AN ECOLOGICAL SURVEY OF ISLE ROYALE, LAKE SUPERIOR

PREPARED UNDER THE DIRECTION OF
CHAS. C. ADAMS.

A Report from the University of Michigan Museum, published by the State Biological Survey, as a part of the Report of the Board of the Geological Survey for 1908.

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PART I. ECOLOGICAL PAPERS

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LETTER OF TRANSMITTAL

To the Honorable the Board of Geological Survey of the State of Michigan:

Gov. Fred M. Warner, President.
Hon. D. M. Ferry, Jr., Vice-President.
Hon. L. L. Wright, Secretary.

Gentlemen:—I beg to present herewith for printing, a report by Dr. Chas. C. Adams on the ecology, that is the natural history, of Isle Royale. This comes to us with the approval of Dr. A. G. Ruthven, our Chief Field Naturalist, and our Board of Scientific Advisers, and is a continuation of the work published in our annual report for 1905.

This contribution to the Biological Survey of the State, which the legislature authorized me to supervise by Act No. 250 of the session of 1905, comes from the University Museum. The explorations were made without expense to the State Survey by means of contributions from friends of the Museum. As this work is in harmony with the aims of the Biological Survey we are fortunate in securing such co-operation. The reports on the Porcupine Mountains and Isle Royale at the north end of the state complement the work on Walnut Lake, Oakland county, and that in Huron and Tuscola counties.

I trust that the present report will be of service to the schools of the state.

Very respectfully,
ALFRED C. LANE,
State Geologist.

INTRODUCTORY NOTE.

Through the generosity of Mr. Bryant Walker, of Detroit, Hon. Peter White* and Mr. H. M. Kaufman of Marquette, the University Museum of the University of Michigan was able, in the summer of 1904, to send a party to the Porcupine Mountains and to Isle Royale, Michigan. The aim of the party was to collect specimens for the museum and to make au ecological survey of the regions visited. The party was only able to spend a few weeks on Isle Royale at that time, but through the continued generosity of Mr. White and Mr. Walker, the survey was continued during the summer of 1905. The present volume on the natural history of the island has resulted from these surveys.

To Mr. White and Mr. Walker the Museum is under special obligations for their hearty and substantial support, not only in the funds provided, but also for their aid in securing the transportation of the party. Many other individuals also assisted in various ways. Those who aided the party in the matter of transportation were: Mr. Henry Russel, of the Michigan Central Railway; Mr. Geo. T. Arnold, of the Union Ticket Office and Dock of Mackinac Island; Mr. II. H. Brigham, of the U. S. and Dominion Transportation Company ("Booth Line"); Mr. Henry Meyering, of the Graham and Morton Line; Mr. M. Adson, of the Duluth, South Shore and Atlantic Railway. The survey is furthermore indebted to Section Director C. F. Schneider of the Michigan Section of the Climatological Service of the U. S. Weather Bureau, for the loan of meteorological instruments; to Major Lansing H. Beach, Detroit, of the Light House Establishment, for permission and suggestions as to camping in the abandoned Light-house at Rock Harbor; to Mr. Geo. C. Stone, Secretary of the Washington Club of Duluth, Minn., for the use of their grounds and many favors from their care-takers, Mr. Chas. Preulx and Mr. Michael Hollinger; to Mr. K. Neutson, of Park Place ("Neutson's Resort"), Rock Harbor, Isle Royale, for many favors during the stay upon the island; to Mr. J. H. Malone, Keeper of the Isle Royale Light, and to his sons, particularly to the Assistant Keeper, Mr. J. A. Malone, for many favors and for their hospitality. It is a pleasure to have this opportunity of thanking these persons for their cooperation.

On the return of the party from the field, work was at once begun upon the collections, and in this a large number of specialists have aided by the determination of the specimens. Acknowledgements are made to such persons throughout the report and will not be repeated here. Those who were not members of the party, but who have prepared papers are: Mr. Bryant Walker, of Detroit, Michigan, Dr. W. M, Wheeler, American Museum of Natural History; Mr. A. P. Morse, Research Assistant of the Carnegie Institution, and Wellesley College; Dr. Jas. G. Needham, Cornell University; Prof. J. S. Hine, Ohio State University; Prof. E. S. Titus, Utah Agricultural Experiment Station; Dr. A. G. Ruthven, University Museum, University of Michigan, and Mr. A. B. Wolcott, Field Museum of Natural History.

*Recently deceased.

The volunteer members of the Museum party should be mentioned in this connection: Dr. R. A. Brown, Dr. H. A. Gleason, Mr. W. P. Holt, Mr. Max Minor Peet, Mr. Otto McCreary, and the writer. It will be evident that the volunteer work of this report comprises the major part of it.

Personally the writer wishes to express his appreciation of the assistance of Mr. Walker and Mr. White; of the cooperation of the members of the party and the many specialists who have examined the specimens; and of the valuable suggestions and assistance of: Mr. Norman B. Conger, Inspector U. S. Weather Bureau, Detroit; Dr. Glover M. Allen, Boston Society of Natural History; Mr. Frank Leverett and Mr. F. B. Taylor. of the U. S. Geological Survey; Prof. H. F. Wickham, State University of Iowa; and to Mr. A. B. Wolcott, of the Field Museum of Natural History. Also to Dr. A. C. Lane of the Michigan Geological Survey for many favors and courtesies, including the preparation of the topographic map, and to Dr. A. G. Ruthven, Chief Field Naturalist of the Survey, for assistance in the publication of the report.

The shortcomings of this report will be no more evident to any one than to the writer. If, however, with its

defects, it preserves some "vanishing data," and presents suggestions for the improvement of such ecological surveys, it will have served the purpose for which it was intended.

CHAS. C. ADAMS.

July 23, 1908.
Hull Zoological Laboratory,
University of Chicago.

ISLE ROYALE AS A BIOTIC ENVIRONMENT.

BY DR. CHARLES C. ADAMS.

I. INTRODUCTION.

1. Itinerary and Personnel of the Party. The University Museum party left Ann Arbor, Michigan, June 20, and reached the abandoned light-house at Rock Harbor, Isle Royale, on the morning of July 5, 1905. The party was composed of the following: N. A. Wood, Dr. R. A. Brown, Dr. H. A. Gleason, W. P. Holt, Otto McCreary, a camp hand, B. F. Savery, and the writer. In general, the duties of the various members were as follows: Mr. Wood, the Museum taxidermist, looked after the trapping of mammals and the preparation of bird and mammal skins. He was assisted by Dr. Brown, who gave most of his attention to the study of the bird life, and who remained with the party until July 25. In the study of bird life, Dr. Brown, Mr. Wood and Mr. McCreary co-operated, the latter devoting his entire time to the ecological phase of the work. Dr. Gleason devoted his attention to the collection and ecological study of invertebrates, particularly molluscs and insects, and most of the photographs were taken by him. In collecting insects about the camps, lie was assisted by B. F. Savery. Mr. Holt's time was devoted to the study of the vegetation. The writer, who was in charge of the expedition, gave special attention to the environmental dynamics, biotic succession, and the general correlation of. the work of the various members of the party.

During the stay at Rock Harbor, *Fig. 1*, the following localities were examined: The shore, from the light-house south to the head of Conglomerate Bay; the region about the head of Rock Harbor and Summer lake; a, line from the month of Benson brook to Sargent Lake and McCargoe Cove.; and the vicinity of Tobin Harbor; in other words, the localities included in Stations I-IV.

The party remained at Rock Harbor from July 5 to August 1, and then moved to Siskowit Bay. Here Mr. Max M. Peet joined the party on August 8, and devoted his attention to collecting birds and mammals. He also took a number of the photographs. While at the Siskowit Camp, the bay and lake of that name were examined, and also the Haytown trail and the islands near the Isle Royale Light. All of these localities are included in Station V.

On August 17 the party moved to Washington Harbor, and was then partially disbanded. The members who remained made their headquarters on the grounds of the Washington Club, at the head of Washington Harbor. After September 5 Mr. Peet alone remained there until the 22nd, in. order that he might continue the study of the fall migration of the birds. He returned on the last boat of the season for Duluth, Minn.

During the previous (1904) season, the Museum party had made a general examination of the vicinity about Washington Harbor, so that it-was now thought desirable to devote more time to other localities. With the exception of bird migration, no detailed work was done in this vicinity in 1905. In addition to the region about the head of the harbor, Lake Desor was also reached from this point by means of the road along the crest of the Greenstone Range.

2. The Aim and Methods of Work. The field work was conducted on the same general plan as that pursued during the previous season in the Porcupine Mountains and at Washington Harbor. Much more ground was covered, however, because it seemed improbable that a third trip could be made to the same region. It therefore seemed desirable to gain some idea of the biota of the island as a whole, because of its Canadian character. Even then, the survey was confined almost exclusively to the region south of the Greenstone Range.

As mentioned in the report for 1904 (Ruthven, '06, pp. 11-12), the aim of the work was not simply to collect specimens, but also to study the relations of the plant and animal life (the biota) to their surroundings. The environment as well as the biota was considered from a dynamic standpoint, and an effort was made to analyze the environment in order that the dominant conditions and processes of which it is composed might be recognized, and their laws of change be perceived and formulated. To resolve such a problem as this must of necessity require more time and detailed investigation than the possibilities of a few months work will permit, and yet it is equally evident that preliminary work should be carried on from a genetic standpoint, because such a method determines upon what facts emphasis should be placed, and the broader and more general relations, as well as the details, are equally subject to a genetic and dynamic treatment. In preliminary work of this character, it is considered of special importance to discover, if possible, the order of the major biotic successions, because these successions must be clearly perceived before their causes can undergo adequate analysis. Our knowledge of causes generally lags far behind our recognition of successions.

Thus throughout the study of the Isle Royale biota a special effort-was made to investigate the genesis or successions of events. The environment has not been considered as limited to habitats alone, but also to include that greater unit, the geographic. To ignore this is to overlook the real background. It is believed that certain advantages are derived from this method of

work, which, although they may be recognized from other points of view, are likely to be subordinated to other facts. It should not for a moment be thought that this method is considered as the only one of approach, but it appears to have certain advantages which seem to justify its adoption. Nor should it be inferred that the genesis of the biota and the habitat is all that should be included in an ecological survey. The problem of succession is only one of several which clearly show the intimate relations and responses between organisms and their environment; others that remain to be investigated involve physiological and structural changes, and various modifications of habit and behavior of both plants and animals.

The ecological relations in the north are so different, in some respects, from, those farther south, that one may easily form an erroneous conception of the conditions under which such a preliminary investigation may be made. A very favorable condition for the work was the fact that practically all the time was devoted to it, instead of only occasional trips being made for the purpose, as is necessary with those busy with other duties. There are also certain advantages in being able to be in the field continuously, as a certain familiarity with conditions is acquired in the beginning, especially where the variety of forms is limited, which otherwise would involve time upon each visit. Although most of the members of our party were upon the island only during July and August, yet at this time those seasonal phenomena were concentrated which require much more, or several times that amount of time for their development farther south. The seasonal contrast is well illustrated when the summer season at the other extreme of the State of Michigan—500 miles away—is contrasted with that of Isle Royale. Such relations are further reinforced by the fact that the species and societies which are dominant in the various northern habitats are very much smaller in number than farther south. This necessarily simplifies the problem, and to a corresponding degree reduces the chances of error in anticipating biotic changes which are correlated with those of the environment. This is a relation of much importance in the study of succession. The writer was especially impressed with the relative *simplicity* of the problem of environmental relations and of the biotic succession upon Isle Royale, and has received further confirmation of the opinion that a tendency to exaggerate the complexity of the environment is prevalent.

An important aid in environmental analysis has been received from the effort to distinguish the major or geographic features of the gross environment from the minor habitat units which make up the mosaic or complex, although their mutual and genetic relations were not overlooked. Some of these relations have been well expressed by Montgomery in his comment on distribution ('06, p. 6) as follows: "And, as is always the case when the method has been consistent and scientific, the factors of distribution and the meaning of it will ultimately be stated in very simple form. These factors appear to us now to be enormously complex, but this is because we have hardly commenced to analyze them."

At this point it should be mentioned that there are certain difficulties which tend to confuse the field worker, which, if clearly understood, will often be of aid in ecological studies. In pursuing field studies, in addition to a knowledge of the species, one of the first essentials is a familiarity with the habits and habitat preferences of organisms; and further, there should be the ability to recognize how the dominance of one society is transformed into that of another. The lack of a sufficient power of constructive imagination makes the detection of such transformations very difficult, perhaps even impossible to some. This limitation almost completely restricts such a student to the purely descriptive phases of field ecology, because the explanatory phase lies beyond his grasp, although there remains for him a large field for useful and valuable activity in the study of habitat preference, and the mutual relations of the associated species in given habitats. A familiarity with the forms studied, under diverse circumstances, develops a certain perspective which is a great help in preventing confusion caused by minor and relatively insignificant details.

The limited time spent in the present investigation did not permit detailed studies of the interrelations of the organisms within the habitat, either in their relation to the environment or to each other. In local studies attention is usually given to detailed life histories rather than to a deliberate study of their interrelations as members of a society. The emphasis which is sometimes placed upon individual life histories would lead one to expect that such histories could be assembled and would give us the same result as if they had been studied as a society. But the points of view are so different that such a result, although theoretically possible, is unlikely to be obtained. At this time we only wish to emphasize the fact that both methods should be used to secure the best results. For example, in applying these principles to the study of birds, the life histories of the dominant species of a society might first be given special attention. Then the relations of the dominant species to others of the association and to the environment may be determined and later on the subordinate kinds considered. This will involve prolonged study in the field (and laboratory) of the habits of nesting, feeding, rearing of young, etc., as influenced not only by other members of the same species, but also by other species in the same habitat. The same general method is applicable to other groups of organisms.

3. Previous Biological Investigations upon Isle Royale. Previous to the investigations by the Museum party in 1904, (Ruthven and others, '06) there seems to have been very little study of the Isle Royale biota. Several collections of plants and animals have been made, but very little has been published about them. In 1848 W. D. Whitney was "ornithologist and botanist" for the government geological survey parties, and he published a list of the plants found. (Foster and

Whitney, '51, pp. 359-381). Incidental mention is also made in these geological reports of the collections of animals (Foster and Whitney, '50, pp. 17, 51, 201; Jackson, '49. pp. 423, 440, 441,); but, so far as known to the writer, no detailed reports were published.

So far as the vegetation is concerned, the most important source of information is the maps of the Ives Linear Survey. Here the general character of the forest, the extent of the swamps, and the underbrush are indicated. Mr. Henry Gilman ('73), of Detroit, made two visits to the island (one of which was in 1873), and his botanical and ethnological collections were presented to Columbia and Harvard Colleges. In 1890 Mr. F. E. Wood made a collection of plants from the vicinity of Rock Harbor and presented them to the herbarium of the Botanical Department of the University of Michigan; and in 1901 W. A. Wheeler ('01) published a short paper on some plants taken on the northeast end of the island.

The invertebrate fauna found in the deep water off Isle Royale was examined by Smith in 1871, and a list of Coleoptera from Isle Royale was published by Hubbard and Schwarz ('78). The writer has recently published a paper on certain phases of the problem of succession, as illustrated by the birds upon Isle Royale. This paper, with some additions, is included in this volume. Detailed references to these papers will be found in the accompanying bibliographies.

From the above remarks, is it quite evident that very little attention has been given to the biological conditions of the island, and much remains to be done. In all probability other naturalists have visited the Isle, but I have not learned of their results.

4. Historical Note. The history of Isle Royale, since its cession by the Chippewa Indians in 1843, is, in brief, one of prospecting, mining explorations, fishing, summer resorts, and scientific surveys of the topography, hydrology, geology, and biology.

