis for a period of maximum emergence in a region where population densities were high. This was compared with semi-weekly data.

A Survey of the Literature

Birge and Juday of the University of Wisconsin represent two prominent pioneers of twentieth century American limnological research. Muttkowski (1918) at Juday's suggestion studied the benthic fauna of Lake Mendota. Lake Mendota is a natural lake with an area of 39 square kilometers in south central Wisconsin. This work done in the second decade of this century first involved collecting in a marked square meter in the littoral zone and later was extended to deeper water using an Ekman dredge. Habitat preference, phenology and distribution were recorded to the species level. Many specimens were reared to adulthood in the laboratory. This is in contrast to most benthic work done to family and generic level. Juday followed this work with measurements of wet and dry weights to indicate standing crops. He found 697 kg/ha wet weight, excluding Pisidium in deeper zones and 360 kg/ha in intermediate zones. Chaoborus dominated deeper zones and Chironomus was most abundant in shallow zones.

Gersbacher (1937) developed a ranking system for benthic faunas in artificial pools of central Illinois streams. The impoundments represent bare areas on which the pool animals become established. He suggests three definite
successional stages with *Chironomus plumosus* (Linne) the youngest, a *Procladius* stage next and *Hexagenia*, *Muscullum* as the oldest stage. He considers peaks of these animals in impoundments of various ages as facies in community development. Scott, Hile, and Spieth (1928), in studying Lake Wawasee in Indiana, found a maximum of large chironomids at the 15 meter depth (881 per square meter). Their measurements indicate an increase in *Chironomus tentans* Fabricius up to that depth and a decline at greater depths. Maximum lake depth was 23 meters where standing crops of 150 *Chironomus tentans* and 120 "other chironomids" per square meter were found. This was a lake 4½ miles long and 1½ miles in width with 15.7 miles of shore-line.

Tebo (1955) studied a small eutrophic Iowa lake and recorded dry weights of 1873 mg per square meter on fibrous peat bottom and 671 mg per square meter on sand and clay bottom. He found that the chironomids made up 93% of the dry weight of deeper waters. Maximum depth was five feet.

The Great Lakes have had extensive work done on benthic fauna. Krecker and Lancaster (1933) investigated shore fauna of Lake Erie recording fauna at 6, 18, 36, and 72 inch depths. They found the greatest number of species reached maximum numbers at the 6" level and the greatest number of individuals at the 18" level. The dominant organisms of their study included *Physa*, *Heptagenia* (*Stenonema*), "Chironomids," *Caenis*, and *Hydropsyche* with the caddis flies and midges most abundant. The critical factors were type of substrate,
character of the vegetation and depth.

Shelford and Boesel (1942) studied the various benthic communities in the western basin of Lake Erie in the island area during June of 1937 utilizing a series of standing crop measurements. They characterized the *Pleurocera-Lampsilis* community on shifting sandy bottoms, the *Hexagenia-Oecetis* community on mud bottom and the *Goniobasis-Hydropsyche* community of shallow stony areas. The relative densities of other components for each community were measured.

Wood (1953 and 1963) also working in the western basin of Lake Erie in 1951 and 1952 studied the macroinvertebrate bottom fauna and its relationship to the substrate. He indicated that the mayfly *Hexagenia* can be associated with cleaner waters and that in a general way the chironomids show a reciprocal relationship with *Hexagenia*. He demonstrated that the sediments that are preferred by *Hexagenia* contain fine sands and that the differences in sediments between the locations optimal for *Hexagenia* and chironomids cannot be detected by feel and sight. He utilized a screening, sorting, and drying technique to arrive at a quantitative value for particle size of the sediments. He found a benthic production of 73.4 pounds of dry weight per acre and compared this with other lakes.

Eggleton (1931) studied profundal faunas of several lakes in Michigan and New York. He classified substrates as "dust fine detritus", clay, ooze, and mud. His studies were done over the seasons of the year and indicated an increase
in numbers from fall to mid-winter in deeper waters and then a gradual decrease to mid-summer when a minimum was reached. He found midges, tubificids, nematodes and Chaoborus in the profundal region of these lakes. Chaoborus was present up to a maximum of 70,000 per square meter. He demonstrated a concentration zone in the upper profundal and lower sublittoral in the summer with a shift of concentration to the deeper water in the fall and to the deepest in the winter. This was followed by a shift to the shallower waters in the spring. He felt that semi-annual overturns had real effects on the benthic fauna and that the anaerobes of the profundal fauna were facultative anaerobes rather than obligate anaerobes. He lists Corethra (Chaoborus), Chironomus, Protenthes, Limnodrilus, Pisolium, Musculium and Hydromermis as typical profundal inhabitants.

A more recent study is that of Oliver (1960). This was on the bottom of Lac La Ronge in Saskatchewan and involved summer dredge samples between 1948 and 1953. The mesotrophic main lake averaged 742 organisms per square meter and had an average standing crop of 7.9 lbs. of dry weight per acre. Numbers were greatest in spring and fall and lowest in summer. Chironomus anthracinus Zetterstedt was the most abundant organism.

Needham (1908) first pointed out the value of utilizing floating traps in ecological work on benthic insects. Adamstone and Harkness (1923) utilized floating tent traps in Lake Nipigon. Their work showed the practicability of
their method, but because their experiments lasted but nine days and involved moving the traps to various depths they did not obtain seasonal data. Ide (1940) utilized tent traps on stream insects.

Miller (1941) working in 20 acre Costello Lake in Ontario utilized five tent traps during the summers of 1937 and 1938. His stations were at one meter, three meter, seven meter, twelve meter, and seventeen meter depths. The traps consisted of wooden and wire frames covered with a cotton net stretched over them. They were floated with one gallon cans. Traps were lifted and insects removed daily. Adult chironomids began to emerge as soon as the ice break-up in early May. From late May until mid-August large numbers of chironomids emerged from the two shallowest stations. In late August emergence from the shallow water decreased and few chironomids were taken after mid-September. Emergence from below the thermocline was light. A major deep water form, Micropsectra, was abundant in September.

Scott and Opdyke (1941) utilized pyramidal tent traps on Winona Lake in Indiana. One of the interesting experiments performed by these investigators involved the use of paired traps, one covered with translucent material and the other with opaque material. During a five day period the "light" trap contained 8.4 times more emerging insects than the "dark" trap. They indicate that pupae are sensitive to weak illumination that must appear as complete darkness to the human eye. They noted a marked decrease in emergence at
deep water (up to 24 meters) stations during all three years of
the investigation. They further found that the lesser number of
deep water emerging insects was not matched by a decreased
number of larvae in deep water bottom muds. This has been
interpreted as possible evidence for some kind of migration
from deeper to shallower waters for emergence. The extreme
activity of Chaoborus in this regard is well known. This may also be
due to deep water emergence at times before and after their study periods.

Britt (1962) utilized similar traps for studies of emerging
mayfly imagos and subimagos at Put-in-Bay on Lake
Erie.

Macan (1949) studied emergence from an English pond
by utilizing weekly samples from tent traps which were re­
moved and serviced in a boat house.

Morgan and Waddell (1961) utilized tent traps in
studying insect emergence from a small trout loch in Scot­
land. Prime consideration was given to the relationship of emergence to fish food and thus weights of emerged insects were considered as well as numbers of individuals and num­
ers of species. Diurnal periodicity was also considered. Traps were set in 6 feet of water and in less than one foot of water. The deeper water trap caught from two to three times as many insects per unit of area as the shallow water trap.

There are definite disadvantages to the relatively fra­
gile floating tent traps. They are frequently damaged by
wind and wave. Several workers have developed submerged funnel traps to overcome this difficulty. One of the earliest of these was developed by Borutzky for reservoir work in Russia (1939a, 1939b, 1955). Brundin (1949) utilized funnel traps suspended just below the water's surface. He indicates that funnel traps can give information on numbers of animals emerging per unit of area per 24 hour period, comparisons of quantitative and qualitative insect forms, and the dependence of emergence on various limnetic environmental factors. The shallow water with a dense growth of macrophytes produced the greatest weight however. The number of chironomids emerging per week was directly proportional to the water temperature.

Jónasson (1954) noted such factors as air in the jar, level funnel base, even depth, smooth internal surfaces, air tight jar and funnel connections as essential to good trapping. He also noted the problem of air disappearance and non-hatching of pupae at 19 meter depths in Esrom Lake. He further warned about the danger of epifauna developing on traps.

Mundie (1956 and 1957) summarized funnel trap construction and provided drawings of several designs. He suspended traps from permanent cables in British reservoirs. The traps were suspended over even sloping bottoms to record emergence from a variety of depths. He found that traps must be emptied at least twice weekly in order to avoid fungal decomposition.
He worked in three reservoirs in Middlesex, England of 16.2, 99.6, and 292.6 hectare areas with a maximum depth of 10.5 meters. Thirty-five funnel traps were utilized in 1950 and 1951. Traps were placed approximately 1 meter above the substrate and were serviced twice weekly. Collections of swarming insects were also made along shore lines. Both sources yielded 62 species. Histograms indicating depths and times of emergence were constructed for all species which showed a significant amount of emergence.

As in other eutrophic lakes the greatest diversity was found in shallow water. *Tanytarsus holochlorus* Edwards and *Procladius choreus* Meigen were the chief insects emerging from the profundal zone. Temperature readings near the mud surface made possible a day degree curve at Kempton Park East reservoir. When compared with emergence histogram material, inferences as to the influence of cumulative temperature on emergence can be made. Quantitative sampling of larvae was done with a Jenkin mud surface sampler. It was felt that fluctuations in larval numbers in late winter and spring was due to wind induced water movements which disturb mud and water and induce larvae to enter the water mass.

Mundie attributes the differences in the profundal communities of two of the reservoirs studied to greater depth resulting in greater stability of stratification and oxygen depletion.

Guyer (1954) and Guyer and Hutson (1955) studied sampling techniques on both immature and adult aquatic insects in
eight Michigan ponds and a reservoir. They utilized tent traps, funnel traps and dredging. A complete study of insect succession between April and August was made in a new pond. Midges were extremely numerous in early samples but predators later caused a decline in the midge population. No significant difference was found in trapping efficiency between funnel and tent traps except for heleid adults which were taken more readily in tent traps. No significant difference was found between suspended funnels and those placed on the pond bottom. It was concluded that adult trapping devices were adequate for making qualitative but not quantitative estimations of the ephemeropteran population. The emergence period was plotted for several species and groups of insects.

