LIMNOLOGICAL STUDIES

of the

DUNDAS MARSH REGION

by

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Contents of the thesis:

A limnological study of the Dundas Marsh region, involving the main physical, chemical and biological factors, and their interrelationships, as investigated during the summer seasons of 1946 to 1948, inclusive.

The account includes a review of pertinent historical and descriptive material on the entire region.

PREFACE

This is a limnological study of the Dundas Marsh, which is located in Wentworth County at the extreme western end of Lake Ontario. The conditions which are described have been studied over a period of three summers, and a representative picture of environmental relations in this area has now been made.

The Summer season of 1946 was devoted to preliminary evaluation of the water conditions. The early phase of the program involved a detailed study of the water basin by systematic sounding. Water samples were obtained at representative locations and analysed by various physical and chemical tests.

In 1947 the study of the physical-chemical factors in the water was made with emphasis on their relations to the fish population of the Marsh. A new field laboratory constructed on the shore of the Marsh at the end of the 1947 season afforded facilities for the continuation of this part of the work. During 1948, the program was enlarged to include a study of zooplankton.

This survey study is a preliminary one. No previous limnological work has been reported for this area, as far as we are aware. The available literature pertaining to the Marsh has reference to historical, geological, and natural history topics which are of no great significance to this survey.

It has been well established through the work of several authors that the summer temperature, dissolved gases (oxygen and carbon dioxide), carbonates, and hydrogen ion concentration, in a body of water are the fundamental units of productivity. These factors, expressed along with the fish life and plankton population, give a relatively accurate picture of the nature of the water.

The above factors were determined in the Marsh, and a discussion of their presence and interactions constitutes the body of this thesis. The observations are discussed and tentative conclusions are drawn from these results.

Acknowledgements

The study involved in this thesis has been made possible through the willing cooperation of many people. I wish to express my sincere appreciation to those who have aided the work, both in the field and in the laboratory. The laboratory phase of this program was made possible through the facilities of McMaster University.

I am indebted to the Research Council of Ontario for the award of a scholarship by which the work involved in this thesis could be carried on throughout the fall, winter and spring seasons of 1947-48. I also wish to express my indebtedness to Dr. A. E. Warren of McMaster University, who first introduced me to this study, and under whose guidance it has been completed.

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CHAPTER I

Introduction

Marsh lands, as recently pointed out by Graham ('47), have been the brunt of a two-fold attack for many years. On the one hand are those who believe that the wet lands should be preserved for wildlife. Opposed to this view are those who believe that the marshes should be utilized for other purposes.

This argument ultimately concerns the question of drainage for the wet lands. As the result of improper utilization of some marshes, drainage has led to the development of a dry, useless desert, but often the marshes, where properly suited for such drainage, have resulted in the establishment of rich agricultural land, more useful than it had been as a marsh. The question of what to do with an existing marsh can be answered only by a correct analysis of the marsh, and from this a proper classification made for its better utilization.

During recent years various government agencies have become increasingly conscious of the importance of proper land and water management. They have often advocated the drainage of marsh areas to increase the cultivated land for agricultural purposes. This type of development has fortunately taken place only after careful analysis of the full capabilities of the area. In most cases the area drained was proved to be far superior agriculturally than it would have been as a wildlife refuge. However, in any consideration of land use, careful consideration must be taken of its potentiality as a wild life refuge, first, before further treatment is given.

Marshlands in an undisturbed form are of great value, and are fortunately in most cases unsuitable for adapting to crop production. They serve best in an undrained condition to provide ground water maintenance in the surrounding land. They maintain conditions suitable for wildlife, such as refuges for muskrats and other types of aquatic animals. They offer havens for migratory birds. They also offer much in a recreational sense. As shoal waters adjacent to large bodies of water, they provide breeding grounds for deep water fish and a natural habitat for warm water species.

According to Storer ('37), the beginning of the present century marked an important step in the utilization of existing marshlands. Owners of a few eastern marshes recognized the value of the muskrat, and treated the marshes as "wild farms" from which they obtained a sizeable annual yield. Bailey ('37) stated that the muskrat industry was recognized as one of the most important resources of the State of Maryland, and that muskrat marshes were as valuable as any other type of farm land. Hewitt ('47) described the profitable conversion of a farm in Southern Ontario into a marsh. With the flooding, natural vegetation rapidly developed over the area, with cattails, bulrushes and submergents all thriving. During successive seasons the profits derived from hunting and fishing were more than the land would have yielded through land crops.

With the wildlife and fishing agencies becoming aware of many former mistakes in draining unsuitable land, the wet lands are now approached scientifically, to obtain the most efficient returns. In some cases, as above, the conversion of dry land to marsh conditions has resulted in increased profits through a better land use. Lessons learned from earlier mistakes have led to the establishment of natural marsh areas as ecological study areas, to indicate the expected yield from other wet lands, for which state such lands are naturally best fitted. A thorough understanding of water classification and of marshlands, leads to more effective management of these areas.

Outstanding in the development of the survey work of natural waters has been the programs of many of the U. S. State conservation departments. In the most usual approach, the field programs include investigations of numerous biological and physical factors, especially related to fish production.

A knowledge of the relations of these factors to each other, and to the organism is important for the interpretation of the conditions occurring in a complex aquatic habitat. Such studies are of first importance to fish culturists, in particular. An inventory of a water area usually includes: charting the water basin, the location and abundance of aquatic vegetation, temperature, oxygen and carbon dioxide determinations, acidity, species of fish, predators and food and spawning conditions. McMurry ('33), Greene ('33), Faigenbaum ('34) are among the many authors who outlined these factors to be important features of survey work.

The branch of science which deals directly with this diversified approach to biological productivity is called Limnology. As defined by Welch ('35) this includes all the influences which determine productivity in inland waters. As a science which deals with fish study, it is necessary to include both biological and hydrobiological methods (Wundsch'27)

In its hydrobiological approach Strøm ('29) showed how it had grown to include such diversified fields as Geography and Geology, Chemistry and Biology. Limnology is mainly a generalizing science, as defined by its founders, Simony and Forel, and is the one discipline of science able to assist in the understanding of fishery conditions, for the eventual increase of fish in fresh waters. (Halbfass, '27)

Among the interpretations of fresh water conditions are those of Thienemann, who early regarded the water as a single "biotype". He looked upon the limnological unit as the culmination of both physiographical and biological approaches. Rawson ('39) termed this biotype a microcosm, and considered the operation of its internal changes as a metabolic activity which directly influenced the activity of the fresh-water inhabitants. These live in a suitable environment where they are able to secure energy for life and at the same time avoid too much competition with others. Livingstone ('34) pointed out that the environmental complex plays just as important a role in determining the performance of an organism as the internal complex within the organism. The severity of life in the environment is greater where there is more variability, and the inhabitants become sorted into a zonal arrangement dependent on the available energy. (Pearse, '34). The importance of the so-called "metabolism" of the water is believed controlled by three principal groups of factors. The nutritive aspect of the water is supplied by the edaphic factors, and the utilization of this nutrient as energy is made possible by the climatic and morphometric factors. Other interpretations of these main features of lake "metabolism" have been made.

The ability of any form to live satisfactorily under any combination of environmental factors is an expression of adaptation. Fry ('47) recently classified these environmental factors as to their effect on the metabolism of the organism. This approach is therefore physiological.

The studies of Strøm ('31) and Naumann ('32) have emphasized the importance of the above factor basis in explaining differences in the productivity of widely separated bodies of water.

In an appraisal of any water area,it is necessary to select basic factors which are of the greatest importance to the environment and to the organisms. The relation of these agents have been proposed by many workers, as we have seen, to include both nutritional and metabolic aspects. The cycle of the nutritional materials depends not only on the biological questions,but as well on topography and geology. Thienemann stated that the factors that controlled the abundance of an organism,were those that presented the least favourable conditions for the developmental stages of that organism. The factor basis has an important bearing on productivity through operations on both growth and development.

The science of Limnology in its early development,revealed much information which had definite relations with fish production. Reighard is credited with coordinating the sciences of fish culture methods and limnological studies,into a direct approach to the study of food habits and activities of the fish fauna. As the science grew, interest was placed in the laboratory work, but later operations have put a more concentrated study on the actual field conditions, supplemented by laboratory problems (Harkness).

In the study of Limnology as related to fish production, the ultimate goal is to obtain an answer to several questions concerning the complex of factors,which makes up the immense ecological network in any fresh water area. The movement of the fish and plankton organisms is but one manifestation of variations in these interrelated factors.

For any given lake or water basin the kind and abundance of the primary nutrients in the drainage area, and the morphology of the basin undergo seasonal and annual changes. These changes are smaller than the changes in the climatic conditions.(Chandler, '44). The hutrient production of a water basin might be expected to be quite uniform if the seasonal and annual changes of the climatic factors were as small as the changes in the edaphic and morphometric factors.

Thus, ih the study of such a wide field as aquatic biology, it is necessary to select very fundamental agents and emphasize their effects on the environmental complex.

Geographical position is the starting point to a complete study of the biological productivity of a water area. (Rawson, '39). The effects of the shape of the lake basin on the fauna and the metabolism of the lake were early proposed by Thienemann ('27) when he pointed out the importance of the mean depth of the basin as the main feature of the determination of lake type. Morphology is responsible for secondary factors such as temperature, dissolved gases and the productivity of plant materials. Thienemann concluded after many observations that the benthic or eutrophic type of basin was the most productive and was generally under

18 meters in depth. Strøm believed that the relation between the total water volume and the extent of surface was the most important factor in developing eutrophy. Certain facts point to the familiar feature of eutrophic lakes in having an increasing amount of bottom mud.

The area of a lake affects its "metabolism" in a number of ways through the effects of exposure to wind and hence to water circulation. The increase of the area diminishes the inshore productive region, and the shore length to total area ratio is reduced. The bottom slope affects the life in a body of water in a way independent of depth and area. Alsterberg ('30) developed the idea of the importance of contact with the water and the bottom surfaces. He considered this contact relation as the main factor in developing eutrophy. Strøm, ('30), considered the littoral development important in developing eutrophy. This is in line with the relation of the marshlands to adjacent productive water areas. The mean depth is also an important consideration, as the water basins with greater mean depth have steeper sides than those with lesser mean depth, and the littoral tendency is restrained though poor shore facilities.

As the shape of the basin is determined by geography. then topography, the materials absorbed by the water are determined largely by geological formations. Strøm described two tendencies always underway in a water body: "The tendency of each lake to form a microcosm, where the evolution of its life processes are determined by morphology of its basin, and the tendency that works toward making the lakes mere products of their areas."

The determination of edaphic and morphologic factors are made and used interchangeably, but Rawson concluded that "while the edaphic factors determine the kind and amount of the principal nutritive substances, the morphology and climate of the basin may to a large extent determine the utilization of these materials."

In a shallow body of water it is not difficult to see how the circulating mechanisms keep their maximum efficiency operating to produce an abundant life pattern. The shallowness, according to Birge ('08), permits of a large growth of life. Wind keeps the water in circulation and the products of decomposition are immediately available for life activities, allowing life to go on unhindered. A large interchange between growth and decomposition takes place all the time, allowing very little organic matter to sink out of usefulness.

The shallow lake is very rich in plant food and consequently supports an abundant crop of plants and animals. The older basins generally produce more organisms than do younger bodies of water. Individual variation in lakes is, however, always a factor to be met with, and chronological age does not necessarily agree with geological age or with productivity. (Harris, '40).

The quantity of life which any water body can support depends ultimately on the supply of inorganic salts in the water and to some extent on the operation of Liebig's "Law of the Minimum". When this law is applied, it can only be done so satisfactorily, to those factors which are limiting and actually enter into the metabolic chain. (Fry '47).

Much work has been done on this aspect of Limnology. The physical and chemical variables in aquatic habitats have been studied extensively by such workers as Birge, Juday, Thienemann, Naumann and many others. At present, the amount of work underway by individuals and survey groups represents a wealth of literature. However, important fundamentals are readily discerned from time to time.

The first studies of the physical chemical conditions in a body of water should provide general information as to the character of the water, in comparison with other water areas, and the expected conditions during the course of a year or a season. A single measure of any of the variables will not give a reliable index of either eutrophy or any kind of productivity, as Harriss ('29) showed in a comparison of two environments. Welch ('35) also mentioned the inadequ cy of a single season's results as a dependable index of expected events in a water environment, and the necessity of having reasonably complete hydrographic data in advance of the physical chemical determinations. With these concepts of environmental complexes based on factor analysis, the first work toward a study was devoted to obtaining the ordinary hydrographic data for the Marsh. Physical, chemical studies were made of depth series samples taken at various sampling stations at the same position during the summer seasons. Knowing the depth series data and the dissolved gases as determined to be a fair index of what conditions will be in other years (Birge, Juday, Scott, Thienemann), this phase of the work was altered during the second season. Efforts were then devoted to the study of the horizontal variations in these variables and to the fish population indigenous to the area. Irregularities in the physical chemical results led to the study of diurnal cycles at several representative stations.

The overall plan of this study was to make a complete hydrographic survey of the water area, to make studies of the physical chemical variables in the water and to determine the relations of these facts to the biological elements, toward an understanding of the Marsh as a useful ecological study area. As stated early in the introduction, it was the prime purpose of the survey to assess the full capability of the Marsh for its most efficient utilization.

Geological History of the Drainage System

In the early Paleozoic era, a large sea covered the entire area today occupied by the Great Lakes. This sea deposited silts along its north shore, known today as the Canadian Shield. Later in the Paleozoic era the land masses rose and formed a large plain sloping to the southwest.

In the period which followed, erosion forces stripped the sedimentary rocks overlying the granites of the Canadian Shield. The weathering of these old rocks formed the Niagara escarpment.

Before the period of glaciation the whole region is believed to have stood much higher, and had a large drainage system which according to Spencer ('07) consisted of one large river, the Laurentian, a predecessor of the St. Lawrence. It flowed near the edge of the ancient Laurentian continental mass, and emptied into Cabot Strait. The Laurentian River system extended northeastward from the deeper part of Lake Michigan to Lake Huron, (Fig. 1) southward to a point opposite the present

Bruce Peninsula, where it was joined by the Huronian River and a branch from the south end of Lake Huron. It then passed the Bruce Peninsula to Georgian Bay, along the escarpment to the region of Lake Simcoe,and southward past Toronto to the Lake Ontario basin,where it was joined by the smaller Dundas branch with the larger Erigan river which drained the Lake Erie basin.

Glaciers were the result of an increasing change in the climate. Most of the northern half of North America was eventually covered by a massive ice sheet. (Fig. 2). In the Pleistocene glaciation period.there were believed to be several advances and retreats of the glacier masses due to modifications in the climatic conditions. There are evidences of two such retreats in which the Lake Ontario basin was free from ice. In these periods it is believed that the basins were occupied by lakes much like the present ones.

With a gradual modification of the climatic conditions the ice sheet moved northeast and the basins formerly drained by the Laurentian river were again exposed. The many small lakes produced by the melting ice drained through valleys to the Mississippi.

The basins increased in size with continued retreat of the glacial masses, and the waters which united along its edge were finally forced to drain to the southeast through lower valley outlets. The final drainage became the St. Lawrence River, which serves at present as the Great Lakes drainage basin. A withdrawal of the ice lobe known as the Saginaw lobe resulted in a connection of the waters of Lake Saginaw and the Erie basins, (Fig. 3). This had become extended into the Ontario basin when the ice

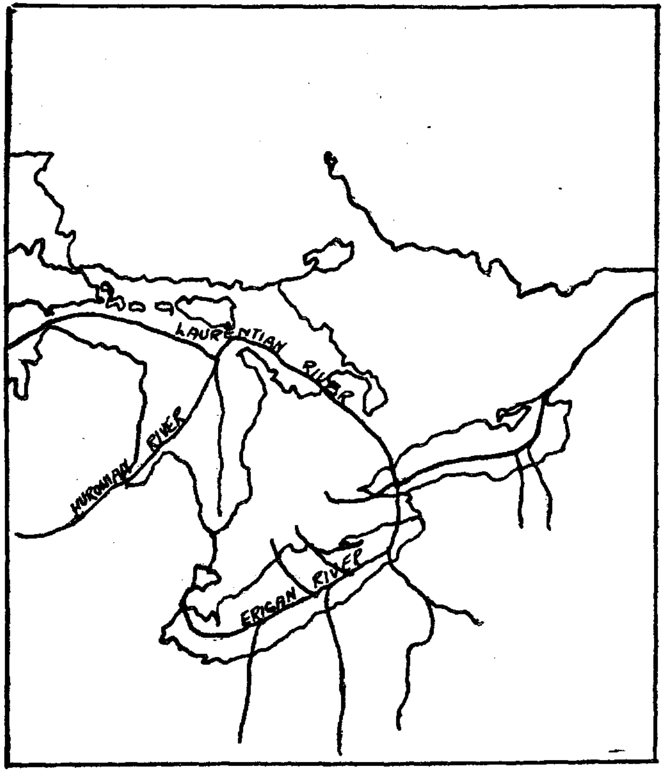

Figure 1. The course of the Laurentian River (Coleman).

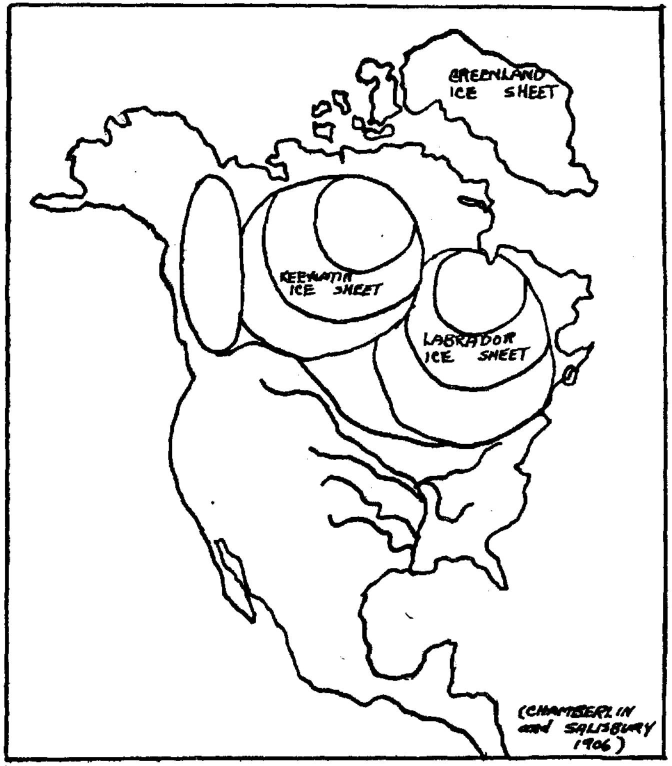

Figure 2. The extent of the Pleistocene glaciation in North America.

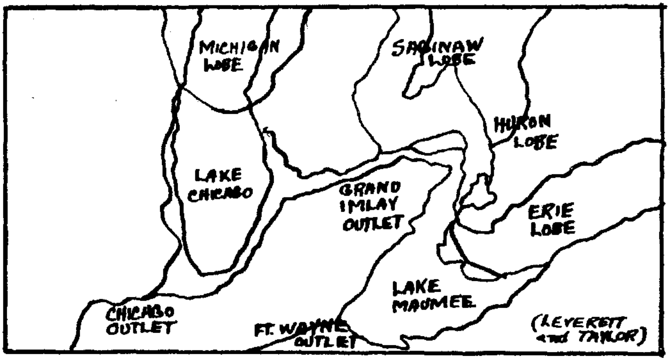

Figure 3. Grand-Imlay Connection

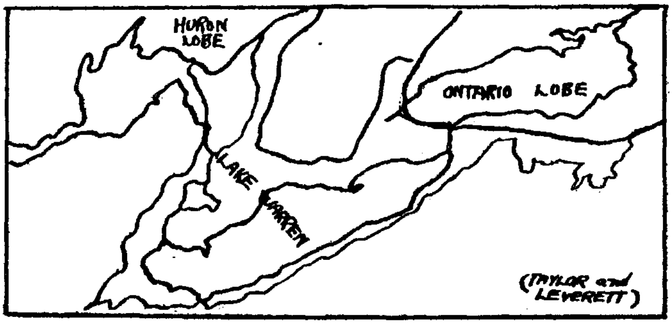

Figure 4. Lake Warren Stage

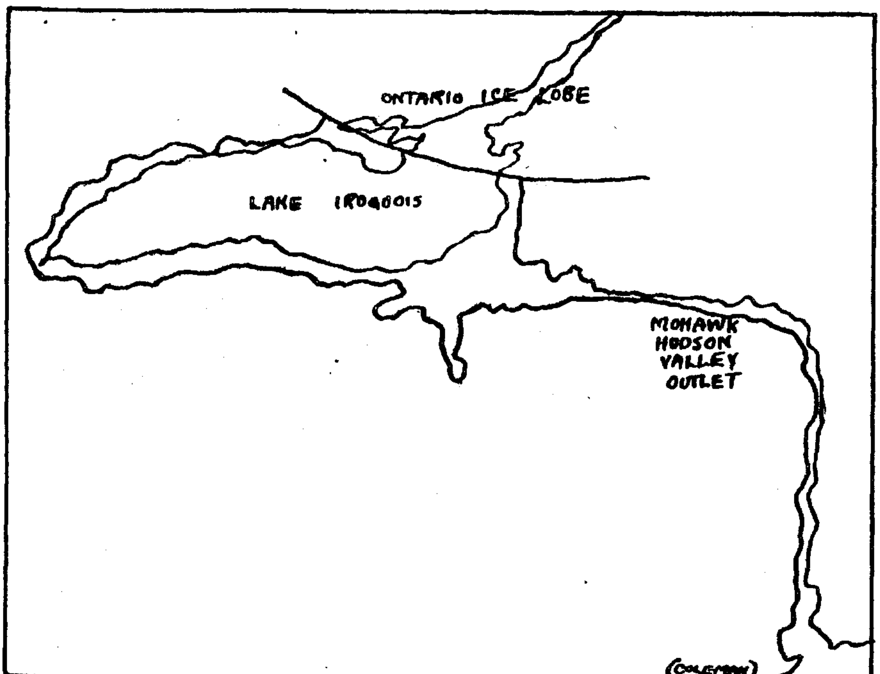

Figure 5. Lake Iroquois

lobe still blocked the outlet through the St. Lawrence valley. This stage is known as the Lake Warren stage and it discharged through the Ubly-Grand river and Fort Wayne outlets (Fig. 4). Lake Warren crept along the glacier in the southern edge of the Ontario basin through the Finger Lakes region of New York State.

The Hudson River outlet was in use through the Lake Warren, Lundy and Iroquois stages, and the escarpment was covered with water. Erosion lowered the outlet and the lake level eventually fell, exposing the escarpment. The waters of Lake Erie emptied into Lake Iroquois over the falls near Niagara and Lake Iroquois, (Fig. 5), existed first as a small strip along the southern and western borders of the Ontario lobe. It drained first through the Mohawk-Hudson valley and then when the lake was set free it consisted of an area slightly larger than the present Lake Ontario. At the western end of Lake Iroquois the shore extended along the Niagara escarpment and included the entire Dundas valley (Coleman, '22).

Geological and Topographical History of the Valley

Dundas valley lies at the western end of Lake Ontario in the form of a rude triangle, having as its base the beach spanning the eastern side of Burlington Bay, and for its two sides the Niagara escarpment. The valley may be divided into three zones. The eastern zone includes Burlington Bay, a body of deep water separated from the middle zone, which contains the marsh, by Burlington Heights, an old beach or ridge which contains fossils of the Hudson river period. The western zone contains the remainder of the valley extending from the town of Dundas to the village of Copetown which is on the elevation of the Niagara escarpment.

Beginning at Burlington Heights, there is a narrow canyon-shaped channel lying in a position about N70°E and somewhat over eight miles in length cut between the walls forming the escarpment. The channel is about four miles wide at the eastern end, and gradually narrows, until at Binkley's Corners on the Hamilton-Ancaster road the valley is three miles, a width it maintains for more than two miles when the westerly escarpment turns east to the village of Copetown.

The portion of the valley from Burlington Heights to the town of Dundas is to a considerable extent occupied by the Dundas Marsh. (Fig. 6) Between the Marsh and the detritus at the foot of the escarpment on both sides, there is a tract of level country lying at a general elevation of eighty feet above the marsh waters. The level plain on the eastern side is frequently cut through to the blue Erie clay by streams of comparatively recent origin. On the western side, the country rises by successive steps to the foot of the escarpment. The western side is peculiar in that there are no streams of any size. The composition of the plain is chiefly clay and silt in alternate layers with patches of conglomerate.

The height of land separating the head of the valley from the drainage system to the Grand River is composed largely of coarse washed sand with broken shales in several places.

The escarpment forming the walls on either side of the valley is composed principally of Medina shales. These are succeeded by thin beds of the Clinton formation, and the whole is surmounted by beds of the Niagara formation. The eastern escarpment is in many ways different from the western side. From Hamilton to Ancaster, this escarpment shows a clear face of hard Niagara limestone and Niagara shales lying upon the shale beds of Clinton and Medina formations, and covered over for a greater part of the distance by a thick band of broken material.

Over the escarpment between Hamilton and Ancaster a number of streams have cut channels as they flowed into the valley. Among the largest of these is Chedoke stream. The walls of its channel show a clear section of the upper band, and in places the heavy band of limestone on which the broken band rests. The limestone is from six to eight feet thick and the broken material eighteen to twenty feet thick. The lower beds of rock and shale are hidden by debris falling from the sides of the channel.

The presence of at least five ancient sea beds within the valley is well indicated. Two of these, Burlington Beach and Burlington Heights, are well defined. The former is a low sand and gravel bar about five miles long and from one hundred yards to half a mile in width. It is the most recently formed of all the beaches.

The second, Burlington Heights, is a beach of much older origin than Burlington Beach. It forms the barrier between the Bay and the Marsh. This beach, with its broken strata of sand, gravel and conglomerate, begins close to the escarpment south of Hamilton and can be traced through the city along the road leading to Burlington. It is separated from the raised level country lying along the escarpment at the northern end by a deep channel which at one time was the mouth of the old canal, and outlet of the waters flowing through the Marsh into Burlington Bay. This has been described by Spencer and Coleman as being derived from backward currents, created by conflict of the shore drift and the Dundas streams, together with storms brought by east winds. This elevation has been called a beach, but the evidence points to it being, more correctly, a sand bar or ridge. It may have been formed during the Lake Iroquois period.

Proof that the ridge was laid down in deep water may be found in the conglomerate composing the beds and underlying the clay in different parts of the valley. This conglomerate is formed by the infiltration of the beds of gravel and sand with lime carbonates. As the carbonates could not penetrate the clays, lying in some places above the conglomerate, it may be reasoned that the water charged with lime was flowing through the valley and depositing this lime before the upper clay beds were formed.

The carbonates were derived from the washing of the waves against the escarpment limestone. Some streams of recent times are so loaded with this material as to form a marl coating on mosses and other plants growing within their spray. It may be that after the wave action against the cliffs the heavy clay deposits were laid down.

As no conglomerate is found beneath the blue clay, it can be inferred that the conglomerate beds with overlying silt and clay are the result of a period succeeding the glacial period when the blue clay was laid down. These beds are the result of the closing up of the mouth of a stream flowing down the valley and a flooding of the area over a long period of time.

The breaking of the bank which closed up the mouth of the stream drained the valley to the extent we now find it, and left the channel occupied by the Marsh. (Kennedy, 1885.)

Early Natural History of the Valley

The following natural history notes are taken from the writings of Charles Durand, who as a boy lived on a farm near Dundas in the period of 1818-19.

> The place called Coote's Paradise was named after a Captain Coote, a wonderful sportsman who used to hunt ducks and game there way back before 1800. It was a paradise for game of all kinds. Immense flocks of ducks and wild fowl, and wild animals innumerable in old times were seen there. It was also the resort of wild fur animals, such as the otter, perhaps beaver, fisher, minks and especially muskrats; snakes were abundant there of all kinds.
>
> The Marsh lay in a deep valley between the heights of Burlington Bay or between the bay and the town of Dundas and beneath the cover of the Hamilton and Flamboro ridges of mountains. A stream always ran in the middle of it from Dundas to the Bay . Around the north end of the Heights and into this stream which was partly clear water, fish came from the Bay, and from the outlet from the Bay into Lake Ontario. Thus all kinds of fish entered the creek or river, as it was in old times, and went up the stream to the mountain in Dundas, where the falls of the mountain stopped them. Beautiful sea salmon used to be caught in abundance from 1800 to 1830, to my Knowledge. The Marsh was a dense watery bog and wild rice, water lillies and flowers that grew in water were abundant. (Durand 1897.)

CHAPTER II

MORPHOLOGY OF THE MARSH

For the preliminary period of this survey, suitable maps of the Marsh area were constructed on a large scale, using as reference material the existing topographic survey maps of the area. The map entitled, Canada, Sheet $30\frac{M}{5}$ Hamilton, Ontario, was used as the main reference source and enlargements of this map scale were used for our further work.

The first step was the sounding of the open water, following the construction of the base maps. The water was known to be of relatively shallow depth and therefore elaborate or highly accurate sounding equipment was not required. For the purposes of achieving the greatest accuracy with the least expense for equipment a stout graduated rope and weighted anchor were used for this part of the survey, in 1946.

The anchor was constructed so that when resting on the bottom it would permit a direct reading of the vertical depth at the point sampled. The rope was indelibly marked in meter and tenth-meter divisions.

Soundings were made over ranges between well defined landmarks. The individual soundings were made at locations determined by a selected number of oar strokes. The average distance covered by the stroke of one individual in calm water varies little after much practice, and it was possible to plot the soundings with reasonable accuracy, considering that the differences in depth at the many locations were very small.

The data were plotted along the ranges on the large base maps, using corresponding distances between sounding positions. Water level records were obtained from the Hamilton Harbour Commission, which maintains a fixed staff gauge on the south shore of the Bay. Records from this shore of the Bay are applicable, with reservation, to the Marsh, and give the variations of the water level over the period observed. No records were made of any seiches that are undoubtedly active, and the data recorded are not inclusive of this occurrence.

The Marsh, called both Coote's Paradise and Dundas Marsh, lies at the western extremity of Lake Ontario within the Dundas Valley. (Fig. 6). It is separated from the lake by Burlington Bay, a body of deep water which serves as a natural harbour for the city of Hamilton, directly east of the Marsh. The area of the Marsh is approximately 648 acres, and is in the shape of a long narrow triangle with the base adjacent to Burlington Heights.