A general historical account is given in Lane's report ('08) on the geology of the island, and need be mentioned here only in outline. There is abundant evidence that in prehistoric times the Indians mined copper on the island. Within three or four years after the cession of the island to the United States, it was invaded by prospectors and explorers, so that by 1847, according to Lane, "the island presented perhaps as lively a scene as ever in its history." At this time the Linear Survey was made by William Ives. But this period of activity was only of short duration, for the decline was almost as rapid as had been the ascent, and by 1855 the "island was a desert once more, with no permanent inhabitants." (Lane). This passive condition of affairs lasted until the Lake Survey engineers arrived in 1867. This survey continued until 1871, during which interval explorations were somewhat revived, and continued for several years, only to be followed by another relapse and still another ascent in 1891, when a number of careful and detailed explorations were made for copper by means of the diamond drill. But this activity also ceased about 1892. A year later, and again in 1895, Dr. Lane visited the island for geological investigations.

The mineral sources are thus seen to have been the main attraction. The forest growth is too stunted and inaccessible to have merited the attention of lumbermen, although several timber prospectors were present during the summer of 1905. During more recent years the fishing and summer resort business have attracted some attention to the island, and have made it accessible during the summer through regular steamboat service. The climate, scenery and the fishing make the island very attractive as a summer resort, but it should be recognized that if the scenery is to be preserved the forests must be protected from fires, because reforestation is exceedingly slow on land with such a shallow soil. It is to be hoped that the geographic isolation may be a protection from such devastation, because the cool summer climate, the rocky coast, the forests, the picturesque scenery, and the surrounding Lake Superior, are natural features which should long remain attractive to summer visitors. If the interest in copper should revive permanently, the biota will become greatly modified, in which case some conception of the conditions upon the island in 1904 and 1905 will be preserved by these records.

[It may be of interest to note here that 86,000 acres of the island were for sale in the winter of 1908 for $150,000. Lane.]

5. Available Maps of Isle Royale. The available maps are not generally known to the public, and are therefore listed here, especially those which are of value from a biological standpoint.

1. The Ives Linear Survey Maps. Because of their large size (2 inches to the mile), and the details concerning the character of the swamps, the forest and the soil, this is the most useful map for the field. Photolithographic copies of the township maps, of which there are eighteen, may be secured for 25 cents each from the General Land Office at Washington, D. C.

2. The U. S. Lake Survey Chart of Isle Royale, (Catalog No. Sh.). This is very useful because it indicates the topography, in part by hachures, and gives the details of the coast, including soundings and the character of the bottom. A large tract of the interior, between lakes Desor and Chickenbone, is unmapped. This map may be secured for 25 cents from the Lake Survey Offices at Detroit and Duluth. An excellent chart of the entire Lake Superior basin may be secured from the same source.

3. Lane's Geological Map. Published by the Michigan State Geological Survey. It accompanies Lane's report ('98) on the geology of the island, and is on a scale of 5/8 of an inch to the mile.

4. Passage Island Topographic Sheet. This is the only sheet published by the U. S. Geological Survey which includes any part of Isle Royale, and it covers only the extreme northeastern end of the island. This may be

secured from the Survey for 5 cents. The contour interval is 20 feet, and the scale one inch to the mile.

5. An English land company is said to own much of the island, and has published a map on a scale of 7/8 of an inch to the mile. The agent for this company is R. R. Goodell, Houghton, Michigan.

II. THE BIOTA CONSIDERED BY STATIONS.

1. The Location of Field Stations in 1905. As a detailed survey of the entire island was impossible, it was necessary to select representative localities and conditions, or habitats, and to devote to these all available time for study and collecting. In order to make sure that these conditions were representative, considerable care was necessary in locating these stations. In general a Station, in the strict sense, stands for a region, while a Substation refers to a particular habitat, usually of relatively limited extent. The character and extent of a Substation, (or, as it is generally called, for the sake of brevity, a "station,") was determined primarily by the relatively homogeneous character of the conditions. Thus a "station," as the Balsam-Spruce forest (V, 4) for example, varied somewhat in its extent with different groups of organisms. In the case of birds it included a greater area than was necessary for many invertebrates, such as land snails, but in every case such a "station" is intended to enable one to determine what organisms were dominant and characteristic of such a sample situation.

Some such system of sampling is generally advantageous or necessary, and this is particularly essential in the case of a surveying party, in order to give definiteness and co-ordinated activity to their work, particularly if the results are to be made at all comparable. Of course some individual judgment is necessary in applying such a plan to different groups, but no more perhaps than is necessary to carry out any other comprehensive plan.

1. Location of Field Stations, 1905.

Station I. Light-house Peninsula, between Rock Harbor and the head of Conglomerate Bay, Sec. 26 and N. E. 1/4 Sec. 34, T. 66 N., R. 34 W.

Sub. 1. Lake and Bay Beaches.

Sub. 2. Natural Rock Clearings, N. E. 1/4 Sec. 26.

Sub. 3. Balsam-Spruce Forest, N. E. 1/4 Sec. 26.

Sub. 4. Tamarack, and Arbor Vitae Swamps, Sec. 26.

Sub, 5. Jack Pine Ridge, S. W. 1/4 Sec. 26 and S. E. 1/4 Sec. 27.

Sub. 6. Sphagnum-Spruce Bog, S. W. 1/4 Sec. 26 and S. E. 1/4 Sec. 27.

Sub. 7. Light-house Clearing, N. W. 1/4 Sec. 26.

Station II. Rock Harbor and McCargoe Cove Trail, Sec. 27, 22, 21, 20, 29, 30, T. 66 N., R. 34 W., and Sec. 25 and 26, R. 35 W., T. 66 N.

Sub. 1. Benson Brook and Ransom Clearing (outlet of Benson Lake), N. E. 1/4 Sec, 27 and S. E. 1/4 Sec. 22, T. 66 N., R. 34 W.

Sub. 2. Tamarack Swamp, S. W. 1/4 Sec. 22 and S. E. 1/4 Sec. 21, T. 66 N., R, 34 W.

Sub. 3. Rock Ridge Clearings (burned over), Sec. 21 and 20, T. 66 N., R. 34 W.

Sub. 4. McCargoe Cove, at end of Trail, N. E. 1/4 Sec. 26, T. 66 N, R. 35 W.

Sub. 5. Forbes Lake, N. E. 1/4 Sec. 28, T. 66 N., R. 34 W.

Station III. Western End of Rock Harbor, Sec. 28, 33 and 32, T. 66 N., R, 34 W., and Sec. 5 and 4, T. 65 N., R. 34 W.

Sub. 1. Small Island, S. E. 1/4 Sec. 32.

Sub. 2. In Harbor at West end of Island, Sub. 1.

Sub. 3. Bulrush Zone and Delta, Sec. 32, T. 66 N., R, 34 W.

Sub. 4. Trail to Sumner Lake, Sec. 33, T. 66 N., R. 34 W.

Sub. 5. Sumner Lake, Sec. 33 and 34, T. 66 N., R. 34 W.

Sub, 6. Southwest Coves of Rock Harbor, Sec. 5 and 4, T. 65 N., R. 34 W.

Station IV. Tobin Harbor and Vicinity, T. 66 and 67 N., R, 33 W.

Sub. 1. Scovill Point, Sec. 26 and 35, T. 67 N., R. 33 W.

Sub. 2. Island No. 14, Sec. 26, T. 67 N., R. 33 W.

Sub. 3. Bayou, North of Monument Rock Trail, N. W. 1/4 Sec. 34, T. 67 N., R. 33 W.

Sub. 4. Trail to Monument Rock, N. W. 1/4 Sec. 34, T. 67 N., R. 33 W.

Sub. 5. Clearing at Neutson's Resort (Park Place), Sec. 4, T. 66 N., R. 33 W.

Sub. 6. Small island in Tobin Harbor, Sec. 5, T. 66 N., R. 33 W.

Sub. 7. Head of Tobin Harbor, Sec. 7, T. 66 N., R. 33 W.

Sub. 8. Trail to Greenstone Range, Sec. 7, T. 66 N., R, 33 W., and Sec. 12, T. 66 N., R. 34 W.

Sub. 9. Mountain Top, Sec. 12, T. 66 N., R. 34 W.

Station V. Siskowit Bay, Lake and Vicinity.

Sub. 1. The Beach, (at camp), Sec. 32, T. 65 N., R. 35 W.

Sub. 2. Heath Zone and Beach, Sec. 33, T. 65 N., R. 35 W.

Sub. 3. Rock Clearing (at camp), Sec. 32, T. 65 N., R, 35 W.

Sub. 4. Trail through Balsam-Birch Forest, Sec. 32 and 31, T. 65 N., R. 35 W.

Sub. 5. Tamarack Swamp, N. W. 1/4 Sec. 32, T. 65 N., R. 35 W.

Sub. 6. Mouth Shore of Siskowit Lake, Sec. 31 and 32, T. 65 N., R. 35 W.

Sub. 7. Haytown Trail, from Siskowit Lake, West Line of Sec. 24, across Sec. 13, T. 65 N., R. 30 W., cf. Lane, '98, pl. XI.

Sub. 8. Arbor Vitae Swamp, at end of Haytown Trail, N. W. 1/4 Sec. 13, T. 65 N., R. 36 W.

Sub. 9. Outlet of Siskowit Lake, N. W. 1/4 Sec. 36, T. 65 N.,. R. 36 W., and Sec. 31, T. 65 N., R. 35 W.

Sub. 10. Long Island Gull Rookery and Menagerie Island, T. 64 N., R. 35 W.

Sub. 11. Tamarack-Spruce Swamp, Sec. 33, T. 65 N., R. 35 W.

The following stations were examined by the Museum party during the season of 1904. Part of these Stations were re-examined and will be referred to by Station number and date, thus: Sta. I, '04.

Station I, '04. Clearing on the Shore of Washington Harbor, Sec. 29, T. 64 N., R. 38 W.

Station II, '04. Washington Creek, Sec. 29, T. 64 N., R. 38 W.

Station III, '04. Trail along the top of Greenstone Range (Desor Trail). T. 64 N., R. 37, 38 W.

Station IV, '04. Washington Brook, Secs. 28 and 32, T. 64 N., R. 38 W.

Station V, '04. Tamarack Swamp, Sec. 20, T. 64 N., R. 38 W.

Station VI, '04. South of Greenstone Range, Sec. 32, T. 64 N., R. 38 W.

Station VII, '04. Lake Desor, T. 64 N., R. 32 W.

Station VIII, '04. Western end of Siskowit Bay, Secs. 27 and 28, T. 64 N., R. 37 W.

Station IX, '04. Southwestern end of Minong Trap Range, Sec. 30, T. 64 N., R. 39 W.

Station X, '04. Washington Harbor, T. 64 N., R. 38 W.

2. General Characteristics of the Stations. In this section, I do not aim to give a completely correlated account of the biota of each station, but to present a general idea of the main characteristics of the various situations examined, and some of their common and representative plants and animals. Photographs illustrating the characteristics of the various "stations" will accompany this section, and should be consulted in connection with the text.

Station I, Substation 1. The Lake and Bay Beaches. This "station" includes the shore line from Rock Harbor, near the light-house, *Fig. 1*, to the head of Conglomerate Bay. The entire shore was not studied in detail, as most of the time was devoted to the beaches which are being formed at the heads of the coves and bays. Quite a variety of conditions are represented along this shore, due not only to the degree of exposure to the waves of Lake Superior, but also to the character of the rocky coast itself. All degrees of shore and beach are developed, from overhanging and vertical cliffs, *Fig. 2*, with bases strewn with large blocks lowered by sapping, to a shore line with a low angle strewn with shingle and gravel, and a sandy beach, as found at the head of Conglomerate Bay. In harmony with the dip of the rocks and the effect of the glacial ice movement upon the valley slopes, which tend to be gentle on the southeastern side, the corresponding shores of the bays and coves are usually at a low angle, except possibly where faulting has taken place, or a wave cut terrace has been developed. The northern sides of the bays are comparatively abrupt, and there is thus a tendency for the cliffs to occur mainly upon the northern slopes and shores. The larger bays are the submerged portions of the valleys, mark the location of the less resistant rocks, and are inherited topographic features; but many of the minor coves and the rocky headlands have been carved by the activity of the present lake. The beaches are only developed at the heads of the coves and bays, and are very largely composed of shingle and gravel. The only extensive sand beach seen was at the head of Conglomerate Bay. The character of the material composing these beaches clearly shows its local origin, and emphasizes the isolation which prevents long shore transportation of such material. Thus only floating material is liable to extensive long shore dispersal, a significant fact that bears upon the dispersal of the snail life along the shore.

During severe storms, the wave action upon this coast is quite intense and even the waves of the summer storms are quite active, as may be seen by referring to *Fig. 3*. The blue deep lake water comes close up to the shore, so that generally no breaker line is developed off shore. In several places there are numerous reefs or islands (usually the isolated continuations of the rock ridges), which tend to break the force of the waves rolling in from the open lake.

No effort was made to study the life of the open lake, only the shallow water of the bays and coves being examined. The major environmental features of the coast are the Lower, Middle and Upper Beaches; but these are only differentiated clearly at the heads of the coves and harbors. The Lower and Middle Beaches are only seasonal expressions of the same phenomena, but ecologically they are fairly distinct.

The Lower Beach. This beach extends from the shallow water to the upper limit of the summer waves. The

submerged portion is not sharply defined above on account of the changes in level of the water surface, due to waves, the periodical and seasonal fluctuations, and the atmospheric pressure (seiches). In time there has been a downward migration of the entire beach zone, a tendency which is in part counteracted by the northward elevation of the land. This is the zone dominated by water, ice, and wave action. It is certainly a sharply defined tension line upon an exposed coast, which clearly suggests that it is not probable that many forms of animals have made the transition from fresh water to the land under such conditions. If we consider the shore habitats as including all stages from a rock cliff to the sand beach, the lower beach and the protected shores are the most favorable aquatic habitats upon such shores.

Upon the sloping rock, shingle, gravel and sand beaches is found a varied fauna. In winter, when the bays are frozen over, a calm is produced which must be favorable to the preservation of the aquatic life upon this stormy coast.

The general character of the sandy beach at the head of Conglomerate Bay is shown in *Fig. 4*. The life of the submerged portion of the shore is quite limited, except on the beaches and protected portions. The vegetation consists of algae, which grows in moderate abundance, though not luxuriantly, as found about the Gull Rookery (V, 10), or at the fishermen's camp at Rock Harbor, a. fact which suggests that the abundance of suitable nitrogenous material is much greater in such places than in the open lake water. With the development of the fall storms, Mr. J. A. Malone states that these rocks (V. 10) are washed free of the algae, thus evidently necessitating a repopulation of these surfaces each season.

The characteristic fauna secured in the shallow water shore margins were the snails, *Limnaea stagnalis*, *L. emarginata*, and *Physa sayii*. A small fish, the Miller's Thumb, *Uranidea franklini*, is also fairly abundant and characteristic of this shore.

Upon low rocky shores beach pools, *Fig. 5*, are occasionally found which, when favorably located, are supplied with water by the ordinary summer waves, otherwise by storm waves and rains. The precarious existence of life in such places is indicated by the general type of the fauna, which shows exceptional power of locomotion, usually coupled with a short life cycle. The immature stages of insects are rather characteristic, as shown by nymphs of the water boatmen, *Corixa*, dragonflies and Caddis fly larvae. Water beetles were represented by *Rhantus binotatus*, and the snails by *Limnaea emarginata* and *Planorbis parvus*. The Gulls and Spotted Sandpipers should be mentioned as birds which frequent these conditions.

The Middle Beach. This beach occupies the strip of shore over which the winter waves retreat as they fall to the upper summer storm limit. It is thus seen that the Middle Beach is only a temporary or summer abandonment of part of the upper shore, which is repeatedly claimed by the winter waves. In summer this strip is exposed to denudation; in the fall and early winter, to the fury of the waves, and, later, it is covered with ice. Driftwood and debris tend to lodge here and to accumulate. It is an important region of biotic invasion for land forms. Beach pools are also developed in this area, upon the abandoned wave cut terraces of earlier lake levels. Upon the cliff faces, sloping rock shores and shingle beaches, little is found that is favorable to life, but upon the protected sand of the Middle Beach, relatively favorable conditions for many organisms are found during its period of exposure. The character of the substratum of the Middle Beach varies from rock to shingle, gravel and sand.