Morgan, Waddell and Hall (1963), working in a small trout loch in Scotland compared floating traps of differing size with each other and with submerged funnel traps. They found significantly fewer total insects and fewer number of species in the funnel traps. They concluded that floating traps of five square feet were of optimum size. They list decomposition of the catch, shading effect of the trap, invertebrate predation, and tilting of the trap as disadvantages of their funnel trap.

The study of diurnal periodicity of aquatic insects has utilized both funnel and floating traps. Miller (1941) made a single 24 hour study in July in Costello Lake, Canada and found greatest emergence of chironomids between 4 and
A. M. This was a time of low light intensity and minimum temperature.

Britt (1962) utilized a tent trap to collect the emerging mayfly *Ephoron album* (Say) at Put-in-Bay and found the emergence period usually lasted considerably less than one hour and was during the period just after sunset.

Palmen (1955, 1956, 1958) summarized the literature (1955) and studied emergence from 1 - 2 meter depths of brackish water in Finland utilizing funnel traps of one square meter mouth size. He found increased emergence in all chironomid species in the hours after sunset and a diel peak around midnight. Some emergence occurred throughout the day with very little between 03 to 21 hrs. He found a time difference in emergence peaks of about two hours in the second generation of several species. He further noted no difference in emergence times with changes in temperature. He suggests that the timing mechanism synchronizing the nearly simultaneous emergence of all individuals which are at the appropriate stage of development is temperature independent. He noted that in *Allochironomus crassiforceps* Kieffer that the emergence pattern persists in darkness for six days and that the bulk of the males emerge before the females.

He interprets the midnight peak as an adaption of the chironomids to nocturnalism.

Morgan (1958) emptied traps on a 2 hour schedule for 48 hour periods twice each month from May until August. He
found a maximum period of chironomid emergence in late evening.

Mundie (1959) working in Lac La Ronge Saskatchewan, utilized coarse plankton nets towed over specific areas. Eight calm nights were utilized for sampling in July and August of 1958. The Tanypodinae were taken in greatest numbers and showed a peak of activity at 10:00 P. M. and 11:00 P. M. Histograms were constructed to show time of emergence. There was a definite tendency for chironomid pupae to ascend at night. In some cases emergence was immediate and for others a delay took place.

Studies on the effects of drawdown on bottom fauna of lakes are rare. Bennett (1962) reports that many weak invertebrate swimmers of the littoral zone such as entomostracans, rotifers, and small insects are stranded as the water recedes. He further indicates that larger insect larvae such as dragonfly and mayfly nymphs may attempt to crawl along the bottom but most die, or are preyed upon by vertebrates. On the other hand crayfish usually move down with the receding water. He indicates that the exposure of lake bottoms to greater oxidation and great decomposition releases fertilizing substances from organic colloidal systems. He regards the fact that whether or not plants grow on the exposed areas as unimportant when compared to the significance of rapid and complete oxidation.

Vallentyne (1952) used funnel traps on an Ontario lake to determine the role of insects in nitrogen and phosphorus
removal. He assumed that 75% of the emerging insects do not return to the lake. He further figured that insects were responsible for the removal of 00.28% of the organic sediments deposited. An average daily emergence of insects from a square meter removed 2.26 mg of nitrogen and 0.15 mg of phosphorus. Macan (1961) lists oviposition behavior, isolation, predation, organic substrate, competition, water movement, temperature, oxygen, and dessication as factors which limit ranges of freshwater animals. He emphasizes the role of predation in limiting ranges and indicates some midges are able to carry on anaerobic respiration.

Lindeman (1941a, 1941b, 1942a and 1942b) has studied the food dynamics and ecological succession in the senescent Cedar Bog Lake in Minnesota. He made careful collections of aquatic plants, plankton, fishes, benthic organisms, neuston and other components of the ecosystem of the small lake and assigned each a niche in the food cycle. Of special interest were the benthic macrofauna which he classified as herbivorous or saprophagous browsers which feed on the substrate, benthic predators, plankton predators, and swimming predators.

Neess and Dugdale (1959) provide a method for computing production of benthic biomass based on standing crop numbers and mean weights per larva. They indicate that this method is applicable to populations of larvae in which a small number of age classes are easily discernible. Fortunately in many lakes larvae of such insects often make up a large mass of the bottom community. They indicate that a ratio of
growth rate to mortality rate determines the shape of growth-survivorship curves. They further indicate that characteristics of production can be determined from growth-survivorship curves. The data of Anderson and Hooper (1956) on littoral studies of *Tanytarsus jucundus* (Walker) are analysed by their computation. By examining ratios of parts of the curves it is interesting to note that 8.7% of the organic matter that might have been produced if all larvae had survived is actually utilized by the cohort. Further it was calculated that 1.6% of that potentially available was realized in bodies of larvae converted to pupae and that 81.89% of that in the cohort remained to be recycled within the lacustrine biota and no more than 18.2% became available to an energy pyramid outside the lake.

Ball and Hayne (1952) investigated the littoral invertebrate fauna for four years in a 10 acre Michigan lake. They found that total volumes of littoral invertebrate animals reached a low point at early summer stratification, increased until ice cover where a maximum was reached, decreased slightly until ice break-up, then dropped off sharply with spring emergences. They further noted a statistically significant increase in invertebrates after poisoning fish populations. Both maximum and minimum standing crops were higher.
A Description of the Study Area

Acton Lake is a man-made recreation lake impounded in 1957 with a surface area of 625 acres located in the Hueston Woods State Park in northern Butler and southern Preble counties of Ohio. The physical characteristics of Acton Lake as given by Winner, Strecker and Ingersoll (1962) are indicated in Table 1.

TABLE I

Physical Characteristics of Acton Lake

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shoreline</td>
<td>8.7 miles</td>
</tr>
<tr>
<td>Length</td>
<td>2.7 miles from inflow to dam</td>
</tr>
<tr>
<td>Surface area</td>
<td>625 acres</td>
</tr>
<tr>
<td>Mean depth</td>
<td>12.8 feet</td>
</tr>
<tr>
<td>10 foot contour</td>
<td>382 acres</td>
</tr>
<tr>
<td>20 foot contour</td>
<td>135 acres</td>
</tr>
<tr>
<td>30 foot contour</td>
<td>20 acres</td>
</tr>
<tr>
<td>Volume</td>
<td>8000 acre feet</td>
</tr>
<tr>
<td>% 0 - 10 feet</td>
<td>62%</td>
</tr>
<tr>
<td>% 10 - 20 feet</td>
<td>29%</td>
</tr>
<tr>
<td>% Below 20 feet</td>
<td>9%</td>
</tr>
</tbody>
</table>
The watershed has an area of 104 square miles, 90% of which is in Preble County, Ohio and the remainder in Butler County, Ohio and in Indiana. The watershed use is approximately 20% pasture and 80% agricultural land. Because of the large amount of agricultural use of the watershed the Four Mile Creek system which supplies the lake carries a variable silt load. The Preble County Inventory of Soils indicates the breakdown of the watershed into the following soil catenas.

35% Russell-Xenia
21% Miami-Celina-Kendallville
15% Crosby-Brookston
12% Ragsdale-Reesville-Birkbeck
11% Fincastle-Brookston
4% Ross-Medway
2% Hennepin-Miami-Kendallville-Milton and Fox-Ockley-Wea-Warsaw

The lake bottom itself is on Ross loam. These podsolic soils have A Horizons which average 12 inches thick, a silty clay-loam B averaging 28 inches thick and a glacial till with 85% of the rock fragments limestone dolmites as the C Horizon.

Deposition in the lake

The Division of Water of the State of Ohio has conducted continuous investigation of reservoir sedimentation in Ohio. In 1958 a map of Acton Lake was prepared. This included the placement of concrete monuments along the shore
line and the establishment of 35 ranges. Those utilized here are indicated in Figure 1.

In August of 1961 workers from the Division of Water made sediment measurements along all of these ranges. A sounding pole, which was lowered to the top of the sediments and then forced through them, was utilized. Readings were made to feet and tenths and appropriate corrections made for the distance from the surface of the lake to the top of the spillway. This information was made available to the writer through the cooperation of Charles L. Hahn, Agricultural Engineer with the Division. The field data closest to the writer's benthos sampling and emergence trapping stations were duplicated and form the basis of the seven sediment profiles which are indicated in Figure 2. These are summarized below:

**Range 2**: This range was in the deepest portion of the lake near the station 30 of Acton Lake limnological studies. Depths ranged up to 33.9 feet. Average sediment deposition was 0.216 feet with the greatest deposition between 10 and 180 feet from the east shore. The highest reading was 0.6 feet of sediment. Station 30 where sampling is done is in the region of heaviest sedimentation. Recent dredging for bottom fauna indicates a considerably greater depth of sediment at the present time.

**Range 4**: This range is close to station R used by the writer for sampling emerging insects. Depths range up to 33.8 feet. Sediment deposition is quite evenly distributed
Figure 1

Selected Ranges for Sediment Study on Acton Lake as Determined by the Ohio Division of Water

Contour lines are 10 feet
Figure 2
Selected Sediment Profiles
across the lake and averages 0.274 feet.

**Range 6:** This range is located southeast of the writer's sampling station 20 and represents the longest range on the lake (2677 feet) and has an average sediment deposition of 0.229 feet. This is fairly evenly distributed with slightly deeper sediments toward the west shore (up to 0.5 feet). Depths average about 20 feet and range up to 25.5 feet.

**Range 8:** This short range (359 feet) extends across an inlet. Deposit is heavy toward the center ranging up to 0.9 feet but averages only 0.382 feet with very low deposition on the southern portion of the range.

**Range 10:** This range extends 2180 feet to the northwest of station 20. Heavy sediments up to 1.8 feet are deposited in the middle of this range. The average deposition is 0.445 feet and lake depths range up to 27.7 feet.

**Range 11:** The sampling station is located near the western extremity of this range. Sedimentation averages 0.324 feet with the greatest depth of sediment between 500 and 600 feet from the east shore. Sand, stone and gravel mark the area near the sampling station.

**Range 16:** This 1360 foot range is in the shallow end of the lake where depths range up to only 12.4 feet and are less than 8 feet for considerable distances. This is the closest range to the inflow streams. Sediments average 0.676 feet and range up to 1.7 feet. Deposition is heavy from the east shore to nearly 500 feet out and about 180 to
280 feet from the west shore. This region is largely out of the water during the winter drawdown and resembles a "mud flat" at that time.