Along the south shore are several deep inlets penetrating into the adjacent residential area. These inlets are choked with vegetation of both aquatic and terrestrial types. The former consists of both submerged and emergent forms. The south end of the Marsh is bounded by highway 102 between Hamilton and Dundas

The north shore is steep and is cut by two deep river channels. The level of the land on the north and south shores of the Marsh is between fifty and eighty feet above the water level. Two peninsulas of noticeable size extend into the open water area. The one from the north shore is known as Bull's Point, a high projection of land extending as far south as the Desjardins canal. It is steep at the canal end, with banks rising to one hundred feet above the water level. On the south

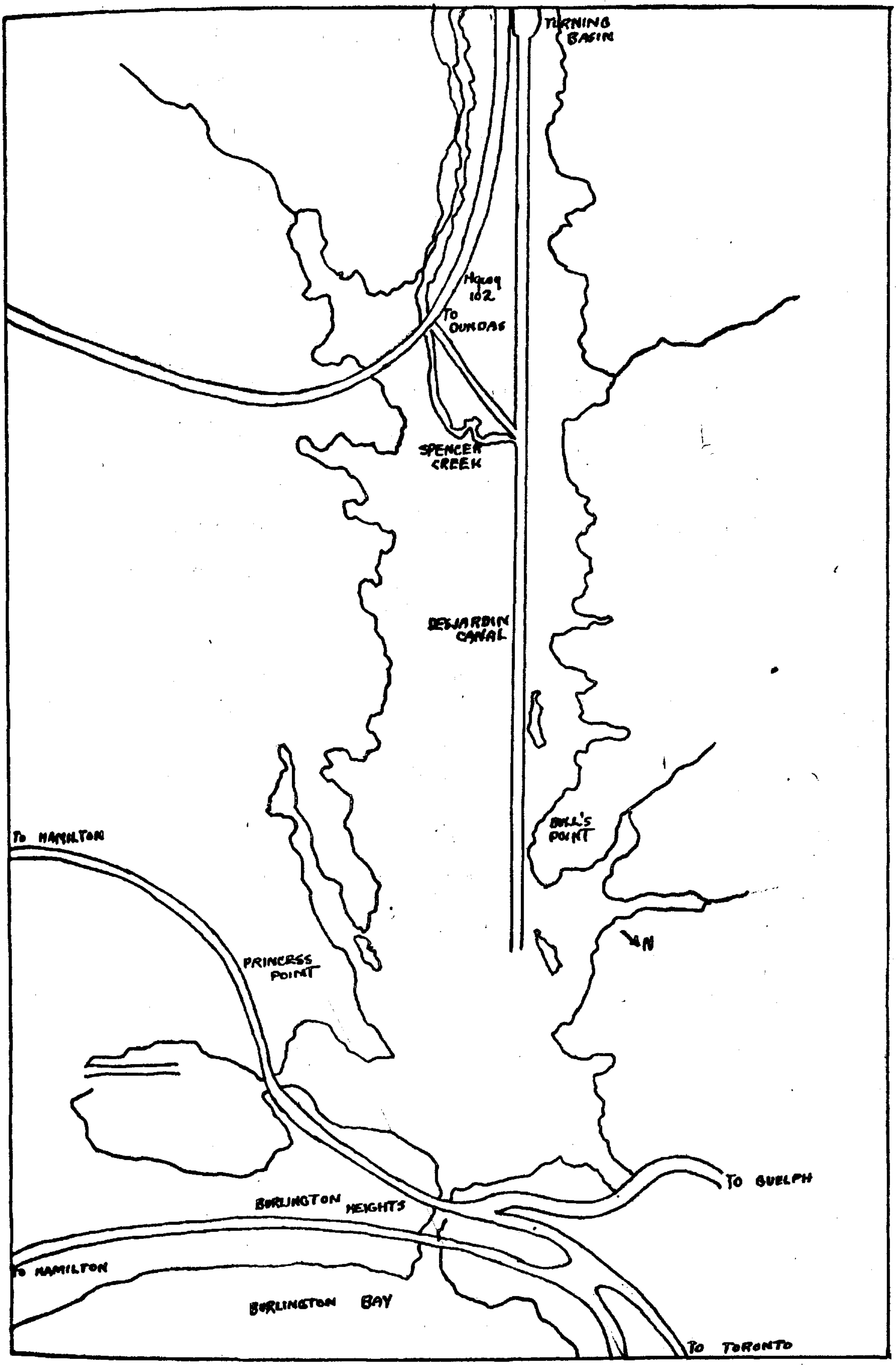

Figure 6. Map of Dundas Marsh

shore is a low peninsula, called Princess' Point. This point of land extends due north into the open water toward the High-Level bridge on Burlington Heights.

There are two small islands in the open-water zone, and one smaller island in the vegetation zone in a southwestward direction from Bull's Point.

The Marsh is bisected by the Desjardins Canal, a waterway navigable for shallow draft boats. The Canal was originally constructed through the Marsh in 1837 to facilitate trade with Dundas. Subsequent exploitation of the railroads led to the building of a railway line into Hamilton along the course of Burlington Heights. A cut was made through the Heights to permit continuing canal traffic to Dundas.

With the gradual disuse of the canal it has become heavily silted from the two incurrent streams. Spencer's creek, which enters the Marsh through Dundas, is the only water course continuously adding water to the marsh, as the other streams become dry beds after the Spring floods. These floods bring large amounts of silt into the Marsh from the high land above the escarpment.

The filling of the Marsh over a period of years of flooding has caused the gradual elimination of much of the marshy area. Filling is proceeding from the western end and will ultimately lead to the obliteration of the water area.

The depth of water in the present vegetation zone is rarely more than 1 meter. The bottom slopes very gradually to the open water zone, where the deepest areas do not exceed 2.0 meters at high water level. In Figure 7 the contour lines are illustrated, with differences of one half a meter. The configuration shows the filling of the basin from the western end due to the sedimentation of the inflowing streams. The sounding of this open water zone was completed during the period of high water in 1946 as shown in Figure 8, which illustrates the seasonal water level fluctuations in the Marsh. These changes occur constantly, both seasonally and annually, and consequently cause a reduction or increase in the amount of aquatic vegetation, which is dependent entirely on suitable water levels for its maintenance. The vegetation at present concentrated in depths of one meter or less wil spread eastward toward Burlington Heights with successive years of low water. The complete obliteration of the open water zone would be the result of any large migration of aquatic plants as a consequence of low water levels. Musham ('43) showed that the levels of the Great Lakes rise and fall according to a regular cycle with periods of about 22-23 years between maximum high levels. Minimum low levels occur regularly midway between these highs. The seasons during which our observations have been made have occurred during one of these maximum high levels of the Great Lakes cycle. It is suggested that the vegetation zones are smaller now than they were ten or twelve years ago. Information supplied by residents tends to substantiate this suggestion. It would seem that the water level cycle is impressed on the vegetation to the extent that it causes fluctuations in horizontal distribution. Such a condition will continue until silting, as explained above, obliterates the water area entirely.

Variations in the water level directly affect the conditions suitable for the muskrat. As a marsh dweller, it depends on plant materials

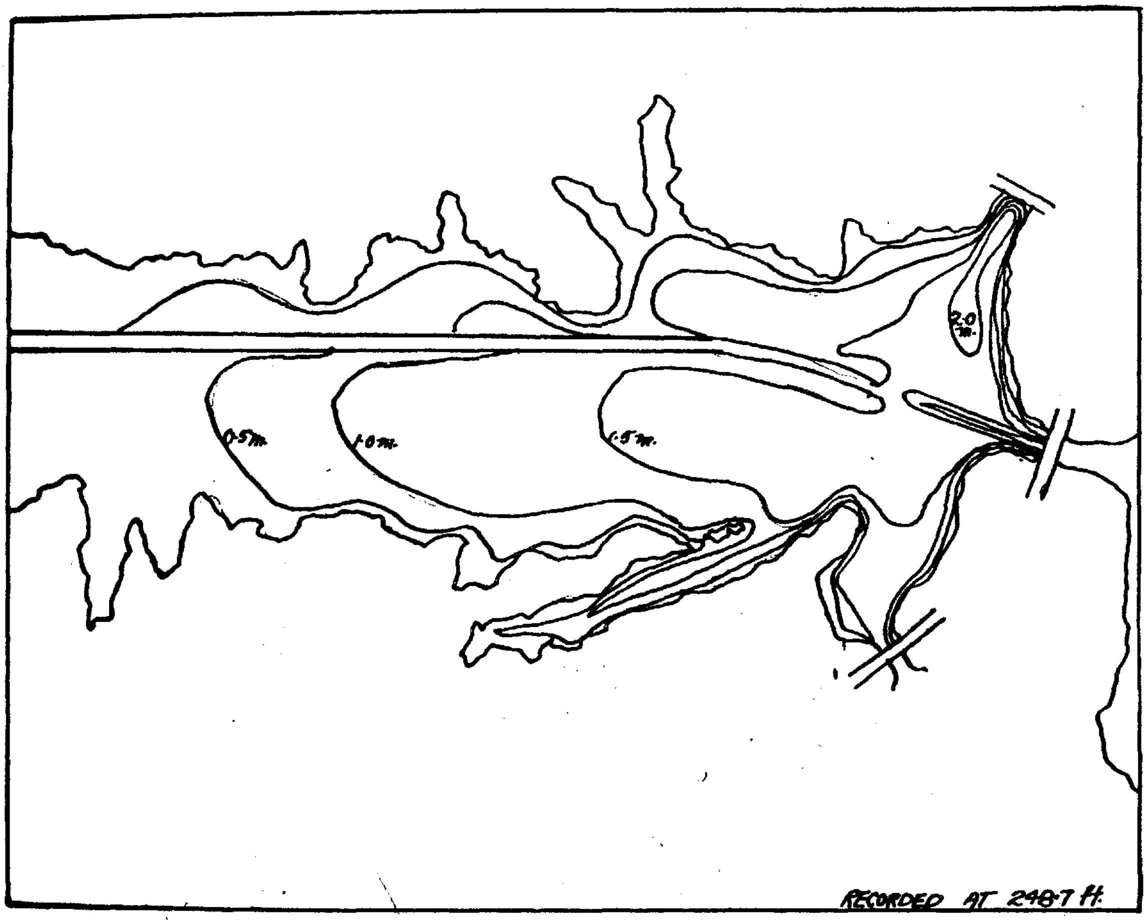

Figure 7. Morphology of the Water Basin

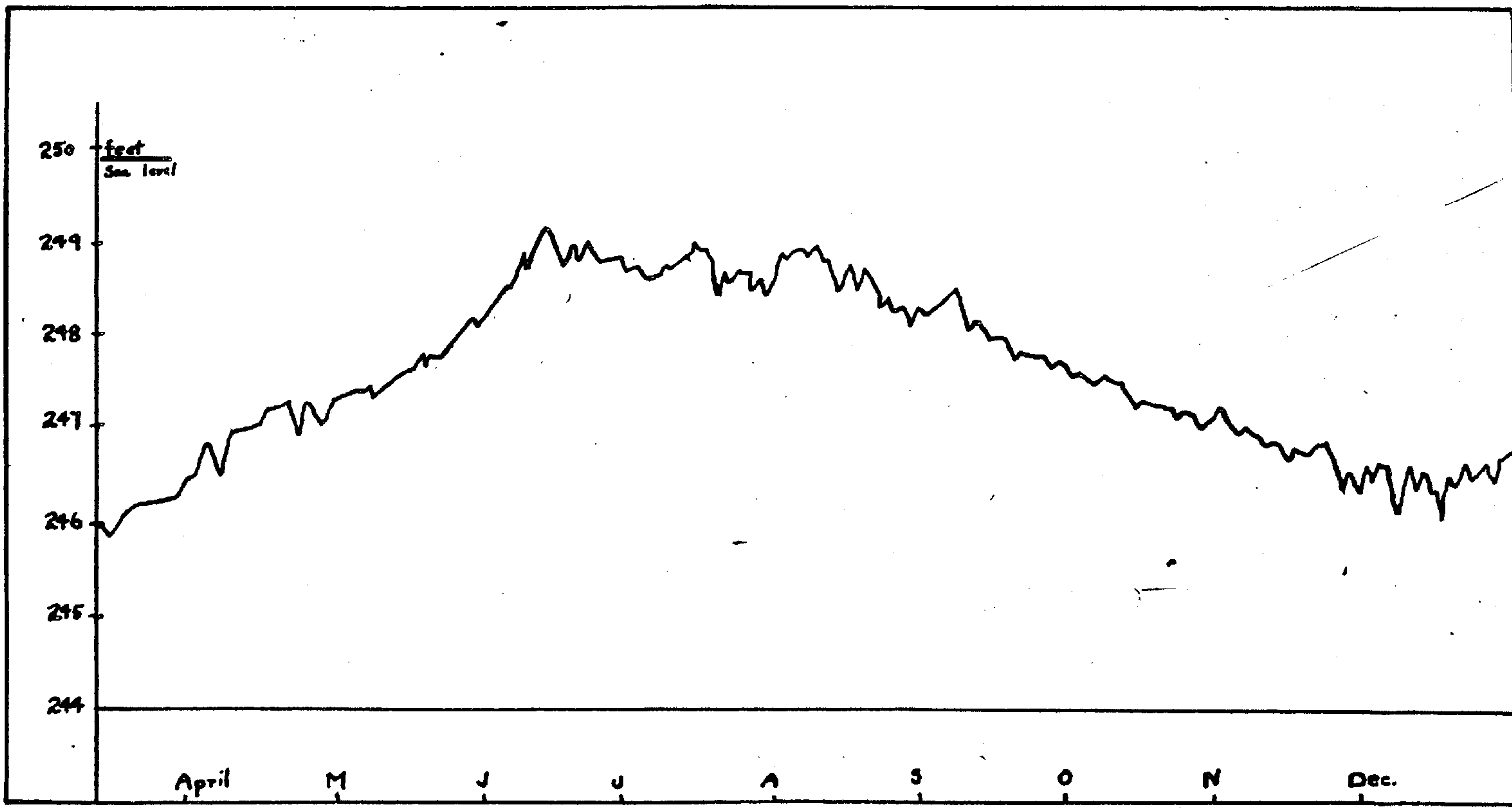

Figure 8. Water Level Variation
May-December 1946
(Courtesy Hamilton Harbour Commission)

for food and shelter and a steady water level favours particularly those species of plants which support the highest proportion of muskrats. Bellrose and Brown ('41) found that where the water level was relatively stable, there was an increase in the number of muskrat houses per unit area over an area where the level was constantly changing.

CHAPTER III

VEGETATION

Fishermen and fish culturists, interested in the welfare of fish and waterfowl, are interested in aquatic plants because they realize that luxuriant vegetation in the water bordering marshes means an area of shelter and a productive source of food (Muenscher '36).

Related directly to the morphology of the Marsh is the production of an extensive vegetation zone. Of the entire 650 acres of area, over one half is covered by an emergent and submergent aquatic flora.

Reference to Table 1. which contains a check list of the plants of the Marsh (Judd '46) shows the presence of over seventy species of plants. Several of these, where not actually aquatic, are listed because of their proximity to the water shore. Among the genera which make up the most important components of the flora, are the Typha and the Glyceria. The latter, Glyceria maxima, is present in the marsh in a large central stand occupying the main vegetation zone. As an integral part of a primary succession, Lambert ('46) showed how its early protraction forms a mattress, which prevents the invasion of other forms. Bordering the Desjardins canal on either side is a row of willows, which extends as far West as the turning basin at Dundas.

The Typha latifolia is found in all parts of the Marsh, concentrated mainly in areas adjacent to the shore line, and merging into submergent types such as Utricularia, Ceratophyllum and Myriophyllum in very shallow water.

A sizeable concentration of these submergents occurs at one point on the south shore, known as the Carp Pond. The water is one meter deep, and as the summer season progresses, these aquatics entirely fill an area of about two acres, making such a dense underwater mat that it is difficult to push a boat through the Pond.

Mixed with the Typha is a large concentration of Sparganum. Also, members of the Najadaceae family, form small concentrations in with the Typha latifolia, in shallow inshore areas. The Cyperaceae family is prominent in all parts of the Marsh, mingled with the Typha. Sagittaria is also present throughout the shallow areas.

Prominent in the Marsh are members of the Lemnaceae. Concentrated groupings of Lemna minor cover the Desjardins canal at many points in the late summer. Much of the shallow water among the inshore stands of Typha is covered by a layer of Lemna minor.

Two large zones of the Nymphaceae are present in the central part of the vegetation area. These include the Nympheae odorata and Nuphar advena. Two or three main stands of Decodon are located on the south shore in shallow water.

No concentration of submerged vegetation was found in the open water, close to Burlington Heights. Along this exposed eastern shore wave action is effective in eliminating any floating leaved vegetation. Only such forms as the Decodon and other hardy species are able to survive.

Among the aquatic plants of greatest value as waterfowl food and cover plants are the following found in the Marsh: Typha latifolia, (common cattail); Sparganum eurycarpum, (giant burreed); Potomageton, (pondweed); Scirpus validus, (softstem bulrush); Lemna minor, (duckweed) and other members of the Lemnaceae and Polygonum (smartweeds).

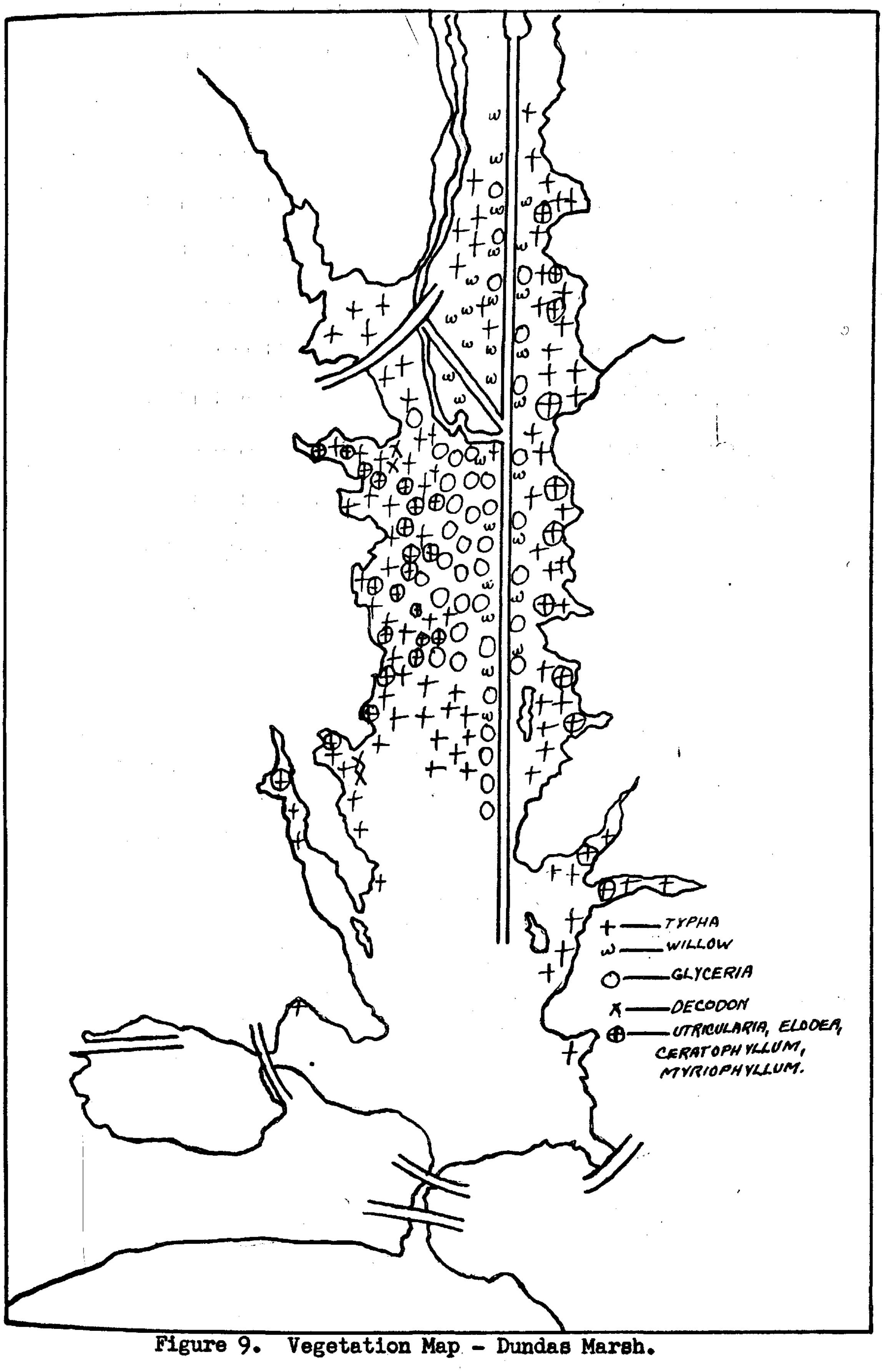

Figure 9. Vegetation Map - Dundas Marsh.

TABLE I

Check List of Marsh Plants of the Dundas Marsh

Ricciaceae -	Ricciocarpus natans L. Corda.
	Riccia fluittans L.
Polypodiaceae -	Onocles sensibilis L.
Equisitaceae -	Equisetum fluviatile L.
Typhaceae -	Typha latifolia L.
Sparganiaceae -	Sparganum eurycarpum Engelm.
Najadaceae -	Potomageton pectinatus L.
	nodosus Poir.
	crispus L.
	zosteriformus Fein.
	foliosus Raf.
	berchtoldi Fieber
Alismaceae -	Alisma Plantago - aquatica L.
	Sagittaria latifolia Willd.
Hydrocharitaceae -	Anacharis canadensis (Michx.)
Gramineae -	Calamagrostis canadensis (Michx.) Nutt.
	Phalaris arundinaceae L.
	Glyceria striata (Lam.) Hitch.
	Glyceria maxima (Hartm.) Holmb.
	Phragmites communis Tren.
	Hystrix patula Moench.
Cyperaceae -	Eleocharis calva Torr.
	Carex diandra Schrank.
	subtrica (Kukenth.) Mack.
	pseudo-cyperus L.
	versicaria L.
	stricta Lam.
	cristatella Britt.
	vulpinoidea Michx.
	Scirpus atrovirens Muhl.
	validus Vahl.

Araceae -	_Calla palustris_ L. _Acorus colamus_ L. _Symplocarpus foetidus_ L.(Nutt.)
Lemnaceae -	_Spirodela polyrhiza_ L. (Schleid.) _Lemna minor_ L. _Lemna triscula_ L.
Juncaceae -	_Juncus tennuis_ Willd. _tennuis dudleyi_ Wieg.
Dioscoreaceae -	_Dioscorea villosa_ L.
Iridaceae -	_Iris versicolor_ L.
Polygonaceae -	_Polygonum coccineum_ Muhl.
Ceratophyllaceae -	_Ceratophyllum demersum_ L.
Nymphaceae -	_Nymphaea odorata_ Ait. _Nuphar advena_ Ait.
Ranunculaceae -	_Ranunculus aceleratus_ L. _pennsylvanicus_ L. _Anemone canadensis_ L. _Caltha palustris_ L.
Crucifereae -	_Rorippa palustris_ L.
Crassulaceae -	_Penthorum sedoides_ L.
Rosaceae -	_Potentilla palustris_ L. (Scop.) _anserina_ L.
Balsaminaceae -	_Impatiens biflora_ Walt. _pallida_ Nutt.
Lythraceae -	_Decodon verticillatus_ Ell.
Onagraceae -	_Epilobium hirsutum_ L. _adenocaulon_ Haussk.
Haloragidaceae -	_Myriophyllum verticillatum_ L.
Umbellifereae -	_Circuta bulbifera_ L. _Sium suave_ Walt.
Cornaceae -	_Cornus stolonifera_ Michx.

Primulaceae -	Steironema ciliatum L. Raf. Lysimachia nummularia L.
Apocynaceae -	Apocynum cannabinum L.
Asclepiadaceae -	Asclepias incarnata L.
Verbenaceae -	Verbena hastata L. urticaefolia L.
Labiateae -	Mentha arvensis L. Lycopus americana Muhl. Scutelleria galericulata L.
Solonaceae -	Solanum dulcamara L.
Scrophulariaceae -	Mimulus ringens L. Chelone glabra L. Veronica americana Schwein.
Lentibulariaceae -	Utricularia vulgaris L.
Phrymaceae -	Phryma leptostachya L.
Caprifoliaceae -	Sambucus canadensis L.
Cucurbitaceae -	Echinocystis lobata Michx. T&G.
Campanulaceae -	Campanula aparinoides Pursh.
Lobeliaceae -	Lobelia siphilitica L.
Compositeae -	Eupatorium purpureum L. urticaefolium Reichard. perfoliatum L.

Check list courtesy Dr. W. W. Judd.

The importance of plants in rendering a lake productive of fish has been described by Klugh ('27). They add nutrients from the soil to the water through the process of organic decomposition, thus adding organic detritus to the water basin as well. Among some of the important relations, they provide forage plants for some animals, and hiding places for fish and other animals. (Kricker, '39). Frohne ('38) concluded that the emergent aquatics stand in a direct "provendering relationship" to many an assemblage of insects. Liebmann noted the value of plants to pollution effects and as a beneficial agent for fish life.

Many other authors have shown that aquatic plants are important considerations if aquatic animals are to thrive. Reighard ('15) showed variations in the fish distribution as related to the bottom conditions and thus to the consequent variant vegetation. Muttkowski ('18) found a more abundant fauna where plants were prominent. Pearsall ('21) stated that a correlation existed between the hydrographic age of a lake and the vegetation and fish life. The plants are of great importance to aquatic vertebrates of all kinds. In relation to productivity Klugh ('26), suggested that the abundance of higher plants might be taken as an indication of the expected productivity, especially in relation to fish.

The soils and bottoms of lakes are important in determining the distribution of plants. Most of the emergents of the open water are growing on a silty, organic bottom. In relation to this factor of satisfactory soils on the bottom, is the absence of Wild Rice, (Zizania aquatica) from the natural vegetation of the Marsh. This annual is probably one of the best and most important waterfowl plants. As the conditions of soil are suitable for its propagation, there must be other reasons for its absence. The first of these is probably the effect of variation in water level, which occurs widely during the Spring growing season. A rise of six inches or more during June or July will reduce the crop as shown by Moyle ('45). A factor of greater significance than the water level fluctuations is the activity of the Carp, (Cyprinus carpio), which inhabits the Marsh in great numbers.

In many shallow prairie lakes which have an extensive vegetation, great damage has been done by the introduced Carp. Hubbs and Eschmeyer ('38) showed that much of the vegetation destroyed was not eaten but merely uprooted or destroyed by roiling the water. During the spawning season the Carp are seen to jump out of the water and roil it in places where coontail (Myriophyllum) is the main submergent. This plant has great resistance to the activity, as growth continues uninterrupted after the spawning period. The roiling action of the Carp is carried on in open water areas, stirring up the bottom mud and causing an increasing degree of turbidity. In addition, the rooted plants which may be commencing growth in the Spring are torn up by this activity. Cahn ('29) reported the harmful effects of Carp in a pond when it became a dominant. Such plants as Potomageton, Ceratophyllum, Vallisneria, were routed out and transparencies of the water were only 30 inches in several cases. Transparency values in the Marsh are less than this and are probably partially due to the activity of the Carp. Plant growth becomes limited by the reduction in transmission of light caused by the reduced transparencies. (Oosting '33).

The control of Carp is of vital interest to fish culturists and several workers have devoted attention to this problem. Struthers ('29) showed the importance of control during the period when the fry were within their first year of life. Control measures during this period are produced by lowering the water level suddenly and destroying the exposed fry. The destruction of Carp in shallow ponds has resulted in a clearing of the water,(Ricker, '40), thus producing conditions suitable for the production of vegetation and consequently increased fish population.

The control of Carp has merited attention in this section because its development and economic importance are directly related to the vegetation. As a dominant type, it is unsuitable in any aquatic habitat, especially if game fish and wildfowl are to be encouraged. Important references have already been made to the absence of Wild Rice in the Marsh. The Marsh leads directly to the Bay, and serves as a breeding ground for Carp. If it is to be allowed access to the Marsh, it will eventually drive all existing good fish faunae out of this habitat. To keep its number reduced, it is advisable that commercial netting be permitted during the early part of its breeding season.

The abundance of the aquatic vegetation is directly dependent on the chemistry of the water and on the type and fertility of the bottom., as we have seen. Frohne ('38) stated that the variations in the hydrophyte zones were invisible indicators of chemical and physical conditions present in the habitat. The waves and wind act as a dominant effective factor in the distribution of these physical and chemical agents in the water.

The relations of the chemical characteristics of the water and the general plant distribution have been investigated by many workers. A detailed report on the many lakes and streams of Minnesota by Moyle ('45) shows that in hard waters the concentration of carbonates is an important factor determining the natural distribution of the aquatic plants. Within the chemical tolerance range the bottom soil and the physical nature of the water are perhaps the major distributional agents of the habitat. As will be seen later, the waters of the Marsh are of a hard carbonate type with a total alkalinity ranging between 100 and 200 p.p.m. Such a range defines the type of vegetation usually present. In hard water lakes many plants often form marl; among these are the Potomagetons, Vallisneria, Ceratophyllum, Castalia and Chara. (Kindle '27). The natural vegetation of such a body of water as the Marsh offers the best indicator as to the interest the Marsh is to satisfy. The quantity of vegetation increases as the water zone ages. Rooted vegetation obtains necessary salts from the soil and obtains other necessary raw materials, such as oxygen, carbon dioxide, nitrates, carbonic acid (free and bicarbonate) and phosphates from the water. These are in turn given back to the water when the plants decay. Therefore, in evaluating any water area, the vegetation assumes prime importance. Its distribution and abundance are helpful in analysing the various factors which must be considered in the effective utilization of the area, especially for the production of fish.

CHAPTER IV PHYSICAL AND CHEMICAL FACTORS

Sampling Stations

In the open water region the physical chemical factors were studied at the stations marked 1, 2, 3, and 7. During 1947 these stations were visited only occasionally, but in 1948 stations 2 and 7 were followed over an extended period. On two occasions during 1948 diurnal cycles were studied at Station 2.