The characteristic features of the vegetation, where the wave action is not too severe, are the fruits which are washed ashore by the waves, together with certain annuals and lichens. The fauna varies with the character of the conditions. The open character of this beach and the relative abundance of animal food makes such situations favorable for spiders, of the genus *Pardosa*. The same open character makes the shores a favorable patrol for certain butterflies, particularly *Basilarchia arthemis*. Insects and snails washed ashore by the waves also characterize this habitat.

The Upper Beach. This part of the beach is beyond the reach of the waves, and forms the transition between the open beach area and the inland forests. The width of this belt varies greatly with the gradient of the shore. Where the beach is continuous with a more or less bare rock ridge, this habitat may be rather extensive and ill defined, as at the ridge south of the light-house (I, 2), but when it borders a depression, as at the head of the rockbound coves, or where a beach is well developed, this transitional zone is more clearly defined and limited. When this beach is wide and grades into the rock openings, as in *Figures 6 and 7*, the crustaceous and foliaceous lichens grow upon the rocks; but If soil accumulates, as is shown in *Fig. 6*, the *Cladonia*—Bearberry society becomes established, and includes some annuals, such as *Solidago*. A limited variety of insects, especially ants, characterize such conditions. Wlien adjacent to the forests, in depressions, this beach is generally bordered by alders, some aspens and young trees.

The fauna consists largely of insects, such as butterflies, certain dragonflies and Hymenoptera, which frequent the open places on wing.

Station I, Substation 2. Natural Rock Clearings. This Station consists of two small rock openings, one just north of the light-house, and the other south of it, on the north side of the entrance to Tonkin Bay, only a short distance from the light-house. They were both park-like avenues extending along the ridges, largely bordered by the Balsam-Spruce forest.

The north ridge will first be considered. The general character of the opening is well shown in *Fig. 8*. The

White Spruce, Balsam, Paper Birch and Arbor Vitae bound the ridge on either side, within which there is a distinct heath zone of Bearberry and patches of *Cladonia*, while along the central aisle there is a shallow residual and humic soil on the almost bare rock. The south slope is rather gradual, but the north slope and the end of the ridge at the shore form a cliff.

The fauna of this location was limited. Snails were found among the *Cladonia*, such as *Vertigo*, *Zonitoides arborea* and *Puramidula cronkheitei anthonyi*. This was also a runway for Hares.

The south opening or clearing is situated on a low sandstone ridge which slopes down to the beach, and is thus in marked contrast to the north clearing, which ended in a cliff. This gradual slope beautifully illustrates the transition from the bare rock beach, through the moss and lichen zone, to the *Cladonia*, Bearberry and *Solidago* flora, (*Figs. 6 and 7*), and on to the crest of the ridge, *Fig. 9*, with its dominance of *Cladonia* and Bearberry. The severity of the conditions is furthered by the weathering of the sandstone into thin scale like layers, about 1/4 of an inch thick, which become loosened and slide down the slope. Thus a vegetation may become fixed to the rock surface, but not permanently to the slope. These scale like fragments are shown in *Fig. 6*. That a greater amount of vegetation would grow here, if the soil were allowed to accumulate, is shown in *Fig.* 6, where such conditions have been produced by the presence of a larger boulder. The *Cladonia*-Bearberry avenue extends along the crest of the ridge, *Fig. 9*. This is bounded by large Jack Pines near the beach, and farther from the shore by the Balsam-Birch forest.

The zonal distribution on the ridges is quite marked; the central strip is composed of *Cladonia*, Bearberry, *Solidago*, and *Linnea borealis*: while this is bordered by a shrub zone composed of *Juniperus nana*, alder, Arbor Vitae and young Balsams, and a bordering tree zone is composed primarily of Balsam. When once the shade of the forest, especially that of the Balsams, encroaches upon the *Cladonia* society, the Bearberry first becomes reduced in number, and is then replaced by *Aster macrophyllus*, and a moss from the forest floor. The former is perhaps the most striking and characteristic shade plant upon Isle Royale. The succession, or order of invasion on the ridge, from the *Cladonia* to the Juniper and into the Balsam forest, is thus briefly shown in the transverse section from the central ridge to its margin. This zonal phenomenon, as will be seen later, is only an expression of the relative rates of invasion, and is not a phenomenon separate from the normal succession.

The soil upon the top of the ridge is about two inches deep. It is residual, supplemented by the humus from a now extinct crustaceous lichen society (that of the *Cladonia*-Bearberry), and at its margins by the Juniper, Balsam, Birch and Jack Pine leaves and debris and further, to an important degree, by the excrement of the numerous Varying Hares which frequent the rock ridges.

In the case of rock ridges which en tend down to the beach and are thus in direct communication, with the shore drift, conditions exist which show how such ridges may have been invaded by lichens from two sources—the shore drift and the exposed beach itself—because of the continuity of the rock habitat. Of course, possibly another origin is to be found in the fact that this ridge was itself once a beach. Ants, grasshoppers and a few other insects characterize this fauna, which is limited in variety, but fairly abundant in individuals. The Hares are abundant and form distinct paths or runways, as shown in *Fig. 9*.

Station I, Substation 3. Balsam-White Spruce Forest. This station included the forest traversed by a blazed trail from near the southeastern part of Sta. I, 2, and extended northward to the clearing about the light-house (I, 7), and beyond it to the north rock clearing (I, 2). Most of the region occupied by the forest is of low relief, with an occasional low rock ridge or hill. The dominant tree was the Balsam Fir, with much Paper Birch and White Spruce. Where the forest was very dense, especially if due to the number of Balsams, the ground was densely shaded and there was almost no herbaceous ground cover; but wherever there was a small opening, due to a fallen tree, or where one had been cut down, there was an abundant growth of Large-leaved Aster and White-flowering Raspberry; and it was in the midst of such conditions that young Balsams abounded. These were very characteristic plants in such conditions. In most cases a thick layer of humus covered the ground, but the tree growth was of small size. The common size of the Balsam was about 4 inches, the larger ones reaching 8 to 10 inches. The Birches averaged larger, usually about 6 inches. No evidence of burns were seen, but probably many trees have been cut from this vicinity, because of its proximity to the light-house, and the former Indian campground now occupied by the fishermen. The Balsam appeared to become dominant at this place, as more young trees of this species were seen than of any other.

The fauna found in this forest was rather limited, and doubtless great numbers of the insects which were taken in the clearing about the light-house (I, 7), bred in the adjacent forests. This is particularly true of the Cerambycids and other wood infesting beetles, the wood-boring Hymenoptera (*Urocerus*), and their parasites. In addition to such species as feed upon Balsam, White Spruce and Paper Birch and their associated vegetation, there were those animals which are dependent upon the shade, moisture, soil, decaying logs and other features associated with forests. To this class belong certain insects which frequent decaying timber or the fungi growing upon them, and the earthworms of the soil, the ground beetles or Carabids, and the ground-inhabiting spiders, Lycosids. Some of the birds found were: Chickadee, Red-breasted Nuthatch, Golden-crowned Kinglet, Whitewinged Crossbill and Purple Finch.

Station I, 4. Tamarack and Arbor Vitae or White Spruce Swamps. This swamp is located in one of the valleys near the head of Tonkin Bay, and extends back from the bay about one-fourth of a mile. It begins just back of the beach and is bordered by a strip of Alders, Paper Birch, Mountain Ash, young Balsams and White Spruces. The rock walls of this valley are about 75 or 100 feet apart and are well shaded and covered by lichens and mosses, the south surface largely by lichens alone. Back of the marginal beach strip above mentioned, comes the dense growth of very large Arbor Vitae trees, intermingled with numerous large fallen trunks, partially decayed and covered with a dense growth of mosses. In the dryer places the ground is covered with a dense litter, and a thick damp or wet mass of mosses, but no pools of water. The undergrowth is composed of young Balsams, Birch and Ground Hemlock, *Fig. 10*.

Proceeding farther up the valley, the Arbor Vitae is replaced by Balsams and Paper Birch; the forest is more open, and the amount of moss on the ground is greatly reduced, and is replaced by a growth of Large-leaved Aster and large quantities of Ground Hemlock—all of this vegetation being indicative of mesophytic conditions. In this region there are scattered pockets or small pools of water containing dogwoods. Still farther up the valley the Balsams and Arbor Vitae continue and Tamaracks are added, but no standing water was found. The valley turns, and returns to the bay on the north side of the ridge which bounds the Arbor Vitae swamp on the north; the entire basin is thus somewhat horseshoe shaped. The returning section becomes almost pure Tamarack and contains numerous small pools of water. The conspicuous feature of this environment is its jungle-like character, the rapid accumulation of litter and humus, and the damp substratum.

The fauna of such a bog is surprisingly limited in variety and amount. A few shells were found, as *Pyramidula cronkheitei anthonyi* and, in the small pools, *Pisidium*. The large numbers of Mosquitoes and Black Flies made up for all deficiencies, and were almost intolerable. The birds frequenting this forest were the Red-breasted Nuthatch, Black-throated Green Warbler and Chickadee.

Station I, 5. The Jack Pine Ridge. This ridge is located near the mouth of Conglomerate Bay, on the north shore. Some general idea of the location is given in *Fig.* 11, which is a view looking toward the head of Conglomerate Bay. Just back of the beach, on an outcrop of conglomerate, was a small rock clearing, with *Cladonia*, *Juniperus nana*, and a wild rose. From here the trail extended through a narrow strip of forest, composed of Balsams, White Spruce and Arbor Vitae, with an undergrowth of Balsam, Mountain Alder, and a ground cover of Large-leaved Aster, and passed on through a belt of young growth of Birch, with the usual White-flowering Raspberry and Large-leaved Aster, *Fig. 12*, and up the face of an escarpment to the crest of the ridge, which had a height of about 100 feet above the lake level. From the abundance and characteristic growth of Jack Pines on this ridge, the station takes its name. Part of the ridge has been burned over, as was shown by the burned and fallen timber, but the part to which our attention was given was apparently an original growth. The Jack Pine was scattered, and largely occupied the depressions and the larger crevices. The ridge is fairly flat topped, but is occasionally broken by transverse gullies, which contain Aspens, Birches, etc. The surface of the lava has weathered but little in some places, the original *roche moutonées* surface being very clearly preserved, and the planed glacial surface but little eroded. Near the escarpment, however, disintegration and decomposition have been much more active, probably influenced in part by lake waves at former levels, thereby developing a talus slope, composed of angular blocks, and in some places forming a stony soil. All intermediate stages are found between these two extremes. In addition to the large amount of bare rock surface, and that covered by only a thin layer of soil and vegetation, the shallowness of the soil is further evidenced by over-turned trees, *Fig. 13*. This soil is of residual and organic origin, the crustaceons lichens and the Cladonia-Bearberry society, and later the Jack Pines, having contributed much to its formation. The excrement of the Hares has also been an important factor in soil formation, and that of the Lynx also, though to a much less degree.

The process of weathering must be relatively rapid on this ridge, because it is exposed to the winds at all seasons of the year, and to the marked seasonal and daily changes of temperature. The heat of the noonday sun is excessive, and the radiation from the nearly bare rock must be rapid, as it also is at night, so that the various influences consequent to temperature changes are allowed full play. Weathering is further favored by the irregularities of the surface, and the crevices, which allow the accumulation and downward conduction of this moisture, thus permitting the prying action of ice.

In general, the succession of plant societies on this ridge appears to be about as follows: Lichens are the pioneers on the rock surface, and these may be of several species, *Umbilicaria*, and the crustaceous and foliaceous forms. As a soil develops in the crevices or on the surfaces, these are followed by *Cladonia*, Bearberry, *Sibbaldiopsis tridentata*, *Solidago*, *Diervilla diervilla* (Bush Honeysuckle); and later, when the soil becomes deeper, by *Amelanchier*, *Primus pennsylvanica* (probably dispersed to these ridges by birds) and *Juniperus nana*. The presence of the Small-toothed Aspen, willow and an occasional Birch probably indicates the next society. In the shade of the Birches and Jack Pines *Solidago* and *Aster macrophyllus* occur, if sufficient soil is developed. From the character of the vegetation in the ravines which traversed the ridge, and upon the talus slope toward the bay, it is apparent that the next society tends to be that of Birch and Aspen with some Balsam, Pennsylvania Cherry, Mt. Alder; and a ground cover of Large-leaved Aster, Large-flowering Raspberry, Ground Cornel and *Lycopodium*. It is clearly seen that among these there are several elements of the

Balsam, White Spruce and Birch forest society, which tends to ultimately possess the ridge.

The fauna of the ridge is quite diversified, and there is a general faunal correlation corresponding with these successions of the vegetation. Thus during the Lichen-Heath stage, ants and spiders, certain shells, and grasshoppers are abundant. As the soil becomes thicker or the crevices deepen, a subterranean fauna, consisting of myriapods, earthworms, etc., develops. As shrubs and trees encroach in patches, the animals frequenting the open tend to perpetuate themselves mainly at the open margins. From this condition on, so far as the fauna is concerned, it is largely a question of an "opening" or a forest environment. So long as this habitat remains open, the grasshoppers, ants, spiders, butterflies, flies, and certain Hymenoptera, Hares and Bats are characteristic, and this condition tends to continue as long as the trees are scattered. The *Cicada* is very characteristic of the Jack Pine stage, and although it occurs elsewhere in young Birches it is not so characteristic as on these hot ridges. With the advent of the Balsam-Birch society, which is slowly encroaching upon the ridges, the forms frequenting the open will disappear, or linger in the open spots where local conditions have retarded the advance of the forest. Only a few birds were seen here, but Hares had been numerous, as was shown by the large amount of excrement, and there was similar evidence of the occurrence of the Lynx. A bat was flushed from under a stone at the edge of the escarpment.

Station I, 6. Tamarack-Spruce Bog. This is a very small bog located at the base of the north slope of the Jack Pine Ridge (I, 5), and roughly estimated as about 250 by 300 feet in extent. The central part is covered with sphagnum, Cassandra, and a scattered growth of Labrador Tea. Widely scattered throughout the bog occur Tamaracks and Black Spruces, small Birches, Dwarf Cranberry, Cotton Grass and alders. No standing open water was found in this area, nor was the bottom quaking. Bordering the sphagnum zone is one of alders, willows, and a tall grass which merged into a zone of Tamaracks, willows, alders, Cassandra and Balsam, *Fig. 14*. Along the western end a narrow strip of water, a few inches deep, was found, which flowed through a ravine across the ridge. Along this outlet the deeper soil and moisture has permitted the development of Balsam, Birch, Small-toothed Aspen, Mt. Maple, Ground Hemlock, Ground Cornel, Large-leaved Aster, and a few Black Ash trees.

The fauna, like the vegetation, was not studied in detail, but the following general relations were observed. In the open central Sphagnum-Cassandra society were numerous large ant nests. A Toad was observed here; and the following birds: Golden-crowned Kinglet, White-throated Sparrow, Cedar Waxwing, and Black-throated Green Warbler.

Station I, 7. Light-house Clearing. This was a small clearing which has been, made about the Light-house: it connects by a path to the fishing camp on Rock Harbor. It covers about half an acre, and was originally, in all probability, a Balsam and Spruce forest like the surrounding forest. A sod covered much of the ground, and there were numerous weeds, of which the Cow Parsnip umbels furnished excellent places for collecting Syrphid flies, Cerambycid beetles and Hymenoptera.

The fauna of this clearing consisted largely of insects which frequent flowers, and butterflies which fly in open places; but a few animals were found about the Light-house itself. The Chipping Sparrow bred in this clearing. *Fig. 1*.

Station II. This station included the clearing at the mouth of the stream which drained Lake Benson, and which we called Benson Brook, and followed the blazed trail to Sargent Lake, and on to McCargoe Cove. The clearing at the beginning of the trail at Rock Harbor marks the site of the former settlement called Ransom on the old maps.

Station II, Substation 1. Ransom Clearing and Benson Brook. The clearing was occupied by scattered Small-toothed Aspens and Birches, and was well sodded with grass and Red Clover. Our attention was called to this locality because of the great number of Garter Snakes (*Thamnophis sirtalis*) which were found there. These snakes were very abundant in a small area east of the mouth of the brook, in a rank growth of grass and among some rails.