An examination of the sediment profiles in Figure 2 indicates a decreasing sedimentation toward the dam proceeding from the inlet streams. There is a great concentration of sediments toward the east shore. This is probably due to the fact that the old stream bed was located in this position.

Brown (1946) has pointed out that the smaller the drainage area the greater the range of sediment production and that both the maximum and the mean rates of sedimentation decline as the drainage area becomes larger. Two factors which are important in the siltation of a reservoir are trap efficiency which is the percentage of sediment entering a reservoir and staying there, and the capacity - watershed ratio. The latter is the ratio of the capacity of the reservoir in acre - feet to the area of the drainage basin in square miles. For Acton Lake this would be:

\[
\frac{8000 \text{ acre ft}}{104 \text{ sq miles}} = 77 \text{ Acre ft/sq Mile}.
\]

It is interesting to compare this with other Ohio reservoirs (Hahn 1955). Sharon Woods in an intensely farmed area of Hamilton County has a capacity - watershed ratio of 59 and in 1949 after 9.9 years had a 28.8% loss of capacity and had a predicted useful life of 21 years. Three hundred and eighty acre Kiser Lake, on the other hand, in Champaign
County had a capacity - watershed ratio of 374 and a loss of 8.9% of capacity after 14.5 years and predicted useful life of 98 years.

If the range means of Acton Lake are averaged, a mean deposition of 0.36 feet has occurred between filling the lake in 1957 and the study of sediments in 1961. This amounts to a loss of 224 acre feet which is 2.8% of capacity. This is an average annual loss of 0.7 of 1% of capacity. If the useful life is figured on 80% of capacity, the useful life might be predicted at 114 years. When the 0.7 of 1% annual loss of capacity figure is compared with other reservoirs in the till plains of Ohio it is greater than 9 but less than 27 and much less than some (Hahn 1955).

The description of the chief soils of the region indicates calcareous till as the chief component of parent material. The alkilithrophic nature of the lake and high calcium concentration are not surprising.

**Geological development**

Very little is known of the Precambrian and Cambrian history of the area. It was during the advances and retreats of early Paleozoic seas that bedrock of the area was laid down. The varied fauna demonstrates two sources of these seas, one from near the present St. Lawrence River and one from the Mississippi embayment.

The limestone bedrock was formed from calcareous skeletal fragments plus secretions of calcium carbonate from
lime bearing marine life. The shales which are interbedded with the limestones are derived from silts and clays eroded from an eastern land mass, probably the Taconic Mountains or from islands in the sea. Ripple marks on rocks indicate that the seas were shallow and probably had turbulent wave activity causing disruption of the bottom sediments. This "reworking" of the bottom in stormy times followed by settling in calm times tended to separate a "lime sand" from finer mud and lime fragments and gives the region's bedrock a very sharply stratified appearance. This limestone is classified as "blue limestone" or Cincinnatian.

An outcrop at Doty's High Bank along Talawanda Creek just below the dam on Acton Lake is described by Lind (1957). There are two major formations exposed. The thicker thirty feet of Blanchester formation is characterized by even bedded fossiliferous limestone and alternating shales. Fossils are *Glyptothris insculpta* (Hall), *Strophomena neglecta* (James), *Strophomena nutans* (Meek), *Resserella meeki* (Miller), *Leptraena richmondensis* (Foerte), and *Rafinesquina alternata* (Emmons). The shallower six foot Clarksville includes *Resserella meeki* (Miller), *Rafinesquina alternata* (Emmons) and *Flexicalymene meeki* (Foerste). This is a part of the "Cincinnati arch". Classically this has been considered to be of Ordovician origin. Scotford (1964) presents evidence from a thorough mineralogical, chemical, and textural analysis of Cincinnati series shales using x-ray diffraction, x-ray spectrochemical and gravitational methods that its origin
is post Ordovician. It is probable that later deposits were denuded by streams which followed the Paleozoic. This erosional surface is known as the Lexington Peneplain. Ver Steeg (1936 and 1938) has stated that drainage during this time was via a river which has approximately the same channel as the Great Miami River today and a stream whose main channel was nearly the same as the present Talawanda Creek. This stream bed, buried under 150 feet of outwash, supplies the present village of Oxford with water.

The Kansan glaciation caused little change in drainage which was probably already to the south. Much of southwestern Ohio, however, was leveled under the Illinoian glacier which left drift deposits of from 25 feet to 300 feet. This was followed by the Sangamon interglacial stage which in turn was followed by the Wisconsin glaciation. The study area was under the Miami lobe of this glacier. The large deposits of this glacier in retreat give the present topography (with a little Illinoian till) to the area. The glacial material fills in low areas and because the region is near the terminus the area is not as thickly overlain with till and is more steeply eroded. This gives a dendritic stream pattern. The Talawanda Creek is unusual as a small stream in an over-sized valley. The valley was well formed before the present stream arose. Geologically speaking, the stream is in maturity.

The till is classified as unstratified ground moraine consisting of pebbles, cobbles and boulders and many glacial
erratics such as granite boulders. The recent alluvial deposits are of sorted silts, sands, and gravels.

**Physical characteristics**

Acton Lake has been investigated continuously since 1959 (Winner, Strecker and Ingersoll 1962 and Winner 1963). This work was supported by the Ohio Division of Wildlife, administered through the Institute of Natural Resources of The Ohio State University through 1963, and since that time has been conducted independently by Winner and others.

**Temperature.** The data accumulated indicates that the lake becomes stratified in late spring and remains that way until fall. Mean summer temperatures for 1959-1962 at the surface 3, 6 and 9 meter depths are given in Table 2. Extremes for the period are given in Table 3.

<p>| TABLE 2 |
| Mean Summer Temperatures for Acton Lake 1959 - 1963 |</p>
<table>
<thead>
<tr>
<th>July</th>
<th>Aug.</th>
<th>Sept.a</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface</td>
<td>27°C</td>
<td>27°C</td>
</tr>
<tr>
<td>3 Meters</td>
<td>26°C</td>
<td>26°C</td>
</tr>
<tr>
<td>6 Meters</td>
<td>20°C</td>
<td>22°C</td>
</tr>
<tr>
<td>9 Meters</td>
<td>14°C</td>
<td>15°C</td>
</tr>
</tbody>
</table>

a1959 - 1962 only.
TABLE 3

Extreme Temperatures for Acton Lake 1959 - 1963

<table>
<thead>
<tr>
<th>Depth</th>
<th>May&lt;sup&gt;a&lt;/sup&gt;</th>
<th>June&lt;sup&gt;b&lt;/sup&gt;</th>
<th>July</th>
<th>August</th>
<th>September&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Surface</td>
<td>27°C</td>
<td>10°C</td>
<td>27.5°C</td>
<td>20°C</td>
<td>29°C</td>
</tr>
<tr>
<td>3 Meters</td>
<td>24°C</td>
<td>19°C</td>
<td>25°C</td>
<td>23.5°C</td>
<td>28.5°C</td>
</tr>
<tr>
<td>6 Meters</td>
<td>21°C</td>
<td>14°C</td>
<td>24°C</td>
<td>16°C</td>
<td>26°C</td>
</tr>
<tr>
<td>9 Meters</td>
<td>14.5°C</td>
<td>10.5°C</td>
<td>16.5°C</td>
<td>11.5°C</td>
<td>18°C</td>
</tr>
</tbody>
</table>

<sup>a</sup>1961 and 1962 only.

<sup>b</sup>1960, 1961, and 1962 only.
During 1964 temperature readings were made frequently during the spring and at irregular intervals during the rest of the time up to drawdown. Figure 3 indicates surface and bottom temperatures as revealed at station 30 during 1964.

It will be noted that a maximum surface temperature of 31°C was recorded July 24 and August 4. This is slightly in excess of the maximum recorded in the 1959-1963 period. It is interesting to note that at the 9 meter depth the temperature extremes of 12°C and 19°C for May 1964 represent a maximum 40°C warmer than the maximum in 1959-1963 and a minimum 2°C warmer than in 1959-1963. This coupled with June temperatures, which were warmer than the extremes for 1959-1963, may indicate 1964 as a warmer than usual year.

Temperature profiles for March 28, August 7, October 3, and November 1, 1964 are given in Figure 4. Temperatures one degree centigrade colder at the surface than at the bottom on April 8 at station 30 and centigrade temperatures one degree warmer at the surface than the bottom April 13 indicate that spring turnover occurred in the April 8 to 13 interval. May 30 station 30 temperatures of 22°C at the surface and 13°C at the bottom indicate definite stratification by that date. The thermocline was lower than 6 meters in late May and moved upward to somewhere between 4 and 6 meters by August 7. Fall turnover must have occurred just after November 1, 1964. Air temperatures as recorded daily at the Miami University weather station were obtained and from these monthly means computed. These are given for 1964.
Figure 3

Surface and Bottom Temperatures, Station 30 Acton Lake 1964

No readings were made in July and August but on the basis of former years, temperatures were quite constant near the lake bottom.
Figure 4
Temperature Profiles
1964

Mar. 28 a
Oct. 3 a
Nov. 1 a
Aug. 7 b

a = Station 30
b = Station 21

Depth in Meters
5° 10° 15° 20° 25° 30°
5° 10° 15°
3° 6°
9°

(centigrade)
Figure 5

Monthly Mean Air Temperatures in Degree Centigrade
Oxford, Ohio
1964

Range of daily means

J F M A M J J A S O N D
Because of the interest in emergent insects, a day degree chart for 1964 was constructed based on information inferred from Figures 3 and 5. This is shown in Figure 6. March 1 was selected as the starting point for 1964 day degrees. At that time ice was completely gone and daily mean temperatures were above the freezing mark. Monthly mean air temperature at Oxford for February 1964 was -1.6°C, and for March 1964 it was 4.8°C. A lake temperature near shore on February 22 was 1°C. Fahrenheit temperatures were converted to centigrade in order to have information comparable to that of Miller (1941), Mundie (1954) and Britt (1962).