Station 10 was located in the Carp pond, referred to earlier as a dense submerged mat of *Ceratophyllum*, *Myriophyllum*, *Utricularia* and *Lemna minor*. Surrounding this location was a large stand of *Glyceria maxima* and *Typha latifolia*. The remaining less important sampling points are shown by number on the accompanying map, (Fig. 10).

The sampling depth varied from 20 cms. to 150 cms. The former represents a surface water sample, and the latter a bottom sample, in most cases, in the open water. The bottom sample depths vary, of course, with the station. The depths are reported in the appendix and graphs, from the surface, so that a reading of 150 cms. means a sample obtained 150 cms. beneath the surface.

On one or two occasions the water of the Bay was sampled for comparative purposes. In this case, where the depth was greater than 35 or 40 feet, a reversing type sample bottle was used. Depths are reported in the same order as for the Marsh sampling points.

Transparency

The amount of silting in a lake is no doubt of great importance in determining favourable or unfavourable biological conditions. Turbidity

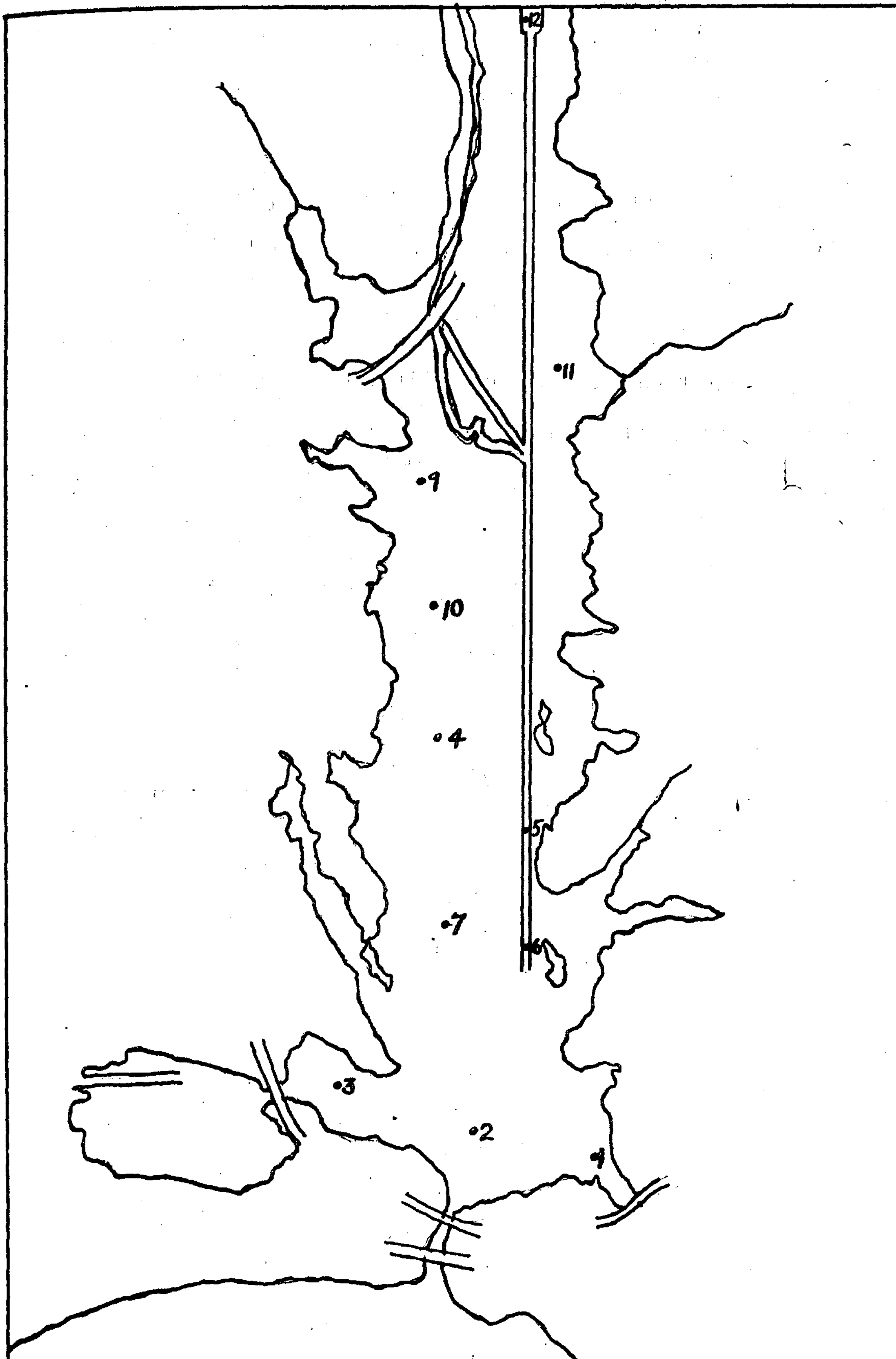

Figure 10. Sampling Stations

is more or less of an index to the rate of silting or filling, in that it would appear that the more consistently turbid waters would tend to smother all life. This property of water to become turbid results in a lowered transmission of light, thus being of direct importance to the aquatic plants which require light for photosynthesis. It has been mentioned previously how the two factors, Spring flooding and the activity of Carp, are responsible for increasing the turbidity of the Marsh water. This turbidity results in a low transparency.

A modified Secchi disc was used to determine the light penetration or transparency. A white enamelled plate was fastened to the lower end of a meter rod, and it was immersed at the various sampling points. Readings were taken only when the sky was bright and the sun directly overhead. No readings were made during rough water. Two readings were taken at each location. The first was recorded as the plate passed down out of the limit of visibility, and the second was recorded as the plate was raised vertically just into the limit of visibility. The average of these two readings is reported in (Table II).

Reference to the table will show the results of several observations taken during two consecutive Summer seasons. The general variation is with a higher transparency during late Fall and early Spring, and a low transparency during the Summer. Several variations from this generality can be seen, and are probably due to many influential agents, two of which have been mentioned above.

The transparency at Station 2 increased from the early Summer low of 25 cms. (6/30/48), to a transparency of 55 cms. (8/9/48/). Increases in

TABLE II

Transparency

(cms.)

Date	1	2	3	4	5	6	7	8	9	10
8/11/47				50						
8/18/47	50			44	50					
8/25/47		60		50			50			100 +
9/30/47	50			50						
10/10/47		40	40	55						
10/15/47		60								
5/19/48		30					77			
6/23/48		32					45			100+
6/25/48		40					45			90 +
6/30/48		25					30			70 +
7/2/48		40					22			80 +
7/5/48		45					35			50 +
7/6/48		43								60 +
7/9/48		55					35			
7/12/48		40					35			
7/14/48		30					25			
7/19/48		35								83 +
7/28/48		50								
8/6/48		35								
8/9/48		55					30			

the values in the Fall were small, and can be seen to be only as great as 60 cms. (10/15/47). Station 7 showed the generalized trend, with 77cms, (5/19/48), being reduced to a low of 22 cms. (7/2/48) during the early Summer. Slight increases resulted in transparencies of not over 35 cms. for the latter part of the Summer. At Station 10, which was a vegetation station, the decay and decomposition of the plant materials caused very little change in overall transparency. The bottom was at all times visible through breaks in the plant mat. Absence of wave action at this location is probably the most important factor in determining the greater transparency.

During the early Spring Station 2 had low transparency values, but variations from day to day are to be attributed to wind action. The bottom materials are made up of soft clay-silt and are easily disturbed by wave action. Station 7 shows the main trend as indicated above. Variations from day to day are not so great as at Station 2, probably due to shallower water with reduced wave action. The growth of plants at Station 10 prevents visibility tests on all occasions but the absence of wind is noticeable at this location.

The relation of Carp activity to lowered transparency has been shown by several authors. The reduction in transparency may not be due entirely to their spawning habits, but to their method of feeding as well. Other variations in transparency, such as the decrease in Summer and the increase in Fall, are probably related to the total plankton present. Colourless forms, both living and dead, all combine to increase the turbidity which reduces the transparency.

The effect of erosion in decreasing the transparency is well known, and was shown by Jones ('39) to result in a reduction of vegetation, especially of the submerged forms. Introduced species of submerged plants were choked out by transparencies rarely over 12 inches. References have been made to the absence of Wild Rice in the Marsh. Its failure to survive may possibly be related also to this problem of turbidity of the open water during the growing seasons.

In relation to the transmission of light for photosynthetic purposes, Chandler ('42) found in studies in western Lake Erie that the transmission of light was greatest in Winter and Spring, and least during the Summer. Turbidity in those waters was primarily due to materials from the bottom. The turbidity was found to affect a number of things, among them, the comparative size and duration of time of the plankton pulses and the distribution of the microcrustacea.

Doan ('42) concluded that higher turbidities were inimical to fish life. In shallow ponds and bays the higher plants may add indirectly to the fish population, as seen above. Where turbidities are high, however, transparency is reduced and the plants are prevented from receiving sufficient light.

Tressler and Domogalla ('31) found transparencies of from 0.5 m. to 2.5 m. for Lake Wingra, a shallow body of water. Bennett ('40) measured a variable transparency of from .45 ft. to 4.8 ft. for Fork Lake, a shallow body of water. In this case it appeared that the transparency varied inversely with the amount of run-off water. As a result of survey work on the upper Mississippi river, it was concluded that erosion silt coming into the water in large quantities was a most serious factor operating to destroy the fisheries of the river. (Ellis, '31). In many cases the increase in turbidity is reflected in an increase of zooplankton in the surface layers. (Doan, '42).

Temperature

Temperature has always been regarded as of great importance in the direct control of the distribution of life in the water. Throughout the period of observations, a reversing thermometer (Negretti-Zambra) was used for all water temperatures. For each sample taken for analysis there was a record made of the temperature at the level of sampling. This required two temperatures, a surface and bottom, and the depths reported are in cms. from the surface.

The only observable effect temperature has on the vegetation is in limiting the growing season because of the time in warming the lake in the Spring. This limiting of the growing season is probably related to the temperature of the bottom mud. According to Pearsall the muds have temperatures much like the waters that bathe them. This was found to be true by Birge, Juday and Marche ('27), except that there is a lag in the change of bottom temperature as compared with the water temperature. Effects of this lag would delay germination and rooting of aquatic plants.

The temperature has little bearing on the type of vegetation other than the above growth conditions; the vegetation, however, has considerable effect on the temperature. (Oosting '33). This is especially true in shallow water where water movements are restricted.

The temperaure of the water is directly related to that of the atmosphere, and changes in the latter are impressed upon the water, so that water temperatures follow that of the air (Fig. 11). In this zone of Ontario the mean annual temperature of 8.8°C. with a range of 16°F between day and night temperatures has been determined by Putnam ('38). Such a range is reflected in the water temperatures recorded during the three Summer seasons.

Obviously the water temperature is closely correlated with the total amount of radiation. There are variations in this both seasonally and annually, which means differences from time to time in the maximum and minimum of recorded temperatures. Reference to Table III will show this to be true. Periods of high temperature are generally related to times when the sky is clear. Alternately with these periods, are low temperatures, brought about by lower atmospheric temperatures. The temperature varies with the time of day as well. When there is a clear sky the maximum temperature of the open water is approached between 4 and 5 p.m. No observations were made within a four-hour period on diurnal studies, and the time of the exact maximum is not known. However, before 4 p.m. and after 5 p.m. the temperatures are obviously lower than they are within this period.

In the vegetation station (10) as compared with the open water, (Station 2), the maximum temperature of a diurnal cycle occurs about an hour later than it does in the open water (Figures 13, 14.) The water temperature is seen to lag behind the air temperature somewhat more slowly at Station 10 than at Station 2. The correlations between the air and

TABLE III

Mean Temperature - Hamilton

Date	1946 July	1946 Aug.	1947 June	1947 July	1947 Aug.
1	25.5	18.3	13.8	22.2	14.9
2	17.2	19.4	11.4	19.1	16.3
3	18.3	20.0	12.8	20.2	16.8
4	19.4	21.1	11.9	22.7	21.0
5	21.6	22.7	18.8	25.2	22.7
6	25.5	21.6	20.3	24.4	23.8
7	22.2	22.2	14.9	20.7	24.9
8	25.0	25.0	10.9	18.6	24.9
9	24.4	25.0	13.3	18.8	23.5
10	21.6	22.0	18.4	21.0	19.7
11	27.2	18.3	19.9	20.8	24.1
12	22.2	18.3	14.9	24.1	27.4
13	22.2	17.7	13.8	25.2	29.1
14	23.3	18.3	13.3	25.2	30.2
15	17.2	20.5	14.9	22.7	24.7
16	18.3	20.5	16.0	23.0	20.5
17	20.5	21.6	14.9	24.1	22.4
18	23.8	20.0	15.5	24.7	26.3
19	25.0	21.1	16.1	18.5	20.5
20	23.8	16.6	12.2	17.5	23.8
21	23.8	18.3	17.4	19.4	24.9
22	21.6	15.5	18.8	16.0	23.8
23	23.8	16.6	19.9	17.4	25.5
24	24.4	16.1	23.3	20.5	27.4
25	18.8	17.2	21.9	23.8	28.0
26	19.4	18.3	22.7	24.6	22.7
27	19.4	20.0	24.1	22.0	20.8
28	21.1	20.5	25.2	22.4	23.3
29	25.5	14.4	29.9	25.7	20.2
30	20.5	15.5	25.8	25.5	23.0
31	20.5	18.3		21.9	24.4

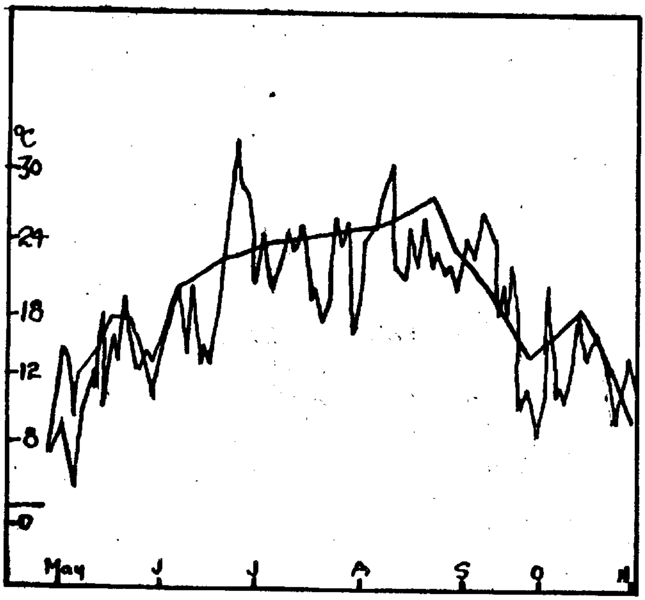

Figure 11
Water Temperature and
Air Temperature Variations
May - November 1947

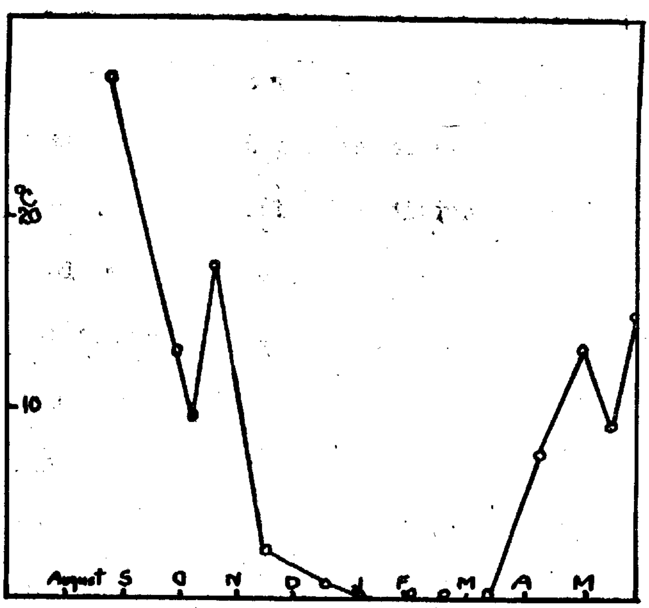

Figure 12
Water Temperature Variations
August–June 1947–1948

water temperatures for both of these stations are seen to be very close. These relations are much more so than in large bodies of water. Ziegelmeier ('40) reported similar conditions for the prompt but reduced temperature changes of water in shallow ponds to that of the air. Minimum values in the open water stations occur between 4 and 5 a.m., depending, of course, on the diurnal fluctuations in the air temperature. It is noted that at these periods the air temperature is lower than the water temperature, especially between the hours of 8 p.m. and 7 a.m. The conditions are exaggerated in the weed bed where the minimum occurs between 4 a.m. and 5 a.m. Air temperatures are again lower than water temperatures between the hours of 7 p.m. and 7 a.m.

An effect of importance during a diurnal cycle is the condition where the surface water temperature becomes lower than the bottom temperature. This is especially true in weed beds, where wind action has no effect in mixing the different strata of the water. Such an occurrence takes place at the minimum point of a diurnal cycle if the air temperature drops unusually low. The correlation of air and water temperatures is very obvious at these times. Baker ('42) found that sudden drops in air temperature seemed to be a contributary cause of fish mortality. Probably such sharp drops would push the water temperature below the incipient lethal level for the species concerned, thus permitting the temperature to act as a lethal factor in such circumstances.

The diurnal range is an important factor in the water temperature of the aquatic habitat. When the night air temperature does not drop very low, the morning water temperature is higher than it was before. Thus very high water temperatures are concentrated and these high periods

TABLE IV

TEMPERATURE

(Surface - Bottom)

Station	2	7	10
Date:			
1/ 7/48		0.2	
		1.5	
4/ 2/48		7.8	7.4
		7.8	7.2
4/13/48			8.5
5/11/48	10.0		
	10.5		
5/19/48	14.0		
6/23/48	19.8	20.0	
	18.6	18.9	
6/25/48		23.2	
		22.3	
6/30/48	24.7	24.0	
	23.1	23.4	
7/2/48	22.8	22.5	
	21.6	22.1	
7/ 5/48	24.2	24.6	24.6
	19.8	23.7	23.1
7/ 6/48	22.0		24.2
	19.0		23.0
7/ 9/48	23.9	25.5	25.0
	23.5	23.5	24.4

Station	2	7	10
Date			
7/12/48	25.0	27.0	25.0
	24.8	25.0	24.3
7/14/48	24.5	24.4	23.5
	24.3	24.5	23.4
7/16/48	23.5	23.6	23.5
	23.8	23.6	23.0
7/19/48	22.2	24.3	23.6
	22.5	24.4	22.2
7/20/48	25.7		24.8
	24.3		22.4
7/23/48	23.5	22.8	23.0
	23.3	23.1	22.2
7/26/48	21.9		21.2
	22.0		21.0
7/28/48	21.9		23.1
	21.5		21.2
7/30/48	25.0	24.4	24.3
	24.7	24.4	22.0
8/ 2/48	21.0		21.2
	18.6		21.4
8/ 6/48	19.4	19.9	18.7
	16.0	20.0	17.7
8/ 9/48	21.4	21.3	24.5
	19.4	19.3	20.0

TABLE V

TEMPERATURE
Diurnal Cycles

	Station 2			Station 10			
Date	Time	Depth cms.	°C	Time	Depth cms.	°C	Air Temp.
7/ 5/48	11:30	20	24.2	10:30	20	24.6	29.2
	a.m.	150	23.6	a.m.	100	23.1	
	3:45	20	24.6	3:00	20	26.0	30.6
		150	24.0		100	22.7	
	7:55	20	25.0	7:15	20	26.1	25.0
		150	25.0		100	24.0	
	11:30	20	24.0	11:00	20	23.5	
		150	24.0		100	23.0	
7/ 6/48	3:35	20	22.1	3:00	20	22.6	21.5
	a.m.	150	21.6	a.m.	100	22.5	
	7:30	20	21.6	7:00	20		23.8
		150			100		
	11:30	20	22.0	11:00	20	24.2	23.1
		150	19.0		100	23.0	
7/19/48	12:00	20	22.2	11:00	20	23.6	22.6
	N.	150	22.5	a.m.	100	22.2	
	4:00	20	25.5	3:15	20	25.0	26.8
		150	24.7		100	23.1	
	7:50	20	24.9	7:20	20	25.1	22.2
		150	24.8		100	23.6	
7/20/48	12:15	20	23.6	11:30	20	22.2	18.9
	a.m.	150	22.3	p.m.	100	23.0	
	4:00	20	22.9	3:30	20	21.4	16.9
		150	23.4	a.m.	100	22.4	
	7:30	20	23.3	7:00	20	22.2	22.2
		150	23.2		100	22.3	
	12:00	20	25.7	11:30	20	24.8	27.8
	N.	150	24.3		100	22.4	

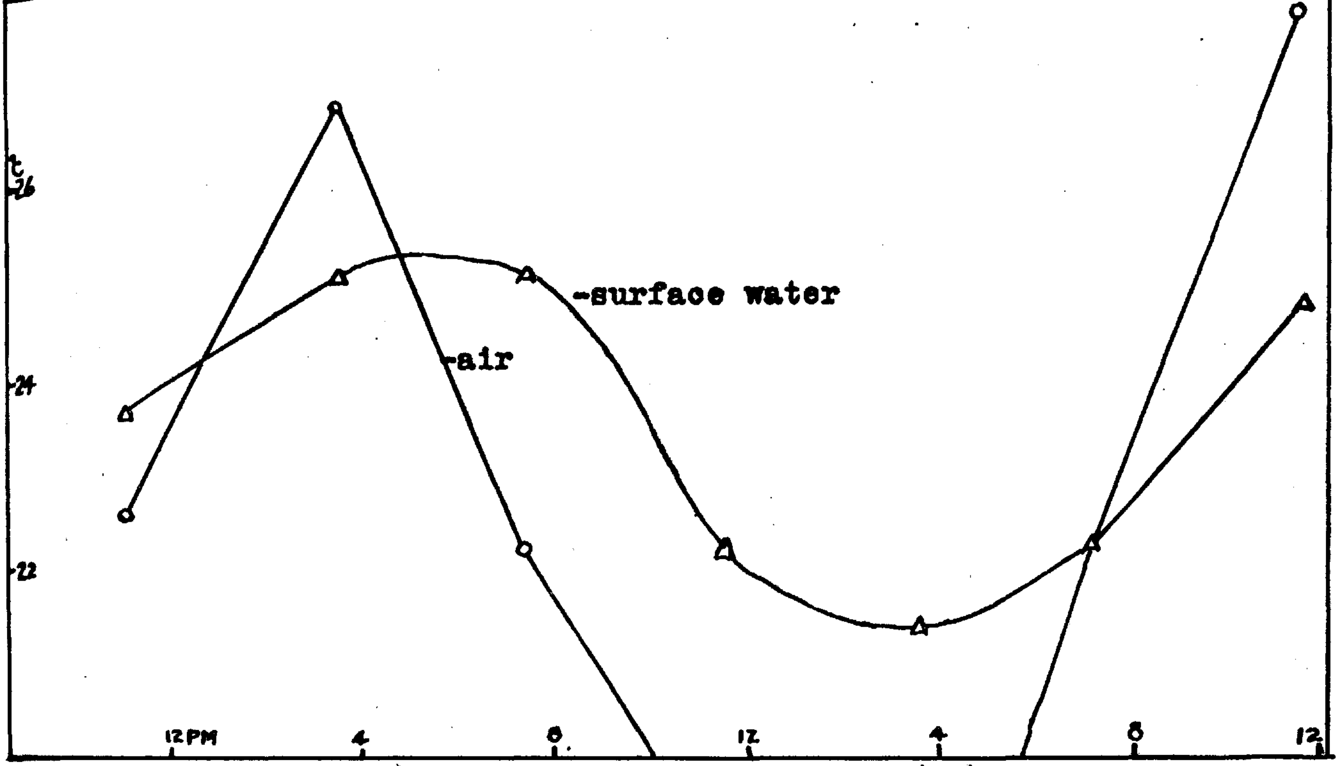

Figure 13. Diurnal Cycle - Station 10 - 7/19/48
Temperature

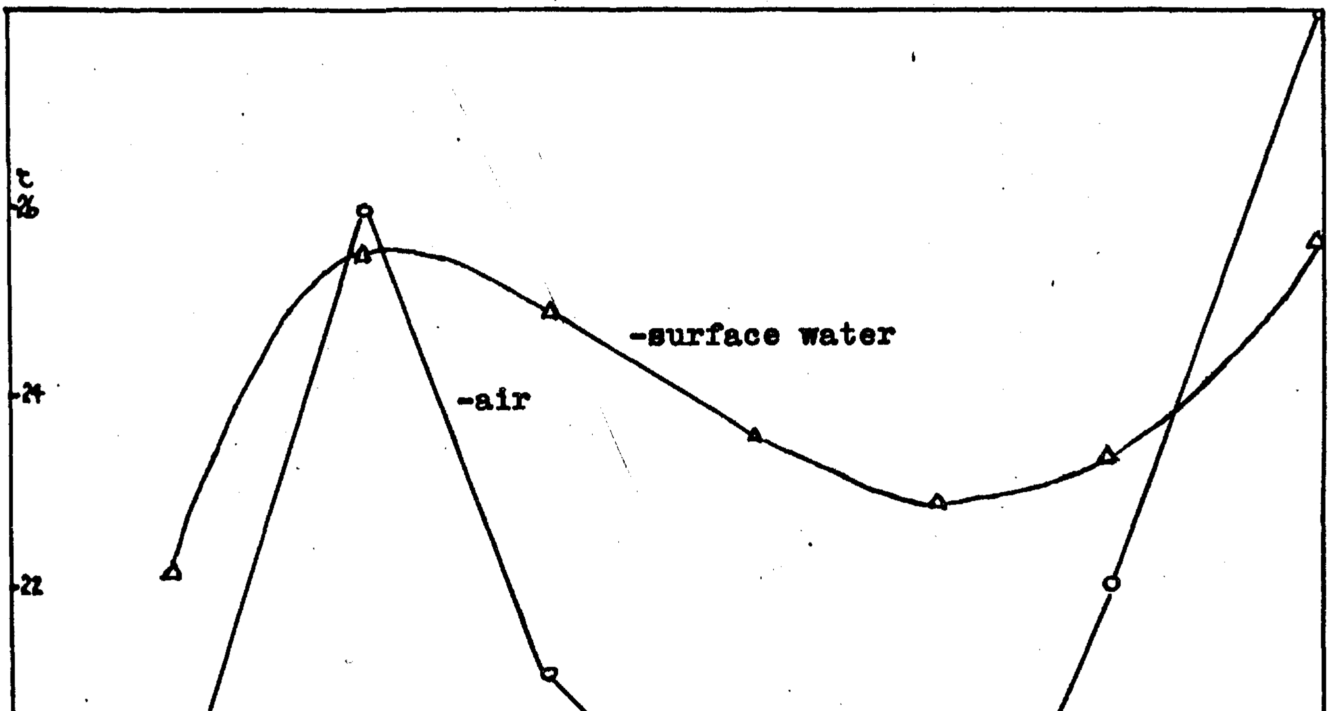

Figure 14. Diurnal Cycle - Station 2 - 7/19/48
Yemperature

may remain for several days. Reference to the figure will show this condition. Differences in surface and bottom temperature are, as a rule, not very great in the Marsh. Depending on the diurnal cycles, differences of from 0C° to 1.5 C° in the open water are common, with occasional greater differences, depending on the air temperature at the time. In weed beds these differences are greater, and may be from 0 - 3 C° from top to bottom. In case of diurnal cycle minima the donditions are reversed and the lower temperature may be at the surface, as shown above.

Throughout the seasons recorded, the wide range of temperature extended from 0° C in winter to 27° C in Summer in the open water. This maximum occurred during a period of extreme heat. Bottom temperatures in the water at this location were as high as 25° C.

Station 2 is located in the central region of the open water zone, in direct line with the cut through Burlington Heights. As an open water station it is subject to much wind action from the south west direction. In 1946, observations were taken only during July and August, during which time the maximum recorded above was reported, 7/24/46 at 10:30 a.m. Reference to the diurnal cycles shows that at this time the maximum is not usually reached, thus a higher water temperature would be expected.

As this station is subject to stirring by wave action, it is apparent that the surface-bottom difference of not more than 1.5° is a result of this action. In 1948 only on two or three occasions did the surface-bottom difference exceed 1.5° C, and then during periods of high air temperature of continued duration. As the Summer progressed, the winds warmed up the upper layers, and this warm water is encountered progressively deeper.

Station 7 is located in open water, but is in a shallower region (1.5 m.) and is not subject to as much wave action. Differences between surface and bottom are less than the 1.5° C difference, as at Station 2.

Station 10 has a dense underwater mat of submerged aquatic plants. Temperatures are generally higher in the surface water than in the open water, and surface-bottom differences are greater, probably due to the inactivity of the wind in stirring the water, and the ineffectiveness of insolation in penetrating the vegetation mat.

Shallow bodies of water are characterized by higher surface maximum temperatures. Tressler ('40) reported the maximum temperature of Buckeye Lake, a relatively shallow lake, as 29°C. Chandler ('44) reported the maximum weekly mean temperature for western Lake Erie as 26.1°C. Lake Wingra, a shallow body of water, registered a maximum of 26°C at the surface in Summer (Tressler '31). Studies at Presqu'Isle Bay in Lake Erie showed the highest temperature of the lake to be 22°C. The surface water was seldom higher than 1° above the bottom (Jennings '33).

The highest mean temperature of many observations seems to be in mid-summer, depending, in this location, on the diurnal fluctuations of the air temperature. Thermal conditions are without the phenomenon of stratification, unless it is micro-stratification, which has not been determined. The minimum temperature is therefore not dependent on the Fall overturn but entirely on the state of the atmospheric conditions. Surface and bottom temperatures are reduced together during the late Fall and into the Winter.

During the Winter the ice forms on the surface water when its temperature reaches 0° C and gives up its heat of fusion. The ice thickens through the season by a down growth of crystallization with the water immediately beneath the ice. The bottom water in the Marsh reached temperatures as low as 1.7° C, much less than the temperature of the maximum density of water. It is possible that in a severe winter a very great depth of ice may be formed, leaving only a small volume of water in contact with the bottom mud. Such a condition is of consequence in the case of the fish life present, as shown by Greenbank ('45). The heat transmitted from the mud to the water during the Winter plays an important part in warming the water during the Winter period.

The temperature of water has important bearings on several factors associated with the general question of fish culture. Such questions as the amount of dissolved gases, rates of bacterial decomposition of organic matter, and the metabolic demands of the higher organisms are all tied up intimately with this primary environmental factor.