The brook contained but little life, although it was carefully examined near its mouth and farther back where the trail crosses the brook. Only a few dead *Physa* were found, and a young fish, at the mouth of the brook.

Station II, Substation 2. Tamarack Swamp. This is a long swamp which is crossed by the trail, and which contains a scattered tree growth of Tamaracks, Black Spruces and Arbor Vitae, a dense shrub growth of Cassandra and Labrador Tea, and a ground cover of Sphagnum and Pitcher Plants. While no water was seen on the surface, it was a wet swamp.

This locality was only examined for birds and mammals.

Station II, Substation 3. Rock Ridges. This station number is given to the open rock ridges which were crossed by the trail between II, 2 and Sargent Lake. These ridges have been burned over and are largely destitute of soil and the *Cladonia* growth usually found on other rock ridges. Small-toothed Aspens generally border these ridges which have a northeasterly southwesterly direction. The heat during the middle of the day is excessive. The scant vegetation which grows in some crevices and depressions in the rock leaves an open area which is decidedly favorable for grasshoppers. In some places they were exceedingly abundant and many ridges were examined almost solely for their grasshopper fauna. In the dry soil on one ridge an anti-lion larva was found in the dust at the base of its funnel, and a large Garter Snake was taken on another. The grasshoppers found here were *Chloealtis conspersa*

and *abdominalis*, *Circotettix verruculatus*, *Melanoplus alaskanus* and *fasciatus.*

Station II, Substation 4. McCargoe Cove. This station simply marks the location of the end of the trail, and the cove where a few molluscs were found. There were dead shells of *Anodonta grandis footiana*, which were abundant at the edge of the water. Here upon the low rocky shore were also found specimens of *Limnaea stagnalis*.

Station II, Substation 5. Forbes Lake. The examination of this small lake was mainly confined to the north shore, as the south shore is rocky and steep, with Birches and other trees growing down to the water. The north shore has been largely burned over, and is being replaced by Birches and Small-toothed Aspens, which are now dominant; the undergrowth consists of alders and the abundant Large-leaved Aster. The water in the lake is brownish. At the western end there are White Waterlilies, near the shore Yellow Waterlilies, *Caltha palustris*, *Equisetum*, and farther back Cassandra and alders, Tamarack, Arbor Vitae, and Black Spruce.

On the north shore a rocky point projects into the water, and east of this along the shore is a floating sphagnum bog, ranging in width from about 40 to 100 feet and containing Pitcher Plants, Low Cranberry, Buckbean, scattered sedges and Blue Flags, and a shrub growth of Cassandra, Labrador Tea and Wild Rosemary. Scattered trees of Tamaracks, Arbor Vitae, and Black Spruce grow to the edge of the water. Water stands in the small depressions over this bog.

The fauna was not studied in detail, but the forms collected were as follows: The spider, *Pardosa glacialis*, with egg masses, was found running about over the wet sphagnum; a dragonfly, *Aeschna*, was seen on wing; two species of grasshoppers were found in the wet Sphagnum; *Melanoplus extremus* and, in the wetter places, nymphs of *Mecostethus lineatus* were quite abundant. There were also great numbers of mosquitoes and Black Flies. Upon some driftwood near the end of the lake was found *Physa gyrina* (No. 71 A.). Yellow Perch were so abundant in this lake that locally it is called Perch Lake. A Canada Jay was seen in the top of a tree.

Station III. Western End of Rock Harbor. This station was intended to include those localities near the western end of Rock Harbor.

Station III, Substation 1 and 2. Small Island. The general character of this island is shown in *Fig.* 15. This is a small, rocky, wooded island, the trees consisting of one large White Pine, about 14 inches in diameter, Arbor Vitae, Birch, Balsam, and White Spruce, the dominant ones being the Balsam, Arbor Vitae and Birch, with a shrub growth of Mt. Alder, Willow, Nine-bark, Mountain Ash, *Amelanchier alnifolia*. Upon the rock occurred *Cladonia*) Bearberry, and Low Juniper, arid toward the western end of the island, where the trees shade the ground, grew *Lycopodium complanatum*, mosses and *Clintonia borealis*.

Of the fauna, the bird life only was examined; Cedar Birds and a Song sparrow nested here, the former being quite abundant.

The submerged western end of this island formed Station III, 2. The bottom was composed of sand and angular rocks. In the shallower water *Anodonta grandis footiana* valves were found, and live animals in water about 18 inches deep. These rocks also furnished a number of *Limnaea stagnalis*, and a dead specimen of *Planorbis bicarinatus*. A few scattered rushes (*Scirpus*) grew at this place.

Station III. Substation 3 and 6. Head of Rock Harbor. These stations include the delta at the mouth of the largest stream flowing into the Harbor, Station 3, and the sandy and rocky shallow water zone extending from III, 2 around the head of the Harbor, Station 6.

The general character of the delta, III, 3, region is shown in *Fig. 16*. This small delta had been formed by a small sluggish brown-stained brook, 15 or 20 feet wide, which enters the Harbor at this point. The channel contained a growth of *Vallisneria spiralis*, *Potamogeton crispis*, and the banks supported a growth of sedges, *Lycopodium complanatum*, *Clintonia borealis*, alders and Mountain Ash. The surface of the delta is strewn with driftwood and other plant remains, upon a clean sandy bottom. Nearer the shore, upon a muddy bottom, were found an abundance of Amphipod crustaceans, *Hyalella knickerbockeri*, *Gammerus limnaeus*, and the small bivalve molluscs, *Pisidium*. The fresh water sponge, *Spongilla lacustris*, was found here, and water striders, *Gerris remigis*, were found on the surface. Individuals were abundant, so that the fauna is relatively varied.

Substation 6 included the southwestern coves of the Harbor. The bottom was rocky, and covered in places with much sand; the water was shallow and contained, near the shore, many patches of rushes, *Scirpus* and *Equisetum*. *Anodonta grandis footiana*, *Limnaea stagnalis* and *Pisidium* were the characteristic molluscs, and a few fish were found. The protected character of the shore is noteworthy, as no beach is developed, because the coves are protected from the heavy lake waves. Another characteristic feature is the sand bottom. This sand is carried toward the head of the Harbor by the currents. Even at higher Lake levels, this Harbor was sandy, as is shown by the sand banks on the north shore, and these are being re-worked by currents and waves and carried up the Harbor. The spit developing from the south shore, *Fig. 17*, illustrates this.

Station III, Substations 4 & 5. Sumner Lake and Trail. The trail to Sumner Lake (III, 4), begins on the south shore of Rock Harbor and extends south about one-half mile to Sumner Lake. It passes through a second growth, of Birch and Aspen (which has followed a burn), a small Arbor Vitae swamp, over a rock ridge to the north shore of the lake, where there are a few large Norway Pines, from 12 to 15 inches in diameter, and a few White Pines. But little attention was given to the life along the trail, although a few observations on the bird

life were made, and some mammals were trapped. However, Sumner Lake proved to be such an interesting locality that attention was given to it more especially than to the trail. This lake has many of the characteristics of a large lily pond, because the White Waterlilies and Potamogetons form such a wide belt around the lake. *Figs. 18-23*. In passing from the interior of the lake toward the shore, the following zones of vegetation are found: The bulrush zone, which is well developed, with its denser growth about the eastern end; then the Yellow Water-lilies, followed by the dense sedge zone which produces a substratum. In the eastern and western ends of the lake the water gradually shallows; but on the sides the change is more abrupt, thus interrupting the shallow water zone of sedges, as shown on the north shore, *Fig. 23*. This encroachment of vegetation upon each end of the lake is very marked, and is much more extensive at the eastern end, where the lake is drained into the head of Conglomerate Bay by a small brook. The encroachment at the western end of the lake is well shown in *Fig. 19*. A partial view of the eastern end of the lake is given in *Fig. 18*. The sedge zone contains a variety of plants, including several orchids, Iris, Pitcher Plants, Buckbean, scattered *Eriophorum* and Sphagnum, Cassandra and Andromeda. The substratum is quaking and sinks several inches below the water level with the weight of one's body; occasionally small but deep holes are found through this substratum, and care must be taken to avoid them. This zone is very broad and contains an abundance of life. Outside the sedge zone occur alders and Tamaracks, which border the forests at the base of the slopes.

The fauna of the open Waterlily, Bulrush and Potamogeton zone consists of insects flying over the water, such as the dragonfly, *Aeschna* and the leaf beetles *Donacia*, which abound, especially about the Yellow Waterlilies. On the surface film were water striders, *Gerris marginatus*, and whirligig beetles, Gyrinidae. Sticklebacks were abundant, and are quite characteristic of such waters, as is another small fish. Loons were frequently seen here, and also a Hooded Merganser. Toward the outer margin of this zone where the lilies are often closely matted on the surface, the insect life and the surface film fauna are the most abundant. A live mussel, *Anodonta grandis footiana*, was found on the bottom; and the snails, *Planorbis companulatus* and *parvus*, were found in small pools in this sedge zone. The bottom in this vicinity, and that bordering the water margin of the ridges, is covered with a mass of partly floating debris, the appearance of which suggested to Wood, who first observed it, that something had exploded and scattered the strands of debris about the surface. It is not improbable that the formation of marsh gases will adequately explain this phenomenon, (Cf. Penhallow, Science Vol. 22, 1905, pp. 794-796).

The dragonflies were *Enallagma hageni*, *Aeschna*, *Somatochlora shurtleffi*, and *Lucorhina proxima*, the last being very abundant.

Where the sedge zone was absent, as at our raft landing at the end of the trail, an abundance of needles, leaves and twigs from the overhanging conifers and hardwood had accumulated art the shore, and were stained almost black. The water of the lake is brownish. At this point a number of invertebrates were taken, including shells, leeches, insects, etc.

Station IV. Tobin Harbor and Vicinity. As very little time was spent at this station, the description will be correspondingly brief. Tobin Harbor is a deep, narrow, protected bay, similar to that at the head of Rock Harbor, but narrower. The adjacent hills are forest covered, largely with Aspen and White Birch. In the vicinity of Neutson's Resort there is a large, cleared area. Mattson's resort is located on an island in this Harbor. The most marked scenic feature of the Island, Monument Rock, is on the north side of Tobin Harbor.

It is a noticeable fact that many of the low islands in Tobin Harbor, and especially those near its eastern end, are clothed with vegetation close to the edge of the water. They are thus in marked contrast with the islands along the southern shore, and to the various points of rocks which project into the water.

Upon a small island, Number 14 on the Land Office map, were found small rock beach pools, just above or near the height of the usual quiet weather waves. The water in one was about a foot in depth and contained a very small amount of algal growth. In this pool were found water striders, *Gerris remigis*, a few other insects (No. 30), and small tadpoles. In another small pool about 10 inches above lake level, and with a temperature of 77° (the Harbor water having a temperature at the time of 50° F.), were many species of *Limnaea catascopium* and a few adult *Physa*. Algae were only seen in the crevices.

Station IV, Substations 1 and 2. Rock Pools and Scovill Point. Scovill Point is an almost bare, glacially planed, narrow and low rock ridge, projecting out into the lake. Numerous small faults occur on the sloping southern side, and these, supplemented by the waves, etc., have produced rock pools. In one case a long row of pools occurred along the line of the fault. The presence of tadpoles about an inch long would suggest that these pools have some duration. The higher summer waves might also reach many of these pools. Water striders, *Gerris*, are abundant upon the surface, and a large deep ravine, near the lake level, contained Sticklebacks, but no shells were observed in any of these pools.

Station IV, Substation 3. Bayou East of the Monument Rock Trail. This is a very small pond which is connected with the Harbor by a small stream just large enough to admit a row boat. It illustrates the last stage of separation of the valleys from the Harbor, as only a very slight fall of the lake level would completely isolate it. In this particular case the outlet is on the south side, and not at one end as is usually the case. The central part of the pond is open water and is surrounded by an almost complete zone of Yellow Waterlilies, and a sedge zone

containing several low shrubs. The Waterlilies were badly infested by a small leaf beetle, *Galerucella nymphaea*; larvae, pupae, and freshly emerged beetles were taken. A few dead shells of *Anodonta marginata* and one of *Limnaea megasoma* (the only specimen taken upon the island) were secured here. An extensive suspended flocculent mud covered the bottom, so that molluscs could not obtain a foothold. At the western end of this pond innumerable small tadpoles formed an almost compact pavement upon the bottom at the edge of the water. A few dragonflies were seen, but were not captured.

Station IV, Substation 4, 8 and 9. Forest on the Greenstone Range. These three stations are combined because they are related to the forest occupying the Greenstone range. The trail to Monument Rock (IV, 4) begins on the north shore of Tobin Harbor and extends northwest about one-half mile to Monument Rock. The forest is dense and is apparently a second growth of Balsam, White Spruce, Birch and Aspen, with underbrush of Mountain Alder, Mountain Ash, Ground Hemlock, and a ground cover of Few-flowered Cranberry, *Clintonia borealis*, *Linnea borealis*, and Wild Sarsaparilla. In the moist places was found Ground Cornel, *Aster macrophyllus*, an *Equisetum*, *Lycopodium*, and, in wet places of the swamp traversed, the Buckbean and Skunk Cabbage. For some distance on the slope down from the base of Monument Rock occur large blocks which are covered by a dense mat of mosses, and the ground is covered with a thick layer of humus, so that the general appearance of the vegetation is that of a mesophytic forest.

The trail up the Greenstone (IV, 8), begins at the mouth of a small brook at the head of Tobin Harbor, and follows the crest of an open burned over ridge southeast for about half a mile. This ridge contains a scanty growth of *Amelanchier oligocarpa* and *alnifolia*, *Prunus pennsylvanica*, Jack Pine, wild rose, *Solidago*, Bearberry and Yarrow. From the end of this ridge a valley crosses to the north and contains large Aspens, Tamarack, Norway and White Pine, and an underbrush of Speckled Alder and Ground Hemlock. After crossing this depression, the trail ascends the slope and crosses the burned ridges where there is a growth of Birch and Aspen. The slope increases more abruptly as the crest of the Greenstone is approached. This is the vicinity of an old signal station and has an elevation of about 460 feet, according to the Lake Survey. This forest along the crest comprised Station IV, 9. The large trees stand above the surrounding second growth, on the burned area, and can be seen for some distance. The Balsam, Birch and Quaking Aspen are the dominant trees, the Balsams reaching a diameter of about 10 to 12 inches, and the Birches and Aspens about 12 to 15 inches. The shrub growth is composed of Mountain Maple, Ground Hemlock, and the Few flowered Cranberry, the ground cover of *Diervilla diervilla*, Large-flowering Raspberry, *Aster macrophyllus*, *Clintonia borealis*, *Linnea borealis*, *Lycopodium*, Wild Sarsaparilla and Brake Fern; the White and Black Spruces being only occasionally seen. This forest produced dense shade. Fallen timber is abundant in places, but no signs of fire were observed. This ridge was bounded on the north by a cliff of perhaps 20 to 30 feet, below which was a long talus slope covered with Birch, Aspen and Balsam. From the top of this ridge there is a splendid view to the north. The crest was followed west to a small open burned area where *Diervilla diervilla* and Large-flowering Raspberry were abundant. The leaves of the latter were badly perforated by the abundant grasshoppers, *Hibbiscus tuberculatus* and *Melanoplus alaskanus*. In the deep wood a Tree Toad, *Hyla versicolor*, was found, and Varying Hares and Bed Squirrels were seen.

Station TV, Substation 5. Clearing, and Vicinity of Neutson's Resort (Park Place). There is a rather extensive clearing at Neutson's Resort, so that very little collecting was done in this vicinity. A collection of grasshoppers was made here by Brown and Wood, and the following list of plants was made by the former from the same vicinity: White Spruce, Birch, Aspen, Mountain Alder, *Juniperus nana*, Wild Red or Pennsylvania Cherry, Red and White Clover, Bush Honeysuckle, *Fragaria vesca*, Cow Parsnip, and *Lycopodium complanatum*.