**Oxygen.** During 1964 oxygen determinations were made using the Burke technique of the Alsterberg modification of the Winkler test. This involved using a 10 ml syringe as a sample container, measuring device, and reacting chamber. This technique had the advantage of easy portability in the small motor boat, and accuracy to the level desired (Burke 1962). Oxygen profiles are given in Figure 7 and oxygen at the 9 meter depth over the late March to early November period is shown in Figure 8. It will be noted that while oxygen approached 0 at the deepest depths, no readings of zero oxygen were recorded during 1964. It is obvious that an oxygen decline began in April and a low oxygen period began in late June and lasted until October.
Figure 6

Day Degrees (Centigrade)
Station 30
Acton Lake 1964
Oxygen Profiles from Acton Lake for 1964

Figure 7

Parts per million

a = Station 30
b = Station 21
Other chemical factors. Tests have been made for calcium, sulfate, magnesium, total hardness, alkalinity and pH during the past six years. In general Acton Lake may be classified as an alkilithrophic, hard water lake with pH values from 7.2 to 9.0 and with hydrogen sulfide in deeper waters in late summer. During 1964 hydrogen sulfide was detected in samples from seven meters and below on August 25.

Biological factors

Phytoplankton. During the summer of 1961 collections of phytoplankters were made by Mr. James Rasdorfer. His list includes the following genera:

- Dactylooccocopsis
- Syneehocystis
- Chroococcus
- Tetragoniella
- Monallantus
- Botrydiopsis
- Cyclotella
- Euglena
- Trachelmonas
- Phacus
- Peridinium
- Ceratium
- Asterionella
- Diatoma
- Platymonas
- Pandorina
- Ankistrodesmus
- Chlorella
- Selenastrum
- Scenedesmus
- Phacotus
- Pediastrum
- Micractinium
- Dictyosphaerium
- Chodatella
- Obcystis
- Crucigenia
- Coelastrum
Gomphonema  
Spirogyra  
Cymbella

The scum on one of the trap floats in 1964 yielded Melosira, Oscillatoria, and Ulothrix. A Cladophora bloom was noted in the littoral zone June 13, 1964.

**Zooplankton.** Fisher (1960) lists the following as components of the zooplanktonic fauna of Acton Lake: Brachionus angularis Goss, Brachionus budapestinensis Daday, Brachionus oalycliforus Pallas, Brachionus furculatus Thorpe, Keratella cochlearis (Gosse), Keratella quadrata Müller, Monostyla quadridentata Ehrenberg, Asplanchna priodonta Gosse, Polyarthra vulgaris Carlin, Polyarthra urpetera (Wierzejski), Filinia longiseta (Ehrenberg), Hexarthra mira (Hudson) and several members of the genus Trichocera.

Fisher lists the copepods Diaptomus pallidus Herrick and Cyclops vernalis Fischer as making up to 11.2% of his metazoan collections.

He indicates cladocerans Bosmina longirostris (Müller) Diaphanosoma leuchtenbergianum Fischer, and Daphnia parvula Fordyce as making up one third of the planktonic crustaceans. Besides the above he lists several ostracods, pseudoplanktonic rotifers, insects, and other cladocerans which were seen only rarely.

Haney (1963) adds Ceriodaphnia quadrangula (Müller) to the lists as the earliest cladoceran plankter to appear in the spring. His studies on the distribution of Bosmina in Acton Lake in 1962 indicate that thermal stratification does
not effectively confine *Bosmina* to any particular depth but that oxygen may play a role in depth penetration by *Bosmina*. Light seemed to be an important fact in *Bosmina*'s vertical distribution and this may be modified by temperature.

**Benthos.** Dredge sampling has been conducted since 1961 and has yielded chironomid, chaoborid, heleid and ephemeropteran larvae and nematodes and annelids. In general the chironomids are more abundant under shallower waters and the chaoborids in the deeper zones. The mayfly nymphs are confined to a rather limited region. More details on benthic collections follow.

**Description and Location of the Stations**

The station locations utilized for trapping and dredge collections are indicated in Figure 9.

**Station 30.** This is the location most utilized by the Acton Lake Limnological Survey and is in the deepest portion of the lake near the dam. Depths in this region were between 9 and 10 meters.

**Station 20.** This location is near the mouth of a large cove with a depth between 5 and 6 meters.

**Station B.** Station B was established to measure the benthic fauna in a region which was purported to have a rapidly increasing depth from shore over a rubble bottom in the old stream bed. The depth in this region was over 6 meters. In many ways this station was similar to station 20.
Figure 9
Location of stations 1964
Contour lines are 10 feet
Station 10. This location was in the zone exposed during drawdown and was between 2 and 3 meters deep when the lake was filled. It was close to one of the two streams which supply the lake. This probably accounted for the fact that frequently this station had one to two degree colder temperature readings at a given depth than stations 20 and 30. It was also somewhat protected from turbulence by wooded hillsides which make up the nearby shoreline.

Station 1. This location was near the west shore slightly to the north of some exposed vegetation which might be termed an island. The area was shallow with parts of it exposed during late summer.

The traps here were located in water about one meter deep during most of the season. The traps were moved out to follow the receding water during drawdown.

Station 21. This station, along with 22, 23 and 31, was established for late summer comparative sampling at mid-lake locations. It had a depth of over 6 meters.

Station 22. This location was midlake and southward from station 21. Depth was 7.5 meters.

Station 23. This location was midlake and halfway between 22 and 30. Depth was 9 meters.

Station 31. The deepest portion of the lake was sought for this station. Depth located was 10 meters. The floats
and traps located at this station disappeared sometime between August 11 and August 13, thus very limited trapping was done at this location.
Two basic instruments were used in the sampling of Acton Lake. These included funnel emergence traps of the Borutzky type and a 6 inch Ekman dredge. Funnel traps were constructed of 0.6 mm stainless steel mesh. The stainless steel mesh was obtained from paper mill rollers through the Diamond National Corporation of Middletown, Ohio.

Mundie (1956) indicates that a 0.4-2 mm mesh was satisfactory for his reservoir work and Brundin (1949) utilized a 0.6 mm mesh. Palmen (1953) used a 0.45 to 0.5 mm mesh. The mesh size clearly limits the lower size range of organisms trapped. It was felt fortunate that stainless steel was available for trap construction. Mundie reported that brass gauze suffered considerable corrosion and that the gauze was easily torn during winter storage. He reported that copper gauze was superior. The stainless steel suffered no corrosion or tearing in two seasons of continuous use. The trap dimensions were patterned after those of Mundie (1956). The frame of the trap was made of stainless steel stock and attachment of the gauze to the frame was accomplished with solder. The emergence jar was an ordinary one quart mason jar with standard threading. These were available from local grocery stores. The neck of the trap was fitted with a brass collar. Copper wire was used to make
the threads of the collar.

The most unique part of the apparatus was the handle. Several features were suggested by Mr. C. D. Pierson, the manufacturer of the traps. These included the attachment of the suspending chain to the handle rather than to the collecting jar. The handle was also made so that it would swivel for convenience in emptying the trap. A device which attached to the boat was made to hold the trap handle during servicing. This permitted two free hands to operate the trap. The entire trap servicing operation was frequently done by one person. Figure 10 and Plate I indicate details of trap construction.

The traps were suspended from a float constructed of a piece of 2 x 4 lumber from 4 to 6 feet in length with styrofoam acid shipping containers attached at each end. These measured 13 inches x 13 inches x 7 inches. For some of the traps in shallow water it was found that one half of one of these half containers was satisfactory. In deeper waters the weight of the suspending chain was great enough to pull the float below the surface. It is recommended that two complete half containers be used as floats. Number 10 cans filled with concrete served as float anchors. One of these was attached to each end of the 2 x 4 by heavy chain. The trap itself was suspended by chain from the middle of the 2 x 4. In most cases a sounding line was used to determine the depth at the float and just enough chain was attached to permit the trap to rest on the bottom. Special experiments
Figure 10

Trap Handle Indicating Cellar and Collecting Bottle
PLATE I

Emergence Trap
were performed with some traps suspended just below the float. This provided comparative information on bottom traps and those just below the surface.

One float with attached trap was placed in the lake during May of 1963 to check its efficiency and to determine emergence at that time. Five traps were placed in the lake in late March of 1964. Several conditions were considered in the placement of the traps. Permission was given by State Park authorities to place traps as long as open waters used by boats were kept clear. Attempts were made to place traps in regions of the lake where stations had been set up for previous studies. Other considerations were differences in lake bottom and depth of water.

Traps at five stations were maintained until drawdown about November 1. Station R, where the trap disappeared in late August was an exception. Traps were serviced on a semi-weekly basis during the study period. An additional trap was placed at station I and was serviced on a daily basis between August 4 and 21. Information from this trap was used to provide a comparison of daily and semi-weekly sampling during a period of high emergence. This trap then was continued as a supplement at station I until September 15 on a semi-weekly servicing. All these traps were placed on the bottom of the lake.

Traps were suspended just below the surface at stations 10, 20, R, and 30 on July 8 and checked on the regular two times per week basis along with the traps on the bottom.
This provided some comparative information. This was continued until August 4.

It was considered desirable to place traps both at the bottom and just below the surface at midlake stations for a limited time. Such permission was obtained providing a special marking buoy was used. Three stations were established. Station 21 was midlake near station 20. Depth was over 6 meters. Station 22 was midlake near station R at a depth of 7.5 meters. Station 23 was midlake between stations R and 30 at a depth of 9 meters. Station 31 was at the deepest portion of the lake near station 30. Depth here was 10 meters. The float at each of these stations was equipped with two traps, one on the bottom and one just below the surface.

Servicing began on these traps August 7, 1964. At some time between August 11 and August 14 the float and traps at station 31 disappeared. This may have been due to the fact that half-acid containers cut in two were used on the ends of the floats instead of full half containers. The additional trap and long chain on the bottom trap combined with a soaking up of water by the 2 x 4 plank may have been enough to submerge the trap. Grappling in the area was not successful in recovering the float and traps. The traps and floats may have been removed by boaters. Equipment at station 21 was removed September 21. Equipment at station 22 was removed October 2. Equipment at station 23 was removed October 13. Equipment at station 10, 20, and 30 was removed
October 30. The trap at station I was removed during the drawdown on November 17.

Trap servicing at all stations except I consisted of coming alongside the float with a small motor boat and carefully pulling the trap so that it was just below the surface. The trap handle was inserted into an attachment on the boat and the jar was unscrewed from the trap. A lid containing 0.6 mm stainless mesh was placed on the jar underwater and the jar label noted. The jars were taken into the laboratory and inverted over chloroform or carbon tetrachloride placed on paper toweling and then emptied. In some cases where insects were stuck to the bottom and edges, the jar was rinsed. Insects were counted at this time and the number of individuals in each family noted. Preservation was in 95% alcohol. Some insects were placed on points on insect pins and preserved in Schmitt insect boxes. A few were mounted in diaphane using the technique of Boesel and Vaughn (1951). At a later date determinations were made to subfamily and to genus.