The consumption of food by three species of fish, (Eupomotis gibbosus, Lepomis incisor and Micropterus salmoides), was found to be increased three times by an increase in temperature of from 10° to 20° by Hathaway ('27). Although many things are known to affect the growth of fish, low water temperatures and a short growing season are among the most important limiting factors on the attainment of the highest possible fish production. The reason seems to be that fish cannot digest food or grow, unless the water is above 55°F or 60°F (Bennett '40).

The variation in quantity of solar radiation delivered to the water surface during the year is the prime factor determining the biological, physical and chemical cycle of changes that take place within the water (Juday'40). The rise of temperature in the Spring speeds up life processes and the increase in solar radiation makes possible photosynthetic activity. Circulation of the water brings substances into ready use for this photosynthesis. The annual energy budget of a lake is the energy received from the sun and sky each year and the uses the water makes of this energy. Decomposition of the organic material derived from the plants affects the chemistry of the water by means of the effects of temperature. The oxidation of organic material creates heat, which is added to the water temperature, affecting in many diverse ways the other factors present.

Dissolved Oxygen

To provide satisfactory results, the sampling for dissolved oxygen and carbon dioxide must be such, that the water in the sample is representative of the water at the depth where the sample is taken. It must be in an unmodified condition when at the surface in preparation for analysis.

Because there was no sampling equipment in the laboratory, an adaptation of Hale's water sampler was constructed. The sampler consisted of a meter stick to which a 500 ml. sample bottle was fastened by a clamp to the zero end. A two-holed rubber stopper was inserted in the neck of the sample bottle, and a glass tube extended through one of the holes to the bottom of the bottle. The upper end of this intake tube was protected by a piece of copper screen. The other hole was filled by a short length of glass tube, to which a long length of rubber tubing was fastened. This tubing led to the intake tube of a large 2 liter collecting bottle. The mouth of this large bottle was closed by a two-holed rubber stopper. One of the holes had a length of glass tubing extending to the bottom of the bottle. The other hole was filled by a short length of glass tubing, to which a hahd bulb syringe was fastened. The intake from the sample bottle extended to the bottom of the larger bottle under a level of water in the bottle. One or two pressures on the syringe were sufficient to allow the water to flow in the intake of the sample bottle at the desired depth. The inflow of water into the large bottle was taken as a signal that the smaller bottle was filled with its own volume plus that necessary to fill the tube and the lower portion of the large bottle. The sample bottle was raised after applying a pinch clamp to the long rubber tube. The rubber stopper was carefully removed from the bottle and a glass stopper inserted, sealing the water in the bottle. Immediately after sampling, as time permitted, the reagents were added to the sample bottles. The samples for dissolved oxygen were prepared for laboratory titrations by additions of the preliminary reagents. Samples for dissolved carbon dioxide were collected in similar fashion and kept cool until returned to the laboratory for titration.

In estimating dissolved oxygen, it is redommended that any sample suspected of containing organic matter, have a preliminary oxidation before carrying out the analysis, otherwise misleading results may be obtained. (Roberts '41).

The determinations of dissolved oxygen were carried out according to the Rideal-Stewart modification of the Winkler method as in "Standard Methods for the Examination of Water and Sewage", ('46). This method takes into consideration the pessibility of organic contamination and allows a preliminary oxidation. More refined methods of oxygen determination based on the dropping mercury electrode, Manning ('40), have been described, but were not satisfactory for our purposes. The following steps in the procedure were completed immediately after sampling. Additions of the reagents were made to the 500 ml. sample bottle by a pipette tip immersed under the surface of the liquid to prevent unnecessary agitation of the sample. The glass stopper was replaced carefully after each addition of reagents.

1. Remove glass stopper and add 1.4 mls. of conc. H_2SO_4, by means of a long narrow 2 ml. pipette, just below the surface of the water. Replace stopper.

2. Remove stopper and add enough $KMnO_4$ to give a violet colour, which should remain for at least five minutes. Small amounts of $KMnO_4$ were added if the colour did not persist. Replace the stopper and allow to stand for the time period.

3. After shaking and standing for at least lo minutes add 1 ml. of 2% oxalate solution. Replace the stopper and invert the bottle several times. The colour of the permanganate disappeared if the oxalate added was sufficient.

4. After the sample is colourless add 2 ml. of $MnSO_4$, and invert the bottle several times, after replacing the stopper.

5. Add 6 mls. of the NaOH-Kl solution by pipette as before. Replace the stopper and invert the bottle several times to mix the precipitate. Allow to stand several minutes and then shake thoroughly again. A clear liquid occupies the upper portion of the bottle after the precipitate settles.

6. After the final settling of the precipitate, add 2 mls. of conc. H_2SO_4 to the side of the bottle and allow it to run slowly to the bottom. Replace the stopper and invert the bottle several times to destroy the

precipitate. The sample is now permitted to stand until reaching the laboratory. The dissolved oxygen in the water is absorbed by the manganous hydroxide. A mixture of higher oxides of manganese is formed, and following the acidification in the presence of an iodide, iodine is released in quantities equivalent to the oxygen content of the sample.

7. An equivalent amount of sample equal to 200 mls. of unmodified water, (correction for loss due to addition of reagents must be accounted for), is transferred to an Erlenmeyer flask. Titrate rapidly with N/40 $Na_2S_2O_3$ solution until the liquid becomes a pale straw colour. Add a few mls. of 0.5% starch solution and continue the titration slowly until the blue colour first disappears. The titration is stopped at this point and the amount of N/40 $Na_2S_2O_3$ which has been added, is recorded.

The correction for the loss, due to the displacement by the reagents, is dependent on the volume of sample retained in the original sample. For satisfactory results, the amount of sample titrated is 200 mls. which gives the oxygen content in parts per million directly from the number of mls. of N/40 $Na_2S_2O_3$ added. For accuracy, the results must take into account the volume of the bottle and the amount of sample lost during the addition of the reagents. This is equal to the following relationship:

$$\frac{(\text{volume of sample bottle X 200})}{(\text{vol. of sample bottle X volume of reagents added to sample.})}$$

In our analyses the average values derived from all calculations gave the amount required for titration as 203 mls. This is equivalent to 200 mls. of unmodified sample.

The calculation of the results depends on the amount of sample used for titration. If 200 mls. are used the number of mls. of N/40 $Na_2S_2O_3$

used is numerically equal to the dissolved oxygen in parts per million. Relative values are obtained where the amount titrated is different (203 mls. from the above figure. Results in terms of percentage saturation are secured by dividing the titration value in mls. by the solubility value as determined by the temperature of the sample. Correction for altitude is made, by means of Rawson's nomogram (Rawson '45).

Waters vary greatly in their individual characteristics, in exposure to climatic conditions and the material carried in their waters. They illustrate differences in the amount and distribution of oxygen. In shallow lakes, oxygen is usually well supplied because of the lack of thermal stratification and the constant circulation which brings the water in contact with the air. As well, the presence of the aquatic vegetation through photosynthetic activity delivers oxygen to the immediate water. Occasionally in a zone of stagnation, oxygen is absent at times of maximum temperature. This depletion depends on the presence of much organic material, which in turn depends on the presence of an aquatic flora. In winter, the ice cover tends to isolate the water from the air, preventing absorption of oxygen, and production from phytoplankton and submerged plants must provide the available supply. Respiration and décomposition continue but at a lowered rate. In Summer the decomposition is highest as well as the photosynthesis, and there may even occur supersaturations of oxygen because of an overbalance of plant activity. Seasonal changes are reflected by diurnal changes which are dependent on temperature and light (Whipple '27).

The range of dissolved oxygen for all the analyses conducted through the three seasons went from 0 p.p.m. (0% Sat.) to 13.6 p.p.m. (165% Sat.).

The former value is quite frequent in the bottom strata at Station 10 throughout the Summer. The latter was the maximum recorded concentration and occurred on 7/19/48 in the open water zone, at noon.

Consideration of the time factor, is perhaps more important for dissolved oxygen data in shallow water areas than for any other factor. The reasons for this consideration are due both to the operation of photosynthetic activity of plants and phytoplankton and to temperature. Temperature effects counteract photosynthesis, because at higher temperatures less dissolved gas is able to be retained in water. Photosynthesis is an insolation effect, and takes place at the period of greatest light which usually corresponds with the highest temperature.

Diurnal studies of oxygen concentration were made at the same time and location as the determinations of temperature. The greatest amount of dissolved oxygen for the open water stations (Appendix) (Fig. 15, 16) (Table VII) occurred at 4 -5 p.m. and about two hours later than this for the weed stations. Minimum diurnal values were found to occur in early morning hours between 2 a.m. and 4 a.m. The maximum O_2 peaks correspond approximately with the peaks of temperature for both the open water and vegetation zones. Minimum values are related to the low temperature readings, showing a relation between photosynthesis and temperature, the former, of course, dependent on light.

Station 2, in the open water area, shows a change from 8.93 p.p.m. (100%) at 7/19/48, 12 N to 12.39 p.p.m. (150%) at 4 p.m. Later in the same cycle the O_2 drops to 9.75 p.p.m. (113%) at 12:15 a.m. During the next four hours between 12:00 a.m. and 4:00 a.m. the minimum value is reached with minimum temperature also falling in this zone. Further increases in time were followed by increases in temperature and the oxygen concentration again reached toward a maximum.

In a vegetation zone Station 10 illustrates lower overall oxygen values because the surface samples were taken 20 cms. below the true surface and thus under the upper mat of plants. At 11:00 a.m. on 7/19/48 the surface (20 cms.) oxygen was 2.26 p.p.m. (20% Sat.). By 4:15 p.m. the amount had increased to 6.31 p.p.m. (75%), and in late afternoon by 7:20 p.m. had reached 9.10 p.p.m. (109%), the maximum recorded for the cycle. This point corresponds with the maximum temperature at the station. Further time increases result in a lowering of the oxygen concentration to a minimum between 2 - 4:00 a.m., 0.71 p.p.m. (7.5%). At 7:00 a.m. the oxygen concentration is 2.19 p.p.m. (24%), and has returned to its original level by 11:30 a.m. of 3.79 p.p.m. (45%). Wiebe, ('34), showed that differences in the oxygen concentration of shallow water in day time is related to the amount of live vegetation, and night differences are due to different quantities of dead plants. The respiration rate of all organisms decreases as the concentration of oxygen is reduced, but bacteria are able to remove all detectable traces of dissolved oxygen in the presence of any oxidizable organic matter (Zobell '40). Thus the lower oxygen values for Station 10, are directly related to the greater amount of organic material in that location.

The surface changes illustrated above, show the wide daily fluctuations in oxygen concentrations and the dependence on temperature effects. In the case of bottom samples these variations are similar, following the surface variations. Differences in the surface and bottom sample may be very small or large, depending on diffusion and wind circulation. For

TABLE VI
Dissolved Oxygen (p.p.m.)
Surface - Bottom
(See Appendix for temperature and % Saturation)

STATION	2	7	10
Date: 6/23/48	10.53	8.33	
	7.68	6.33	
6/25/48	8.89	7.70	
	9.29	7.24	
6/30/48	6.01	6.59	
	5.57	6.95	
7/ 2/48	6.89	5.21	
	7.09	5.21	
7/ 5/48	9.95	8.83	
	6.02	7.21	
7/ 6/48	7.71		
	5.81		
7/ 9/48	11.10	12.28	9.43
	9.17	8.32	6.36
7/12/48	9.50	8.99	6.19
	6.52	3.38	0.67
7/14/48	6.08	4.70	4.26
	6.27	4.23	0.99
7/16/48	7.16	7.31	5.91
	7.07	6.72	3.19
7/19/48	8.93	8.27	2.26
	6.92	7.57	0.61
7/20/48	13.62		3.79
	8.78		0.71
7/23/48	7.79	7.79	3.26
	8.11	7.78	2.13
7/26/48	8.82		0.0
	8.21		0.0
7/28/48	8.98		0.31
	8.80		0.0
7/30/48	10.08	11.59	1.22
	9.73	11.17	0.0
8/ 2/48	10.86		3.04
	8.69		0.0
8/ 6/48	8.68	10.0	0.0
	4.74	9.45	0.0
8/ 9/48	11.97	10.25	6.62
	9.23	4.25	0.0

TABLE VII
Dissolved Oxygen
Diurnal Cycles

STATION:	2				10			
Date	Time	Depth	p.p.m.	%Sat.	Time	Depth	p.p.m.	%Sat.
7/ 5/48	11:30	20	9.95	116	10:30	20	5.52	65
		150	6.02	65		100	0.52	5
	3:45	20	11.20	132	3:00	20	2.78	34
		150	9.83	115		100	0.85	10
	7:55	20	9.75	115	7:15	20	8.20	100
		150	9.38	111		100	0.50	6
	11:30	20	8.14	95	11:00	20	0.91	10
		150	15.94	190		100	0.85	9
7/ 6/48	3:35	20	7.09	80	3:00	20	1.25	14
	a.m.	150	6.09	60	a.m.	100	0.94	10
	7:30	20	7.63	-	7:00	20	0.77	
		150	7.70	-	a.m.	100	0.36	
	11:30	20	7.71	87	11:00	20	2.82	33
		150	5.81	61		100	0.62	7
7/19/48	12:00	20	8.93	100	11:00	20	2.26	26
	N	150	6.92	79	a.m.	100	0.61	7
	4:00	20	12.39	150	3:15	20	6.31	75
		150	9.70	115		100	1.63	18
	7:50	20	11:44	136	7:20	20	9.10	109
		150	12:33	145		100	0.23	2.5
7/20/48	12:15	20	9.75	113	11:30	20	3.01	34
		150	7.98	90		100	0.63	7
	4:00	20	9.8	113	3:30	20	0.71	7.5
	a.m.	150	5.01	58	a.m.	100	0.74	8
	7:30	20	10.03	116	7:00	20	2.19	24
		150	8.74	97	a.m.	100	0.53	5.5
	12:00	20	13.62	165	11:30	20	3.79	45
	N	150	8.78	104		100	0.71	7.6

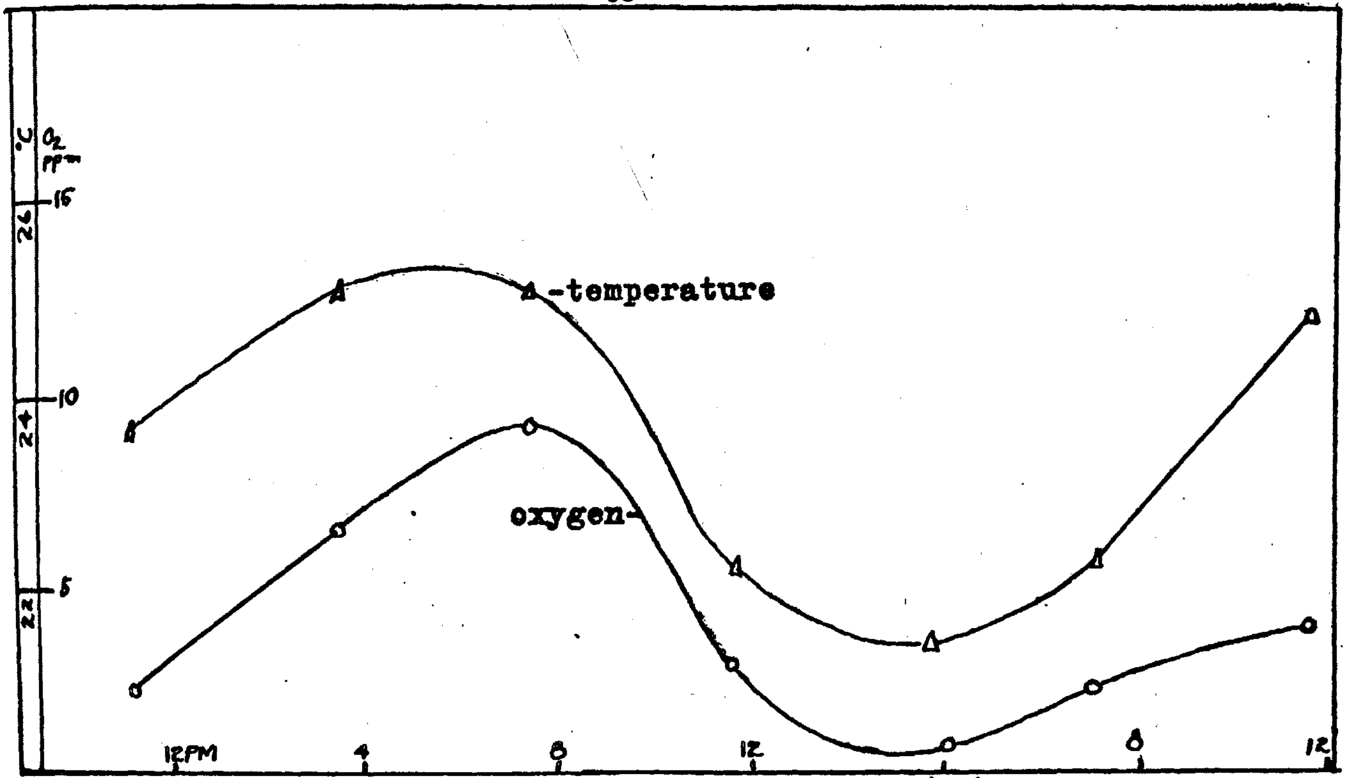

Figure 15. Diurnal Cycle - Station 10 - 7/19/48
Temperature - Oxygen

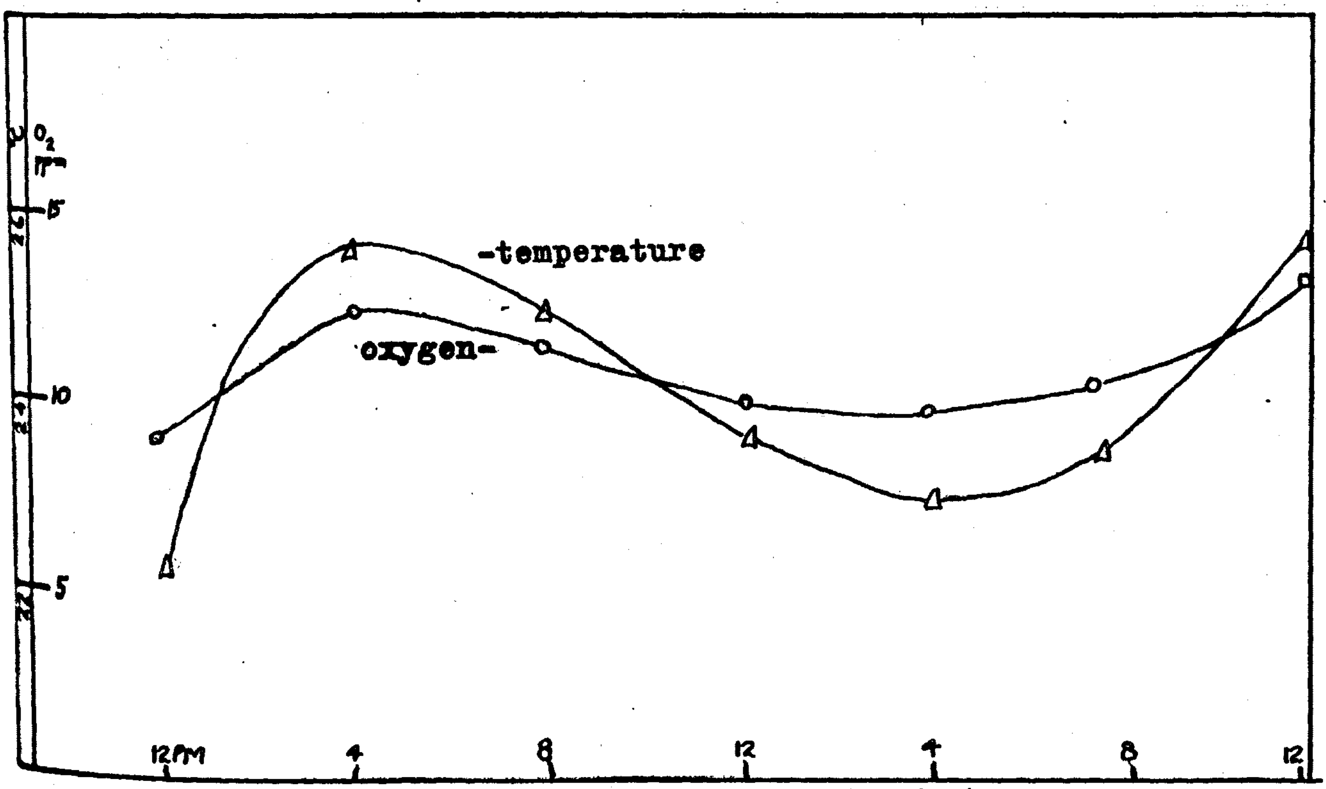

Figure 16. Diurnal Cycle - Station 2 - 7/19/48
Temperature - Oxygen

Station 10 the differences during the cycle are as follows: 1.65, 4.68, 8.87, 2.38, 0.03, 1.66, 3.08. These have a direct relation to the sequence of events in the photosynthetic cycle. The large difference of 8.87 corresponds with the point of maximum oxygen in the surface layers. Similarly 0.03 corresponds with the minimum oxygen value in the surface. Such correlations do not always hold, but the bottom oxygen concentrations are usually lower than the surface values in the weed beds and shallow water, with mucky, organic bottom.

Diurnal changes in open water zones are not drastic changes, as shown in the tables and graph. However, as we have shown, the changes in the vegetation zone are large enough to cause a migration of organisms from these areas during the low oxygen part of the cycle, or to result in the absence of fish and aquatic animals at all times. The lack of oxygen, with other factors was shown by Bennett ('31) , to cause the death of more fish than any other factor. These changes during a daily cycle must be reckoned with, in presenting data on dissolved oxygen for shallow waters in Summer. In Winter, Scott ('31) found no great diurnal variation in the dissolved oxygen.

The dissolved oxygen of the open water area was rarely found below 5 p.p.m., at any time of the investigation for seasonal or diurnal changes. The minimum value recorded was 4.54 p.p.m. for a bottom sample at Station 7 in 1947. Most values of the surface water were saturated from 60-130%, depending on the time and temperature. The supersaturation conditions are dependent on an excess of photosynthetic activity.

In the vegetation stations, the general case was for bottom samples to have from 0 - 3 p.p.m. dissolved oxygen, rarely higher. Surface samples as shown for Station 10 are under the first layer of the vegetation mat, and do not show the true surface conditions of the plant activity. However the fluctuations are wide, with relatively low values compared with the open water. Laurie ('42), showed that the oxygen content in a vegetation region barely reached that of the open water even when at the periods of the diurnal maximum. Effects of the vegetation covering, in reducing the absorption of oxygen from the air and also photosynthetic activity of the submerged plants was shown by Stepanova ('28). Roach, ('34), found oxygen concentrations of the open water of Buckeye Lake to be 5.5 p.p.m. but where the vegetation was plentiful the average concentration was only 0.2 p.p.m.

Surface bottom differences are evident in all cases with the lower values on the bottom. During the seasons studied there was no special seasonal cycle observed, probably because of the special environmental complex of shallow water and consequent diurnal changes.

Low dissolved oxygen was found where the organic decomposition would be expected to be high, as in regions of concentrated plant growth. High dissolved oxygen occurs throughout the open water area, indicative of conditions suitable for fish and aquatic faunae. So long as the bottom contains some oxygen, no other gas than carbon dioxide is produced from decomposition. If the oxygen is removed, then anaerobic conditions produce other gases such as methane and hydrogen sulfide (Birge '08).

In Winter the snow covering has a result in reducing the oxygen below the minimum requirements of certain or all species of fish. Small shallow lakes with highly organic bottoms are the most susceptible, and if they receive sewage as well,the oxygen demand is increased and may well exhaust the supply and result in fish mortality. Greenbank, ('45), found that the oxygen changes in small eutrophic lakes under the ice were correlated with the depth of snow on the ice,and in turn the oxygen depletion was correlated with the general organic richness in the lake.

For the final evaluation of field observations on dissolved oxygen, experimental data covering the requirements of aquatic animals must be considered. The amount of oxygen consumed by the fauna,and the minimal amounts which barely support life , vary with the environment oonditions operating at the time. Temperature, carbon dioxide and pH are also important and will be covered presently.

Carter, ('30), found that in heavily vegetated areas the fauna are controlled mainly by the oxygen of the water. Low oxygen was produced by temperaure changes failing to mix the water layers because of the protection afforded by the aquatic plants. The movement of game fish and forage fish in a body of water was shown by Harkness to be controlled by temperature, oxygen and carbon dioxide content. Epidemics of fish mortality have been reported by Pruthi, ('36), and are believed due to the exhaustion of the dissolved oxygen in bottom layers of water, as a result of the rapid decay of accumulated organic matter. The absence of fish is definitely correlated with low oxygen content.

Many observers have pointed out that the metabolism of fish and other aquatic animals follows the Van't Hoff law with respect to temperature, so that the amount of oxygen removed from the water by the fish varies with the temperature of the water regardless of the amount of oxygen present , until a near lethal point is reached (Keyes '30). Boericke, ('33), stated that the bulk or weight of aquarium fish was a true index of their oxygen consuming capacity. Ruttner, ('26), found that the oxygen consumption of many aquatic animals is almost doubled with each rise of 10° C within letahl limits, and Powers, ('22), had earlier pointed out the correlations between the utilization of oxygen by fish at low oxygen tensions.

The delimitation of dissolved oxygen thresholds for various species of fish was shown by Moore, ('42), It was found that oxygen tensions near the critical level were only slowly lethal. Oxygen concentrations of less than 3.5 p.p.m. at temperatures of 15-26° were fatal within 24 hours; 5 p.p.m. and over was not lethal, 1 p.p.m. and under was fatal at any temperature to all species except the occasional Ameiurus. The amount of dissolved oxygen tolerated by the yellow perch, steel coloured shiner and blunt nosed minnow was found to be 2.25 p.p.m. at 20-26° (Wilding '39). The oxygen consumption of Cyprinus carpio depends on the time of day and the habits of the fish. Thus Oya, ('38), found a relation between the oxygen consumption and the environmental temperature.

The variation in the amount of oxygen consumed by fresh water fish of different species is apparent from many workers. The lower limit for dissolved oxygen is a point difficult to define. Thompson, ('25), states that Carp and Buffalo have been found living in water with as little as 2.2 p.p.m. dissolved oxygen. As a rule, he found a variety of fish only when 4.4 p.p.m. of dissolved oxygen was present, and the greatest variety of fish when the oxygen was over 9 p.p.m. He showed that fish died overnight in waters of less than 2 p.p.m. , this figure being in accord with the work of Moore. From many references it seems that the upper limit of dissolved oxygen at which asphyxia may be expected in fresh water fishes if there are no complicating factors is in general about 3 p.p.m. at 25° C, an amount greater than is found in the vegetation zone. As 3 p.p.m. is approximately the lower limit of dissolved oxygen at which fish can survive, and as waters carrying 5 p.p.m. or more dissolved oxygen are favourable for many fishes, (Ellis '37), it is of interest to make reference to the Tables and Appendix in regard to dissolved oxygen concentrations in the Marsh, to see the expected distributional pattern of the mixed fish faunae.

Dissolved Carbon Dioxide and Carbonates

The sampling procedure was similar to that for the determination of dissolved oxygen. The samples were transported to the laboratory as soon after sampling as practicable. During transit they were cooled to prevent undue temperature variations in the water. As the carbon dioxide escapes from the water easily it was believed that some variations from the true concentration might occur during transit. Check tests on this procedure by titration in the field ruled out any significant variation if the samples were kept cool and the transit time was short. The prodedure in the laboratory was as follows for dissolved carbon dioxide:

1. Pour carefully, to prevent agitation, 100 mls. of sample into a 250 ml. Erlenmeyer flask. The sample was measured satisfactorily by means of a buret.

2. Add 10 drops of phenolpthalein indicator solution.

3. Add N/44 NaOH from a buret while moving the flask in a slight circular motion until the first pink colour appears.

The amount of "free" carbon dioxide in p.p.m. is obtained by multiplying the number of mls. of N/44 NaOH by 10.

The procedure for the determination of the carbonates is divided into two parts: the first, a measure of the carbonate alkalinity determined by the phenolphthalein and the second a measure of the bicarbonate alkalinity determined by the use of the indidator methyl orange.

I. 1. Add 100 ml. of sample to a 25 mls. Erlenmeyer flask.

2. Add 4 drops of phenolphthalein indicator. If colour appears, normal carbonate is present.

3. If sample becomes pink, add N/50 H_2SO_4 from a buret until the colour just disappears.

The alkalinity in p.p.m. $CaCO_3$ equals the number of mls. of N/50 H_2SO_4 times 10.

II. 1. Add 100 mls. of sample to a 250 ml. Erlenmeyer flask as above.

2. Add 2 drops of methyl orange indicator to sample. If a yellow colour appears, then bicarbonate is present.

3. Add N/50 H_2SO_4 from the buret until a faint orange colour first appears. The methyl orange alkalinity in p.p.m. of $CaCO_3$ is equal to the number of mls. of N/50 H_2SO_4 times 10.

In the relations of the dissolved gases oxygen and carbon dioxide, the surface waters tend to be in equilibrium with the atmosphere in which the balance is held by prevailing conditions of temperature, since the quantity of dissolved gas varies in inverse relation to the temperature, if the pressure is constant. Below the surface, saturation conditions are altered by the processes of organic activities. Plants release the oxygen and absorb the carbon dioxide in photosynthetic processes. Animals and plants take in oxygen and release carbon dioxide in the process of respiration, thus resulting in a constant gaseous exchange. Some factors that influence the gas content are the temperature, the light, and the proximity of plants which are responsible for the major part of the gas exchange. Wind velocity is also of some importance, as it causes mixing of the water and affects the surface concentrations.

The variations in dissolved carbon dioxide in water are in inverse relation to variations in the oxygen content. Respiration and decompostition tend to increase the quantity of carbon dioxide. Photosynthesis reduces the amount of carbon dioxide. The equilibrium between the water and air amounts to about 4 parts per million, and except during the periods of maximum photosynthesis the percentage of carbon dioxide in the water is greater than in the air (Denham, '38). The relations of carbon dioxide in water have been studied by such authors as Birge and Juday ('11), Kemmerer ('23), Scott ('31) among many others. Carbon dioxide is readily soluble in water and may occur as a free dissolved gas. It is more usually found in union with the elements magnesium and calcium, as a carbonate. A bicarbonate, if formed by the union of carbon dioxide and the carbonates, is always able to make available the carbon dioxide for photosynthesis. The amount of gas is dependent on its partial pressure, and thus the amount in water is limited, making the gas available from the bicarbonate very important for the life in the water. The amount of carbonate present determines the free and bicarbonate carbon dioxide available in a water and consequently the expected productivity of the water. Aquatic life is primarily dependent on photosynthetic activity and hence an available carbon dioxide.