The grasshoppers were: *Chloealtis abdominalis*, *Camnula pellucida*, *Hippiscus tuberculatus*, *Circotettix verruculatus*, *Melanoplus alaskanus*, and *huroni*. Two butterflies, *Argynnis atlantis* and *Pyrameis cardui*, and the dragonfly *Lestes unguiculatus* were also taken here. In Rock Harbor, at Neutson's, leech egg capsules of *Nephalopsis obscura*, and *Physa* were taken. On a small island across the Harbor to the south, in a Sphagnum, Pitcher Plant and Tamarack swamp, a number of Wood Frogs, (*Rana cantabrigensis*) were taken.

A Red-bellied Snake (*Storeria occipitomaculata*) was reported to have been killed in the clearing, during July.

Station IV, Substation 6. Small Island in Tobin Harbor. This station includes the sedges and shallow water at the west end of a small inland in Tobin Harbor. The bottom was covered with sand and large angular blocks of rock. *Limnaea stagnalis* was very abundant and occurred in water with a depth of about three feet. The shells are very fragile. Upon the rocks *Physa* occurred in limited numbers and was widely scattered, but they were abundant on the stems of the sedges not far below the surface. The young of *L. stagnalis* occurred with the *Physa*. A specimen of *Gordius aquaticus* was secured here.

Station IV, Substation 7. Head of Tobin Harbor. A small brook empties into the head of the Harbor, and its brown water brings into the bay quantities of vegetable remains and flocculent debris. These cover the bottom near the mouth of the stream, and although carefully examined, were found to be singularly free of animals. Upon patches of *Potamogeton perfoliatum* occurred a few *Physa*, and in the shallow water a few fish were found. (No. 35.)

Station V. Siskowit Bay, Lake, and Vicinity. This station includes all the localities in the vicinity of Siskowit Bay and Siskowit Lake, except that of VIII, '04, which is at the head of Siskowit Bay.

Station V, Substation 1 and 3. The Bay Beach at Camp, and the Rock Clearing. The beach (V, 1), is protected from the waves of the open lake and bay by large off-shore islands. The rock composing it is vesicular lava, and slopes to the water at an angle of about 10 degrees.

The Rock Clearing about Camp (V, 3), begins at the beach and extends up the slope backward to the Balsam, Spruce and Birch forest as a park-like opening. The soil, mainly of residual and humic origin, is very shallow and completely lacking in places. The surface of the rock is rough, showing that it has been eroded since glaciation. In places the rocks are more or less covered by crustaceous and foliaceous lichens, or, where there is more humus or soil, by *Cladonia*, *Fig. 24*. Where the soil is deeper is found Bearberry, Narrow-leaved Cow-wheat, *Solidago*, grasses and moss. A scattered shrub growth is composed of *Juniporus nana* and *Amelanchier*, *Fig. 25 and 26*, and the bordering tree growth consists of Balsam, Black and White Spruce, Birch and Arbor Vitae. In the shade of these bordering trees, *Aster macrophyllus* develops in abundance. The above description also outlines the probable succession of plant societies upon this surface, all stages of which are now to be found within this area. Many smaller patches of this open condition are found scattered through the forest and are becoming shaded and converted into the forest as a soil develops, *Fig. 27*.

The fauna of the openings is rather characteristic and abundant. Of course many species range over a variety of plant societies and only recognize a clearing or forest society, and not their varieties. Yet others are much more sensitive to smaller environmental units. This is well shown by certain ants. Ant nests of *Formica fusca* as illustrated by *Fig. 28*, and certain spiders, as *Pardosa*, are quite characteristic of the *Cladonia-Bearberry* plant society. The opening, as contrasted with the forest, is frequented by grasshoppers, such as *Melanoplus fasciatus*; butterflies, as *Argynnis* and *Basilarchia arthemis*; and the dragonflies, *Sympetrum*, which were very abundant and characteristic (*Aechna* patrols the margins of such openings). The robber fly, *Asilus annulatus*, frequents such open sunny areas where animal food abounds.

The vertebrate frequenters of the open were the Flickers, which were observed by McCreary to destroy ant nests. Several of such demolished nests were seen. Toward night a nocturnal association frequented the open; the bats on wing; and the hares came from the forest to feed, having been in hiding during the day.

No doubt the presence of this opening, in part, determined the location of the log cabin used by our party. The logs were thoroughly infested by beetle larvae, and attracted vast numbers of parasitic Hymenoptera. For this reason, insect collecting about the cabin was of an exceptional character, and included a considerable variety of species. From the adjacent forest a number of trees had been cut, but this did not materially influence this locality, except near the shore.

Station V, Substation 2. Heath Zone and Beach. This locality includes a strip of rocky coast on the south shore of the island, a short distance east of the entrance of Siskowit Bay, *Fig. 29*, and extends from the edge of the water back to the forest. This is an exposed section of the coast and is unprotected by offshore islands, so that easterly storms from the open lake have full sweep on this shore. The slope is a fairly uniform rock surface, with an upward slant of about 10 degrees, and is composed of amygdaloidal lava. Crevices of various dimensions, from a mere crack to a deep rock ravine, extend obliquely up the slope. One of these ravines, the only large one, divides this station into two sections east and west. The eastern section of the slope is covered by a *Cladonia-Juniperus procumbens* society, while the western section is occupied by a *Cladonia-Juniperus nana*-Huckleberry society. Thus there are three fairly well defined natural divisions of this part of the coast, the beach, the *procumbens*, and the *nana* societies.

1. *The Beach*. The low angle of the slope, and the exposed situation and deep offshore water all combine to make the beach zones quite wide (four or five paces) upon this slope. No collections were made upon the submerged beach and only a few specimens were taken upon the lower. The characteristic species, however, were a small hemipterous shore insect, *Salda ligata*, a caddis fly, and ants. Above the lower beach is a wide upper one, characterized by a dark green moss (*Grimmia*) and crustaceous lichens.

A number of rock pools occupy the oblique crevices which extend up the beach. The largest of these is shown in *Fig. 30*. This is a pool about 4 x 8 feet in diameter and contains about 15 to 18 inches of water. On the surface of the water were fragments of insects, water striders, *Gerris remigis*, and on the bottom, dragonfly nymphs (No. 14), while caddis fly larvae crawled upon the sides and bottom. No algal growth was visible. The character of this insect life suggests a pool of some duration, but the absence of shells suggests a lack of permanent water. Numerous basin-like depressions, a few inches in depth, occur on the lower beach and on the foliaceous lichen-covered portions of the middle beach. The sharp angles of some of the pools show that these are occasionally produced by the removal of small blocks of rock. Most of the pools, however, occur in crevices. From one of the large pools a frog, *Rana clamitans* (No. 120), was taken, clearly showing how tadpoles may reach such pools.

In the crevices and behind angular rock projections occur Hare-bells, Yarrow, Ninebark, and an interesting succulent Saxifrage, *Saxifraga aizoon*, *Fig. 31*, and some grasses. In the crustaceous lichen zone is a greenish moss, *Grimmia*, and in the crevices are Bearberry, *Juniperus procumbens*, and Arbor Vitae.

2 . *The Cladonia-Juniperus procumbens Society of the Eastern Section*. About ten paces farther up the slope, *Fig. 32*, this crevice society spreads out, and, with the addition of *Cladonia* and some *Juniperus nana*, forms interrupted patches or streaks. *Fig. 33*, which farther up the slope fuse and form a solid mat, completely covering the surface of the rock, *Figs. 33 and 34*. The dominant forms are *Juniperus procumbens* and certain species of *Cladonia*. This was the only place where *J. procumbens* was found growing on such an extensive scale, or associated in abundance with *Cladonia*. This formed a novel and beautiful sight, the light-colored patches of the Reindeer-lichens in places intermingled with the bright green of the *procumbens* to form a variegated mat. The beauty of color and pattern is lost in a general view, as in *Fig. 34*. The White Spruce invades the slope in crevices, just in advance of the solid mat formation, but the soil is so shallow that it may be blown over, as is shown in *Fig. 33*. *Procumbens* grows so densely and close to the ground that it greatly favors the formation and retention of the soil, and it apparently precedes, on this slope, the *Cladonia*. In the large crevices within this zone grow patches of White Pine, Balsam, Mountain Alder, Spruce, Birch and Arbor Vitae. The general relations of this slope can easily be seen by a comparison of *Figs. 32, 33 and 34*, in which is shown the transition from the bare wave washed beach, the flat growing lichens, the pioneers of the mat formation invading the crevices, and the -dominance of the *J. procumbens-Cladonia* society with its scattered trees, up the slope into the Balsam-Spruce forest. This same order probably also expresses the succession of plant societies at this place. As previously mentioned, the fauna of the lower beach is quite limited, the greater variety occurring in the pools; but farther up the slope appear various forms which frequent the open. On the scattered part of the *Cladonia-procumbens* zone occurred the spiders, *Pardosa glacialis* and *sternalis*, the grasshoppers, *Circotettix verruculatus*, *Melanoplus alaskanus* and *fasciatus*. A ground beetle, *Pterostichus femoralis* was found under *Cladonia*, and under similar conditions were found an abundance of shells, *Acanthinula harpa*, *Strobilops virgo*, *Vertigo tridentata*, *Vitrina limpida*, *binneyana*, *Euconulus fulvus*, *Euconulus chersinus polygyratus*, *Zonitoides arborea milium*, *Agriolimax campestris*, *Pyramidula cronkheitei anthonyi*, *Helicodicus parallelus*, and *Cochlicopa lubrica*. The number of these shells which have a distinctly boreal range is particularly noteworthy, suggesting that such a habitat has some of the characteristics of a "boreal island."

3. *The Cladonia-Juniperus nana Society of the Western Section*. Here, as at the eastern section of this slope, the bare lake beach bounds this area shoreward. A general view up this slope is shown in *Fig. 35*. The bare wave-washed lower beach is in the foreground, and the green moss and light colored lichen zone is a broad belt above it, followed in turn by foliaceous lichens, and in the crevices by Aspen. The rock surface is considerably rougher than that of the east beach. In general appearance this beach is much more like that about the camp at Siskowit Bay (V, 3) than the *Cladonia-procumbens* section, and contains more to the Low Juniper rather than the Procumbent Juniper. There is also much more exposed rock, and a much more diversified flora. In places the Low Huckleberries are very abundant, while they are not at all conspicuous on the eastern section. To get an idea of the general appearances *Figures 34 and 36* should be compared.

Figure 34 shows the marked dominance of *procumbens*, which was not abundant on the west slope. The plant life is more varied, with the foliaceous lichens and bunches of coral-like *Cladonia*, ferns, grasses, *Solidago*, and the willows and aspens in the crevices, *Fig. 37*. These forms give a very different aspect to the pioneer society from that of one composed of a *Cladonia-procumbens* mat. The open or patch like character of this society suggests that the retarded development of the vegetational cover may be related in some way to the scarcity of *J. procumbens*, which is such an excellent agent in soil formation. But why this shrub should not thrive here is not known.

Associated with these conditions were the snail *Polygyra albolabris*, and the grasshopper *Melanoplus fasciatus*. The absence of the dense mat, and less soil, greatly reduced the variety of animals frequenting such conditions.

Taking the station as a whole (V, 2), it is one of the most interesting places seen on the island. The beauty of the variegated *Cladonia* mat, the extensive area of the open habitat, the boreal character of the lichens, the Saxifrage and many of the shells, the apparent completeness of the preservation of the stages in the transformation from the lower beach back to the forest, all combine to make this situation one of the most interesting and important of those examined.*

*This slope is very favorable for the study of the ecological distribution of lichens, and at this point attention is directed to some papers on lichen societies by Professor Bruce Fink, of Miami College. These are the most important papers on this subject.

1902. Ecological Distribution an Incentive to the Study of Lichens. Bryologist, 5, pp. 39-40.

1903. Some Common Types of Lichen formations. Bull. Torrey Bot. Club., 30, pp. 412-418.

1903. Some Talus Cladonia Formations. Bot. Gaz., 35, pp. 195-208.

1904. A Lichen Society of Sandstone Riprap. Bot. Gaz., 38, pp. 265-284.

Contributions to the Study of Lichens of Minnesota:

I. Lichens of the Lake of the Woods. Minn. Bot. Stud., 1, 1896, pp. 693-701.

II. Lichens of Minneapolis and Vicinity. Minn. Bot. Stud., 1, 1896, pp. 703-725.

III. The Rock Lichens of Taylors Falls. Minn. Bot. Stud., 2, 1898, pp. 1-18.

IV. Lichens of the Lake Superior Region. Minn. Bot. Stud., 2, 1899, pp. 215-276.

V. Lichens of the Minnesota Valley and Southwestern Minnesota. Minn. Bot. Stud., 2, 1899, pp. 277-329.

VI. Lichens of Northwestern Minnesota. Minn. Bot. Stud., 2, 1901, pp. 657-709.

VII. Lichens of the Northern Boundary. Minn. Bot. Stud., 2, 1903, pp. 167-236.

Station V, Substation 4. Trail through Balsam-Spruce Forest. This station begins at the opening about camp (V, 3) and extends northwest to the south shore of Siskowit Lake, opposite the eastern end of an elongated island. The topography of the region traversed is one of low relief, with only occasional low rocks, hills, or ridges, 15 to 20 feet in height, and a few shallow and moist ravines. A thick layer of humus covers the surface, except on the ridges. The trail first passes through a forest of White Spruce, Balsam, Birch and scattered Tamaracks. Among these trees are many fresh windfalls, due to the winds and the shallow soil. In the more shaded portions the ground cover consists of a dense growth of mosses, liverworts, *Fig. 38*, with *Aster macrophyllus* in the less shaded portions. There are open patches 10 to 15 feet in diameter scattered about through the forest, especially on low rock ridges, which contain a growth of *Cladonia*, and illustrate the last stages of the decline of the openings.

In the moist depressions was found an abundance of Bound-leaved Cornel, alder, and also Ground Hemlock, Mountain Ash, Balsam, White Spruce, and the Ground Pine (abundant.) There were many fallen and decayed logs. In and characterizing the more open places, such as were associated with large Birches, are the Large-flowering Raspberry, Sarsaparilla (dominant), and *Clintonia borealis*, but *Aster macrophyllus* was not as abundant here as elsewhere. The larger Birches averaged about 12 to 15 inches in diameter. The general appearance of the conditions is shown in *Fig. 39*. This patch of birches was near the swamp (V, 5). From this Birch colony, on to the end of the trail to Siskowit Lake, the forest was dominated by large Birch, with a few quaking Aspen, Balsam and White Spruce, while in the damper places Ground Hemlock and Dogwood were abundant. On the ridges there are small "islands" of *Cladonia*, mosses, Bearberry and a ground pine. The general appearance of this forest, in an open place, is shown in *Fig. 40*.

While there are thus minor differences which prevent absolute homogeneity in the general conditions of the forest, yet these differences do not seem to particularly influence the environment as a whole. The general transition from the openings, as found on rock ridges like those about camp (V, 3), to the Balsam-Spruce forest may be seen by a comparison of *Figures 25, 26, 27 and 38.*

The fauna of the forest (V, 4) is rather varied. The shells are represented by *Acanthinula harpa*, *Zonitoides arborea*, and *Pyramidula cronkheitei anthonyi*; the beetles by the carabid, *Calathus*, the fungus-inhabiting beetles, *Boletobius*, *Tritoma* and *Grophaena*, and doubtless many of the other species which were taken about the flowers and the camp. The wood-boring Hymenoptera, as *Urocerus*, are also characteristic of this kind of forest. Hares remained concealed in the forests during the day, but at dusk they came in large numbers into the clearings to feed. The birds had begun to migrate when this location was examined, so that little attention was given to their habitat preferences.