Dredge sampling data from the Acton Lake Limnological Survey for 1960 were utilized. The 1964 dredge sampling began on January 2 through 14 inches of ice and continued throughout the year. Fifty-eight samples were collected at and near stations 10, 20, R, 30, and I. These were made by combining five 6 inch x 6 inch Ekman dredge hauls in one tub. The tub was taken to shore and washed through two screens of 34 meshes per lineal inch and 15 meshes per lineal inch. The debris and benthic fauna were removed and taken into
the laboratory. The organisms were counted and sorted as to major groups. The groups included chaoborids, chironomids, annelids, ephemeropterans, planarians, heleids, acellids, gastropods, odonates, hydropsychids, and sarcophagids. A wet weight was made of each sample of benthic biomass. A Sartorius balance was utilized and readings made to 0.001 grams. Material was preserved in 95% ethyl alcohol in stoppered vials.

A water sample obtained with a Kemmerer water sampler was obtained from the bottom at monthly intervals during 1964 and temperature and oxygen determinations made. The oxygen determinations utilized the Burke and Alsterberg modifications of the Winkler technique and the temperatures were measured with a standard centigrade laboratory thermometer.

Johannsen and Townes (1952) has been utilized for subfamily, tribe, generic and specific determinations. The names used there are used throughout except for the term chironomid which is used here because of its wide international acceptance. It is used here to include the entire family and equals Tendipedidae of Townes.
The Results Obtained

Analysis of samples obtained by dredging

Data was obtained from the Acton Lake Limnological Survey for 1960. Sampling for the survey was done at a variety of locations in the lake but followed no apparent pattern. These collections were made between June and August and were sorted as to chironomids and chaoborids. These were categorized by the writer into 0-2 meter, 2-4 meter, 4-7 meter and over 7 meter depth groups. Where more than one collection was made at a close time interval within a depth range they were averaged. This information is summarized in Figure 11. At least two generalizations appear from this information: (1) Chaoborids seem more prevalent in the deeper region of the lake. (2) At both the 2-4 meter and the 4-7 meter depths the early summer samples are considerably larger than late summer standing crops.

Figures 12 to 14 indicate standing crop biomass as obtained from Ekman dredge samples during 1964. Sampling extended from January up to drawdown and in the case of station I exposed mud was sampled twice following drawdown. Figure 12 shows the biomass at station 30 is higher than that at other stations. This was reached in early spring when total biomass per square meter reached 31.8 grams. This high in biomass was presumed to be due to the growth of
Figure 11
1960 Standing Crop in Organisms per Square Meter as Obtained by the Acton Lake Limnological Survey
Figure 12

Wet Weight of Macroinvertebrates
Fenae in Grams per Square Meter
at Stations 20 and 30
1964
Figure 13
Wet Weight of Macroinvertebrate Fauna in Grams per Square Meter at Station E 1964

Figure 14
Wet Weight of Macroinvertebrate Fauna in Grams per Square Meter at Stations 10 and 1 1964
the organisms. The station 30 sample for March indicates a higher number of organisms but a much higher biomass than the January sample. Presumably the January to April period is one of growth. A rather marked drop in biomass can be noted in late spring at station 30 with a decline to near zero in September. A small recovery of biomass occurred in October.

Station 20 has less concentrated standing crop biomass in early spring than the deeper station 30 but our samples showed a higher standing crop biomass by mid-summer at station 20. A low standing crop similar to that of station 30 was indicated for September with less than 1 gram of biomass per square meter. Station R (Figure 13) had the shortest sampling period, late April through late August, and appeared to have the same pattern as stations 20 and 30 with an early spring high and an August low of less than one gram per meter.

Station 10 (Figure 14) was in an area of the lake which was out of the water during the drawdown period. There was no significant amount of biomass until June when a high of over 15 grams per square meter was reached. This was followed by a decrease in biomass in late June and July, a low in August and September of less than two grams per square meter, and a slight increase in October.

Station I proved to be the most difficult to sample effectively because of the stones on the bottom. This area was out of the water during drawdown and had only about one
meter of depth during most of the season. A mid-July sample indicated a biomass of over 10 grams per square meter. This was followed by a relatively low August and September biomass, and an increase to nearly four grams per meter in October.

Both stations over 4 meters deep (20 and 30) for which samples are available over the full season show spring highs of over 15 grams per square meter and September lows of less than one gram per square meter. Stations I and 10 can be considered littoral stations. These have higher standing crop biomasses during the September-October period than the profundal stations. A generalized curve of biomass for the entire lake is indicated in Figure 15 provided the sampling stations are considered representative. Figures 16 to 20 indicate dredge collections from stations 30, 20, R, 10 and I based on the relative numbers of individuals. The "other" organisms represent ephemeropterans, heleids, odonates, trichopterans, and sarcophagids.

By far the heaviest concentration of both chironomids and chaoborids was found at station 30. It will be noted that the greatest number of chironomids was found in early spring and that no chironomids were found after the early May sample. The data indicate that these organisms either emerged or left the profundal habitat between early May and mid-June. Very few organisms were taken in samples between June 15 and July 17. During the late summer period station 30 was nearly all chaoborid larvae. Annelids were rather
Figure 15
Generalized Macroinvertebrate Standing Crop
Expressed as Grams per Square Meter
Wet Weight Biomass
Acton Lake
1964
Figure 16

Standing Crop Expressed as Organisms per Square Meter at Station 30
1964
Figure 16
Figure 17

1964

at Station 50

Percent Square Meter

Standing Crop Expresed as Organisms

Ammonia

Orthotrophs

Chemosynthetic
Figure 20

Standing Crops in Number of Organisms per Square Meter From Station I
Acton Lake 1964
sparse throughout the year at this station.

Station 20 had no chaoborids in the early spring sample but had them in all others except one. The chaoborids outnumber the chironomids in only two samples, late May and late August. The total number of organisms was less in the early spring than at station 30 but during the low June and July period there were more organisms at station 20 than at station 30.

Station R had the fewest samples taken and tended to be quite like stations 30 and 20. It was located between these stations and had a depth similar to that at station 20. The April sample from R indicated all chironomids and the August 29 sample was all chaoborids. Late July and early August samples contained very few organisms.

Station 10 was out of the water during the drawdown period. After May, chironomids were the most frequently encountered organism; however annelids made up a significant percentage of some collections, and on August 17 they made up over half of the collection. Chaoborids were found in one half of the collections and in no case did they exceed 50% of the total number of organisms. The maximum number of organisms at station 10 was found in May and was totally chironomid. Station I was located in very shallow water and during the late summer the top of the trap located there extended from the water. At this location only one chaoborid was found all season. The chironomids were the organisms most frequently encountered. Ephemerids and heleids were
also found at this location.

In ecological surveys of benthic fauna, two aspects are often considered. One of these is the distribution of animals at any one time within the lake under study and the other is the changes which take place in this distribution throughout the seasons. Both of these are indicated in the foregoing for Acton Lake with depth as a variable within the lake.

One of the problems of sampling benthic fauna is acquiring a representative and adequate sample. Mundie (1957) indicates the advantage of taking several small samples rather than one large one. He further emphasizes the likelihood that benthic populations will deviate from randomness and occur in patches.

When Acton Lake was considered as a whole, January samples averaged 1452 organisms per square meter. This was based on the January sample shown in Figure 16 and another sample in a midlake region normally about 4 meters deep but less than one meter during the drawdown period. There were no chaoborids in the latter sample indicating a probable midwinter concentration of these organisms in deeper waters. A June fauna of 1166 organisms per square meter was found at station I. It is most interesting to note the 43 organisms per square meter at station 30 and 1512 organisms per square meter at station 20.

The early September mean was 264 organisms per square meter for the lake as a whole. This period appeared to be
low for the season, however station 10 had 566 organisms per square meter. Results from bottom sampling can be misleading. It is probable that during late summer great numbers of the benthic fauna are in the egg stage and in larval stages below that which can be effectively sampled with the usual screens employed.

Mundie (1957) indicates that there is generally a gradual decrease throughout the winter under ice covered lakes and a sharp dip in larval numbers following breakup. This did not appear to be the case for Acton Lake in 1964.

**Analysis of emerged insects**

Insects collected from traps were sorted and counted. Results are indicated in Figures 21 to 28 and Table 4. For analysis by taxonomic groups, samples were grouped into three periods per month, the first to the tenth, the eleventh to the twentieth, and the twenty-first to the end of the month. All figures were converted to emergence per square meter.

A total of 3691 insects was removed from the five traps in position from April throughout the season. This included the trap at station R which disappeared in late August. Of these 2891 or over 78% were the tribe Tendipedini of the subfamily Tendipedinae. The tribe Calopsectrini of the same subfamily produced 26 insects or less than 1% of the total catch. The subfamily Pelopiinae made up 12% of the catch with 425 individuals. Subfamily Hydrobaeninae accounted for 172 insects and 5% of the total. When considered together
Figure 21
Emergence of Tendipedini in Organisms per Square Meter From Station I 1964
Station I

Figure 21
Figure 22

Emergence of Pseudopedini in Organisms per Square Meter from Stations 10, R, 20, and 30 1964
Figure 23

Emergence of Pelopinae in Organisms per Square Meter from All Stations 1964
Figure 24

Emergence of Hydrobaeniinae in Organisms per Square Meter from All Stations 1964
Figure 25

Emergence of Chaoboridae in Organisms per Square Meter from All Stations 1964

Figure 26

Emergence of Trichoptera in Organisms per Square Meter from all Stations 1964
Figure 27

Emergence at Station I in Organisms per Square Meter 1964
Figure 27
Station I

Pelopininae

Tendipedini

Hydrobaeninae

Trichoptera

Figure 28
Emergence at Stations 10, 20, 20 and 30 in Organisms per Square Meter 1964
<table>
<thead>
<tr>
<th></th>
<th>Heleidae</th>
<th>Ephemeroptera</th>
<th>Calopsectrini</th>
</tr>
</thead>
<tbody>
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<td>April</td>
<td></td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>May</td>
<td></td>
<td></td>
<td>I, R</td>
</tr>
<tr>
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<td>I</td>
<td></td>
<td>R</td>
</tr>
<tr>
<td>July</td>
<td>I</td>
<td>I</td>
<td></td>
</tr>
<tr>
<td>August</td>
<td>I, 20</td>
<td>I, 20</td>
<td>R</td>
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</tr>
<tr>
<td>October</td>
<td></td>
<td></td>
<td>20</td>
</tr>
</tbody>
</table>
the family Tendipedidae made up over 96% of the total.