Free carbon dioxide occurs only in small amounts at any time in the open water zone. Amounts of over 5 p.p.m. are of unusual occurrence. Conditions are different in the vegetation zone, where there is always a large amount of the free gas available. Samples taken at noon or early afternoon have lower values than samples of the morning, thus indicating the presence of a time factor as for oxygen and temperature. The tables and the appendix list the complete series of observations taken over the three summers and show the location of difference between the open water and vegetation stations. The free gas is generally lower in the surface layer than at the bottom where we have seen the oxygen supply is reduced. The processes of decomposition use oxygen and add carbon dioxide to the water in contact with the organic materials. The relations of oxygen and carbon dioxide are seen to be inverse with a low oxygen concentration accompanied by a high carbon dioxide content, as shown in (Figures 17, 18) of a diurnal cycle at Stations 10 and 2.

In the vegetation zone, Station 10 shows a decrease of dissolved carbon dioxide during the late afternoon, at a period when the oxygen was at its maximum, along with the temperature in the photosynthetic phase of the diurnal cycle. During early morning conditions are reversed, and the carbon dioxide increases to a maximum about 3 and 4 a.m. at the same time as the oxygen approaches a minimum. Similarly the temperature is at a minimum at this phase of the cycle. Further changes result in a constant value for carbon dioxide, depending on the available light or a decreasing value with resumption of photosynthesis. Surface and bottom changes are similar.

In the open water zone a diurnal cycle shows the addition of small

TABLE VIII

Dissolved Carbon Dioxide
p.p.m.
(Surface - Bottom)

STATION:	2	7	10		2	7	10
Date:	p.p.m.	p.p.m.	p.p.m.	Date:	p.p.m.	p.p.m.	p.p.m.
6/23/48	0.0	2.7					
	1.7	3.5					
6/25/48	1.9	0.0		7/19/48	0.0	0.0	13.5
	2.6	0.0			2.0	0.0	15.1
6/30/48	5.1	3.7		7/20/48	0.0		12.9
	4.8	3.4			0.0		13.2
7/ 2/48	1.1	3.9		7/23/48	0.0	0.0	14.8
	4.1	5.6			0.0	0.0	18.3
7/ 5/48	0.0	0.0	13.3	7/26/48	0.0		10.2
	3.8	3.8	20.6		0.0		16.0
7/6 /48	3.5		21.8	7/28/48	0.0		14.2
	54.0?		25.1		0.0		10.1
7/ 9/48	0.0	0.0	10.6	7/30/48	0.0	0.0	6.9
	0.0	0.0	11.1		0.0	0.0	17.2
7/12/48	0.0	0.0	9.3	8/ 2/48	0.0		10.8
	1.7	6.5	15.0		5.3		12.7
7/14/48	0.0	0.0	8.7	8/ 6/48	0.0	0.0	15.1
	0.0	0.0	5.9		4.3	0.0	10.7
7/16/48	0.0	0.0	0.0	8/ 9/48	0.0	0.0	6.6
	0.0	0.0	9.6		0.0	0.0	10.0

TABLE IX

Dissolved CO_2 - Diurnal Cycles

2			10		
Time	Depth	p.p.m.	Time	Depth	p.p.m.
11:30	20	0.0	10:30	20	13.8
a.m.	150	3.8	a.m.	100	20.6
3:45	20	0.0	3:00	20	12.1
	150	0.0		100	19.9
7:55	20	0.0	7:15	20	6.2
	150	0.0		100	23.0
11:30	20	0.0	11:00	20	14.3
	150	0.0		100	24.5
3:35	20	0.9	3:00	20	12.9
a.m.	150	3.9	a.m.	100	15.8
7:30	20	0.0	7:00	20	19.9
	150	0.0		100	14.9
11:30	20	3.5	11:00	20	21.8
	150	54.0?		100	25.1
12:00	20	0.0	11:00	20	13.5
N	150	2.0	a.m.	100	15.1
4:00	20	0.0	3:15	20	9.1
	150	0.0		100	10.2
7:50	20	0.0	7:20	20	7.8
	150	0.0		100	13.6
12:15	20	0.0	11:30	20	11.5
a.m.	150	3.9		100	14.0
4:00	20	0.0	3:30	20	12.3
	150	0.0	a.m.	100	12.5
7:30	20	0.0	7:00	20	10.3
	150	0.0		100	9.4
12:00	20	0.0	11:30	20	12.9
N	150	0.0		100	13.2

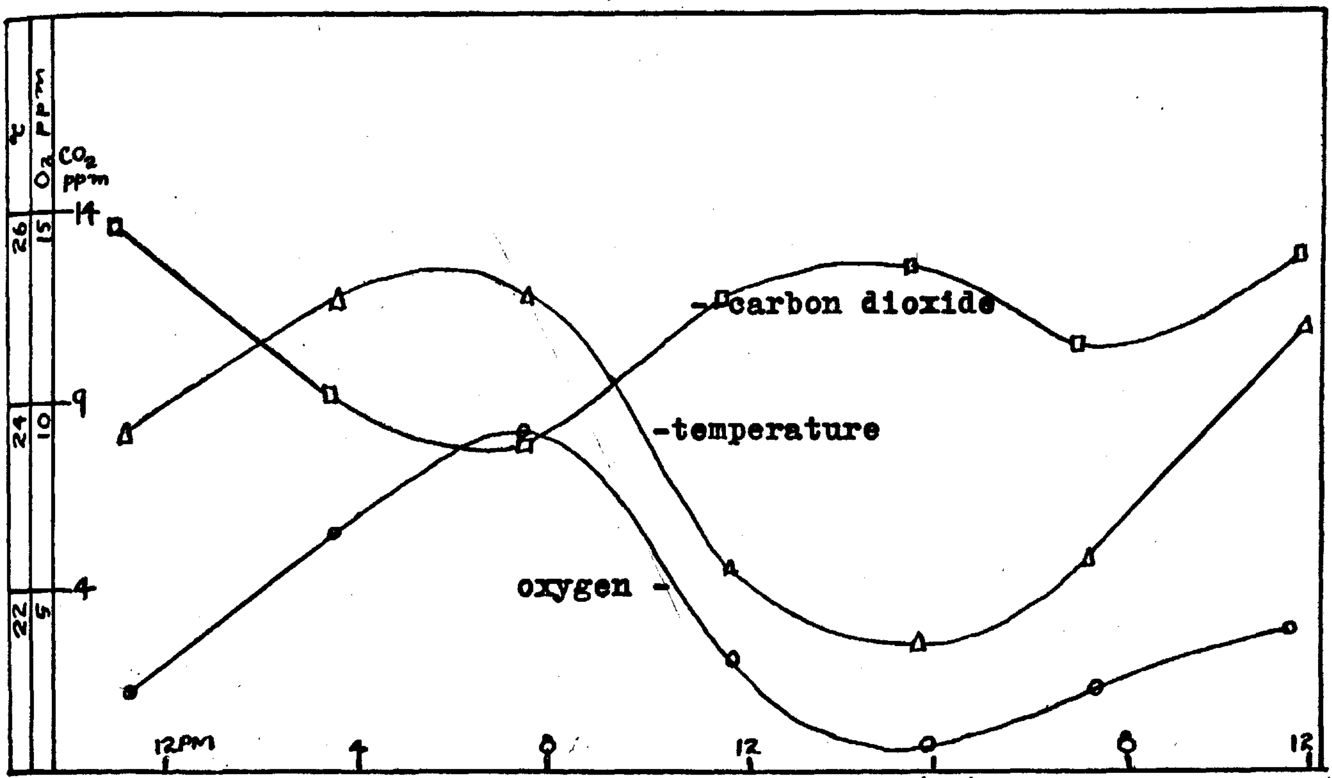

Figure 17. Diurnal Cycle - Station 10 - 7/19/48
Temperature, Oxygen, Carbon Dioxide

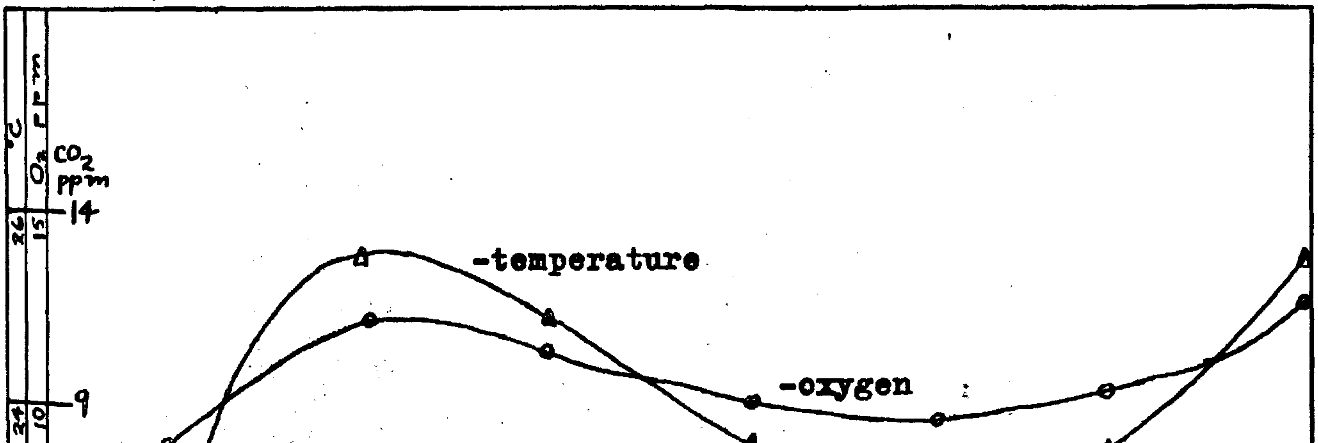

Figure 18. Diurnal Cycle - Station 2 - 7/19/48
Temperature, Oxygen, Carbon Dioxide.

quantities of dissolved carbon dioxide to the water in the early morning hours. Miki ('29) showed similar conditions in a shallow pond. Normally there is no dissolved carbon dioxide, or at the most a very small amount, in both the surface and bottom strata of the open water stations. The slight additions of gas occur at the expected period of oxygen depletion. Differences between the open water and the vegetation zones are in quantity only dependent on greater changes in photosynthetic and respiratory activities.

When photosynthesis is not proceeding in the open water the water contains small fractions of carbon dioxide which are present due to absorption from the atmosphere. If decomposition of the organic detritus of the bottom materials is being carried on due to increased temperatures as the season experiences an atmospheric maximum, the amount of carbon dioxide will increase, and shows this at several places in the open water zones despite the reduced solubility of the gas at raised temperatures. In the vegetation regions where the concentration of plants is not as great as at Station 10 the assimilation of the plants may reduce the gas entirely and make the water alkaline to phenolphthalein by the production of normal calcium carbonate. Shallow water areas with much vegetation have usually a supply of carbon dioxide in the surface water. Results of studies of this occurrence have been reported by Chandler ('44), Tressler ('31), Cowles ('23), Birge ('08) and Jennings ('33) among many authors.

In any discussion of the role of nutritive compounds dissolved in water as factors affecting the productivity, the relations of carbon dioxide as it is present in the form of carbonates and bicarbonates must be considered (Maucha, '43). The buffer action of the carbonates present in

TABLE X

Alkalinity
(Surface - Bottom)

STATION:	2		7		10	
Date:	Phth.	MO	Phth.	MO	Phth	MO
7/14/48	10.4	122.3	10.4	132.1	-	166.3
	7.4	116.9	11.0	132.5	-	171.1
7/16/48	8.0	102.4	21.4	136.4	117.0	142.5
	9.4	101.4	15.4	139.5	-	152.5
7/19/48	17.8	117.4	16.2	133.1	-	182.1
	-	110.9	19.6	130.6	-	186.4
7/20/48	35.0	116.0			-	176.6
	13.8	117.8			-	182.8
7/23/48	13.2	109.2	9.8	122.0	-	186.8
	17.8	102.3	11.0	115.8	-	190.3
7/26/48	18.8	131.0			-	194.2
	16.2	129.6			-	209.1
7/28/48	14.0	106.3			-	196.4
	7.2	107.3			-	196.5
7/30/48	21.2	110.4	14.6	111.2	-	183.1
	21.6	110.2	14.4	110.2	-	196.3
8/ 2/48	25.0	105.0			-	193.6
	-	105.7			-	202.1
8/ 6/48	9.0	124.2	24.6	118.8	-	198.3
	-	106.9	38.0	166.2	-	200.6
8/9 /48	18.2	102.6	30.4	106.1	-	181.3
	16.6	121.2	10.4	138.5	-	194.1

TABLE XI

Alkalinity
Diurnal Cycles

STATION:		2				10		
Date;	Time	Depth	Phth	M.O.	Time	Depth	Phth	M.O.
7/19/48	12:00 Noon	20	17.8	117.4	11:00 a.m.	20	-	182.1
		150		110.9		100	-	186.4
	4:00	20	34.8	108.0	3:15	20	-	178.5
		150	28.4	115.8		100	-	184.2
	7:50	20	22.2	124.8	7:20	20	-	162.6
		150	20.6	120.6		100	-	182.3
7/20/48	12:15 a.m.	20	19.0	125.4	11:30	20	-	172.6
		150		116.6		100	-	163.6
	4:00 a.m.	20	16.2	124.2	3:30 a.m.	20	-	180.1
		150	10.4	119.4		100	-	179.5
	7:30	20	23.2	113.5	7:00 a.m.	20	-	179.6
		150	12.0	120.4		100	-	176.2
	12:00 N	20	35.0	116.0	11:30	20	-	176.6
		150	13.8	117.8		100	-	182.8

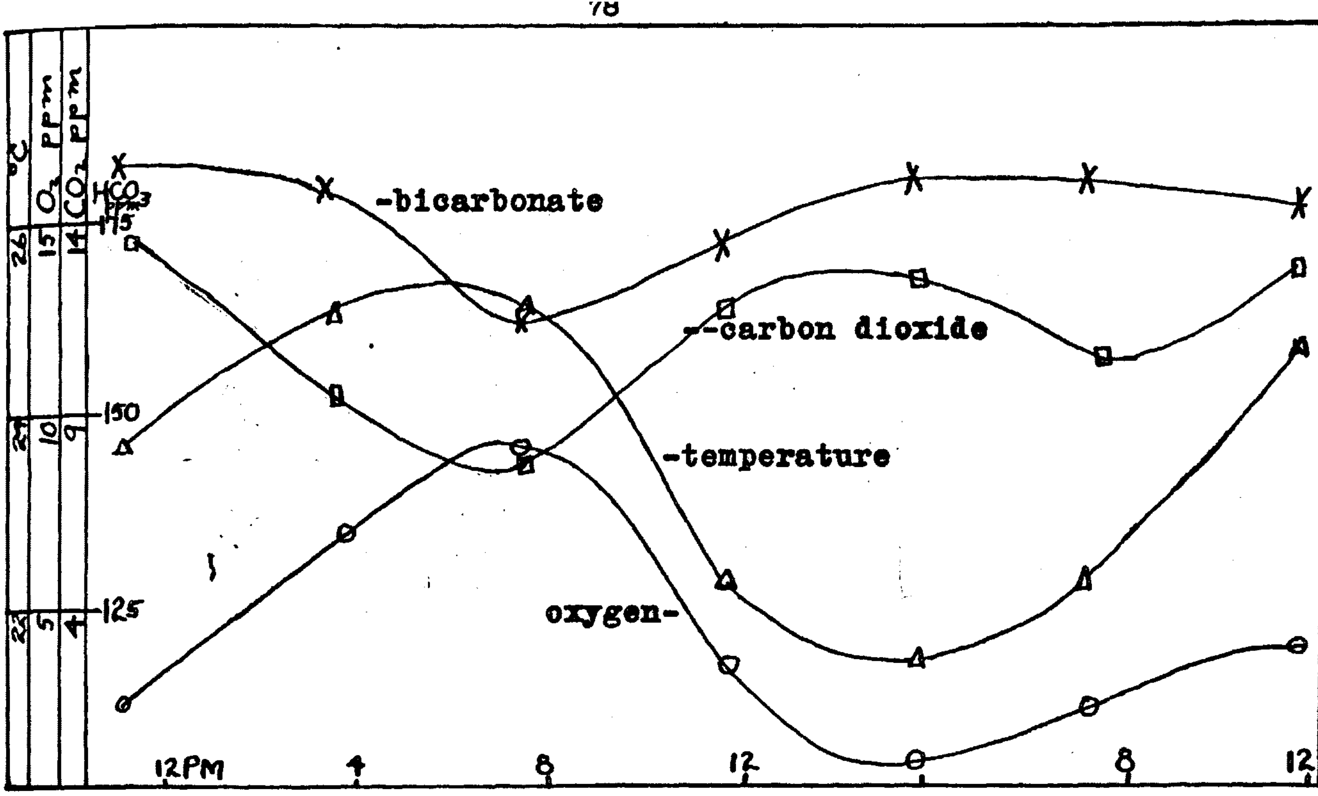

Figure 19. Diurnal Cycle - Station 10 - 7/19/48
Temperature, Oxygen, Carbon Dioxide, Bicarbonate.

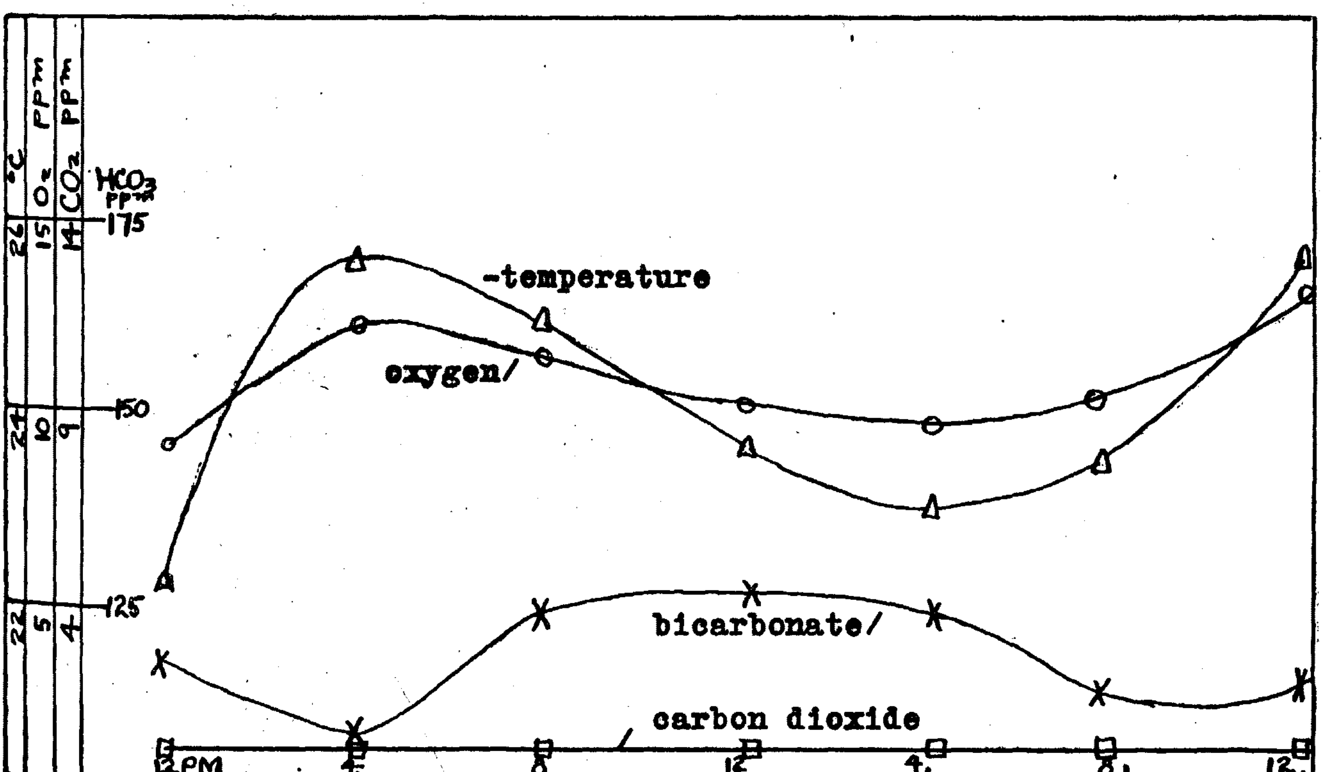

Figure 20. Diurnal Cycle - Station 2 - 7/19/48
Temperature, Oxygen, Carbon Dioxide, Bicarbonate

the water acts primarily as a carbon dioxide regulator. The depletion of carbon dioxide by plants is compensated by the liberation of carbon dioxide from the bicarbonate in water of high alkalinity. The carbonates in the water come chiefly from the geological drift material. Surface streams accumulate ground water and carry the carbonates to the drainage basin. (Broughton, '41). The methyl orange alkalinity of the water as carbonate, in the Marsh, has a range of from 101.4 p.p.m. to 209.1 p.p.m., which means that the water basin is part of a hard water lake, and thus several general qualities are present dependent on this classification. Among these is a definite flora related to the hardness of the water. The values reported are inclusive of open water and vegetation zones, their respective locations having different mean values depending on the other chemical factors.

From the tables and graphs it is seen that the methyl orange alkalinity is lower in the open water than in the plant zone. Differences of as much as 80 - 90 p.p.m. are found between these two locations. This is probably due to the absence of growing plants which produce enough carbon dioxide through their respiratory activity for photosynthesis. In the open water the bicarbonates are reduced by the loss of the "halfbound" carbon dioxide for photosynthesis, producing a quantity of normal carbonate. Thus in diurnal cycles in the open water the bicarbonate reaches its minimum values when there is a complete absence of free carbon dioxide. At the same time the maximum carbonates are recorded during the 24 hour cycle. The minimum and maximum reported above occur respectively in late afternoon, at a time when maximum oxygen and temperatures of the cycle are found.

For Station 10, as shown before, the carbon dioxide is sufficient ll times to supply any requirements for photosynthesis. However, the rbonates show a reduction in amount at the same time as at the open er station, namely when the oxygen approaches a maximum. As the carbon oxide is readily available it is used for photosynthesis. It is probable at carbon dioxide is removed simultaneously from the bicarbonate, leaving n insoluble carbonate which becomes a marl coating on many of the plants n this vegetation mat. The amount of bicarbonate is sufficient for such n occurrence. The formation of marl by the action of plants in shallow, protected bays has been described by Kindle ('27). He showed that many plants were responsible for the formation of marl, among them Elodea, Potamogeton, Ceratophyllum, Castalia and Chara. Plants like Potamogeton occasionally deposit showers of lime incrustation to the bottom, as well as being encased in a lime film on their leaves and stems. Many plants, when brittle to the touch, often slough off a brown, gritty material if the plants are crushed in the hand. This is more noticeable as the season progresses through the summer in weed beds protected from agitation of the wind and wave. The assimilation of plants by using bicarbonate is described by Gessner ('37) and it is shown how the carbonate is released to form the marl coating.

Carbon dioxide produced by aerobic decomposition is available for plant uses in the water basin. Marsh gas has no relation to plants and any substances converted to it through anaerobic decomposition are lost in the food cycle. In shallow lakes the circulatory mechanisms have maximum efficiency with the production of a large amount of life. Carbon dioxide and decomposition products are used over and over. The photosynthesis of plants in the upper strata reduces both the free carbon dioxide and the half-bound carbon dioxide as the daily, and, it is expected, the yearly cycles prodeed. In the lower levels, decomposition of the plant materials reverses the gas relations, using oxygen and releasing carbon dioxide.

According to Ruttner, the assimilation of the submerged plants causes a variation in the conductivity of the water, as this half-bound carbon dioxide is used from the HCO_3, in photosynthesis or marl manufacture. In the evening the conductivity increases and reaches a maximum in the night, and is reduced to a minimum in the late afternoon. These conditions are explained by the assimilation of carbon dioxide. The presence of high carbon dioxide values is shown to be not an important factor in plant growth. (Bourn, '32). This is in accord with the ability of plants to extract required carbon dioxide from the bicarbonates present in the water.

Aquatic animals are not so able to control the carbon dioxide tensions of the external environment. Regulation in the animal must depend on its inner physiological processes. This regulation must be rapid when there is a rapid change in the external carbon dioxide tension or in the amount of oxygen present as shown above. The more rapidly it can adjust itself to the changes, the more independent it is of its habitat. Many authors have shown that fishes do react to differences in carbon dioxide tension, and that the reactions to oxygen differences are very indefinite, showing that the carbon dioxide is probably of better index value for satisfactory fish life. Shelford and Allee ('13) suggested that the carbon dioxide content, with strong alkaline waters excepted, was probably the best index of the suitablity of water for fish.

Carbon dioxide tolerances of fish have been studied by many authors such as Wells ('18), Powers ('38) and Fry ('39). Powers has stated that fish can absorb oxygen satisfactorily in the presence of carbon dioxide in the concentrations usually found in natural habitats. The factor which causes mortality is a sudden increase in the carbon dioxide concentration to which the fish cannot adjust themselves. It is reported by Thompson ('25) that fish exhibit avoiding reactions toward low oxygen and to high carbon dioxide (Wells '18).

The difference in the sensitivity of various species of fish to adverse conditions has been variously reported. Fry ('39) listed these differences on the basis of the effect of carbon dioxide on oxygen utilization. Moore ('42) listed the order in which several species resisted low oxygen at low temperatures. Most authors agree that species such as the perch, sunfish and bass are more sensitive to lower oxygen tension than are the rough fish such as bullhead, carp and dogfish. Possibly within species there are tolerant and susceptible physiological races, and differences occur within single populations (Greenbank '45).

Hydrogen Ion Concentration (pH)

Directly related to the changes in the dissolved gases, is a usual seasonal and diurnal cycle in conductivity, and an acid or alkaline reaction as measured in terms of pH. The acidity is due to the presence of dissolved carbon dioxide and the pH of alkaline waters is thus governed by the carbon dioxide content. The hydrogen ion concentration is definitely related to the amount of carbon dioxide present, as shown by Greenfield and Baker ('20), Shelford ('23), Juday, Fred and Wilson ('24) among others. Saunders ('26) and Powers ('30) showed that the pH depends on the carbonate, bicarbonate and the temperature.

During the first season the pH was determined colorimetrically with a Lamotte-Kenny soil colorimeter. In 1947, the pH determinations were made electrometrically by means of a Beckmann Industrial Model pH Meter. A specially designed extension lead for the electrodes permitted readings to be made at any required depth in the Marsh water. The instrument was calibrated at regular intervals against prepared buffer solutions.

The instrument was carried in the boat and at the point of sampling the electrodes were immersed to the required depth. They were protected from breakage by a brass screen housing which could be easily removed for calibration of the electrodes. It was necessary to have the boat as motionless as possible during the procedure, as the vertical motion of the electrodes caused a swaying of the needle. Readings were taken only after the electrodes had been at the desired level for at least one minute.

The pH, as determined during the three summer seasons, showed a wide range of values. Lower values were not less than pH 7.0 and the upper range varied from pH 9.2 in the open water, to 9.7 in the vegetation mat. This latter reading was recorded during late afternoon of 7/19/48. Such a wide range is dependent, of course, on the variable environmental conditions, but primarily on the carbon dioxide factors present at each location of sampling. Diurnal changes are the dominant factor in explaining the seasonal fluctuations. The water, for the most part, was not more alkaline than pH 8.6 in the open water., and not less alkaline than pH 7.6. Water more alkaline than pH 8.6 was found in the surface strata, except at photosynthetic peaks during the diurnal cycles when occasional bottom samples even reached pH 8.9. The samples less alkaline than 7.6 were formed at the bottom layers in the plant zone where the organic detritus was creating an oxygen demand and producing much carbon dioxide, especially during early morning. One or two readings as low as pH 6.7 were recorded for bottom samples in the plant zone. In general, the pH in the surface waters of the Marsh differed by about 0.8 between the open water and the vegetation stations during a diurnal cycle. Seasonal differences are similar with an average pH, 0.8 units higher in the open water than in the vegetation zone.

As the range for the pH of the surface water remains above pH 7.6 for the summer season, the Marsh is definitely alkaline. Although buffered by the carbonates the pH may approach neutrality because of the extensive areas of organic decomposition which produce large amounts of carbon dioxide as shown above. These conditions are to be expected, as the waters of the Marsh are drained from areas rich in limestone materials, and also the vegetation zone builds up an annual detritus yield to the floor of the basin. Surface bottom differences are not great, as the bottom samples are rarely more than 0.5 pH units lower than the surface water.