Station V, Substation 5. Tamarack Swamp. This swamp lies between Siskowit Lake and the western end of the trail through the Balsam-Spruce forest (V, 4). This is a valley swamp/bordering a small stream which flows through the swamp. The central open part of the swamp is occupied by a small pool or pond, *Fig. 41*, which is invaded by Yellow Waterlilies. Surrounding this is a zone of Buckbean and sedge, the overgrowing sedge being more conspicuous. This sedge zone is quite wet and quaking. The current of the stream passed through this zone and parted the sedges in a wet line two or three inches wide. At its outer border, the zone becomes invaded by small Tamaracks, 4 to 5 feet high, alders, willow, scattered Cassandra and Pitcher Plants, and Wild Rosemary (common). *Eriophorum*, the Blue Flag and the Purple Cinquefoil occur in some of the depressions. A very few small Arbor Vitae also occur here. A strip of trees bordered the stream, while farther south occurred the Cassandra and Sphagnum zone proper. The latter contained scattered Blue Flags, and upon dry hummocks, colonies of *Cladonia*, which seemed rather out of place. The margin of this area was invaded by the Tamarack, Black Spruce and Labrador Tea. The general appearance of this forest is shown in *Figs. 42-43*. Near the margin of the swamp, where the spruces are quite large and the ground well shaded, the growth of Labrador Tea and Sphagnum was very luxuriant. The growth of Sphagnum at this place was by far the most luxuriant seen upon the island. It grew in hillocks over fallen trees and stumps, and stood considerably above the general level of the swamp. This ground cover was not limited to the swamp, but invaded the Balsam-Spruce forest in large billow growths, such as is shown in *Fig. 44*. In other places the undergrowth and ground cover of the Balsam-Spruce forest apparently invaded the swamp, as was seen by the intermingling of the two plant societies. Here there is a mat of the Sphagnum and Labrador Tea intermingled with Ground Cornel, *Clintonia borealis* and young Balsams. As in *Fig. 44*, this might also be interpreted to mean an invasion of the Balsam-Spruce forest by the swamp; but the vigor and dominance of the Balsam society favors the interpretation that this is an invasion of the swamp by the Balsam society. It is not surprising that along such a tension line either society may dominate at times.

The fauna of this bog consisted of a Garter Snake (*T. sirtalis*), found near the small brook flowing into the western or upper end of the bog. Here also was found *Hyla pickeringii*, *Rana clamitans*, and *R. cantabrigensis*, and a water strider, *Gerris*, running on the surface. In the Cassandra and Sphagnum hummock zone were

found the grasshoppers, *Mecostethus lineatus*, *Melanoplus extremus*, and *Stenobothrus curtipennis*. Nearer the central lilypond, among the sedges and Cassandra, were found the dragon flies, *Tetregoneuria spinigera*, *Aeschna*, *Leucorhinia hudsonica* and *Sympetrum obtrusum*, and the spider *Epeira patagiata*. Through the central area of the bog the stream was only indicated by the parting of the sedges, but at the lower or eastern end it again became well defined, and contained the small Stickleback, *Eucalia inconstans*. Beetles taken from this bog were *Haliplus ruficollis*, *Hydroporus tristis* and *Agabus congener*. The molluscs were represented by the small bivalves, *Pisidium*.

Station V, Substation 6. South Shore of Siskowit Lake. This situation is simply the end of the trail through the forest, and marks the location of some collecting in the lake. The shore is rocky, with rather low and overgrown banks.

Station V, Substation 7. The Haytown Trail. This trail begins almost directly opposite the outlet of Siskowit lake, where a large White Pine has been marked "36 W. 65 N., 19 E." This area has been burned over, but farther inland the blaze on the older trees enables one to follow the trail. The course is shown by Lane, ('98, Pl XI), but we examined it only to about the point where it is crossed by the outlet of Hatchet lake, at which place there was a Tamarack swamp with very large trees (V, 8). After crossing the burned area near Siskowit lake, this trail passed through dense Arbor Vitae bogs and a large area of Balsam-Birch forest. In general the area traversed was rather deeply covered with soil and contained very few rock exposures, those observed probably being due to fires.

The general character of the upland forest, of mixed conifer and hardwood, is indicated by the following list: Balsams, Birch and Aspens (all about 10 inches in diameter), scattered Arbor Vitae (10 to 15 inches), a few scattered White Pines (about 3 feet in diameter), and a few Hard Maples (some 8 inches). It is thus seen that the largest abundant trees are the White Pine, Arbor Vitae, Birch, Hard Maple and Aspen. The large amount of hardwood present was an unexpected feature. This forest may be considered transitional between the Balsam, White Spruce forest, and the Hard Maple, Yellow Birch, Balsam and Arbor Vitae forest as found on the Desor Trail (III, '04).

The undergrowth consisted of Ground Hemlock in abundance, Mountain Maple, Beaked Hazel, young Balsams and Birches. The ground cover was composed of *Clintonia borealis*, *Lycopodium lecidulum*, *Clabonia* on dry rotten wood, *Aster macrophyllus*, Large-flowering Raspberry and Wild Sarsaparilla.

Mountain Maples and young Balsams showed a marked tendency to take possession of the trail. The lack of an undergrowth in the dense swamps was particularly noticeable, and the clearly defined old trail through such places indicated relatively stable conditions.

A very marked characteristic of this trail was its limited fauna. Very few birds were seen, and Red Squirrels were not at all abundant. Several times we saw the remains of Balsam cones where a Red Squirrel had taken a meal. Almost no effort was made to collect invertebrates.

Station V, Substation 8. Arbor Vitae Swamp. This swamp marked the end of our Haytown Trail, and bordered on a small stream. The dark colored soil contained much humus and was soft and spongy. The vegetation bordering this stream was composed of Speckled Alder, Skunk Cabbage, Marsh Marigold, *Clintonia borealis*, scattered Blue Flags, and Ground Cornel; in the moderate shade, *Coptis trifolia*, Mountain Ash, young Arbor Vitae and Balsams, Twayblade, and, in the damp places, away from the stream, *Mitella nuda*.

In the dense and apparently well drained swamp there was a firm humic soil covered by a thick layer of leaves, conifer needles and twigs. The ground cover was composed of Ground Cornel, *Clintonia borealis* and Wild Sarsaparilla, with an undergrowth of Mountain Maple, Ciliated Honeysuckle, numerous young Balsams, young Arbor Vitae, Ground Hemlock, Mountain Ash, and Beaked Hazel. The large Tamaracks were about 3 feet in diameter, and the Arbor Vitae about 2 feet, others about 20 inches in diameter were abundant. It is thus seen that this was an old and mature swamp with some very large trees, under which the ground was quite open. With better drainage, the young or suppressed undergrowth would succeed the Tamarack society.

The old trail through this swamp was remarkably well preserved and distinct because the dominance of the large shade-producing trees prevented the development of an undergrowth. No animals were collected.

Station V, Substation 9. Outlet of Siskowit Lake. A trail or path ran from the head of 'the outlet of Siskowit Lake south to the Siskowit Bay beach, a distance less than a quarter of a mile. The area traversed had been burned, and second growth had developed, the best of which was in the depressions where the soil is deeper. The open ridges near Siskowit Lake, where the soil is thin, have an open growth near the head of the trail and support *Primus pennsylvanica*, Birch, *Dierville dierville*, Mountain Ash, Mountain Maple, *Amelanchier oligocarpa*, Ground Cornel, Everlasting, Wild Rose, White Clover, Fire Weed and mosses. In the depressions among the underbrush in the deeper soil and in shade is found *Diervilla diervilla*, Fire Weed, *Prunus pennsylvanica*, Mountain Maple, Mountain Ash, Birch, Mountain Alder, Willow, Sarsaparilla, Wood *Equisetum*, Oak and Ladies' Fern, Large-flowering Raspberry, *Cornus stolonifera* and *Clintonia borealis*.

The open arid character of much of this station is reflected in the grasshopper fauna, as follows: *Hibbiscus tuberculatus*, *Melanoplus alaskanus*, *fasciatus* and *Circotettix verruculatus*. The butterfly, *Basil-archia arthemis* was also taken here. The rare dragonfly, *Ophiogomphus columbrinus* was also taken at this

station, probably because of the proximity of the rapid flowing outlet, which forms a trout stream.

Station V, Substation 10. Long Island Gull Rookery and Menagerie Island. This station was examined solely for its bird life, which will be discussed elsewhere in this report. This large Gull rookery is on Long Island, *Fig. 45*, which lies about one mile west of Menagerie Island where Isle Royale Light is located. This bird clearly breeds upon the middle and upper beaches. Long Island is formed by the upturned edges of red sandstone and is exposed to the full sweep of the lake waves, as is clearly evidenced by the bare rocks. The vegetation on the island was not examined, as the time that could be devoted to the examination of the rookery was limited. But mention should be made of the abundance of algae in the lake bordering the rookery, and of their abundance in the rock pools on the beach.

Station V, Substation 11. Tamarack-Spruce Swamp. This station includes a waterlily pond surrounded by zones of sedge, heath shrubs, Tamarack and Black Spruce. A general view of the pond is shown in *Fig. 46*. It was located almost due west of the western end of Station V, 2, and only a short distance northwest of the boat landing.

In the pond, submerged, was Utricularia, Yellow Waterlily, *Potamogeton*, and *Brasenia* (Water Shield); practically all the open water was occupied by the Yellow Water Lily. At the edge of the water grow the sedges, *Fig. 47*, which form a distinct zone, and the Buckbean. The sedge zone also includes the *Equisetum*, Purple Cinquefoil, *Comarum palustre*, a willow, *Hypericum*, Water Hemlock (*Cicuta bulbifera*), and the White Bog Orchid. Beyond the sedge zone comes *Sphagnum*, *Andromeda polifolia*, Cassandra, patches of Labrador Tea, *Oxycoccus oxycoccus* (Small Cranberry, abundant), Alder, *Chiogenes hispidula* (Creeping Snowberry), Bunch Berry or Dwarf Cornel (*Cornus canadensis*), *Kalmia glauca*, Pitcher Plants, *Drosera intermedia*. The trees do not extend to the inner limit of the Cassandra zone. *Cladonia* grew upon dry hummocks in this zone. In a few places, in depressions in the tree zone, Eriophorum was found. The trees are Tamarack, Black Spruce, and small Arbor Vitae. The general appearance of the Cassandra and tree zones are shown in *Fig. 48*.

The invertebrate fauna of this station was abundant and varied, but the vertebrates were more limited. In the Water Lily and Potamogeton zone the Stickleback, *Eucalia inconstans*, was taken, and at the sedge margin, *Rana clamitans*. Water bugs are represented by *Belostoma* and *Corixa* nymphs, and on the surface by the Water Strider, *Gerris rufoscutellatus*. A small shell, *Physa aplectoides*, was found in small foot-print like pools in the outer part of the Buckbean and sedge zone. In the Cassandra zone were taken the dragonflies *Enallagma hageni*, *Aeschna*, *Leucorhinia proxima*, the grasshopper *Melanoplus alaskanus*, and the butterfly *Pyrameis cardui*. From this bog were also taken the Arachnids, *Lacinius ohioense*, *Drassus neglectus* and *Pardosa glacialis*.

The stations at Washington Harbor were not examined in 1905 in as much detail as were other localities, and the descriptions will therefore be correspondingly brief, and will be supplementary to a similar account by Ruthven, '06, pp. 48-52.

Station I, '04. Clearing at the Head of Washington Harbor. This clearing is the property owned by the Washington Club of Duluth, Minn. Much of it is sodded, pastured and under some form of cultivation. These conditions were particularly favorable for grasshoppers, which occur in great numbers. The following species were taken: *Stenobothrus curtipennis*, *Chloealtis abdominalis*, *C. conspersa*, *Mecostethus lineatus*, *Camnula pellucida*, and *Melanoplus alaskanus*. This area appeared to be a favorable resort for migrating birds, as shown in the accompanying report by Peet.

Station II, '04. Washington Creek. This is the small trout stream which flows into the head of Washington Harbor.

Station III, '04. Trail along the Top of the Greenstone Range, the "Desor Trail." This trail follows the road which has been opened from the Club House (I, '04) to Lake Desor (VII, '04). At the western end this road traverses a forest which varies considerably in its composition. In places it is dense and apparently original, but at one place it has been burned and replaced by an abundant growth of Birch. The original forest is dense and composed of large trees, and the proportion of .hardwoods is surprising, since the Balsam-Spruce forest is so prevalent elsewhere upon the island. The hardwoods are really dominant. The forest *Fig. 49*, is composed of Yellow Birch, Balsam, Arbor Vitae, and a few Sugar Maples, and the undergrowth of Mountain Maple and Ground Hemlock. Farther out on the trail, toward Lake Desor, the Maple becomes dominant and forms an almost pure stand, so dense that in places there is almost no undergrowth, and the forest appears quite open with a scattered ground cover. A loose thick layer of leaves and twigs covers the forest floor. In the more open places the ground cover is composed of Large-flowering Raspberry, Wild Sarsaparilla, *Clintonia borealis*, *Lycopodium*, mosses, Ground Cornel, and the shrubs, Mountain Maple, Beaked Hazel, Round-leaved Cornel, Mountain Ash and Red Cherry. The Yellow Birch is a large tree, with a diameter of about 2 feet; White Pine is very rare, but the trees are large, even about 3 feet in diameter; Arbor Vitae reaches about 2 feet. A few Large-toothed Aspens, Black Oak and Black Ash were seen, the Aspens about 20 inches in diameter and the Maples 10 to 15 inches.

Red Squirrels were seen in the forest, the body of a Lynx was found hanging on a tree where it had been left by a trapper, and several Toads were seen. Invertebrate life was abundant. In an Arbor Vitae stump, galleries of an ant, *Camponotus herculeanus whymperi* (140 A), were found in both the seasoned and the decayed wood. A few beetles were taken along the trail; *Quedius fulgides*,

Tachinus memnomius and *Geotrupes blackburnii*. Shells were abundant: *Strobilops virgo*, *Vitrea binneyana*, *Euconulus chersinus polygyratus*, *Zonitoides arborea*, *Z. exigua*. *Pallifera dorsalis*, *Pyramidula alternata* and *P. cronkheitei anthonyi*.

Station IV, '04. Washington Brook. Cf. Ruthven, '06, p. 50. This station was examined on the slope back of the Club-house. It is a swamp forest along the border of a very small stream. *Fig. 50*. Part of the forest is being cleared.

Station V, '04. Tamarack Swamp. This swamp was not visited in 1905. Cf. Ruthven, '06, p. 50.

Station VI, '04. North Slope of Greenstone Range. Cf. Ruthven, '06, p. 49.

Station VII, '04. Lake Desor. Cf. Ruthven, '06, p. 51. A few additional records are: The dragonfly, *Enallagma exsulans*, the water strider, *Gerris remigis*, the fish, *Coregonus artedi*. At the end of the trail (III, '04) at Desor, the beetle, *Melanotus paradoxus*, and the spider *Dolomedes idoneus*, were taken.

Station VIII, '04. Western End of Siskowit Bay. The large clearing and burned area at the head of Siskowit Bay marks the site of a former town, the county seat. A well-defined graded road leads from near the north shore of the Bay westward and north to an old mining camp. This road is being invaded in places by Birches and Aspens. This extensive clearing was overgrown with many introduced plants and was given only a cursory examination. The following vertebrates were observed: Sharp-tailed Grouse, (of which several were seen), the Hare, Toad and Garter Snake. The snails, *Polygyra albolabris* and *Pyramidula alternata*, and the grasshopper *Stenobrothrus curtipennis* were found here. The limits of this station were changed somewhat from those given in 1904.

Station IX, '04. Southwestern End of Minong Trap Range. Cf. Ruthven, '06, p. 51-52. No additional collections were made here in 1905.

Station X, '04. Washington Harbor. Cf. Ruthven, '06, p. 52. No additional collections were made at this station in 1905.