The family Chaoboridae produced over 2% of the total with 92 insects and the family Heleidae accounted for 11 insects making up 0.3 of 1% of the catch. This means that dipterans made up nearly 99% of the total. Trichopterans accounted for 55 insects or about 1% and Ephemeroptera accounted for only 0.14 of 1%.

Figures 21 and 22 represent the emergence of the tribe Tendipedini. It will be noted that the greatest quantity of emergence occurred at station I and that the scale employed on Figure 21 is smaller than on other similar figures to accommodate this greater emergence. Members of the tribe Tendipedini were most frequent at all stations except 30 where they were outnumbered by chaoborids (figures 22 and 25). The tube building midge Phytotendipes (Glyptotendipes) lobiferus (Say) appears to be the most frequently encountered species. Figure 22 demonstrates the fact that the deeper water stations show an earlier emergence than those in the littoral zone. This is probably associated with the drawdown procedure. It will be noted that station 10 reaches a peak emergence in May. Station I, which is out of the water during drawdown, far exceeds others in quantity of emerged adults trapped from June through the rest of the emergence period.

A rather large epifauna was noted on traps in the August - September period. This probably tends to distort the emergence pattern of this period. It seems logical that many insects were mating in the collection bottle, ovipositing in
the trap and then larvae were building on the trap itself.

Figure 21 may indicate this with a late June peak of over 300 insects emerging per square meter, a late July peak of 600 per square meter followed by a decline, and then a continuous high emergence in the mid-August through September period. It was felt that many of the eggs from the late June insects provided the late July adults and the August and September adults were from eggs produced by the July adults.

There was no emergence from station 30 after May.

It was speculated that the August and September emergences from stations 20 and 10 may have been due to bivoltine species.

The Pelopiinae which made up 12% of the total are shown in Figure 23. Procladius and Pentaneura were the genera most frequently encountered and are considered subsequently. It will be noted that with this subfamily the emergence from station I was as early as at other stations. This indicates an invasion of the littoral zone by larvae from regions under water during the winter period. As with all the taxonomic groups except Chaoborinae and Calopsectrini the emergence is greater at station I. The distribution among the stations, however, is more evenly distributed than that for the Tendipedini.

The Hydrobaeninae as indicated in Figure 24 were found most frequently at I and reached fairly high numbers during the October-November period. Indications are that most members of this subfamily show a strong preference for shallow
The genus *Cricotopus* was most frequently encountered in this subfamily.

The Chaoboridae are shown in Figure 25. This group shows a definite profundal preference with station 20 showing the most frequent emergence closely followed by station 30. When compared with other groups, the Chaoboridae emerge late. It is difficult to select any one period of greatest emergence except that July seemed to be the month in which the greatest number of emerged chaoborids was trapped. The fact that none was trapped at station R is surprising.

Trichopterans shown in Figure 26 were found at R and I only. It is possible that the underwater logs at station R provide an ideal substrate for the construction of cases. Many more were taken in the shallow water station I than at R. August appears to be the time of emergence.

Table 4 indicates the distribution according to time and station of the three groups least frequently found as trapped adults. These groups together constituted about 1.1% of the total insects trapped. It will be noted that all were taken at station I and that the Calopsectrini were more frequently found in the deeper water 10, R, and 20 stations than in the shallow I.

The small number of the family Heleidae is not surprising when it is considered that Guyer (1955) demonstrated an apparent avoidance of funnel traps by members of this family.

Figures 27 and 28 compare stations I, 10, R, 20 and 30
by groups of organisms. Station I was by far the most productive region sampled. A total of 3123 insects was taken in the semi-weekly samples. This represented 85% of the total from the five stations sampled over the year. Insects of the tribe Tendipedini made up 83% of the total from this location. Very high numbers of these emerged in August and September. The emergence of the Chaoborinae at stations 10, 20, and 30 has already been referred to. If stations I and 10 are considered littoral it is interesting to note that over 92% of the emergence sampled is in this zone. This region, however, is only 14% of the total lake area.

Table 5 indicates total April to November emergence from each of the five stations in organisms per square meter. If the mean emergence of stations I and 10 is representative of the zone less than 3 meters, the emergence from station 20 is representative of the 3 to 9 meter zone, station 30 emergence representative of the deepest zone and appropriate considerations given to the relative areas of these depth zones in the lake, then an average of 1400 organisms per square meter is reached for the lake as a whole. Such figures must be treated with extreme caution. Morgan, Waddell, and Hall (1963) and Guyer (1955) among others have indicated the fact that funnel traps do not successfully trap all emerging insects and are more effective for some groups than others. The presence of epifauna distorts in the direction of more insects than might ordinarily be present.
**TABLE 5**

**TOTAL EMERGENCE ALL STATIONS**

<table>
<thead>
<tr>
<th>Station</th>
<th>Pelopiinae</th>
<th>Hydrobaeniidae</th>
<th>Calopsectrini</th>
<th>Tendipedini</th>
<th>Heleidae</th>
<th>Ephemeroptera</th>
<th>Trichoptera</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>1,236</td>
<td>672</td>
<td>32</td>
<td>10,404</td>
<td>36</td>
<td>16</td>
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</tr>
<tr>
<td>10</td>
<td>256</td>
<td>8</td>
<td>4</td>
<td>720</td>
<td>72</td>
<td></td>
<td></td>
<td>1,060</td>
</tr>
<tr>
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<td>380</td>
</tr>
<tr>
<td>20</td>
<td>120</td>
<td>4</td>
<td>5</td>
<td>212</td>
<td>4</td>
<td></td>
<td></td>
<td>528</td>
</tr>
<tr>
<td>30</td>
<td>76</td>
<td>85</td>
<td>124</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>288</td>
</tr>
</tbody>
</table>

*Trap B disappeared between August 28 and September 1.*
Emergence of selected species and groups

Several species and genera were recognizable and calculations of these emergence patterns were made. Determinations were made with the aid of the keys in Johannsen and Townes (1952) and nomenclature used there is applied here.

Genus Procladius. This genus was frequently found at all stations. The following species were encountered: Procladius adumbratus Johannsen, Procladius bellus Loew, Procladius culiciformis (Linne) and Procladius choreus Meigen. P. adumbratus was taken in two samples, May 13 from station I and May 2 from station R. P. culiciformis appeared in five samples, May 6, October 6 and October 27 at station I, October 6 at station 10 and August 28 at station R. P. choreus was taken five times at station I, April 13, April 15, April 19, June 4 and August 7. It was also found at station R July 28. The fact that over twenty individuals appeared in the early April samples indicates that this species was one of the first to emerge. The most frequently encountered members of this genus varied in size so that they could run to either P. bellus or P. pusillus in the key with many intermediate in size. The author called all specimens Procladius bellus. The emergence pattern for this species is shown in Figure 29. All stations over a wide range of depth are represented by emergence. There appears to be a definite May emergence peak. The data indicate that this is a bivoltine species at Acton Lake with the late summer generation.
Figure 29

Emergence of Procladius bellus in Organisms per Square Meter from All Stations 1964
Figure 29

Station 30

Station 20

Station 10

Station I

May June July Aug Sept Oct Nov
more frequent in the littoral zone than in the profundal. Guyer (1954) noted an emergence period for P. bellus from mid-June to mid-August.

Genus Pentaneura. Members of this genus are recognizable by the non-produced costal wing vein and ringed legs. Most of the specimens appeared to be Pentaneura monilis (Linne). Figure 30 indicates that this genus emerged most frequently at station I. There was no emergence of this species at station 30. Emergence extended from mid-April through October. Mundie (1957) found one and two meter depths as optimum for P. monilis in his studies at Kempton Park East Reservoir in England. He found very little emergence before July but a steady emergence from July to mid-October. Guyer (1954) noted an emergence period of a species of Pentaneura probably monilis of mid-June into early September. He was dealing with ponds near Lake City, Michigan.

Genus Cricotopus. There appear to be at least two species of this genus represented among emerged insects. Fourteen June 4 and fourteen June 13 specimens from station I are definitely Cricotopus trifaciatus (Panzer). The two station 1 October specimens and several of the June specimens appear to be Cricotopus tricolor (Meigen). All station 10 specimens were C. trifaciatus. The rather meager emergence available indicate that possibly C. trifaciatus is univoltine and C. tricolor is bivoltine in Acton Lake. Members of this genus seem to have a definite preference for
Figure 30

Emergence of Pentamecura in Organisms per Square Meter from All Stations 1964
Figure 31

Emergence of Cricetopus in Organisms per Square Meter from Stations 10 and I 1964
the littoral zone. Figure 31 indicates the 1964 emergence for this genus.

Phytotendipes (Glyptotendipes) lobiferus (Say). This species of the tribe Tendipedini (Chironomini) appeared to be the most frequently encountered organisms in the mid-summer months. It first appeared in mid-June collections at station I and lasted until mid-October at this same station. It was also encountered at stations 10 and 20. Some of the most interesting information on this fauna came from the experiment involving daily trapping at station I. This trap was placed August 3 and was serviced daily until August 21. Large numbers of Phytotendipes (Glyptotendipes) lobiferus began to appear August 13 and by August 15 it was found in extremely large numbers. This species builds a crude tube on a suitable substrate and when station I traps were removed large numbers of these tubes were found. It was interpreted that tube building probably began about August 3 when the trap was placed at station I and the large daily emergences of August 15 to 21 represent largely individuals which had built tubes on the trap. This same phenomenon was occurring at the regulation station I trap and it is probable that the very high September emergences at that location were due to insects which had used the trap as a substrate.

This species along with Tendipes plumosus (Linné) and Tendipes decorus (Johannsen) has been characterized as one which is tolerant to anaerobic conditions and which are often
associated with pollution (Thienemann, 1954; Leathers, 1922; Lindeman, 1941a).

Lindeman (1941a) characterizes _P. lobiferus_ as the most prominent "ooze browser" in the senescent Cedar Bog Lake in Minnesota. He states that flocculent particles of the planktonic ooze, settled plankton, and ooze film organisms serve as food.

Townes (1945) indicates that _Phytotendipes (Glyptotendipes) lobiferus_ is probably conspecific with _Glyptotendipes gripekoveni_ K. of Europe. Thienemann (1954) describes the tube building of this organism and indicates that it is both a leaf miner and builder of tubes in the mud. He also cites Lindeman's Cedar Bog work as indicating three generations per year. There are at least that many generations per year and possibly more at Acton Lake.