Diurnal variations at Station 2 on 7/19/48 as shown in (Figure 22) show the development of a maximum pH in late afternoon followed by a decrease to a minimum at 3-4 a.m., corresponding with the carbon dioxide curve in inverse fashion. The curves for Station 10 illustrate a similar trend of pH with the peak pH 9.3)7/19/48) somewhat less in value than the peak at the open water station. Philip ('27) reported similar changes in the Hydrogen ion activity of a shallow vegetation zone. Changes of pH 7.4-9.6 were registered over a diurnal cycle. Bottom samples at Station 10 registered the lowest pH of 7.0 as the period of maximum carbon dioxide was

TABLE XII

Hydrogen Ion Concentration
(pH) (Surface - Bottom)

STATION:		2	7	10
Date:	5/19/48	8.9		
		8.8		
	6/23/48	8.5	8.5	
		8.1	8.2	
	6/25/48	8.8	8.7	
		8.7	8.6	
	6/30/48	8.2	8.3	
		8.0	8.2	
	7/ 2/48	8.7	8.3	
		8.4	8.1	
	7/ 5/48	8.9	8.6	8.1
		8.1	8.4	7.9
	7/ 6/48	8.5		7.7
		8.2		7.5
	7/ 9/48	9.2	9.1	
		8.8	8.3	
	7/12/48	8.1	8.1	7.5
		7.4	7.3	6.8
	7/14/48	7.4	7.5	7.4
		7.2	7.3	6.7
	7/16/48	8.3	8.6	8.0
		7.7	8.4	7.4
	7/19/48	8.9	8.7	8.2
		8.4	8.2	7.7
	7/20/48	9.0		8.5
		8.4		7.6
	7/23/48	8.7	8.5	8.2
		8.6	8.3	7.7
	7/26/48	8.5		8.1
		8.3		7.4
	7/28/48	8.7		8.0
		8.3		7.5
	7/30/48	8.9	8.6	7.9
		8.8	8.3	7.5
	8/ 2/48	9.1		8.5
		8.4		7.9
	8/ 6/48	8.4	8.7	7.4
		7.9	8.6	7.0
	8/ 9/48	8.9	8.8	8.2
		8.6	8.0	7.2

TABLE XIII

Hydrogen Ion Concentration
(pH) Diurnal Cycles

STATION:		2			10	
Date	Time	Depth	pH	Time	Depth	pH
7/ 5/48	11:30	20	8.9	10:30	20	8.1
	a.m.	150	8.1		100	7.9
	3:45	20	9.0	3:00	20	8.1
		150	8.9		100	7.5
	7:55	20	9.1	7:15	20	7.9
		150	8.9		100	7.2
	11:30	20	8.9	11:00	20	7.8
		150	8.8		100	7.5
7/ 6/48	3:35	20	8.4	3:00	20	7.6
	a.m.	150	8.1		100	7.5
	7:30	20	8.6	7:00	20	7.6
		100	8.4		100	7.3
	11:30	20	8.5	11:00	20	7.7
		150	8.2		100	7.5
7/19/48	12:00	20	8.9	11:00	20	8.2
	N	150	8.4		100	7.7
	4:00	20	9.2	3:15	20	8.3
		150	8.9		100	7.6
	7:50	20	9.7	7:20	20	9.3
		150	9.5		100	8.0
7/20/48	12:15	20	8.6	11:30	20	7.7
	a.m.	150	8.0		100	7.1
	4:00	20	8.4	3:30	20	7.4
		150	7.9	a.m.	100	7.1
	7:30	20	8.7	7:00	20	7.7
		150	8.4		100	7.2
	12:00	20	9.0	11:30	20	8.5
	N	150	8.4		100	7.6

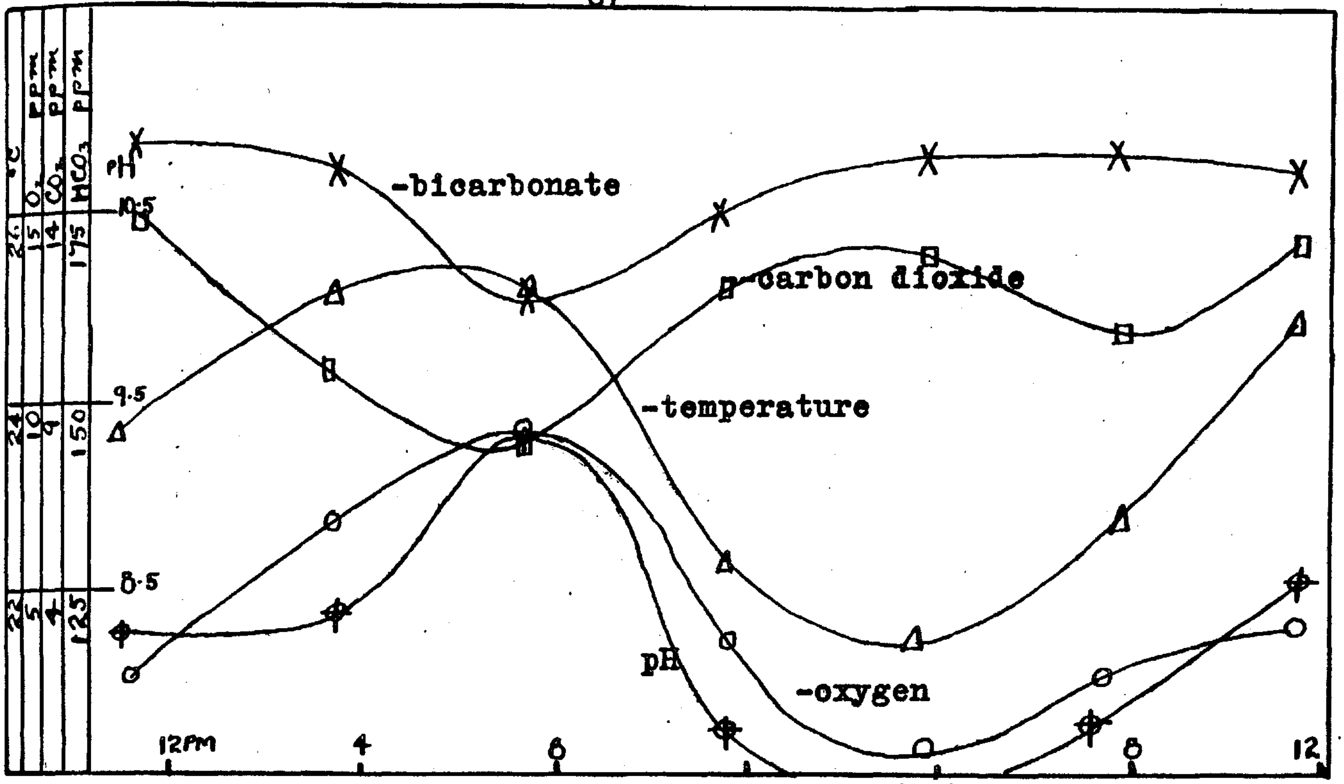

Figure 21. Diurnal Cycle - Station 10 - 7/19/48
Temperature, Oxygen, Carbon Dioxide
Bicarbonate, pH

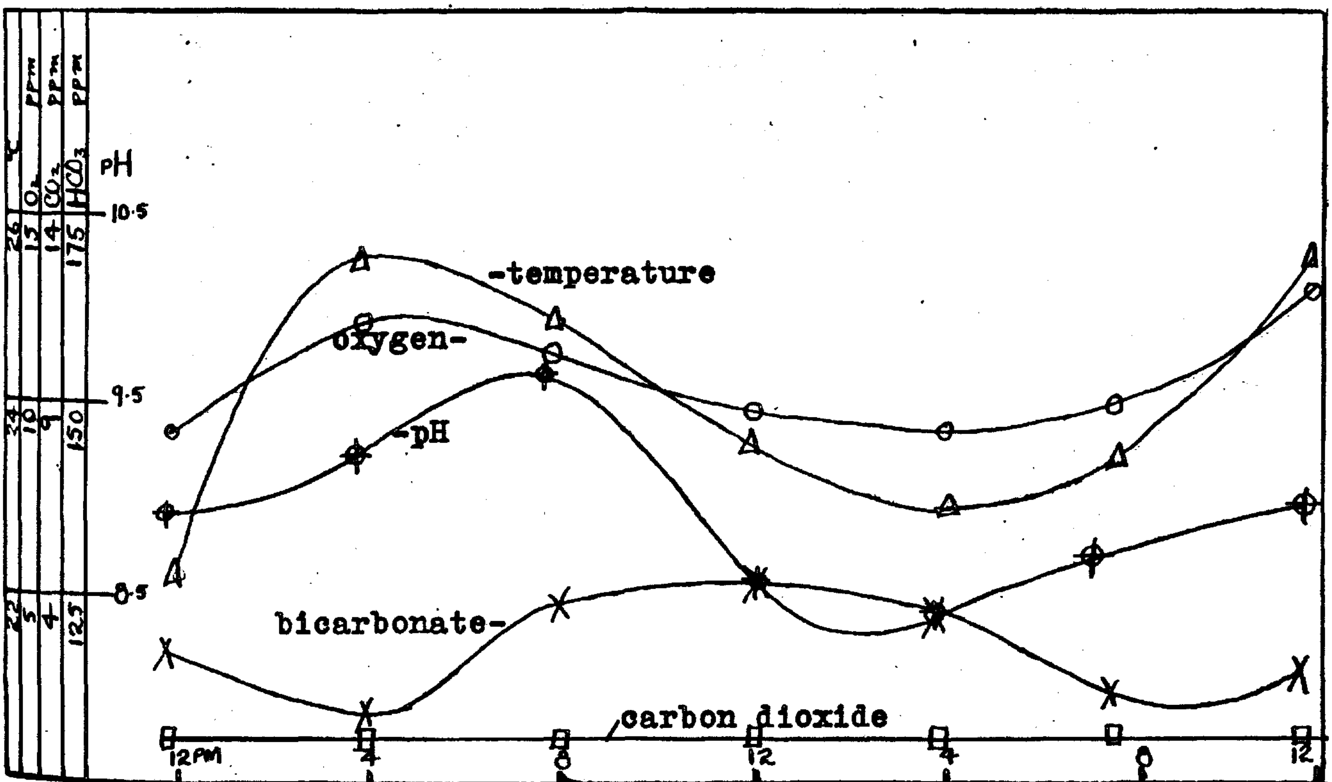

Figure 22. Diurnal Cycle - Station 2 - 7/19/48
Temperature, Oxygen, Carbon Dioxide
Bicarbonate, pH.

approached. Following a carbon dioxide decrease the pH rose to pH 7.6, equal to its original value at the beginning of the cycle.

The relation of aquatic organisms to the pH has been extensively studied. Some organisms occur within a very wide range of pH for their environment; others have a more restricted zone of tolerance. The effects of pH on vegetation are not so noticeable, as the results the vegetation has in altering the pH values. Effects of a Sphagnum mat in lowering the pH is a well known factor in the development of acid peat.

A study of the pH of fresh water in relation to vegetation was made by Wehrle ('27). For a pool with Potomageton the extent of the pH variation, he found, was about 0.2 units for the bottom but o.8 units for the top layers during a diurnal change. With considerable green vegetation present a pool showed a rise in its top layer from a morning pH of 6.6 to an afternoon and evening value of pH 7.75; for the bottom layers the change was from 6.5 to 7.0.

At Station 10 which has a dense mat of Ceratophyllum, Myriophyllum and Lemna minor, the surface layer showed a rise in its pH value from 8.2 at noon to 9.3 in late afternoon, a pH change of 1.1 units. Bottom values showed a rise of from 7.7 at noon to 8.0 in late afternoon during the period of maximum photosynthesis.

Evidence that the pH measurements are indicative of environmental conditions is apparent, yet it is not easy to demonstrate that the H^+ ion concentration has any effect on the inhabitants living under natural conditions. The importance of pH determinations lies in their measurement of carbon dioxide relationships to the water environment, according to

Saunders ('26).

Singh-Pruthi ('27) believed that the carbon dioxide pressure was of greater importance than the pH. It is true that increases of pH in the water can be explained by the loss of carbon dioxide through aeration and photosynthesis, whereas decreases in pH are directly related to the accumulation of carbon dioxide as the result of decay(Underhill, '39).

In shallow water the pH is modified by the flora and fauna much more than in a deep body of water. The pH is lowered when water flows slowly or decaying vegetation is present. Cowles ('23) showed the relations of pH to carbon dioxide in shallow lakes, these relations holding if the bound carbon dioxide remains constant. He found that at a vegetation station photosynthesis tended to reduce the carbon dioxide sufficiently to give a rise in pH which occurred at about 4 p.m., the maximum period. Reference to (Figure 21) will show this relation to hold for Station 10.

The plankton of fresh water is the ultimate biological factor affected in the complex of physical and chemical interactions. The pH is a relative index of the plankton content as the maximum and minimum values have been shown to bear some relationship to the distribution of the plankton. Consideration of the pH relations is the important connection to understanding the productivity of the life processes in the aquatic habitat. Lowndes ('28) studied the ranges of pH for over 40 species of copepods and found that gradual changes in pH have no direct or toxic influence on the plankters, although there may have been an optimum value for each species.

Fish appear to be capable of living in a wide pH range. For several species the range seems to be satisfactory between pH 6.8 - 8.4 (Behre, '28) On the point of preference by fish, Brown and Jewill ('26) found that fish withstood transference from a lake of one pH to water of another pH value. The fish withstood abrupt changes even through the whole range. The authors concluded that fish select the pH to which they are individually accustomed rather than the optimum for the species. The fact that fish can live in acid waters, yet have been killed by excess carbon dioxide even in the presence of abundant oxygen, suggests the importance of discrimination between the effects of carbon dioxide and pH.

CHAPTER V

BIOLOGICAL FACTORS

Zooplankton

Plankton samples were collected at three main locations during the Summer of 1948. The samples were obtained from the surface water by passing 10 liters of water through a silk bolting cloth cone. The mesh of the net was no. 20 grade, which consists of about 6,000 meshes per sq. cm., with openings averaging 0.001 sq. cm. The cloth was formed into a cone to which a small brass cylinder was securely fastened at the lower end. A small piece of the bolting silk was applied over the open end of the cylinder and acted as a collecting surface for the plankters. This cloth was removed after each sampling and the organisms were washed with filtered water into a vial for storage. Formalin was added to make a 4-5 % fixing solution. For enumeration, 1 ml. of sample of the concentrate was placed in a Sedgwicke Rafter cell and the total count of representative organisms was recorded.

Station 2. - The water at Station 2, while comparatively shallow, (1.5 - 2.0 m.) represents the deepest water of the open water zone. The station is remote from the vegetation zone to the west, and represents part of the Marsh which is continually exposed to agitation by the wind. Prevailing winds from the south west cause a mixing of the water so that the physical and chemical factors are relatively stable and similar for top and bottom strata. The seasonal change of these factors is not wide enough to detect any main trends. Outside of the diurnal cycles the factors may be regarded as constant. Temperature is the only factor which represents any general trend and is dependent, of course, on the diurnal variations in atmosphere temperature for its intimate changes. The maximum surface temperatures were recorded in late July.

The Cladocerans which were observed were numerous during the midsummer. The predominant forms which were counted were Bosmina and Daphnia. Of these two, Bosmina was the most numerous. Cyclops was the most abundant copepod during the period of this study. Canthocamptus was not seen at this station and Diaptomus was observed on only two occasions.

The nauplii were by far the most numerous of the copepods and were present throughout the entire season. The largest number obtained was 225 per liter on July 25-48.

The Rotifera were very abundant. Annuraea cochlearis, Annuraea aculeata and Polyarthra were the predominant forms. Asplanchna and Brachionus were fairly abundant, the latter no appearing until early July. Noteus was present in low numbers through the season. Notholca was found on only three occasions, reaching a peak of 58 per liter during September.

The presence of the diatom Asterionella in large numbers at the beginning of the season promted the enumeration of these forms during the entire season. The peak value of 32,705 per liter at the end of April soon dropped to zero in the latter part of July. It was apparently a Spring form that was observed at its peak during the first sampling.

Station 7 is more related to the vegetation zone, and being shallower than Station 2 does not experience as much wave action and shows some difference in the physical and chemical factors.(Appendix). The Cladocerans were numerous at this station. They did not appear, however, until May 21, somewhat the same time as at Station 2. The Bosmina were again the predominant form, reaching a peak of 805 per liter on July 9. _Daphnia_ was less abundant. _Cyclops_ was the only adult copepod observed during the season. The nauplii were very abundant, reaching a peak of 234 per liter on July 16.

Polyarthra was the most abundant rotifer. The _Annureae_ were present in about the same numbers as at Station 2. _Asplanchna_ and _Brachianus_ were both present in relatively larger numbers than at Station 2. _Notholca_ was observed dubing September only. _Noteus_ was more abundant than at Station 2, reaching a maximum number of 92 per liter (July 2).

Asterionella showed the same distribution of numbers as at Station 2. The maximum number was at the first sampling date, after which it became less abundant.

A smaller plankton population was found at Station 10. At this station the physical chemical factors have been shown to have their greatest variation both seasonally and diurnally. The _Bosmina_ were the more abundant of the Cladocera and show maximum numbers of 286 per liter on July 9. The Daphnia are less in numbers but have greater variety of types than at the other stations. _Cyclops_ was the most abundant copepod. _Canthocamptus_ was seen only on one occasion. Nauplii were present throughout the season.

Ostracoda were seen on three sampling dates in mid-July and were only found in the vegetation zone. The _Annureae_ and _Polyarthra_ were present in about equal numbers through the summer. _Notholca_ was seen only on two occasions. _Asplanchna_ was present in very small numbers, as was _Brachionus_, which was found only during mid-July. _Noteus_ was present in about the same numbers as at Station 2.

TABLE XIV

Zooplankton - Station 2
(per litre)

	Apr. 23	May 11	May 21	June 25	July 2	July 9	July 16	July 23	July 30	Aug. 9	Sept. 13
Temp.	13.0	10.0	15.0	22.4	22.8	23.9	23.5	23.5	25.0	21.4	
ADOCERA											
smina			20	300	90	32	816	56	184	148	52
aphnia			1	50	4			12	8	42	20
isc.					4		208				
PEPODA											
nthocamptus											
yclops		2	47	163	44	24	32	34	20	62	28
auplius	22	17	104	225	86	214	112	134	56	146	64
iaptomus					2						2
TIFERA											
nureae	1	6	4	338	56	80	336	64	80	32	90
olyarthra		84	26	275	226	222	132	62	14	50	32
iarthra											
otholca				3					2		58
splanchna		11	6	86	52	6		26	8	62	10
achionus					86	252		164	30	52	16
oteus			5	5	22	14	8		2	8	
ATOMS											
sterionella	32705	10080	3672	1900	160	320	-	200	-	40	-

TABLE XV

Zooplankton - Station 7
(per litre)

	Apr. 23	May 11	May 21	June 25	Jul. 2	Jul. 9	Jul. 16	Jul. 23	Jul. 30	Aug. 9	Sept. 10
Temp.	13.3	9.0	15.0	23.2	22.5	25.5	23.6	22.8	24.4	21.3	
CLADOCERA											
Bosmina			21	25.0	580	805	278	136	62	230	80
Daphnia	2	2		40	104	35		32	6	10	26
Misc.							22				
COPEPODA											
Canthocamptus											
Cyclops	3	5	43	235	192	305	22	16	68	66	20
Nauplius	42	14	57	200	136	200	234	208	38	170	118
Diaptomus											
ROTIFERA											
Annureae	2		2	495	200	215	50	100	28	48	36
Polyarthra		7	10	640	692	380	88	140	10	120	100
Triarthra											
Notholca											6
Asplanchna			1	120	156	5	14	36	14	76	10
Brachionus				195	180	175	44	300	14	112	2
Nobeus			7	5	92	75	20	40	2	4	
DIATOMS											
Asterionella	22440	576	550	4750	280			200			

TABLE XVI

Zooplankton - Station 10
(per litre)

	Apr. 23	May 11	May 21	June 25	Jul 2	Jul 9	Jul 16	Jul 23	Jul 30	Aug 9	Sept 13
Temp.	13.5	9.5	15.2	22.4	22.3	25.0	23.5	23.0	24.3	24.5	
CLADOCERA											
Bosmina	2		1	6	28	286	82	112	26	28	6
Daphnia	2			6	2			308	10	2	54
Misc.				28		22	14				
COPEPODA											
Canthocamptus										2	
Cyclops	10	2	17	16	7	64	6	138	4	38	54
Nauplius	167	32	86	60	113	24	58	34		2	32
Diaptomus											
OSTRACOD						32	12	8			
ROTIFERA											
Annureae		2		6	18	96	26	80	28	62	38
Polyarthra			3	22	16	114	64	2	8	4	4
Triarthra											
Notholca									2		14
Asplanchna	11	2	1	4	5		2	8	6	10	
Brachionus					12	4		16			
Noteus		4	3	22	30	12					
DIATOMS											
Asterionella	323										

TABLE XVII

Zoo Plankton
Seasonal Average (per litre)

Station	2	7	10
Cladocera			
Bosmina	154	222	52.4
Daphnia	12	23	35
misc.	19	2	5.8
Copepoda			
Canthocamptus	0	0	0.1
Cyclops	41	88.6	32
Nauplius	107	128.8	55
Diaptomus	0.3	0	0
Ostracoda	0	0	0.4
Rotifera			
Annureae	98	106.9	32
Polyarthra	102	197	21.5
Triarthra	0	0	
Notholca	5.7	0.5	0
Asplanchna	24	39.2	4
Brochionus	54	92.9	2.9
Noteus	5.8	22.2	6
Diatoms			
Asterionella	4461	2618	29

Asterionella was found only during the first sampling. The presence of large amounts of green algae at Station 10 was one difference noticeable over the other stations. The seasonal variations for the three groups, Cladocera, Copepoda and Rotifera are interesting, for the changes in numbers are dependent on the physical chemical factors. During the latter part of June the Cladocera at Station 2 reach a peak, which is soon followed by a decrease which continues until July 9. A sudden increase reaches the maximum summer value of 1024 per liter, due largely to an increase of Bosmina. The following week shows a sharp drop to 68 per liter. On July 30 the number is increased to 192 per liter and it then tapers off smoothly to the end of the season. The Copepods were most numerous at Station 2 at the end of June. Then followed a decrease until another peak was reached on July 9. Further increases resulted in a low value of 76 per liter on July 30. A sharp rise on August 9 was due to an increase of Nauplii. This was followed by a drop on September 13. The major peak of the Rotifera is reached on June 25, followed by a decrease to a minimum on July 30. Then there is a rise to the end of the season. The Asterionella falls from its peak on April 23 through the summer season and is absent after the first week in August.

An examination of (Table XVII) shows that the Bosmina was the most abundant Cladocera, and at Station 7 this organism was more abundant than at any other location. Daphnia was present in lesser abundance but was predominant at Station 10. Station 2 had the greatest average number of miscellaneous Cladocerans.

The largest number of Copepods was present at Station 7. The genus

Cyclops was responsible for the large numbers at this location. *Diaptomus* and *Canthocamptus* were very infrequent. The nauplii were present in large numbers at each station, but predominated at Station 7.

Station 7 had also the largest numbers of *Rotifers* for the season, mainly due to the *Annureae*. *Polyarthra Asplanchna*, *Brachionus* and *Noteus* were also more abundant at Station 7 than at Station 2. *Notholca* was the only Rotifer present in greater numbers at Station 2 than at Station 7. The *Astrionella* were much more abundant at Station 2 than at the other stations.

Attempts to explain the difference in distribution of the zooplankton must take into account all the various factors which may be responsible for such differences. From (Table XVII) it is apparent that the stations in order of productivity are 7, 2, 10. Station 10 is a heavily weeded location and offers several disadvantages to plankton production. It offers impediments to migration, and plankton forms which are present among the weeds have little chance to move their location either seasonally or diurnally. Apart from this condition, its physical and chemical factors are greatly different from the open water stations. The temperature relations are similar, if reference is made to the Appendix, but greater differendes are found in the oxygen, carbon dioxide, pH and carbonate values, particularly in a diurnal cycle. The great variation in these factors probably explains partially the overall reduced productivity, compared with that of an open water station. The vegetation station did produce the greatest number of *Daphnia*, probably because they were protected by the plants. In the open water the *Daphnia* are vulnerable as fish food and so are found in reduced numbers.

As for Stations 2 and 7, it is more difficult to see differences in the distribution mechanisms. From a review of the physical chemical data, it is seen that Station 7 has a less average transparent water than Station 2. This fact is shown to be important by Doan ('42) who found that turbid water causes the plankton to come to the surface. It is possible that such a difference, however slight, might explain the over-all greater average productivity at Station 7. Temperatures for the two stations are similar. Oxygen values and diurnal changes are almost identical. Carbon dioxide values are occasionally higher at Station 7 than at Station 2. Reasons for this difference are probably due to the presence of more organic detritus at Station 7 because the station is closer to the immediate vegetation zone. The carbon dioxide values are reflected in a slightly higher total alkalinity and bicarbonate at Station 7. PH values are almost identical for the two stations. The factors of turbidity, carbon dioxide and alkalinity, might appear to have some distributional effect. At Station 10, however, where the carbon dioxide, carbonates and alkalinity are all much higher than at either 7 or 2 , the plankton productivity is very low.

The presence of such forms as Bosmina, Cyclops and the Rotifera in such large numbers is interesting in the light of work published by Denham ('38). He found that in portions of a river which pollution was entering, the Bosmina and Cyclops were the predominant Crustacea, and Rotifera, were present in very large numbers. Metcalf ('42) found that the number of copepods and cladocera was greater at a sewage effluent than in an open water zone. The forms of plankton are thus increased because of the greater particulate food which comes in with the effluent. Fish are attracted to the resulting high plankton population. He found no other correlation than the above between the plankton, temperature, wind direction and velocity. Hupp ('43) found a high plankton population to be downstream from the point of sewage pollution. The plankton peak seemed to be governed also by the rate of river flow above the effluent. Brinley ('43) showed the relations of plankton populations to the entrance of sewage into the water. Near the source of effluent he found algae and dissolved oxygen to all but disappear, while the coliform bacteria are numerous.

It appears that there are other factors besides the physical and chemical ones, for relationships to plankton productivity. The physical features of the basin and the plants both have an effect on the plankton through their interaction on the chemical nature of the water. Water areas along shore zones and in shallow ponds have been shown to be more productive than dense beds of submerged aquatics, or even of open regions.

Pollution

The known sewage effluents into the Marsh were of two main sources. One is located at the west end of the Desjardins Canal at Dundas. The other is from the south east corner of the Marsh at the Longwood Road Bridge. Samples of water were collected periodically from the surface for an estimation of the coliform organisms. Water samples were collected in sterile bottles and transported to the laboratory as rapidly as possible within the six-hour period stated as the safe limit (Whipple, '27). Dilutions of the water and subsequent incubations were made with Bacto-MacConkey

Agar, which is a differential plate medium containing neutral red, which colours the coliform organisms. It acts as a distinct medium for the determination of colonies of coliform bacteria, which form brick red spots in the medium. The action is due to the acids, formed by fermentation of the lactose, upon the bile salts and the adsorption of neutral red. The typhoid and dysentry bacteria, even if present, do not ferment lactose and thus do not alter the appearance of the medium. After dilution and innoculation of the plates, they are incubated at 37° C for 24 hours, when a colony count is made. The colonies arre reported as plate counts with the number representing the colonies present. This phase of the survey was made possible with the laboratory assistance of Miss H. Eydt, during 1947-48.

The effects of pollution on many of our waterways are well known because of the harm done to fish life. The fact that many incidences of pollution could be remedied and turned into beneficial effects is an argument for the need for understanding all the foregoing factors. The presence of statutes limiting pollution hazards in this province is a means of limiting, perhaps, the harmful effects of pollution in non-surveyed waterways, before studies of the interrelated factors can show that some degree of pollution is beneficial, for the purposes to which the water is best adapted. Excess sewage and industrial wastes are unquestionably harmful, and can reduce an area to one destitute of fish and other aquatic life.

The various effluents may be detrimental to fish and aquatic life either indirectly, through quantitative alterations in those substances which give water its inherent characteristics, such as oxygen, carbonates and pH, or directly, because of specific physiological effects on the organism. The various substances carried in solution and suspension in the water determine whether the water is favourable or unfavourable for aquatic life. The definition of the amounts of these substances which are sastisfactory for fish life is a very complex relation.

Water standards for fish and aquatic organisms are not identical with the standards which define water suitable for human use. Water suitable for aquatic life is further complicated by the fact that the various species have differences in tolerance ranges. Conditions which reflect pollution are the dissolved gases, pH, carbonates and the plankton forms present.

The stations listed in (Table XVIII) represent ampling points in a linear series commencing at the Dundas effluent and ending at Station 2 in the open water as shown in (Figure 23).

Station 4 is off this straight line, and is located at the same point as Station 10 of the physical chemical series.

The highest average Escherichia coli count was found at the Dundas effluent as expected. Station 2 shows a much reduced count at the entrance of Spencer's Creek. Station 3 below the prominence of Bull's Point in the Canal, has a reduced average count of 245 colonies. Station 5 corresponds to Station 7 of the physical chemical series, and has counts again lower than the previous bacteria station. The lowest average counts occur at Bacteria Station 6 in the open water.

In the vegetation zone, the Escherichia coli counts are higher than all other locations, except at the sewage effluent. The reason for this is not known, but probably has to do with the temperature effects, which approach higher values here than anywhere in the Marsh, because of the stillness of the water among the weed mat. Such high temperatures present in this location act as a suitable stimulus for the rapid multiplication of bacteria.

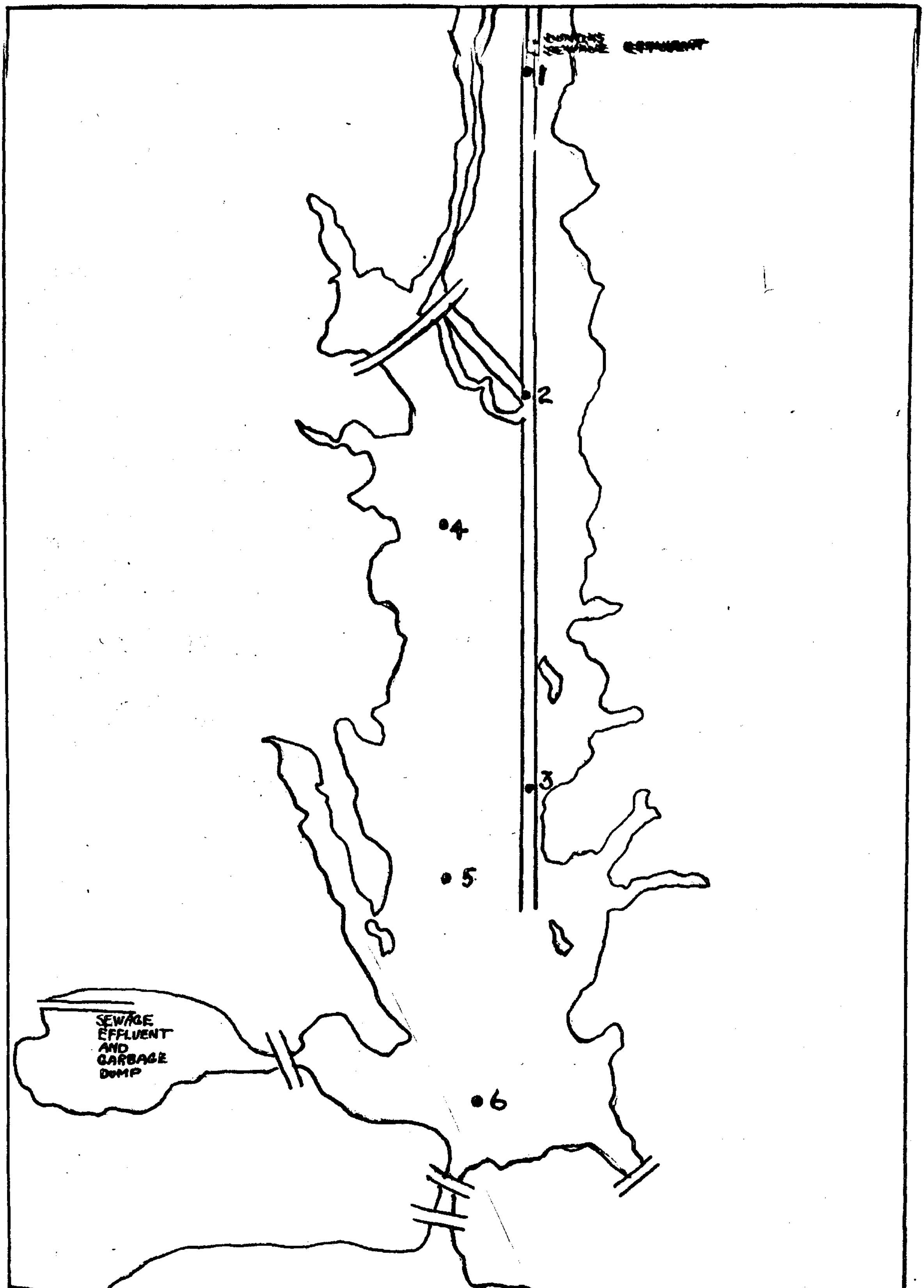

Figure 23. Bacterial Sampling Points

TABLE XVIII

Pollution
E. coli counts (per ml.)