III. THE EVOLUTION OF THE GROSS ENVIRONMENT.

1. Ecological Succession. In his report on the Porcupine Mountains, Ruthven ('06) has summarily outlined the general geological history of the Lake Superior region. It is only necessary, therefore, for our purpose, to repeat some of this history and to enlarge upon those phases peculiar to Isle Royale. The structural geology of Isle Royale has been studied in detail by Lane ('98) and is relatively simple. The different rock formations are in narrow strips nearly parallel with the long axis of the island, while the dip of the rocks is toward the basin of Lake Superior. The rocks north of Siskowit Bay consist of the truncated beds of ancient lava flows, interrupted by a small amount of inter-bedded sedimentary rocks. Although these tilted and truncated beds are inclined at a high angle, this was not their/original position; in all probability they were formed in a nearly horizontal position by fissure eruptions under the sea, because the lavas are interbedded with shales, sandstones and conglomerates. In thickness these lava beds vary from a few inches to hundreds of feet. The narrow beds often show upper and lower surfaces filled with small cavities (amygdules) in contrast with the denser central part. These cavities were formed by gas or vapor while the lava was hot, and leave such a rock porous and less resistant to disintegrating agencies and to erosion. The same principles also hold for the thicker beds of lava; the outer parts are more porous and softer than the central part. This structural difference is clearly shown in the topography of the island; the ridges mark the central or more resistant parts of the truncated lava beds, while the valleys, in general, have been worn into the softer outer parts of the lava and into the interbedded sedimentary rocks. These beds are of Keweenawan or pre-Cambrian age; their formation ceased with an elevation of the land from the sea and their destruction was begun by the agents of subaerial erosion. These processes continued until the titled strata were truncated and reduced to a base level. Again the region was depressed and upon this eroded surface were deposited unconformably those red sandstones and conglomerates which now characterize the Siskowit Bay region and to the southward, and are of Cambrian age. Once more the region was elevated, titled and subjected to prolonged erosion and the strata truncated as had been done with the Keweenawan. Similar processes continued until the marked elevation of the land, which took place at the close of the Tertiary, and which initiated the repeated glaciations of the Ice Age.

With the extension of the last or Wisconsin ice sheet in the Superior basin, Isle Royale was completely overridden by the movement of an ice sheet from the northeast that moved almost parallel to the ridges, but was somewhat more inclined from the east (Lane '98, p. 183). For this reason there was a tendency to plane down the southeastern slopes and to preserve the steeper ones which had been formed on the northwestern side (Foster & Whitney, '50, p. 202). As the island has a topography which indicates subaerial rather than marine erosion, it must have had at one time a residual soil, which, unless it had been swept away by a former ice invasion or the waves of some body of water, was probably removed at this time with the minor inequalities of the surface. In this manner the Superior lobe buried the island under several thousand feet of ice and continued its movement far to the southward, leaving a glacial desert in its wake. This condition of affairs lasted until the return movement broke up the great ice sheet into lake basin lobes and brought the receding ice front into the Superior basin. As soon, however, as this lobe wasted away from the margin of this basin, the water from the melting ice accumulated

before it and formed a lake which, overflowing the rim, found its way through the St. Croix valley to the Mississippi river, as indicated in *Fig. 51*. But, as the ice wall continued to retreat toward the northeast, these ponded waters Increased in area and formed the highest beach lines now preserved on the north shore of Lake Superior. The evidence for this is found on Mt. Josephine, located on this shore just north of the southwestern end of Isle Royale, which reaches an elevation of about 800 feet above the Lake. Far up on its slopes, according to Lawson ('93, p. 253), evidence of beach lines are found, about which he says: "These two terraces at 585 and 607 feet are remarkable for being the highest strand lines which have thus far been observed on the coast of Lake Superior." Under such conditions it seems that Isle Royale would undoubtedly have been submerged. The ice retreat continued and finally Isle Boy ale, freed from the ice and in part from the lake waters, emerged as a narrow rocky ridge—the crest of the Greenstone Range which today rises, at the northeastern end of the island, to a maximum elevation of about 550 feet. As the ice wall retreated the Michigan and Huron basins became confluent, and an outlet to the east (Trent valley, Ontario) at first, later the Port Huron and possibly the Chicago outlet (Goldthwait, '09, p. 65) became available, *Fig. 52*, and at about this time the Glacial Great Lakes became isolated from the Mississippi drainage. The lake level was lowered, and it was perhaps at this level that the beach lines were formed on the north side of Lake Superior, which are now 400-500 feet above, the present lake level (Taylor, '97, p. 126). Similar evidences of ancient beaches have been recognized by Lane ('98, pp. 188-191) upon Isle Boy ale, but he is inclined to place the level of this Glacial Lake Algonquin at about 485 feet. It is probable that more field work will be necessary before adequate correlations of these beaches can be made.

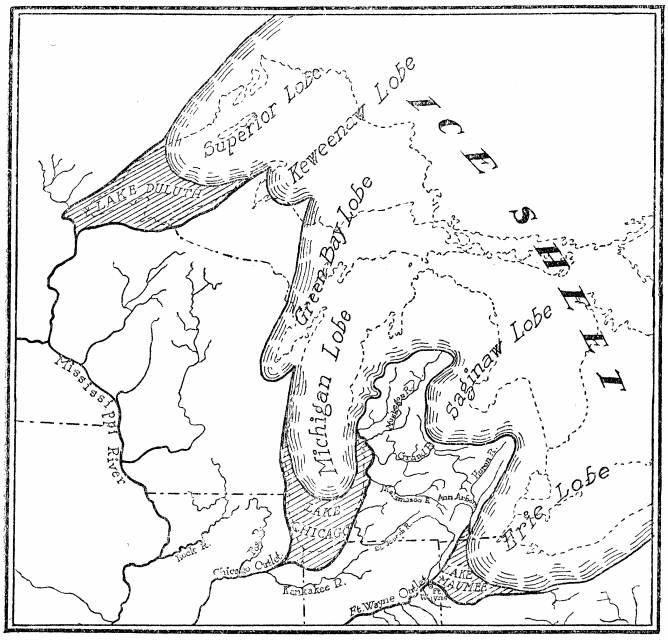

Figure 51. Showing origin of the Glacial Lakes, their relation to the ice sheet and their Mississippi drainage.

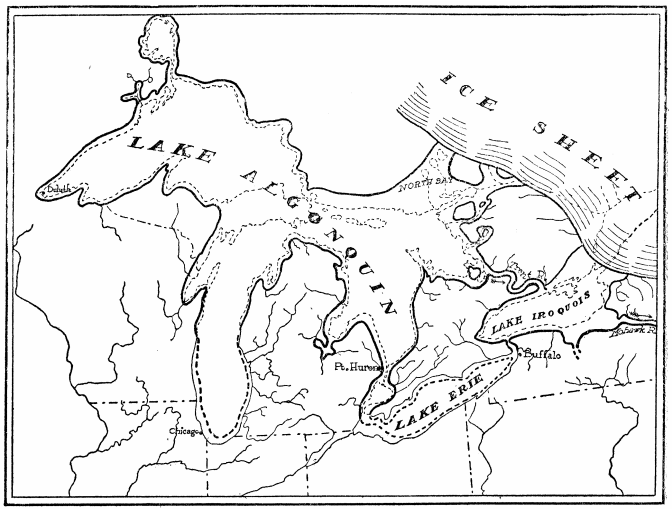

Figure 52. Showing the Algonquin stage of the Great Lakes. A water barrier to northward dispersal of the land biota.

Some general idea of the extent of the island at this stage may be gained by reference to the 460 foot contour on the accompanying map, *Fig. 53*. At this time, *Fig. 52*, the ice sheets had retreated far enough to the northeast that the climate of the Superior basin must have been so greatly ameliorated that animal life could have lived in its water. This inference seems probable because fossil shells have been found in the beach lines of the same lake farther to the south by Lane and Walker (Lane '07, pp. 248-252), and at Port Huron, Michigan by the writer in company with Dr. J. W. Goldthwait and Dr. A. G. Ruthven (Goldthwait, '07, p. 118). Here were found an abundance of *Goniobasis livescens*, occasional valves of *Sphaerium striatimum* Lam. and Unionid fragments, a fauna like that of the present beaches. It is therefore not improbable that this fauna invaded the Great Lakes drainage from the Mississippi during the early stages of the great glacial lakes, when they still overflowed into the Mississippi drainage.

The time of invasion and the sources of the Glacial and post-Glacial supply of life which invaded the northern land and waters presents several interesting problems. At this point the origin of the aquatic biota is of special interest. From what is known of the fresh-water aquatic biota of the far north, it is very probable that the Glacial Great Lakes, at least in their later stages, were not utterly devoid of animal life. So it seems reasonable to infer that such forms as lived during Glacial times near the ice margin were among the first to succeed the retreating ice sheet.

As the lake fauna is one of the most characteristic features of the life of northeastern North America, the question naturally arises as to where this fauna was preserved during the Ice Age. Today there is no extensive development of lake fauna south of the glaciated region. Where then was such a fauna preserved? On the west were the arid plains, and to the south an old land area of mature drainage and very few lakes. Such relations as these suggest that this fauna must have occupied the lakes formed on the rejuvenated

glacial topography or in the adjacent streams. Had there been extensive lake areas to the south to act as regions of preservation, it seems probable that the present fauna of the Great Lakes would have been much richer. Undoubtedly the most important fresh-water preserve was the Mississippi system, on account of its direct communication with the glacial drainage, thus allowing a southward escape into more favorable climatic conditions. This was also a water communication of considerable duration, lasting even into early post-Glacial times, and one which has greatly influenced the origin of the present fauna of the Great Lakes. In all probability it was this Glacial and post-Glacial water connection and barrier that retarded the northern extension of so many land species, and at the same time favored the extension of certain aquatic animals. The later development of the eastern outlets did not open up such a favorable source of supply as occurred farther west.

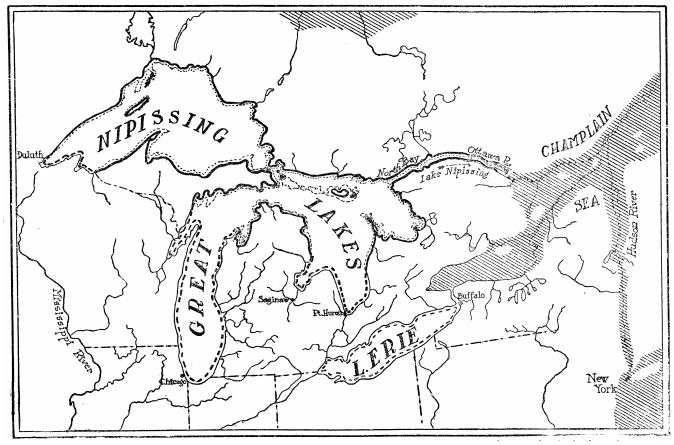

Figure 54. The Nipissing Great Lakes. Showing the fresh water highway or barrier in the west and the sea barrier in the east.

So much for this phase of the problem. Now let us continue with the history of the Superior basin since Algonquin times. The fall in the lake level did not take place suddenly, since a series of beach lines are preserved which show that it halted for some time at different levels, but none were of any remarkable duration until it reached a level marked by a very extensive series of beach lines now preserved at about 60 feet above the level of Lake Superior. This well defined beach represents; the; shore of the Nipissing Great Lakes, post-Glacial lakes whose general outline was much like that of the present lakes in the same basins, as is indicated in *Fig. 54*. The low outlet of this lake was to the east through the Ottawa valley into the Champlain Sea, and is of special interest in that it is suggestive of how certain Great Lake animals of marine affinities (*Mysis, Pontoporeia, Triglopsis*) might have invaded the upper lakes in post-Glacial times. At one time it was thought that there had been a Glacial salt water communication between Lake Superior and the Hudson Bay region, but this view has been abandoned (cf. Taylor, '97, pp. 127-128; '96, pp. 255-256, and Coleman, '06, pp. 193, 198-199). It is definitely known, that the land was depressed to the north of Lake Superior, but this period of depression was at a time when it was covered by the ice sheet, and thus the salt water was excluded. An alternative hypothesis is that these animals are adapted to a constant and low temperature rather than to fresh or salt water, and that during Glacial times they were dispersed far to the south in fresh water and have only been preserved in restricted favorable localities. The low temperature of Glacial times would be a period especially favorable for the acclimatization of marine forms to fresh water on account of the favorable conditions which accompany the slow rate of changes at low temperatures.

The long duration of the Nipissing Great Lakes is well attested by the character of the beach. As Taylor ('96, p. 398) remarks: "It is altogether the most remarkable littoral feature of the Great Lake region. It is a shore line well advanced towards old age. All other beaches of the lakes are youthful in comparison . . . . . Instead of the slender spits and barrier bars of the Algonquin and other beaches, the Nipissing beach has what may be called barrier plains, made up of many, sometimes forty or fifty, massive beach ridges laid one against the other. Many bays were entirely filled by these beach plains and others were cut off, so as to form small littoral lakes. Some of these plains are a mile to a mile and a half wide. In some instances the old deltas of other beaches are large and conspicuous, but the constructive products of wave action have no comparison to those of the Nipissing beach." From a biological standpoint these facts are of special significance. The maturity of the beach line is a condition decidedly favorable to the development of a littoral biota. The sandy shore, spits, bars, beach pools, cut-off ponds and lakes furnish a variety of favorable habitats in marked contrast with the poverty stricken character of life frequenting an exposed and topographically youthful lake shore. Such an old beach is both qualitatively and quantitatively favorable to the biota, and not only favors an abundant supply but also its dispersion along shore and by currents throughout such a body of water. The long duration of such conditions is of evident advantage to an extensive dispersal of such life.

As the basin of the Nipissing Great Lakes in the Superior basin was so much like that of Lake Superior, it is not improbable that the lake currents were much the same in both lakes, so that our knowledge of the present lake currents should aid in the interpretation of those of the Nipissing Great Lakes. Such relations as these suggest that at the Nipissing stage, and perhaps even earlier, the lake currents tended to people Isle Royale with north shore drift. By this time the island was quite large, though smaller than the present island by the subtraction of the area, below the 60-foot contour. At this time the climate of the region must have become greatly ameliorated so that the north shore of Lake Superior was perhaps repopulated from the south, largely around the western end of the lake. With the advent of an abundance and diversity of plant and animal life, a new element enters the environment, whose influence is far

reaching. The vegetation tends to blanket the surface with a humus layer and thus to bind the soil so that it retards erosion and becomes a geological agent. The influence of animal life is also far reaching and may be conspicuous if beavers are abundant. But these influences will only be mentioned here.

The development of the Nipissing beach upon Isle Royale has not been so clearly recognized as elsewhere. Thus Lane ('98, p. 187) considers the present beach as the most distinct of any found upon the island. In a way this is not surprising when we recall the fact that at former lake levels the small area of the island did not permit of an extensive stream development, hence the limited quantities of sand, gravel and boulders. Thus the overriding of the ice, the isolation of the island in deep water, and the steep shores of resistent rocks are conditions unfavorable for supplying tools with which the waves could work. All of these conditions would tend to preserve the youthful topographic features and exaggerate the apparent relative rate at which the island emerged from the waves and the small time during which the waves beat at any particular level. The materials available to the present waves have therefore been cumulative. Lane ('98, pp. 188-189) has recognized several evidences of a 60 foot level.

After the formation of the Nipissing beach there was an uplift toward the north, as shown by Taylor's ('97, p. 127) study of this beach on the Canadian shore north of Isle Royale. In the vicinity of Port Arthur this beach is at 60 feet; at Nipigon 90 feet, and 110 to 115 at Peninsula Harbor. Such an assumed variation or tilting near Isle Royale suggests the necessity of great caution in attempting to correlate the various beaches and emphasizes the desirability of further field work upon this subject. Lane ('98, p. 192) suggests that this northward tilting has tended to pond the northeastward flowing streams and to drain the ones flowing in the opposite direction. Such tilting as this would have considerable influence upon the biota. Even in an uplift of a few feet per mile, in the case of Isle Royale 45 miles long, would be sufficient to have a marked influence upon the swamp environment, which is one of the most characteristic features of the island. In this manner a swamp and its biota might migrate several miles, become a pond or lake or even become drained, and other fates are suggested for ponds, lakes and other environments when such a distinct trend or dynamic tendency is present in a given region.