_Dicrotendipes punctipennis_. The distribution of the Dicrotendipes in bottom sediments is indicated in Figures 16 to 20 and the emergence of this group is indicated by Figure 25. _Dicrotendipes punctipennis_ (Say) appears to be the species represented in the collections. The tendency of this species to reach high numbers in the winter in the deepest portions of the lakes and then to move toward the littoral has been reported by Wood (1956) and by others. Wood (1956) reports that the life cycle is of a one year duration in Little McCauley Lake in Ontario. A June drop in his numbers of organisms in bottom sediments indicates an emergence. The
author's emergence data indicate emergence from June and July into September. The fact that the numbers of benthic larvae were very low in July may have been due to the fact that this organism is frequently limnetic and many may have been in the water mass during the time of sampling. Wood (1955) reports that larvae tend to become more limnetic in the summer months. This was frequently observed in our studies by the presence of larvae in emergence traps. The larvae appear to be most limnetic just after hatching and just before emergence. These two facts together would tend to account for our low benthic numbers during the period of highest emergence. Our emergence data also point to a single generation a year in Acton Lake.
Analysis of Sampling Techniques

**Daily sampling vs. semi-weekly sampling**

In order to check the efficiency of semi-weekly sampling a series of collections was made on a daily basis. The station was selected because of the high number of insects emerging in that vicinity. A second trap was placed nearby on August 3 and checked on a daily basis. Total numbers of adult insects taken in the daily collections, totals of the daily collections during the same time period as regular collections and the regular collections are shown in Table 6.

It will be noted that during the experiment 1419 insects were collected in the daily checks while 601 insects were collected with the semi-weekly method. This is approximately double for the daily basis. This might be interpreted that seasonal collections should be doubled to attain a number of insects caught by the traps during the sampling season. It is probable, however, that fewer insects decompose during the cooler spring and autumn months.

**A comparison of traps placed on the bottom and below the surface**

One of the problems involved in utilizing funnel emergence traps is the placement of these traps. Guyer (1955) found no significant difference in catches using traps on the bottom and suspended traps in his work in small Michigan
### TABLE 6
A Comparison of Daily and Semi-Weekly Sampling

<table>
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<th>Date</th>
<th>Insects Daily Sample</th>
<th>Total from Sampling Period</th>
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<td>14</td>
<td></td>
<td></td>
</tr>
<tr>
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</tr>
<tr>
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<td></td>
</tr>
<tr>
<td>Aug. 9</td>
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<tr>
<td>Totals for Experimental Period</td>
<td>1,419</td>
<td></td>
<td>601</td>
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</tbody>
</table>

X = Invalid Sample
lakes. It was desired to check this for Acton Lake. Two experiments were performed. The first involved the placement of traps below the surface of the water from the ends of the floats used regularly at stations 10, 20, R, and 30. The results of the sampling period July 9 to August 4 are given in Table 7. It will be noted that when all stations are considered together there were 62 adults taken in traps on or near the bottom and 61 adult insects in traps which were placed beneath the water's surface below the float. It was noted, however, that station R and station 30 both had more insects in the surface traps.

A second experiment was performed to check the validity of the increased catch in the station 30 surface trap. Floats at four midlake deep water stations were anchored during the August to October period. Station 21 was over a depth of six meters, station 22 was at a depth of over seven meters, station 23, was at nine meters, and station 31 was at a depth of ten meters. Station 31 disappeared shortly after the experiment began and is not considered as a part of it. The results are given in Table 8. It is interesting to note that 34 adult insects were trapped near the bottom while 129 were taken in the traps suspended below the surface.

If all surface traps are considered as a group and all bottom traps are grouped, the difference in numbers may be considered significant at the .01 level with a t statistic of 4.03 (Freund, Livermore and Miller 1960).
### TABLE 7

A Comparison of the Number of Adults Obtained from Traps Placed on the Bottom and Below the Surface

<table>
<thead>
<tr>
<th>Date</th>
<th>Station 10</th>
<th>Station 2D</th>
<th>Station R</th>
<th>Station 30</th>
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<tr>
<td></td>
<td>Bottom</td>
<td>Surface</td>
<td>Bottom</td>
<td>Surface</td>
</tr>
<tr>
<td>July 10</td>
<td>3</td>
<td>1</td>
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<td>0</td>
</tr>
<tr>
<td>July 14</td>
<td>14</td>
<td>12</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>July 17</td>
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<td>July 28</td>
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<td>July 31</td>
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<td>6</td>
</tr>
<tr>
<td>Aug. 4</td>
<td>3</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>TOTALS</td>
<td>24</td>
<td>21</td>
<td>23</td>
<td>15</td>
</tr>
</tbody>
</table>
TABLE 5

A Comparison of the Number of Adults Obtained from Traps Placed on the Bottom and Below the Surface

<table>
<thead>
<tr>
<th>Date</th>
<th>Station 21</th>
<th></th>
<th>Station 22</th>
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<td>Aug. 14</td>
<td>0</td>
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<td>3</td>
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<tr>
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<td>1</td>
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<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Aug. 21</td>
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<td>x</td>
</tr>
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<td>Aug. 25</td>
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<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
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<td>Aug. 28</td>
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<td>0</td>
<td>1</td>
<td>0</td>
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<td>3</td>
<td>7</td>
<td>1</td>
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<td>3</td>
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<td>3</td>
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<td>0</td>
<td>x</td>
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</tr>
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<td>7</td>
</tr>
<tr>
<td>Sept. 18</td>
<td></td>
<td></td>
<td>1</td>
<td>1</td>
<td>11</td>
<td>3</td>
</tr>
<tr>
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<td></td>
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<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Sept. 25</td>
<td></td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>7</td>
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<td>0</td>
<td>4</td>
</tr>
<tr>
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<td>3</td>
<td>6</td>
<td>0</td>
<td>3</td>
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<tr>
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<td></td>
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<td>0</td>
<td>6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

X = Invalid Sample
Midlake stations compared with shoreward stations

In planning the initial experiments, care was taken to avoid placing traps and buoys in areas used frequently by boats in the more open parts of the lake. It was felt that profundal zone fauna could be measured using stations fairly close to the east shore and thus stations 20, R and 30 were utilized. Permission was obtained in August to use special buoys on three midlake stations. This was done to check the assumption that the stations 20, R and 30 were measuring the same thing. Two traps were attached to each station, one below the water's surface and one near the bottom. The results are given in Table 8. When these traps are paired with the nearest trap closer to the shoreline, the results are given in Table 9. A t-test was applied to each of the pairs to test the equality of the means. Means at 20 and 21 were 3.1 insects per collection and 1.2 insects per collection. This provided a t statistic of 2.08 which indicates that this difference is significant at the .05 level with 28 degrees of freedom. Traps R and 22 had means of .86 and .29 insects per collection and the t statistic of 1.2 did not indicate a significant difference with 22 degrees of freedom. Traps 30 and 23 each had means of 1.0 insects per collection. The similarity of the 20 and 23 collections, the near similarity of the R and 22 and 30 and 23 collections and the greater collection from 20 than from 21 indicate that the shoreward deep stations collect at least as many insects as those at midlake locations.
A Comparison of the Number of Adults Obtained from Midlake Stations 21, 22, and 23 and Stations 20, H and 30

<table>
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<th>30-23</th>
</tr>
</thead>
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</tr>
<tr>
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<td>0</td>
</tr>
<tr>
<td>Aug. 18</td>
<td>8, 1</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Aug. 21</td>
<td>1, x</td>
<td>0</td>
<td>7</td>
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Discussion

Productivity. There is frequently confusion between standing crop measurements and productivity. It is hoped that the standing crop data presented here, coupled with emergence information, can be used to give some indication of the role of benthic organisms in the total productivity of Acton Lake. March sampling in 1964 indicated a wet weight invertebrate biomass of 15.5 grams per square meter or 155 kg/ha for the lake as a whole. At this time of year more than at any other the energy of the lake is in the form of macroinvertebrate benthos. Lindeman (1941a) gives the advantages of using wet weights instead of dry weights in studies of bottom productivity. The chitinous portions of insects are not digestible and thus do not enter the trophogenic cycle and if insects are oven dried they are not available for taxonomic purposes and future reference. Lindeman (1941a) has devised a scale of conversion factors between moist and dry weights. He gives Chaoborus a value of 12.0 - 16.0 and Chironomus a value of 5.0 - 6.0. Textbooks have values of from 65% to 95% water for various animal tissues. Because the organisms in this study are largely a mixture of chironomids and chaoborids, it is felt that a value of 10% of the wet weight is a reasonable dry weight value for comparison with other workers.
If mid-June and early September dredge samples are given values appropriate to the lake areas at these depths, wet weights of 19.7 kg/ha and 14.7 kg/ha are obtained respectively. Our average results seem to be in the same magnitude as obtained by Oliver (1961) in Lac La Ronge, Saskatchewan (88 kg/ha) and Tebo (1955) in Lake Lizard in Iowa (187 kg/ha over fibrous peat and 67 kg/ha over sand and clay). It is much less productive than the 824 kg/ha found in Lake Erie by Wood (1953). The need for bottom samples at a variety of times to indicate productivity is indicated.

The mean mass per organism for March, June and September provides interesting information. These masses are .015 grams, .002 grams and .007 grams respectively. Neess and Dugdale (1959) utilize this kind of information along with the number of organisms per unit of area to produce a productivity curve of Tanytarsus jucundus (Walker). Their curve is based on a cohort in which individuals grow at approximately the same rate and emerge together. Because our samples contain several cohorts, their method does not apply but several facts may be observed. The smaller individual biomass of June organisms compared to March organisms indicates that either the large insects have emerged leaving the smaller ones to emerge later or the larvae are of second generation individuals for the season and thus are small. Both cases are probably true. Emergence records indicate that several large midges such as Tendipes staegeri (Lundbeck) and Tendipes crassicaudatus (Malloch) have been trapped in the April to
mid-June period. The emergence of these large insects de­
plicated numbers and decreased average size. The increase in
mean mass from June to September was .0023 grams to .0074
grams. When insects trapped during the April to mid-June
period are tabulated and values appropriate to lake depth
are assigned, a value of 325 insects per square meter is
reached for the lake as a whole. This value is probably
more accurate than values which could be derived for later
parts of the season because: (1) there is less fungal de­
composition in the collecting bottles than later, (2) there
is less likelihood of mixing two generations at this time
and (3) the traps have not yet collected any epifauna and
served as breeding chambers.