Station Date 1948	1	2	3	4	5	6
June 28	825	300	125	310	106	14
July 5	750	151	215	335	625	233
July 12	1550	343	180	950	80	111
July 19	1000	293	375	250	156	163
July 26	6500	246	276	575		350
Aug. 9	17500	725	300	265	142	65
Av.	4687	343	245	447	201	166

The results illustrate the principle of dilution, over the series described, and show that although the Marsh is heavily polluted there is a purifying system in operation which reduces the Escherichia coli counts to a minimum in the open water area. From (Table XVIII)and (Table XIX) it is evident that the amount of sewage pollution going to the Bay from the Marsh via the Canal is negligible.

The earliest phase of the reduction in numbers of the Escherichia coli colonies takes place soon after the entrance of the effluent material at Dundas. At the source the sewage material is added in relatively unaltered form, and it is not unusual to find the dissolved oxygen at a relatively high concentration. As the rate of flow is exceedingly slow,it means that the "oxygen sag" common to such conditions will be quite close to the effluent.

Farther down the canal from the effluent,the products of decomposition have become organized by oxidation as nitrites and nitrates,and can be utilized as fertilizers. (Table XIX). The water is in this way enriched for the development of abundant plant and animal life. The bacteria of the water and of the sewage material act as decomposition agents for this material. Brinley ('43) stated that in such a condition of the water the plankton increases, resulting in a greater fish production. The sewage, if properly treated originally, does not result in a typical "sag"in the water flowage but the nutritive effect becomes immediate. Brinley ('42) studied the relation of domestic sewage to stream productivity by comparing the aquatic population of heavily polluted streams and clear streams, in the Ohio River basin. The phytoplankton and mixed fish populations in the polluted stream some distance below the point of entrance of raw sewage were many times

TABLE XIX

Analysis - Dundas Marsh

11/19/47

D.H. Matheson

Source	E. coli	Alk	pH	NH_3 p.p.m.	NO_2 p.p.m.	NO_3 p.p.m.
Turning Basin Dundas	100	328	8.0	10.0	.20	1.0
Sewage outlet	100,000	345	7.7		1.0	
Spencer's Creek outlet	1	239	8.1	.65	0.02	0.8
St. 5 (Physical Chemical)	10	225	8.0	0.60	0.05	0.5
St. 2 (Physical Chemical)	1	108	7.9	1.0	0.08	0.8
Bay	1	100	7.8	0.95	0.06	0.2

higher than in the clear stream. Raw sewage in high concentrations is, however, detrimental to phytoplankton and fish life, but farther downstream where the sewage has been reduced to available plant foods, there is a marked increase in the production of plankton and fish.

The increase in river flow, or wind effects in producing currents, may reduce coliform counts through dilution, and at the same time may increase the number of organisms in a relatively polluted stream by washing in organic matter. The greatest instance of coliform organisms was during mid-summer, due to the favourable effects of temperature on proliferation.

A heavy growth of vegetation can act as natural activated sludge, as shown by Liebmann. Such an effect is of especial importance in the Marsh where great masses of vegetation are in intimate contact with introduced sewage material. Any solid materials carried down the canal are filtered and broken up, the material falling to the bottom and increasing the organic material. The plants act, as we have seen, to reoxygenate the water and afford protection and attachment for organisms essential to the self-purification process. It has been shown by Nightingale ('27) that domestic sewage free from industrial waste is not harmful to fish life unless it reduces the oxygen content to less than 30% saturation. The coliform organisms may lower the oxygen content to asphyxial levels because of their aerobic nature. When the oxygen is fairly high, as in vegetation beds, and in aerated open water, and the plankton types are favourable for fish food, the fish are abundant, including many shallow water forms such as perch, carp, catfish and suckers, even though the coliform colonies may be relatively high.

The colon bacillus is a normal inhabitant of the intestinal tract of all warm blooded animals. It probably is harmless itself but it serves as an effective indicator of the presence of sewage and a measure of the infectiveness of that sewage. If it is recognized that all we are attempting to do is demonstrate the presence of sewage, and that where there is sewage there may be disease bacteria, we are still not detracting from the original purpose of assessing the factors responsible for the great biological productivity of the Marsh. It is intersting to note that where the water may be satisfactory from all biological aspects,it may actually be far beyond the safety standards allowable for human use.

Fish

At present at least 35 species of fish are known to inhabit the waters of Dundas Marsh. (Turner '47). Several migratory species may enter the Marsh at times other than during the periods recorded. The list of species as studied during 1946-1947 is shown in (TABLE XX). A review of this list shows that most of them are warm water fish. The presence of several deep water fish illustrates the condition of migration into the Marsh for feeding and spawning. Such is the case in regard to the Alewife (pomolobus pseudohorengus) which moves into the Marsh in large numbers during the month of July. The absence of the Salmonidae is significant in relation to the other species which are mainly warm water fish. The evidence presented earlier in the report on dissolved oxygen and temperature readily explains the absence of cold water fish, for trout prefer water below 18° c and 21° C is the approximate upper limit in which trout can be maintained. The oxygen requirements are also higher than for several of the warm water species.

TABLE XX
Species of Fish - Dundas Marsh

Lepisosteidae:	Lepisosteus osseus (Linnaeus)	Long nose gar
Amiidae:	Amia calva (Linnaeus)	Bowfin
Clupeidae:	Dorosoma cepedianum (Le Sueur)	Gizzard shad
	Pomolobus pseudoharengus (Wilson)	Alewife
Corregonidae:	Corregonus clupeaformis (Mitchill)	Whitefish
Catastomidae:	Catastomus commersonnii(Lacepede)	Sucker
Cyprinidae:	Cyprinus carpio (Linnaeus)	Carp
	Semotilus atromaculatus (Mitchill(	Horned dace
	Rhinichthys atratulus (Hermann)	Black nose dace
	Notemegonus crysoleucas (Mitchill)	Golden shiner
	Notropis rubellus (Agassiz)	Rosy face shiner
	Notropis cornutus (Mitchill)	Common shiner
	Notropis hudsonius (Clinton)	Spot tail minnow
	Notropis heterodon (Cope)	Blackchin shiner
	Notropis spilopterus (Cope)	Spotfin shiner
	Notropis deliciosus (Gerard)	Sand shiner
	Notropis heterolepsis (Eigenmann and Eigenmann)	Blacknose shiner
	Hyborhynchus notatus (Rafinesque)	Bluntnose minnow
Ameuiridae:	Ameuirus nebulosus (Le Sueur)	Brow Bullhead
	Schilbeoides mollis (Hermann)	Tadpole madtom
Esocidae:	Esox lucius (Linnaeus)	Pike
Cyprinidontidae	Fundulus diaphanus (Le Sueur)	Killifish
Serranidae:	Lepebema chrysops (Rafinesque)	White Bass
Percidae:	Perca flavescens (Mitchill)	Yellow perch
	Stizostedion vitreum (Mitchill)	Pike perch
	Percina caproides (Rafinesque)	Log-perch
	Boleosoma nigrum (Rafinesque)	Johnny darter
	Poecilichthys caeruleus (Storer)	Rainbow darter
Centrarchidae:	Huro salmoides (Lacipede)	Large mouth bass
	Lepomis gibbosus (Linnaeus)	Pumpkinseed
	Pomoxis nigromaculatus (Le Sueur)	Black crappie
	Pomoxis annularis (Rafinesque)	White crappie
Atherinidae:	Labidesthes sicculus (Cope)	Brook silversides
Cottidae:	Cottus cognatus (Richardson)	Millers thumb
Gadidae:	Lota lota (Linnaeus)	Burbot

The tables and graphs which earlier presented data on temperature and dissolved oxygen for the Marsh show that in midsummer the temperature of the open water zone may rise well above the suitable level for the cold water fish. The oxygen concentrations are suitable, however, at any point in the eastern area of the Marsh for warm water fish. These observations point out that the conditions are suitable for a certain type of fish, and where unsuitable for others, as the salmonids, their absence verifies the conclusion based on physical and chemical conditions. The constant turbidity is one other hazard for the Salmonidae and its presence has earlier been shown due to the action of inflowing silt and to the action of the Carp.

As to the warm water fish for which the variations in dissolved oxygen, temperature and transparency are less severe hazards, the physical and chemical factors nevertheless have a limiting action on the movement of fish within the Marsh.

The reasonably stable midsummer water level, permits of a large extent of submerged and emergent vegetation as shown above. This vegetation is important in supplying indirectly all kinds of fish food. The effect of the vegetation in producing very large changes in the dissolved oxygen content is reflected in the absence of most of these fish from dense weed beds, with their main distribution in the open water area to the east of the Marsh itself.

A review of the findings on substances available for plankton production in natural bodies of water shows that the Marsh should be rich in plankton. The ammonia content, nitrites and nitrates are shown to depend to a great extent on the addition of the sewage material at Dundas, and in the décomposition of plant products. The ammonia content of these waters and the total non protein nitrogen were satisfactory as shown (Table XIX) for the production of an abundant plankton population.

Besides the plankton and vegetation, the other main source of fish food is the bottom mud. The bottom as described above is very rich in organic material, and as shown by the dissolved oxygen data has a very high oxygen demand. It would be expected that the bottom fauna would be plentiful, especially in the open water region. Unfortunately no information is at hand as to the type or abundance of such organisms. The organic detritus formed from the plants of each succeeding generation forms a constantly replenished supply of food materials. These, along with the nitrogen materials produced from the sewage effluents assure a constant supply of fish food and the basin should support a high annual fish production .

CHAPTER VI - CONCLUSIONS

From the physical, chemical, and biological factors that have been studied and described above, several tentative deductions can be made concerning the expected productivity of this area and other similar shallow water basins.

The Dundas Marsh is a very old basin. Its beginnings were established in the early post-glacial period when the waters levels of Lake Iroquois were washing the upper levels of the escarpment. Subsequent lowering of the inland glacial lakes caused the formation of Burlington Heights, which acted as a barrier for the waters retained within the Marsh. Further lowering of the water levels resulted in the formation of the Marsh, as we know it today.

The first important development after the lowering of the water was the establishment of an extensive aquatic vegetation. Originally this vegetation extended over a much larger area and the open water zone was pushed farther east. The amount of aquatic vegetation present in any season is in direct relation to the water level of the Marsh, which in turn depends on the water level fluctuation cycle of the whole Great Lakes basin.

It has been shown that the level of water in the Marsh fluctuates widely. The development of extensive vegetation depends primarily on the relatively stable periods between these wide variations. During the stable periods the vegetation will advance or regress to and from the existing open water area. Such movements of the plants, together with the inflowing sediments will eventually deprive the Marsh of any open water area. It has been shown that older basins support a greater variety and quantity of plants than do the younger basins. Sedimentation is higher in an older basin and results in turbidity when the wind is able to circulate the shallow water. Other factors influencing the turbidity are the temperature and the plankton population as shown.

The plants have a great importance in affecting the life cycle of the water basin. They provide food and protection for the aquatic animals but most important of all, they cause variations in the physical-chemical factors, which are the basic features of the life cycle.

The temperature of the water is directly and intimately controlled by changes in atmospheric conditions. Currents in the water and winds are secondary distributive factors. The temperature regulates plant activity and insures the repetition of the chemical pattern of the water. Plant activity of early Spring leads to a reduction of dissolved carbon dioxide and an increase in dissolved oxygen, when it is most needed for animal growth. Several salts which are in the water are combined by the plants during the Summer into more complex substance suitable for plant and animal nutrition. These are supplied along with the oxygen to insure growth and development. Assimilating water plants shift the pH of the water toward alkalinity, which will in turn have the effect of reducing the assimilation later in the season.

Many fresh water studies in the past assigned a pH value to the water at one particular time and place with little regard for any variable factors. It has been shown that such values are quite inadequate unless more comprehensive data are available to qualify them.

The hydrogen ion concentration would seem to be only a fair index of conditions in the Marsh at any time. More reliable information is furnished when the pH values are accompanied by data on dissolved oxygen and carbon dioxide. The maximum pH occurs during late afternoon at a time coinciding with maximum photosynthesis. At the same time maximum oxygen values occur in the vegetation zone. Along with the rise in pH and oxygen was the accompanying rise in temperature. All these factors reached a maximum at approaximately the same time. Minima for these factors at all stations were in the early morning hours when respiration becomes the dominant plant activity. Carbon dioxide as a respiratory by-product was produced at its maximum amount during early morning hours and showed an inverse relation to the above factors. The carbonates including both bound and half bound carbon dioxide show similar diurnal changes as the free carbon dioxide. A decrease in bi-carbonate is taken to mean utilization of the half bound carbon dioxide in photosynthesis, and as a result of such a removal, a hard lime marl is left. The Marsh waters are highly alkaline, receiving the supply of carbonate from the immediate ground water and the inflowing streams.

The open water area is satisfactory for all warm water fishes. Oxygen values at all points are above the minimum of 5 p.p.m. selected by Ellis as the lowest point desired by good mixed fish faunae. Carbon dioxide values are low and are not believed to be in any way harmful to fish life. The temperature rises to summer peaks much higher than that selected by cold water fish and consequently such forms as the trout are not found in the water at any location.

The difference in these factors between the open water zones and the dense weed beds are very great. Diurnal and seasonal fluctuations have been shown to be much more pronounced in the areas of dense vegetation than in the open water. Such wide fluctuations mean that life conditions are unsuitable for any but the hardiest of species, and we find only the Carp in the dense vegetation mat, during its spawning season.

With the type of fish life observed, it is apparent that with increasing age a water basin develops a faunae of inferior fish. The game fish are forced out of the habitat to seek more muck-free spawning grounds.

The productivity of the water is limited by the fertility of the bottom and the nutrients in the water. The link between these is the presence of water bacteria which convert the organic matter into available nutrients for the use of other organisms.

Many attempts have been made to use the results of the quantitative investigation of plankton as a basis for estimating the productiveness of water basins in fish life. The problem is of great importance as it is related to the field of fish culture. One may ask if the plankton volume is a relative index of the productive capacity. The question has been discussed for a long time and as yet no satisfactory answer can be found. Some workers are of the opinion that as the plankton is not a basic food for all fish it does not tell much about the production of fish in the water. This is true for some fish which are feeders on crustaceans, mosquito larvae, worms and other bottom organisms. It might be assumed that the bottom organisms would offer a better index of productive capacity. Such studies will be required for this area before a complete picture of productivity can be obtained.

The average content of the plankton in the water may be regarded as an indicator of productivity even though the plankton-eating fish are absent. Phytoplankton and zooplankton form the connections between the gases and mineral salts dissolved in the water and the fish which are used for food for higher organisms. The plankton, if not used for food by the fish, is used by the bottom organisms, and the fish productivity is indirectly but nonetheless related to the plankton content.

The present investigation was to determine the nature of the Marsh area from the aspect of the limnological factors present in making it productive of fish. It has been shown that there is a large population of fish, and as well a very abundant zooplankton population consisting of Rotifers, Cladocera and Copepoda in large numbers especially in the open water area. As we have seen above, these factors are dependent on all the other interrelated physical and chemical conditions.

The sewage pollution, at first believed to have a deleterious effect on the Marsh waters, has been shown to be probably responsible for the extensive productivity of both plants and animals. With the growing plants and aerated water, the Marsh is able to utilize this material effectively without the danger often associated with excess waste. The materials are broken down effectively by bacteria into the nitrites and nitrates that are responsible for increasing both plankton and fish.

The Marsh is seen to be a very productive region and suitable as a habitat for many aquatic organisms. It is not a static area, however, and must be expected to evolve much farther until its possible extinction. In order to preserve its present features and provide an area of increasing usefulness it is necessary to consider measures which can make this possible. The presence of Carp has been mentioned at great length in earlier sections. Its harmful effects on both the plant and fish life are not easily dismissed. The elimination of the Carp from the Marsh is the only way of maintaining this area in a state of increasing usefulness. The only immediate method of doing this is to continue netting the Carp at spawning season before their eggs are laid. For future consideration, it should be possible to construct a dam beneath the High Level Bridge to separate the Marsh from the Bay. This would allow the level of the Marsh to be raised above that of the Bay and maintained at that level throughout the year. It would then be possible to effect a sudden change of level of the Marsh water to destroy many of the Carp fry each season.

Such a project might permit the Marsh to become a more static area. The vegetation would assume a configuration dependent on the water depth, and, if necessary, deep holes could be dredged in the central area for establishment of conditions suitable for game fish. If the Carp were eventually removed, it is probable that the water would clear as it has been shown to do in other impounded waters when Carp were removed.

The effects of this program would not be detrimental to any of the existing physical and chemical relationships. The sewage pollution, barring excess garbage wastes, would continue to offer a supply of nutrient materials to enrich the water. The industrial wastes, which are believed not to be of importance at present, could be prevented from becoming a future menace from expanding industries by satisfactory legislation concerning this area. Such a project would permit the Marsh to become an even more useful and valuable area for many diverse aspects of recreation and ecological research.

CHAPTER VII

SUMMARY

1. Dundas Marsh is a very old water basin formed from the receding waters of Lake Iroquois. It is separated from Lake Ontario by Burlington Heights, an old beach ridge of the Lake Iroquois period of post-glaciation.

2. The Marsh consists of an area of approximately 650 acres. Half of this area is occupied by extensive aquatic vegetation. At least 70 species of plants are recorded. Among the plants are the following main types: _Glyceria_, _Typha latifolia_, _Ceratophyllum_, _Myriophyllum_, _Utricularia_, _Elodea_.

3. The water depth in the vegetation zone is not greater than 1 meter at high water. Deeper areas are in the eastern end adjacent to Burlington Heights. Fluctuations in the water level occur seasonally and annually.

4. The bottom of the open water zone is composed of a silty organic detritus. In the vegetation zone the bottom is a thick mat of organic material

5. The water is constantly turbid. Secchi disc transparencies were not found greater than 0.6 meters and occasionally were as low as 0.25 meters.

6. The temperature range for the Marsh water is from 0° C in winter to 27° C in summer. The water temperature is intimately related to the air temperature and shows close correlation during a diurnal cycle. Maximum temperatures occur between 4 - 5 p.m. Minimum temperatures are between 3 - 5 a.

7. The dissolved oxygen in the open water was found to be above 5 p.p.m. at all times. In the vegetation zone the photosynthetic and respiratory activity of the plants causes wide fluctuations in the diurnal cycle. Diurnal maxima are between 4 - 5 p.m. and minima at 2 - 4 a.m.

8. Carbon dioxide is present in minimal amounts in the open water. In vegetation zones the amount of free gas is often high, probably due to the large amount of decomposing plant materials. Diurnal maxima are between 5 - 7 p.m. and minima between 3 - 4 a.m.

9. Total alkalinity measured in terms of $CaCO_3$ is between 100 and 210 parts per million. Bicarbonate alkalinity is higher in the vegetation zone than in the open water region. Diurnal fluctuations occur in direct relation to the free carbon dioxide.

10. The pH of the Marsh water is between pH 7.0 and pH 9.2 over the entire range of sampling. The pH of the water for the most part is between pH 7.6 and pH 8.6. Diurnal fluctuations vary inversely with the carbon dioxide.

11. The zooplankton was abundant. Bosmina was the most prevalent Cladoceran. Cyclops was the most abundant Copepod with the Nauplii present in large numbers through the entire season. Annureae, Polyarthra, Asplanchna and Brachionus were the dominant Rotifera.

12. Pollution from the sewage effluents was high, but the effects of this

are shown to be beneficial to the productivity of the water.

13. Thirty-five species of fish have been recorded in the Marsh. The dominant forms are Carp, Perch, Shiners and other warm water types.

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APPENDIX

Station	Date	Time	Weather	Temp. Air	Temp. Water	Transp.	O_2 p.p.m.	O_2 %Sat.	CO_2 p.p.m.	pH	Alk. phth.	Alk. m.o.
1. 20 cms.	7/18/46	10:00	clear		26.0		8.31		0.0	7.6		
50					23.0		7.32			7.6		
80					22.5		6.95		0.0	7.6		
20	7/25/46	10:05	clear		23.6		7.63		0.0	7.6		
50			N.E.		23.6		7.25			7.6		
80					23.5		7.13		0.0	7.6		
20	8/8/46	10:55	clear		24.5		12.32		0.0			
50					24.0		11.49					
80					23.4		11.38		0.0			
20	8/15/46	11:45	S.E.		21.5		8.35		0.0	8.8		
50					21.5		9.02			8.8		
80					21.3		6.72		0.0	8.8		
20	8/22/46	11:50	N. cloud		20.4		10.09		0.0	8.4		
50					20.4		9.94			8.2		
80					20.1		9.41		0.0	8.2		
20	8/29/46	10:50	N. cloud		20.3		7.00		0.0	8.5		
50					20.4		6.48			8.4		
80					19.6		5.02		0.0	8.0		
50	6/19/47		S.W.	16.1 m	20.0		7.28		5.6			
150							5.46		4.4			
50	7/17/47	12:40	N.E.	30.5 m	26.0		7.76		2.9	8.6		
150				24.1 m	25.2		7.53		4.5	8.0		
	8/18/47			26.3 m		50						
20	9/30/47		N.		12.5	50						
150					12.4							
25	3/12/48		ice 15"	-6.1	0.2		6.58		1.5	7.4		
30			snow 1"		0.2							
100					1.1							

Station	Date	Time	Weather	Temp. Air	Temp. Water	Transp.	O_2 p.p.m.	O_2 %Sat.	CO_2 p.p.m.	pH	Alk. phth.	Alk. m.o.
2. 40 cms.	7/17/46	12:00	clear		22.5		11.77		0.3	7.5		
90					21.5		6.51			7.5		
140					21.5		8.33		1.7	7.6		
40	7/24/46	11:30	clear		23.5		6.58		0.0	7.6		
90					22.5		5.29			7.6		
140					22.5		3.72		2.5	7.6		
40	7/31/46	11:00	E.		22.5		10.82		0.5	7.6		
90					22.0		8.64			7.6		
140					22.0		8.42		2.0	7.6		
40	8/14/46	11:15	clear		21.0		9.67		0.0	8.4		
90					20.6		9.80			8.6		
140					20.5		9.52		0.0	8.6		
40	8/21/46	11:40	cloudy		19.0		2.95		11.81	7.2		
90					18.5		5.19			7.8		
140					18.5		5.41		7.20	8.0		
40	8/28/46	11:55	S.W.		21.2		8.15		8.90	8.3		
90					20.0		7.95			8.2		
140					20.0		6.66		4.10	8.2		
20	8/25/47			28.0		60						
20	10/10/47				14.8	40						
50					14.9							
20	19/15/47				17.3	60						
50					16.2							

Station	Date	Time	Weather	Temp. Air	Temp. Water	Transp.	O_2 p.p.m.	O_2 % Sat.	CO_2 p.p.m.	pH	Alk. phth.	Alk. m.o.
2. 10	4/23/48				13.0							
100					12.6							
10	5/11/48				10.0							
100					10.5							
10	5/19/48		N.E.		14.0	30						
100												
20	6/23/48	9:30	E.	23.9	19.8	32	10.53	119	0.0	8.5		
50					19.2					8.5		
100					18.6					8.3		
150					18.5		7.68	80	1.7	8.1		
20	6/25/48	2 p.m.	clear	25.0		40	8.89		1.9	8.8		
50										8.8		
100										8.8		
150							9.29		2.6	8.7		
20	6/30/48	12:00	S.W.	27.6	24.7	25	6.01	71	5.1	8.2		
50					24.6					8.1		
100					23.1					8.1		
150					19.7		5.57	60	4.8	8.0		
20	7/2/48	2 p.m.	hazy		22.8	40	6.89	79	1.1	8.7		
50					22.5					8.7		
100					21.6					8.6		
150					20.6		7.09	77	4.1	8.4		
20	7/9/48	2 p.m.	E.		23.9	55	11.10	130	0.0	9.2		
50					23.8					9.2		
100					23.5					9.2		
150					22.6		9.17	104	0.0	8.8		
20	7/12/48	12:30	clear		25.0	40	9.50	113	0.0	8.1		
50										7.9		
100										7.8		
150					24.8		6.52	77	1.7	7.4		
20	7/14/48	10.30	E.		24.5	30	6.08	72	0.0	7.4	10.4	122.3
50					24.5					7.3		
100					24.3					7.2		
150					24.3		6.27	74	0.0	7.2	7.4	116.9

Station	Date	Time	Weather	Temp. Air	Temp. Water	Transp.	O_2 p.p.m.	O_2 % Sat.	CO_2 p.p.m.	pH	Alk. phth.	Alk. m.o.
2. 20	7/16/48	2:30	Rain		23.5		7.16	84	0.0	8.3	8.0	102.4
50					23.8					8.2		
100					23.8					8.0		
150					23.8		7.07	82	0.0	7.7	9.4	101.4
20	7/23/48	2 p.m.	S.W.	23.0	23.5		7.79	89	0.0	8.7	13.2	109.2
50					23.5					8.7		
100					23.3					8.7		
150					23.3		8.11	94	0.0	8.6	17.8	102.3
20	7/26/48	1 p.m.	S.W.	21.2	21.9		8.82	100	0.0	8.5	18.8	131.0
50					22.0					8.4		
100					22.0					8.3		
150					21.7		8.21	92	0.0	8.3	16.2	129.6
20	7/28/48	12 n.	W.	25.0	21.9	50	8.98	100	0.0	8.7	14.0	106.3
50										8.7		
100										8.6		
150					21.5		8.80	99	0.0	8.3	7.2	107.3
20	7/30/48	3 p.m.	S.W.	26.0	25.0		10.08	120	0.0	8.9	21.2	110.4
50					24.8					8.9		
100					24.7					8.9		
150					24.7		9.73	115	0.0	8.8	21.6	110.2
20	8/2/48	1:30 p.m.	cloudy	20.0	21.0		10.86	120	0.0	9.1	25.0	105.0
50					20.8					8.9		
100					20.8					8.7		
150					18.6		8.69	91	5.3	8.4		105.7
20	8/2/48	5:30 p.m.	S.W.	21.9	21.9		12.99	145	0.0	9.1	23.8	107.4
50					22.0					9.0		
100					21.9					9.0		
150					20.6		11.38	125	0.0	8.9	28.2	103.3
20	8/6/48	2:30 p.m.	cloudy	21.5	19.4	35	8.68	94	0.0	8.4	9.0	124.2
50					18.6					8.4		
100					17.2					8.1		
150					16.0		4.74	47	4.3	7.9		106.9
20	8/9/48	2 p.m.	E.	22.2	21.4	55	11.97	135	0.0	8.9	18.2	102.6
50					20.5					8.9		
100					20.2					8.6		
150					19.4		9.23	100	0.0	8.6	16.6	121.2

Station	Date	Time	Weather	Temp. Air	Temp. Water	Transp.	O_2 p.p.m.	O_2 % Sat.	CO_2 p.p.m.	pH	Alk. phth.	Alk. m.o.
3. 20	7/17/46	13:50	E.		25.0		14.90		1.1	7.6		
50					25.0		15.79			7.6		
80					24.0		13.68		3.1	7.6		
20	7/24/46	12:00	clear		26.5		8.91		0.0	7.6		
50					26.5		8.64			7.6		
80					26.5		7.46		0.0	7.6		
20	7/31/46	11:30	E.		23.0		10.71		2.0	7.6		
50					23.0		10.51			7.6		
80					22.5		6.86		5.2	7.3		
20	8/14/46	12:35	clear		22.3		19.32		0.0	8.8		
50					21.8		18.21			8.8		
80					21.4		15.43		0.0	8.6		
20	8/21/46	11:05	S.W.		20.5		14.12		0.0	8.8		
50					19.0		10.09			8.8		
80					18.5		9.23		0.0	8.4		
20	8/28/46	12:20	S.W.		21.7		7.15		0.0	8.2		
50					21.6		7.10			8.2		
80					21.5		6.18		0.0	8.2		
20	6/11/47				19.7		8.64		8.7			
100					18.7		8.44		14.7			
50	7/15/47	14:00	E.	25.0	24.3		5.58		8.5	7.6		
150					24.2		3.72		8.7	7.3		
20	10/10/47				15.03	40	13.70		0.0			
100					15.01		13.28		0.0			
20	1/7/48		ice 9"		0.1		11.12		10.4	7.8		
82					1.8		1.95		24.8	7.3		

Station	Date	Time	Weather	Temp. Air	Temp. Water	Transp.	O_2 p.p.m.	O_2 % Sat.	CO_2 p.p.m.	pH	Alk. phth.	Alk. m.o.
4. 30	7/23/46	1035	S.W. clear		25.0		7.13		0.20	7.6		
60					24.5		5.17			7.4		
80					24.5		3.71		2.90	7.3		
30	7/30/46	1020	cloudy		23.0		7.18		5.3	7.4		
60					23.0		6.75			7.3		
80					23.0		6.65		5.2	7.3		
30	8/13/46	1200			21.5		5.42		1.0	8.6		
60					21.0		5.54			8.4		
80					20.5		5.24		4.4	8.4		
30	8/20/46	1510			21.0		10.37		2.50	8.6		
60					21.0		9.94			8.2		
80					21.0		8.74		3.50	8.2		
30	8/21/46	1115	clear		20.5		5.95		7.70	7.7		
60					20.0		5.89			7.5		
80					20.0		5.62		9.40	7.5		
50	7/16/47	1430	E.	26.0	25.0		3.87		2.7	7.9		
150					24.3		2.36		2.7	7.9		
50	8/11/47			30.5	26.4	50	11.53		1.3	8.8		
150					26.4		9.53		1.5	8.5		
	8/18/47			26.3		44						
20	8/25/47	1:15 p.m.	S.W.	28.2	27.1		8.01		3.1	8.7		
150					25.1		3.15		4.7	8.0		
20	9/30/47				12.2	50						
100					12.2							
20	10/10/47				14.5	55						
100					14.3							

Station	Date	Time	Weather	Temp. Air	Temp. Water	Transp.	O_2 p.p.m.	O_2 % Sat.	CO_2 p.p.m.	pH	Alk. phth.	Alk. m.o.
5. 50	7/18/46	1240	clear		25.5		10.71		0.0	7.6		
100					22.0		7.42			7.6		
140					22.0		7.32		1.1	7.6		
50	7/25/46	1145	N.E.		23.5		7.41		0.0	7.6		
100					23.2		6.56			7.6		
150					22.4		5.79		0.0	7.5		
50	8/8/46	1115	clear		23.6		7.74		1.0			
100					22.4		6.35					
150					22.4		4.81		5.9			
50	8/15/46	1350	S.E.		21.5		6.88		0.0	8.6		
100					21.0		6.11			8.2		
150					19.5		5.19		7.2	8.2		
50	8/22/46	1350	N.		20.4		8.04		0.0	8.8		
100					19.0		4.78			8.0		
150					18.7		4.03		7.4	8.0		
50	8/29/46	1345	N.		20.0		6.98		0.0	8.4		
100					19.0		6.09			8.6		
150					18.5		5.97		4.30	8.3		
50	7/17/47	1515	S.E.	25.0	26.0		3.87		5.6	9.2		
150					24.4		2.12		6.8	9.6		
20	8/6/47	1130	E.	24.8	24.1		7.81		2.7	8.2		
100					23.8		2.12		2.0	7.9		
50	8/18/47			26.3		50						
6. 30	7/16/46	1100	E.				7.34		0.90	7.7		
60							9.16			7.7		
90							5.56		7.0	7.7		

Station	Date	Time	Weather	Temp. Air	Temp. Water	Transp.	O_2 p.p.m.	O_2 % Sat.	CO_2 p.p.m.	pH	Alk. phth.	Alk. m.o.
7. 40	7/16/46		E.				8.52		5.30	7.7		
80							9.05			7.7		
120							8.72		4.80	7.8		
40	7/23/46	1130	S.W.		26.0		8.11		0.0	7.6		
80					25.0		4.39			7.4		
120					24.5		4.02		0.0	7.2		
40	7/30/46	1050			23.5		10.32		2.8	7.4		
80					23.5		10.32			7.6		
120					23.5		9.25		3.8	7.6		
40	8/13/46	1230			21.5		6.96		0.0	8.8		
80					21.5		9.86			8.6		
120					20.5		4.47		0.0	8.6		
40	8/20/46	1550	S.W.		21.0		6.33		0.0	8.4		
80					21.0		7.50			8.3		
120					21.0		6.10		0.0	8.3		
40	8/27/46	1145			21.0		6.59		0.0	8.6		
80					20.0		5.71			8.4		
120					19.5		4.86		2.4	8.2		
50	6/12/47			14.9	21.7		7.9		5.6			
150					20.8		6.64		5.9			
E 50	6/26/47		S.W.	22.7	22.2		4.83		6.4			
150					21.6		4.54		5.4			
W 50	6/26/47		S.W.	22.7	21.6		4.61		5.3			
150					21.6		2.77		4.4			
50	7/15/47	1100	E.	23.7	24.0		6.11		5.2	8.3		
150					24.0		4.94		4.9	8.2		
50	8/25/47			28.0		50						
50	10/15/47				17.0							
					15.8							

Station		Date	Time	Weather	Temp. Air	Temp. Water	Transp.	O_2 p.p.m.	O_2 % Sat.	CO_2 p.p.m.	pH	Alk. phth.	Alk. m.o.
7.	20	11/21/47		E wind	2.0	2.6							
	100												
	10	12/15/47		S.W.		0.6		12.79		12.7	7.9		
	100					1.6		10.87		15.7	7.8		
	150					1.7							
	20	1/7/48		ice 9"		0.2							
	100					1.5							
	20	4/2/48				7.8							
	140					7.8							
	20	6/23/48	1115	S.W.	27.6	20.0	45	8.33	90	2.7	8.5		
	50					20.0					8.5		
	100					19.6					8.5		
	150					18.9		6.33	67	3.5	8.2		
	20	6/25/48	1145	clear		23.2	45	7.70	90	0	8.7		
	50					23.0					8.7		
	100					22.4					8.7		
	150					22.3		7.24	81	0	8.6		
	20	6/30/48	1120	S.W.	27.6	24.0	30	6.59	76	3.7	8.3		
	50					23.9					8.3		
	100					23.9					8.2		
	150					23.9		6.95	80	3.4	8.2		
	20	7/2/48	1145		19.4	22.5	22	5.21	60	3.9	8.3		
	50					22.6					8.3		
	100					22.4					8.2		
	150					22.1		5.21	59	5.6	8.1		
	20	7/5/48	12 N		29.2	24.6	35	8.83	105	0	8.65		
	50					24.3					8.6		
	100					24.1					8.55		
	150					23.7		7.21	84	3.8	8.4		
	20	7/9/48	1130	E.		25.5	35	12.28	147	0	9.1		
	50					24.9					9.0		
	100					23.4					8.95		
	150					23.5		8.32	96	0	8.3		

Station	Date	Time	Weather	Temp. Air	Temp. Water	Transp.	O_2 p.p.m.	O_2 % Sat.	CO_2 p.p.m.	pH	Alk. phth.	Alk. m.o.
7. 20	7/12/48	12 N			27.0	35	8.99	110	0	8.1		
50										7.45		
100										7.4		
150					25.0		3.38	40	6.5	7.3		
20	7/14/48	1015		20.6	24.4	25	4.70	55	0	7.5	10.4	132.1
50					24.5					7.4		
100					24.5					7.4		
150					24.5		4.23	50	0	7.3	11.0	132.5
20	7/16/48	215 P.M.	Rain		23.6		7.31	85	0	8.6	21.4	136.4
50					23.6					8.45		
100					23.7					8.4		
150					23.6		6.72	77	0	8.38	15.4	139.5
20	7/19/48	1245	S.W.		24.3		8.27	98	0	8.7	16.2	133.1
50					24.3					8.6		
100					24.4					8.5		
150					24.4		7.57	90	0	8.2	19.6	130.6
20	7/23/48	1215	S.W.		22.8		7.79	89	0	8.5	9.8	122.0
50			Rain		23.0					8.4		
100					23.1					8.3		
150					23.1		7.78	89	0	8.3	11.0	115.8
20	7/30/48	1215	S.W.		24.4		11.59	136	0	8.6	14.6	111.2
50					24.4					8.45		
100					24.4					8.35		
150					24.4		11.17	130	0	8.25	14.4	110.4
20	8/6/48	2 P.M.	W.		19.9		10.0	108	0	8.65	24.6	111.8
50			Drizzle		20.0					8.65		
100					20.0					8.65		
150					20.0		9.45	104	0	8.6	38.0	166.2
20	8/9/48	12 N	E.		21.3	30	10.25	114	0	8.8	30.4	106.1
50					20.1					8.75		
100					19.5					8.1		
150					19.3		4.25	45	0	8.0	10.0	138.5

Station	Date	Time	Weather	Temp. Air	Temp. Water	Transp.	O_2 p.p.m.	O_2 %Sat.	CO_2 p.p.m.	pH	Alk. phth.	Alk. m.o.
9. 8	7/15/46						1.67		20.40	7.3		
28							2.59		14.90	7.3		
8	7/22/46	10:30	E.		24.0		2.35		6.0	7.3		
28					23.5		1.50		7.1	7.2		
8	7/29/46	11:20	clear		22.6		6.38		5.2	7.5		
28					21.5		4.80		4.9	7.4		
8	8/12/46	10:20	S.W.		20.0		5.02		11.8	7.4		
28					19.0		2.59		13.0	7.2		
8	8/19/46	10:30	S.W.		22.0		3.55		11.0	7.2		
28					21.5		2.94		15.4	7.4		
8	8/26/46	10:15	N.E.		17.0		12.41		8.0	8.0		
28					16.5		5.14		11.9	7.6		

Station	Date	Time	Weather	Temp. Air	Temp. Water	Transp.	O_2 p.p.m.	O_2 % Sat.	CO_2 p.p.m.	pH	Alk. phth.	Alk. m.o.
10. 10	7/15/46		clear				9.08		9.0	7.6		
25							8.43		15.3	7.5		
50							4.77		18.25	7.2		
10	7/22/46	1100	E.		25.0		5.68		4.0	7.6		
25					23.5		4.84		5.9	7.2		
50					23.5		2.97		7.4	7.2		
10	7/29/46	1320	clear		21.8		8.52		3.3	7.6		
25					20.5		1.07		5.5	7.2		
50					20.5		0.00		7.0	7.2		
10	8/19/46	1155	E.		23.5		7.64		9.10	8.6		
25					21.0		0.83		13.20	8.4		
50					21.0		0.41		32.20	7.2		
10	7/10/47	1305	N.E.	21.5	25.0		10.03		4.3	8.9		
50					21.0					7.7		
150					20.8		2.43		4.5	7.6		
50	7/16/47	1315	E.	27.0	24.1		3.15		2.5	7.8		
150					22.6		1.75		4.2	7.5		
20	8/11/47	1130		27.7	25.0		5.03		7.6	8.1		
100					23.2		0.00		2.2	7.9		
100	8/25/47			28.0		100						
20	8/25/47	1230	S.W.	28.2	24.6	90	1.18		4.7	7.9		
150					23.0		0.00		5.7	7.6		
20	10/2/47		bright		10.0		6.95		18.2			
60					9.7		6.53		19.6			
20	4/2/48				7.4							
90					7.2							
10	4/13/48			4.0	8.5							

Station		Date	Time	Weather	Temp. Air	Temp. Water	Transp.	O_2 p.p.m.	O_2 % Sat.	CO_2 p.p.m.	pH	Alk. phth.	Alk. m.o.
10.	20	6/23/48	1015	S.W.	23.9	20.8	100+	5.71	64	6.5	7.9		
	50					19.8					7.9		
	100					19.4		3.02	32	11.1	7.8		
	20	6/25/48	1100	clear	28.9	22.4	90+	2.71	31	10.0	8.0		
	50					22.2					8.0		
	100					21.4		0.36	3	12.9	7.8		
	20	6/30/48	1030	S.W.	27.6	24.0	70+	1.59	18	17.9	7.7		
	50					23.6					7.55		
	100					23.3		0.00	0	21.4	7.45		
	20	7/2/48	1100	hazy	19.4	22.3	80+	1.75	19	12.9	8.0		
	50					21.9					7.9		
	100					21.2		1.62	18	18.9	7.7		
	20	7/9/48	1100	E.		25.0		9.43	111	10.6	8.4		
	50					24.0					8.1		
	100					24.4		6.36	75	11.1	7.8		
	20	7/12/48	1130	clear	31.0	25.0		6.19	74	9.3	7.5		
	50										7.2		
	100					24.3		0.67	7	15.0	6.88		
	20	7/14/48	9.45	E.	79.9	23.5		4.26	50	8.7	7.4		166.3
	50					23.4					7.2		
	100					23.4		0.99	17	5.9	6.7		171.1
	20	7/16/48	1 p.m.	E.		23.5		5.91	69	0	8.0	17.0	142.5
	50					23.9					7.5		
	100					22.0		3.19	40	9.6	7.4		152.5

Station	Date	Time	Weather	Temp. Air	Temp.	Transp.	O_2 p.p.m.	O_2 % Sat.	CO_2 p.p.m.	pH	Alk. phth.	Alk. m.o.
10. 20	7/23/48	1145	S.W.	24.6	23.0		3.26	37	14.8	8.2		186.8
50					22.4					8.1		
100					22.2		2.13	24	18.3	7.7		190.3
20	7/26/48	12 N	S.W.	20.9	21.2		0.0	0	10.2	8.1		194.2
50					21.1					7.7		
100					21.0		0.0	0	16.0	7.4		209.1
20	7/28/48	11 A.M.	W.	24.7	23.1		0.31	3	14.2	8.0		196.4
50					21.2					7.85		
100					21.2		0.0	0	10.1	7.5		196.5
20	7/30/48	1130	S.W.	29.0	24.3		1.2	14	6.9	7.9		183.1
50					23.1					7.8		
100					22.0		0.0	0	17.2	7.5		196.3
20	8/2/48	1230		22.0	21.2		3.04	34	10.8	8.5		193.6
50					21.4					8.3		
100					21.4		0.0	0	12.7	7.9		202.1
20	8/2/48	4:15 P.M.		23.5	23.6		7.49	86	0	8.65	11.8	167.2
50					22.4					8.1		
100					21.7		2.00	22	11.3	7.65		186.3
20	8/6/48	1130	W.	22.8	18.7		0.0	0	15.1	7.4		198.3
50					17.6					7.1		
100					17.7		0.0	0	10.7	7.0		200.6
20	8/9/48	1230	E.	23.0	24.5		6.62	77	6.6	8.2		181.3
50					22.0					7.5		
100					20.0		0.0	0	10.0	7.2		194.1

Station	Date	Time	Weather	Temp. Air	Temp. Water	Transp.	O_2 p.p.m.	O_2 % Sat.	CO_2 p.p.m.	pH	Alk. phth.	Alk. m.o.
11. 20	7/19/46	1105	S.W.		26.5		9.06		0.0	7.6		
40					26.5		9.71		0.0	7.6		
20	7/26/46	1100	clear				9.50		0.0	7.6		
40							9.00		0.0	7.6		
20	8/9/46	1120	S.W.		25.5		6.85		3.0			
40					25.5		6.85		4.3			
20	8/16/46	1045			22.5		4.18		10.31	7.8		
40					22.5		3.81		11.10	7.8		
20	8/23/46	1120	N.E.		19.5		8.69		0.0	8.2		
40					19.5		8.34		0.0	8.0		
20	8/30/46	1140	S.W.		18.0		7.60		0.0	8.6		
40					18.0		7.23		0.0	8.6		
20	7/28/47		N.W.		24.0		10.26		2.3	8.5		
100					24.0		2.39		2.3	7.9		
12. 50	7/19/46	1310	S.W.		23.5		5.48		3.9	7.6		
100					22.5		1.06			7.4		
150					22.5		1.79		6.0	7.5		
50	7/26/46	1200	clear		22.0		5.31		6.0	7.5		
100					21.0		1.07			7.4		
150					21.0		0.39		6.3	7.4		
50	8/9/46	1145	S.W.		22.5		3.36		8.50			
100					22.3		2.08					
150					22.3		0.32		13.6			
50	8/16/46	1110	drizzle		21.0		2.29		15.0	7.6		
100					20.5		0.31			7.2		
150					20.5		0.34		18.0	7.2		
50	8/23/46	1145	N.E.		19.5		9.19		17.60	8.0		
100					19.0		2.93			7.8		
150					19.0		3.45		18.80	7.6		
50	8/30/46	1210	S.W.		18.5		6.35		14.70	7.8		
100					18.5		5.34			7.6		
150					18.0		4.06		18.20	7.8		

Station Diurnal	Date	Time	Weather	Temp. Air	Temp. Water	Transp.	O_2 p.p.m.	O_2 % Sat.	CO_2 p.p.m.	pH	Alk. phth.	Alk. m.o.
2. 20	7/5/48	12.30	Bright		24.2	45	9.95	116	0.0	8.9		
50					24.1					8.9		
100					23.6					8.8		
150					19.8		6.02	65	3.8	8.1		
20		4.45	Bright		24.6		11.20	132	0.0	9.0		
50					24.3					9.0		
100					24.2					8.9		
150					24.0		9.83	115	0.0	8.9		
20		8.55	Sun set		25.0		9.75	115	0.0	9.1		
50										9.1		
100										8.9		
150					25.0		9.38	111	0.0	8.9		
20	7/6/48	12.30	S.W.		24.0		8.14	95	0.0	8.9		
50		a.m.								8.8		
100										8.8		
150					24.0		15.94		0.0	8.8		
20		4.35			22.1		7.09	80	0.9	8.4		
50		a.m.								8.3		
100										8.2		
150					21.6		6.09	66	3.9	8.1		
20		8.30					7.83		0.0	8.6		
50		a.m.								8.6		
100										8.6		
150							7.70		0.0	8.4		
20		12.30			22.0	43	7.71	87	3.5	8.5		
50		noon								8.5		
100										8.2		
150					19.0		5.81	61		8.2		

Station Diurnal		Date	Time	Weather	Temp. Air	Temp. Water	Transp.	O_2 p.p.m.	O_2 % Sat.	CO_2 p.p.m.	pH	Alk. phth.	Alk. m.o.
2.	20	7/19/48	1:00	S.W.	19.6	22.2		8.93	100	0	8.9	17.8	117.4
	50		p.m.			22.6					8.8		
	100					22.9					8.7		
	150					22.5		6.92	79	2.0	8.4		110.9
	20		5:00	S.W.	26.0	25.5	35	12.39	150	0	9.2	34.8	108.0
	50		p.m.			25.3					9.2		
	100					25.0					9.0		
	150					24.7		9.70	115	0	8.9	28.4	115.8
	20		8:50		20.9	24.9		11.44	136	0	9.7	22.2	124.8
	50		p.m.			25.0					9.6		
	100					24.9					9.6		
	150					24.8		12.23	145	0	9.5	20.6	120.6
	20	7/20/48	1:15		19.0	23.6		9.75	113	0	8.6	19.0	125.4
	50		a.m.			24.0					8.6		
	100					23.9					8.5		
	150					22.3		7.98	90	3.9	8.0		116.6
	20		5:00		18.0	22.9		9.8	113	0	8.4	16.2	124.2
	50		a.m.			23.4					8.3		
	100					23.5					8.2		
	150					23.4		5.01	58	0	7.9	10.4	119.4
	20		8:30		22.2	23.3		10.03	116	0	8.7	23.2	113.5
	50		a.m.			23.3					8.7		
	100					23.3					8.4		
	150					23.2		8.47	97	0	8.4	12.0	120.4
	20		1:00		28.0	25.7		13.62	165	0	9.0	35.0	116.0
	50		p.m.			25.0					9.0		
	100					24.6					8.9		
	150					24.3		8.78	104	0	8.4	13.8	117.8

Station	Diurnal	Date	Time	Weather	Temp. Air	Temp. Water	Transp.	O_2 p.p.m.	O_2 % Sat.	CO_2 p.p.m.	pH	Alk. phth.	Alk. m.o.
10	10	8/12/46	11:00	S.W.		22.0		8.44		7.9	7.7		
	25					19.0		1.10		10.9	7.2		
	50					19.0		1.43		12.8	7.2		
	10		15:00	S.W.		23.0		9.61		7.10	7.7		
	25					20.5		2.08		12.00	7.4		
	50					20.0		0.00		15.10	7.3		
	10		19:00	S.W.		22.5		3.10		13.1	7.6		
	25					21.5		3.34		12.2	7.2		
	50					21.5		1.84		10.9	7.2		
	10		23:00	S.W.		20.5		1.0		13.50	7.6		
	25					20.5		1.48		13.50	7.6		
	50					20.5		0.84		15.00	7.8		
	10	8/13/46	03:00	bright moon		19.5		1.33		16.7	7.6		
	25					19.5		0.19		15.8	7.6		
	50					19.5		0.27		14.2	7.8		
	10		07:00	E.		18.5		0.68		19.0	7.2		
	25					19.0		0.14		15.0	7.2		
	50					19.0		0.00		14.3	7.2		

Station	Diurnal	Date	Time	Weather	Temp. Air	Temp. Water	Transp.	O_2 p.p.m.	CO_2 p.p.m.	pH
10	10	8/26/46	1100	N.E.		18.0		7.06	9.30	8.0
	25					16.5		1.43	13.60	7.4
	50					17.0		0.00	15.20	7.4
	10		1500	N.E.		22.0		6.27	7.40	7.6
	25					19.0		3.18	10.60	7.2
	50					18.5		1.70	17.30	7.2
	10		1900	cloudy		23.0		11.03	7.2	7.8
	25					20.0		4.04	14.0	7.4
	50					19.0		3.12	16.0	7.2
	10		2300			19.0		3.30	11.5	8.0
	25					19.0		2.50	15.6	7.8
	50					18.5		2.10	17.3	7.8
	10	8/27/46	0300	cloudy		17.5		0.75	14.1	7.8
	25					17.5		0.52	20.8	7.6
	50					18.0		0.47	25.5	7.6
	10		0700			16.5		0.10	16.9	7.6
	25					16.5		0.0	13.5	7.4
	50					17.0		0.0	17.4	7.2

Station	Diurnal	Date	Time	Weather	Temp. Air	Temp. Water	Transp.	O_2 p.p.m.	O_2 % Sat.	O_2 p.p.m.	pH	Alk. phth.	Alk. m.o.
10	20	7/5/48	11:30	W.	29.2	24.6	50¢	5.52	65	13.3	8.1		
	50		a.m.			23.3					7.9		
	100					23.1		0.50	5	20.6	7.85		
	20		4:00	S.W.	30.6	26.0	90¢	2.78	34	12.1	8.05		
	50		p.m.			24.3					7.8		
	100					22.7		0.85	10	19.9	7.5		
	20		8:15	S.W.	26.0	26.1		8.20	100	6.2	7.9		
	50		p.m.			24.0					7.7		
	100							0.50	6	23.0	7.2		
	20	7/6/48	12:00			23.5		0.91	10	14.3	7.8		
	50		mid.								7.6		
	100					23.0		0.85	9	24.5	7.5		
	20		4:00		21.5	22.6		1.25	14	12.9	7.6		
	50		a.m.								7.5		
	100					22.5		0.94	10	15.8	7.45		
	20		8:00		23.8	[illegible]		0.77		19.9	7.6		
	50		a.m.								7.5		
	100							0.36		14.9	7.3		
	20		12:00		23.1	24.2	60¢	2.82	35	21.8	7.65		
	50		noon								7.5		
	100					25.0		0.42	7	25.1	7.45		

Station	Diurnal	Date	Time	Weather	Temp. Air	Temp. Water	Transp.	O_2 p.p.m.	O_2 % Sat.	CO_2 p.p.m.	pH	Alk.	Alk.
10	20	7/19/48	12:00	S.W.	22.6	23.6		2.26	26	13.5	8.2		182.1
	50		noon			22.3					8.1		
	100					22.2		0.61	7	15.1	7.7		186.4
	20		4:15	S.W.	26.8	25.0	83/	6.31	75	9.1	8.3		178.5
	50					23.7					7.8		
	100					23.1		1.63	18	10.2	7.55		184.2
	20		8:20	S.W.	22.2	25.1		9.10	109	7.8	9.3		162.6
	50		p.m.	sun sets		23.5					8.3		
	100					23.6		0.23	2.5	13.6	8.0		182.3
	20	7/20/48	12:30	full moon	18.9	22.2		3.01	34	11.5	7.7		172.6
	50		mid.			22.8					7.5		
	100					23.0		0.63	7	14.0	7.1		163.6
	20		4:30		16.9	21.4		0.71	7.5	12.3	7.4		180.1
	50		p.m.			22.2					7.2		
	100					22.4		0.74	8	12.5	7.1		179.5
	20		8:00		22.2	22.2		2.19	24	10.3	7.7		179.6
	50		a.m.			22.1					7.45		
	100					22.3		0.53	5.5	9.4	7.15		176.2
	20		12:30	S.W.	27.8	24.8		3.79	45	12.9	8.5		179.6
	50		noon			22.6					7.8		
	100					22.4		0.71	7.6	13.2	7.6		182.8

Station		Date	Weather	Temp. Air	Temp. Water	Transp.	O_2 p.p.m.	CO_2 p.p.m.	pH
N. Stream mouth	50	7/29/47	N.W.	29.0	21.0		5.25	2.7	8.0
	120				19.6		2.89	3.2	7.8
N. Stream	50	7/29/47	N.W.	29.0	20.0		2.02	4.4	7.6
	80				19.2		2.52	5.0	7.7
Hamilton Sewage outlet									
	100	7/31/47	N.	21.4	25.0		4.04	14.24	7.5
Ref. Weed Bed	10	6/18/47	lemna minor cover	15.5	18.5		3.57	4.1	
Ref. Weed Bed	10	6/18/47	clear	15.5	18.8		6.88	5.6	
Princess Inlet end									
	20	6/11/47	19.9	22.7			4.38	6.8	
	50			22.5			4.57	5.9	
Princess Inlet mouth									
	50	6/12/47	14.9	22.0			10.38	4.4	
	150			22.0			7.10	4.8	
Princess Inlet mouth									
	50	6/17/47	14.9				7.0	2.9	
	150						5.8	3.3	
Princess Inlet mouth									
	20	9/30/47		12.4		50	9.77	2.6	
	100			12.5			9.50	4.9	
Princess Inlet mouth									
	20	10/14/47		17.6					
	100			15.1					
Princess Inlet mouth									
	20	10/15/47		16.4		54			
	100			15.5					
Princess Inlet mouth									
	30	10/15/47		16.1					8.4
	60								7.7

Station	Date	Time	Weather	Temp. Air	Temp. Water	O_2 p.p.m.	O_2 % Sat.	CO_2 p.p.m.	pH	Alk. phth.	Alk. m.o.
Bay7/100	7/31/47		N.	25.0	19.1	5.49		2.0	8.1		
20	10/15/47				16.1				8.7		
100					15.8				8.6		
0.2^{m}	6/30/48					6.50					
2.0						6.73					
4.0						5.94					
6.0						5.11					
8.0						4.33					
10.0					14.5	2.36					
1^{m}	7/14/48				23.9	7.82	92	0		15.2	95.3
2					23.5	8.44	98				
4					23.3	8.08	94				
6					22.9	6.93	80	1.8			102.9
8					16.3	3.57	36				
10					16.1	4.36	44	5.5			107.8
1^{m}	7/28/48	1:30 p.m.									
3											
5											
7					20.9	6.58					
9					17.9	4.85					
11					16.9	3.89					
13					16.2	2.11		8.6			105.6

WATER LEVEL RECORDS - 1946

(Hamilton Harbour Commission)

Date	March	April	May	June	July	August	September	October	November
1	246.0			248.08	248.6	248.50	248.33	247.50	247.16
2		246.60		248.16	248.6	248.91	248.16	247.58	
3	245.6			248.25	248.6	248.91	248.16	247.58	247.25
4	245.6			248.41		248.83	248.16	247.58	247.25
5	245.75	246.75	247.41	248.50	248.6	248.91			247.08
6	246.0		247.41		248.6	248.91		247.50	247.00
7	246.0	246.50	247.41	248.50	248.6	248.91		247.50	247.00
8	246.0		247.41	248.60	248.6		248.50	247.58	247.00
9		246.83	247.33	248.75	248.83	248.83	248.50	247.58	
10	245.91	247.0	247.41	248.91	248.83	248.83	248.50	247.50	247.00
11	245.91			248.66		248.83	248.08	247.50	
12	246.0	247.0	247.50	248.83	248.83	248.66			
13			247.60			248.66	248.08	247.41	246.83
14	245.91	247.0	247.60	249.16	249.0	248.50	248.08	247.43	246.83
15			247.60	249.00	249.0	248.50	248.00	247.33	246.83
16			247.60	248.91	249.0	248.83	248.00	247.33	
17	246.0	247.16	247.66		248.91	248.66	248.00	247.33	246.66
18		247.16		248.83	248.91	248.50		247.33	246.83
19	246.08		247.75	248.83	248.83	248.50	248.00		
20			247.60		248.83	248.66		247.25	246.75
21	246.16		247.75	249.0	248.66	248.66		247.25	246.83
22			247.75	248.83	248.66	248.50	247.91	247.25	246.83
23		247.25	247.83	249.0	248.60	248.41	247.83	247.08	
24	246.16	246.91		249.0	248.66	248.41	247.83	247.16	246.91
25				248.8	248.66	248.41	247.83	247.16	246.58
26		247.25	248.0	248.8	248.66	248.41	247.83		
27	246.16		248.0		248.50	248.33	247.83	247.16	
28		247.00	248.08	248.8	248.50	248.33		247.08	246.25
29		247.08	248.16	248.8	248.60	248.33	247.66	247.08	
30		247.33	248.08	248.75	248.41	248.16	247.66	247.08	246.50
31			248.08		248.50	248.33		247.16	

WATER LEVEL RECORDS - 1947

(Hamilton Harbour Commission)

Date	March	April	May	June	July	August	September
1	246.0			248.08	248.66	248.5	248.3
2		246.60		248.16	248.66	248.9	248.16
3	245.6			248.28	248.66	248.9	248.16
4	245.6			248.41		248.8	248.16
5	245.7	246.75	247.41	248.50	248.66	248.9	
6	246.0		247.41		248.60	248.9	
7	246.0	246.50	247.41	248.50	248.60	248.9	
8	246.0		247.41	248.60	248.60		
9		246.83	247.33	248.75	248.60	248.8	
10	245.91	247.00	247.41	248.91	248.83	248.9	
11	245.91			248.66	248.83	248.83	
12	246.0	247.00	247.50	248.83		248.6	
13			247.60			248.6	
14	245.9	247.00	247.60	249.16	249.00	248.5	
15			247.60	249.00	249.00	248.5	
16			247.60	248.91	249.00	248.83	
17	246.0	247.16	247.66		248.91	248.6	
18		247.16		248.83	248.91	248.5	
19	246.08		247.75	248.83	248.83	248.5	
20			247.60		248.83	248.66	
21	246.16		247.75	249.0	248.66	248.6	
22			247.75	248.8	248.66	248.5	
23		247.25	247.83	249.0	248.60	248.4	
24	246.16	246.91		249.0	248.66	248.4	
25				248.8	248.66	248.4	
26		247.25	248.0	248.8	248.66	248.4	
27	246.16		248.0		248.50	248.3	
28		247.00	248.0	248.8	248.50	248.3	
29		247.08	248.16	248.8	248.60	248.3	
30		247.33	248.08	248.75	248.41	248.16	
31	246.33		248.08		248.51	248.3	