The 325 emerged insects represent 28% of the March
standing crop obtained by dredge sampling. It is probable
that somewhere between 30% and 50% of the March standing
crop have emerged by June. The remainder has: (1) remained
as a part of the mid-June standing crop, (2) become limnetic
(Chaoborus), (3) died and been reduced by benthic bacteria
or (4) become the prey of secondary consumers and been raised
to a higher trophic level. Doxtater (1962) has indicated
that chironomids were in 76% of the bluegill, Lepomis mach­
rochirus Rafinesque, stomachs that he examined from Acton
Lake. He found chironomids in 67% of the one inch specimens,
and 100% of the two, three, and four inch fish and lesser
amounts in larger fishes. He further noted that Chaoborus
was not used by Acton Lake bluegills. Predation by fishes
and emergence probably account for most of the decrease in March to June biomass.

Nees and Dugdale (1959) using the data of Anderson and Hooper (1956) estimate that no more than 18.2% of the energy of the cohort of *Tanytarsus jucundus* in a Michigan lake left the lacustrine ecosystem. Our emergence information indicates that considerably more than that leaves the ecosystem at Acton Lake during the March to November period.

**Temperature and emergence.** Miller (1941) found temperature to be the most influential factor in chironomid development in Costello Lake in Canada. Unfortunately none of the species for which he had abundant temperature information was a species that was found in abundance in the Acton Lake studies. Several comparisons are possible, however, with results obtained by Mundie in British reservoirs. As indicated in Figure 29 *Procladius bellus* has two and possibly three emergences per year. Using the day degree curve of Figure 6 it appears that the first generation emerges after about 400 day degrees in the spring. A second larger generation appears early in August in the littoral zone. There appear to be about 1900 day degrees between these generations. If the October specimens represent a third generation at station 1, there appear to be 1300 day degrees between the August and October generations. If there are two generations at station 20 which is below the thermocline, there are 2500 day degrees between generations. These fluctuating values are all greater than 1230 day degrees which
Mundie lists for the *Procladius choreus* - *Procladius crassinervis* complex in England. It seems probable that the small August emergence represents an intermediate one from the profundal zone. This would indicate about 1600 day degrees for the development of a generation. It is logical to assume some accumulation of day degrees between October and May in the first generation to appear. Probably between 1300 and 1500 day degrees are required for the development of *Procladius bellus* in Acton Lake.

The genus *Pentaneura* shows littoral zone peaks in June and August. There appear to be 1300 day degrees between them. If April emergence from deeper stations represent a first generation and the June emergence from the littoral region a second, a difference of 1300 day degrees is recorded. Mundie (1957) found August and September peaks of pentaneurid emergence and his day degree curve yielded a value of 1400 day degrees between them. About 1300 day degrees appear to be required for the development of Acton Lake pentaneurids.

*Cricotopus tricinctus* appears to be bivoltine in June and October. About 2800 day degrees elapse between June and October emergences. If the 600 post-October day degrees in the littoral zone are added to the 1200 spring day degrees, a total of 1800 day degrees plus those accumulated in the winter are required. It would appear that this species has higher cumulative temperature requirements than some of the other species and groups studied.

*Phytotendipes* (*Glyptotendipes*) *lobiferus* appears to have several generations a year and during mid-summer may
require as few as 600 to 800 day degrees.

Chaoborus which appears to have a single generation per year at Acton Lake first emerged in June indicating an accumulation of 1000 1964 day degrees in the spring. Whether or not this is a factor in Chaoborus development is not known.

**Trophic levels.** The watershed provides nutrient materials necessary for food production in the lake. Studies are now in progress to compare the concentration of inorganic ions and productivity as measured by oxygen production of phytoplankters. This is being conducted on Acton Lake and on several other southwestern Ohio reservoirs. Lindeman (1941a) has demonstrated that benthic ooze bacterial activity is much greater among aerobes than anaerobes and that heterotrophic bacteria play a major role in providing a supply of nutrients to the lake ecosystem.

The nutrients which come in from the watershed and those which are made available by heterotrophic bacteria are incorporated into the food web by the photosynthetic activity of phytoplankton and nannoplankton. These organisms in turn provide food for zooplankters. The remains of both zooplankters and phytoplankters form benthic "ooze" which, along with sediment from the watershed and surrounding shoreline, form the bottom materials. Some chitinous parts of planktonic organisms are lost to the cycle and may become a permanent part of the bottom as microfossils. Of special interest in Acton Lake is the role of the "ooze browser". Lindeman (1941a) defines browsers as organisms
which are herbiverous or saprophagus and which feed primarily on the substrate. The large number of Phytotendipes (Glyptotendipes) lobiferus which fill this niche has already been mentioned. Lindeman (1941a) feels that distinctions cannot be made between "ooze browsers" and "plant browsers". The well known habits of Phytotendipes as leaf miners and builders of tubes in the mud and on bottom rubble demonstrate this. These organisms probably form a significant link between synthesized organic matter and practical fish productivity. The benthic predator niche at Acton Lake is filled by such organisms as Procladius bellus, Procladius culiciformis, Pentaneura sp, Chaoborus punctipennis, and the Calopsectrini. Chaoborus can be considered both a component of the benthic zone and the limnetic zone. Its habits as both a plankton browser and predator are well known. It is interesting to note that this organism was not found in blue-gill stomachs by Doxtater (1962). Whether this is due to the fact that this organism is fragile and easily overlooked or is not eaten by bluegills at Acton is not known. Bluegills feed in fairly shallow water and it may well be that they do not feed in the deeper portions of the lake where Chaoborus is prevalent. Any effort to improve fish production should consider the large Chaoborus population and the possibility of its incorporation into a higher trophic level.

Drawdown. The annual drawdown provides a section of lake out of the water between mid-November and March. This probably reduces the number of higher aquatic plants and this
reduction reduces the number of insect forms associated with leaf mining. Phytotendipes (Glypotendipes) lobiferus however is abundant as a mud tube dweller. Figures 19 and 20 indicate that littoral stations 10 and I are invaded by annelids shortly after the lake level is raised and probably by insect larvae as well. Figures 27 and 28 indicate an early emergence of the Pelipiinae at both stations and the Tendipedini at station I. The high productivity and turnover of the very shallow littoral area is indicated by the relatively low standing crops indicated in Figure 20 as compared to the high emergence as indicated in Figure 27.

In general it may be stated that the drawdown procedure tends to concentrate the benthic fauna in the deeper waters. Any reduction in the shallow waters due to this procedure is temporary.

Samples of exposed muds taken in January indicate that no larvae large enough to be trapped by the screens employed survive. The fact that 235 larvae per square meter were found in exposed mud behind the retreating water in November and 25 per square meter were found in frozen mud in December indicates that this portion of the fauna is lost as developing insect larvae but is available as a constituent of littoral ooze.
Summary and Conclusions

1. Studies of sedimentation data collected by the Ohio Division of Water indicate an average deposition of 0.36 feet between impoundment in 1957 and 1961. A useful life of 114 years was predicted based on this rate.

2. Temperature information in 1964 indicates an accumulation of 3600 day degrees at the bottom in the deeper waters and 4600 day degrees at the surface.

3. Oxygen determinations were as high as 14 parts per million to less than one part per million. The latter was at the bottom in deeper waters.

4. Benthic sampling was done at several profundal and littoral stations with an Ekman dredge. This was done through the ice in January and lasted until after drawdown in November. The lake as a whole showed a January average of 1452 organisms per square meter, a June average of 863 organisms per square meter and a September average of 264 organisms per square meter. Average individual larval mass increased from 0.003 grams to 0.007 grams between June and September.

5. Midwinter and early spring samples showed a mixture of chironomids and chaoborids in deeper waters. Summer dredge samples indicate that chironomids are found chiefly
in the more littoral zones and Chaoborus in the profundal.

6. Chaoborus has definite limnetic tendencies in Acton Lake.

7. Trapping was done utilizing funnel emergence traps of the Borutzky type. Of 3691 insects removed from five traps, over 78% were of the tribe Tendipedini, 12% were of the subfamily Pelopiinae, 5% were of the subfamily Hydrobaeniinae, 2% were of the family Heliidae and 2% were of subfamily Chaoborinae. The remainder were trichopterans, ephemeropterans, calopsectrans, and miscellaneous forms.

8. By far the greatest number of adults emerged in the shallow water with totals reaching up to 500 per square meter per day emerging in August and September. Ninety-two per cent of the emergence was from the littoral zone which made up 14% of the total lake area.

9. Emergence trap information coupled with dredge results indicated that between 30% and 50% of the March standing crop had emerged by June. The remainder had become limnetic, been preyed upon, died and been reduced by bacteria or was a part of the June standing crop.

10. A total lake emergence of 1400 organisms per square meter over the April to November period was calculated by considering trap results from all depths and compensating for areas of the lake at various depths.
11. *Procladius bellus* Loew was trapped at all depths and appears to be bivoltine at Acton Lake. Between 1300 and 1500 day degrees appear to be required for its development.

12. Members of the genus *Pentaneura* emerged most frequently in the very shallow water but were not limited to this zone. About 1300 day degrees appears to be required for development.

13. *Phytotendipes* (*Glyptotendipes*) *lobiferus* (Say) was the organism most frequently encountered in the emergence traps. This organism is an "ooze browser" and builds crude mud tubes. It used the traps as a surface to build on. Three or more generations per year were recorded. Day degree requirements were as low as 600 to 800.

14. *Chaoborus punctipennis* (Say) has one generation per year with emergence extending from June into October. Emergence was greatest from the deeper waters.

15. During the warmest part of the year daily sampling yielded twice the number of insects per unit of area per unit of time as did twice weekly sampling. This was the time when the greatest decomposition in the collecting bottle could be expected.

16. Shoreward deep water stations collect at least as many emerging insects as traps at midlake, deep water locations.
17. Traps placed just beneath the water's surface did not collect significantly more insects than traps placed near or on the bottom at depths less than six meters. Traps just below the surface trapped significantly more insects than bottom traps at depths greater than six meters.

18. A maximum amount of benthic fauna was found in March when 155 kg/ha was found for the lake as a whole. This declined to 19.7 kg/ha by June and to 14.7 kg/ha by early September. Increases were then recorded for October.

19. The drawdown procedure in November tends to limit higher aquatic plant growth in the littoral zone. A low littoral standing crop is found in the spring but recovery follows quickly. Drawdown tends to concentrate benthos in deeper waters but some midge larvae and annelids are lost behind the receding water in November. These contribute nutrients to the bottom materials however.