The change from the Nipissing to the present lake level was not a sudden one, as Lane ('98, p. 191) has recognized beaches at various-levels showing its gradual character; the 30 and 15 foot levels are, however, the most distinct. A few observations were made upon two of these abandoned beaches, but their height was not determined. One was located just south of the mouth of Conglomerate Bay in a small cove about 60 or 70 feet wide. There was an abundance of fresh drift wood a few feet from the edge of the water, back of this a zone of weathered and decayed drift, and beyond this a high boulder beach containing disintegrated boulders with foliaceous lichens, while back of the lichen zone came Wild Cherry, Paper Birch, Bear-berry, Wild Rose, Jack Pine, Alders and Columbine. The back slope then declined into a Jack Pine growth. This beach is interesting because it illustrates the various stages from wave-washed, clean sand and gravel back into the forest growth. Lane ('98, p. 185) refers to a lichen covered beach on Sec. 10, T. 65, R. 34. The second of the beaches mentioned is located on the south shore near the eastern end of Siskowit Bay (Sec. 26, T. 65 N., R. 35 W.). The present beach is. locally known as the "Greenstone beach" and forms a good boat landing.

2. The Topography and its Origin. The most conspicuous and characteristic topographic features of the island are its parallel flat-topped rock ridges with the intervening valleys and numerous swamps. These ridges project far out from the main body of the island and form the narrow rock ridges bounding the harbors, and forming a vast number of small islands and low rocky reefs. The tilting, faulting and truncation of these narrow beds clearly shows that the dependence of the topography upon rock structure is one of the most characteristic features of the island.

The main ridge, the Greenstone Range, is a divide which extends the entire length of the island, and is from about 400 to 500 feet high, with a maximum height of about 550 feet at the northeastern end of the island. At only one place does a drainage line cross the Greenstone. This is a small stream heading in Sec. 17, T. 64 N., R. 37 W. and a tributary to Washington River. This ridge is a truncated lava bed whose outer softer part has been eroded, thus throwing into prominence the compact resistant central core. Thus erosion, faulting and the dip of the rocks have combined to produce a northwestward facing escarpment nearly throughout its extent. The fairly flat topped truncated ridges of the island clearly show that their origin must be due to a period of base leveling and is no doubt related to those extensive processes which have produced the Laurentian peneplain (cf. Ruthven, '06, p. 45) of the Superior region. The ridge of second importance is the Minong Trap Range, which lies parallel with the Greenstone, about a mile to the northwest, and reaches a height of about 400 feet. Between these ranges lies a valley containing five fairly large lakes, all of which drain across this range to the northward, and the probable faults indicated by Lane (‘98, pl. 1) at Todd Harbor and McCargoe Cove are suggestive as to how the ridge has been broken through. Faults seem to have influenced the location of several lakes, such as Angleworm, Lesage, Livermore, Chickenbone, Feldtmann and also the outlet of Lake Richie into Chippewa Harbor. In addition to these main ranges there are great numbers of lower ones whose heights range from 100 to about 300 feet. East of Lake Feldtmann there is a bold escarpment 130 feet high, which was said by Mclntyre (Foster, ‘50, p. 506) to afford the "finest view that I have seen on the island." The drainage of the island presents some interesting

features. At each end of the island the drainage is mainly along the valleys into the harbors at their ends. Between these two extremes, roughly marked by the area between lakes Desor and Sargent, the drainage, although it may follow the valleys for some distance, is yet to a marked degree across the strata or ridges. Taken as a whole the drainage is very imperfectly developed. Although the island is not extensive, it contains numerous small independent streams which drain into the lakes or directly into Lake Superior, but it has no master stream. It seems probable that this is also related to faulting, as also in the case of the stream, which may be called Malone Creek, that flows into the head of Siskowit Bay. The probable influence of faulting upon the location of lakes has previously been mentioned, and combined with its influence upon streams reinforces the idea of the dominance of structure upon the topography and consequently upon the drainage. But when in the field the most conspicuous features of this imperfect drainage are the vast strips of swamp land found in the valleys and bordering the lakes and streams. The rock bound character of the basins and the southward tilting of the surface must greatly influence the form and extent of these strips. The stream channels have not cut deeply but are largely bordered by swamps, and the divides between many of them are very low or may even be swamps, so that the drainage from either end of a swamp may be into a different drainage line. Such imperfection of the drainage means that evaporation rather than run off is the pronounced feature, and this condition, combined with the insular location, must greatly influence the relative humidity of the atmosphere. The brownish waters of even the largest lake upon the island, Siskowit, 54 feet above Lake Superior, cleary shows the influence of the imperfect drainage and the extensive swamps of its drainage basin.

The general character of the soil was indicated by Ives on the Linear Survey map. This is as a rule shallow, the deeper being at the southwestern end (T. 64 N., R. 38 W.) and is characterized as "sandy loam and stony, second rate sufficiently deep for cultivation." At the head of Siskowit Bay (T. 63 N., R. 37 W.) he records soil stony, 2nd and 3rd rate land. Soil varies from a few inches to 3 or 4 feet in depth. And near McCargoe Cove (T. 66 N., R. 35 W.) the soil is from 1 to 10 feet deep. The soil then in general may be said to be shallow, second and third rate stony, sandy loam. In the swamps and valleys there is a large amount of vegetable debris, although it is probable that this is generally not deep. No bog lime or marl has been observed. Large strips of the ridges are destitute of soil, especially those which have been burned. No morainic materials were recognized, although the ice overrode the island, and glacial boulders are abundant in places, as about the head of Washington Harbor. Dr. Lane writes me that there is some till, "especially on the lee end near Washington Harbor."

The origin of these soils appears to be relatively clear as there are only a few possibilities available. Some of the pre-Glacial residual soil may have been preserved but it has not been recognized. As above mentioned there are some Glacial boulders and till. The post-Glacial disintegration and decay of the rocks has been the most important source, supplemented by organic remains, from the vegetation in particular. A fourth source is the lake deposits of sand and clay as the waves have worked over the entire surface. These are best preserved in what were once harbors or places protected from the waves. In many localities the origin of the soil is diverse, several different processes having contributed a part.

From the above topographic relations it is seen that the flat-topped ridges and depressions are due to the structure of the rock, the influence of base leveling processes and probably also to faulting. The present drainage is not sufficient to explain the primary ridges and valleys; these must therefore have been inherited from past conditions. The present drainage is therefore consequent and in its infancy, hence its imperfection. From a biological standpoint these facts are significant because such conditions favor isolation of small streams, swamp and lake habitats affect the relative humidity and produce a prominent zonal and linear arrangement of the habitats along the ridges and valleys. The absence, residual, or organic character of the soil is also an important factor of the environment.

3. The Atmospheric Influences and their Evolution.

a. Climate. Unfortunately there has been no continuous series of climatological records made on Isle Royale. A few records were made by our party with instruments loaned by Mr. C. F. Schneider of the Michigan Weather Service, that, while very imperfect, are suggestive. The mean temperature for 26 days in July is 58° F., the minimum record is 46°, and the maximum 79°. From August 2 to 17 the mean is 59°; the mean maximum is 71° and the mean minimum is 47°. For the same period the maximum is 80° and the minimum 36°. There was but little rain although it rained all day on July 15.

Very fortunately, however, these meager records may be supplemented by those from Port Arthur, about 25 miles distant on the Canadian shore.[1] This data has been kindly furnished by Mr. B. C. Webber of the Canadian Meteorological Service. The records cover the decade of 1896 to 1905, and show the mean monthly and annual temperatures, maximum and minimum temperatures, and the precipitation for the same period.

[1]For a general account of the Canadian climate see Stupart '98 and '05.

The table of temperature, Table 1, shows that the decade average of the mean monthly temperatures for February is 7.65° F., with a maximum during July of 62.24° and an average annual of 36.07°. The monthly averages of the maximum temperatures for January is 38.1° and for July 85.8°, with an average annual of 36.7°. The lowest average monthly temperature for the same period is—27.5° for January, and for July 42.0°.

The average minimum temperature for this ten years is—30.8°. The monthly averages for 5 months are below zero.

TABLE NO. 1.—MEAN, MONTHLY AND ANNUAL TEMPERATURES AND AVERAGES FOR 10 YEARS. PORT ARTHUR, 1896–1905.

Mean Temperatures in °F.

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Ann'l mean.
1896	9.3	12.4	15.9	35.5	51.6	59.8	63.5	60.2	51.0	38.5	19.7	16.0	36.1
1897	6.9	13.2	19.5	36.1	46.5	53.7	64.0	59.6	57.0	44.4	23.1	11.3	36.3
1898	10.4	10.6	24.2	35.5	47.9	54.5	60.4	59.6	55.9	41.7	28.1	12.2	36.1
1899	3.2	1.4	9.9	36.3	46.6	55.9	61.8	60.8	48.8	44.3	36.7	14.3	35.0
1900	14.8	1.5	16.6	40.6	50.8	57.9	61.9	63.5	54.7	49.3	25.1	17.2	37.8
1901	7.6	5.6	17.8	38.3	49.2	56.8	64.0	62.1	52.6	42.3	24.7	12.1	36.1
1902	10.9	15.0	27.5	35.8	46.7	52.6	63.2	58.9	50.2	40.6	30.7	11.7	37.0
1903	7.8	7.9	24.0	35.2	46.4	56.9	61.8	57.3	50.0	43.4	26.0	7.5	35.4
1904	4.4	0.5	18.4	33.3	47.4	55.5	60.4	58.4	50.2	41.0	30.9	10.1	34.2
1905	4.4	8.4	21.6	35.3	45.8	54.6	61.4	61.4	54.6	40.3	26.9	18.7	36.1
Average	7.97	7.65	19.54	36.19	47.89	55.82	*62.24*	60.18	52.5	42.58	27.19	13.11	*36.01*
S. E. Michigan (Mean)	24.1	22.2	30.8	46.9	56.7	67.1	*71.9*	69.1	62.6	50.6	36.5	27.0	*47.2*

Highest Temperatures in °F.

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Ann'l min'm
1896	36.0	47.0	47.0	59.0	89.0	88.0	91.0	87.0	77.0	66.0	46.0	47.0	91.0
1897	42.0	33.0	45.0	67.0	73.0	86.0	84.0	83.0	88.0	74.0	47.0	38.0	88.0
1898	35.0	38.0	43.0	60.0	76.0	80.0	85.0	82.0	78.0	64.0	61.0	43.0	85.0
1899	38.0	42.0	32.0	74.0	78.0	81.0	86.0	82.0	78.0	67.0	60.0	43.0	86.0
1900	46.0	32.0	54.0	66.0	84.0	83.0	86.0	82.0	78.0	68.0	57.0	40.0	86.0
1901	36.0	38.0	44.0	67.0	77.0	85.0	90.0	85.0	82.0	70.0	48.0	37.0	90.0
1902	35.0	41.0	49.0	69.0	81.0	76.0	83.0	80.0	71.0	64.0	53.0	34.0	83.0
1903	34.0	43.0	48.0	61.0	71.0	85.0	87.0	82.0	76.0	63.0	69.0	34.0	87.0
1904	37.0	33.0	41.0	66.0	81.0	80.0	84.0	81.0	70.0	65.0	48.0	44.0	84.0
1905	42.0	41.0	54.0	67.0	77.0	77.0	82.0	79.0	73.0	77.0	52.0	39.0	82.0
Average	*38.1*	38.8	45.7	65.6	78.7	82.1	*85.8*	82.3	77.1	67.8	54.1	39.9	*86.2*

Lowest Temperatures in °F.

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Ann'l ma'xm
1896	-33.0	-26.0	-18.0	6.0	31.0	38.0	41.0	34.0	23.0	14.0	-21.0	-24.0	-33.0
1897	-30.0	-26.0	-15.0	2.0	26.0	28.0	50.0	37.0	25.0	20.0	-11.0	-21.0	-30.0
1898	-19.0	-26.0	-3.0	1.0	30.0	36.0	37.0	40.0	30.0	14.0	-11.0	-30.0	-30.0
1899	-37.0	-37.0	-17.0	8.0	27.0	37.0	43.0	41.0	20.0	24.0	-14.0	-22.0	-37.0
1900	-24.0	-30.0	-16.0	18.0	25.0	34.0	41.0	44.0	31.0	28.0	-4.0	-25.0	-30.0
1901	-25.0	-30.0	-26.0	16.0	29.0	32.0	42.0	40.0	28.0	20.0	0.0	-29.0	-29.0
1902	-30.0	-18.0	-11.0	5.0	23.0	34.0	44.0	39.0	25.0	21.0	-6.0	-20.0	-30.0
1903	-22.0	-31.0	-10.0	2.0	16.0	34.0	40.0	37.0	29.0	21.0	-8.0	-26.0	-31.0
1904	-34.0	-26.0	-13.0	12.0	25.0	37.0	40.0	35.0	30.0	20.0	-1.0	-23.0	-34.0
1905	-21.0	-24.0	-16.0	16.0	24.0	35.0	42.0	33.0	28.0	10.0	-12.0	-11.0	-24.0
Average	*-27.5*	-26.4	-14.5	8.6	25.6	34.5	*42.0*	38.0	26.9	19.2	-8.8	-23.1	-30.8

The precipitation during the same period is shown in Table 2. The minimum average monthly rainfall for the period is .002 inches for February, with a maximum of 4.25 inches in July, and an annual total of 21.73, inches, more than half of which fell during the growing season for the vegetation—June, July and August. The snowfall averaged a maximum for January with 4.59 inches and an annual total of 25.44 inches. The deep snows of this region are thus seen not to be due so much to the abundant precipitation as to its preservation by the low temperature.

TABLE NO. 2.—PORT ARTHUR, 1896–1905.

Rainfall.

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
1896	0.00	0.00	0.12	2.32	4.10	2.04	1.75	1.73	1.41	3.04	1.28	0.00	17.79
1897	0.57	0.00	0.00	0.64	2.06	3.39	6.53	4.65	1.12	1.44	0.57	0.00	20.97
1898	0.00	0.00	0.33	0.07	3.04	6.94	4.58	2.42	5.40	2.78	0.65	0.00	26.23
1899	0.00	0.00	0.00	2.57	3.40	3.84	3.52	3.76	3.65	1.79	1.34	0.78	24.65
1900	0.00	0.00	0.00	0.50	0.36	2.48	3.33	6.77	6.14	5.20	0.49	0.12	25.39
1901	0.00	0.00	0.00	1.57	0.95	3.76	6.24	2.92	1.98	2.47	0.38	0.00	20.27
1902	0.00	0.02	0.36	0.55	1.89	5.18	3.03	3.01	1.99	2.78	1.29	0.00	20.10
1903	0.00	0.00	0.14	0.23	3.14	1.60	3.29	1.97	5.56	2.61	0.27	0.00	18.81
1904	0.00	0.00	0.36	0.32	2.37	2.36	2.94	2.65	3.41	3.62	0.15	0.06	19.24
1905	0.00	0.00	0.88	0.69	2.14	2.36	7.33	1.30	4.58	2.27	2.29	0.00	23.84
Average	.057	*.002*	.22	.95	2.35	3.39	*4.25*	3.12	3.52	2.8	.87	.09	*21.73*
S. E. Michigan	*1.94*	2.16	2.42	2.27	*3.53*	3.19	2.68	2.38	2.30	2.73	2.88	2.03	*30.22*

Snowfall.

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
1896	5.5	2.1	6.4	6.8	.....	.....	.....	.....	.....	1.1	13.4	1.6	36.9
1897	1.6	8.6	9.2	8.1	.....	.....	.....	.....	.....	*	4.9	4.6	37.0
1898	5.1	4.6	5.4	.....	.....	.....	.....	.....	.....	.....	1.2	2.8	19.1
1899	5.0	5.7	3.4	*	.....	.....	.....	.....	.....	.....	.....	4.7	18.8
1900	8.5	2.0	2.9	.....	.....	.....	.....	.....	.....	.....	1.8	1.8	17.0
1901	8.4	0.6	6.6	.....	.....	.....	.....	.....	.....	.....	3.3	3.5	22.4
1902	5.0	2.4	0.4	*	.....	.....	.....	.....	.....	.....	4.8	4.6	17.2
1903	2.3	2.9	8.1	15.8	0.3	.....	.....	.....	.....	1.0	0.8	1.8	33.0
1904	2.3	1.8	7.8	0.4	.....	.....	.....	.....	.....	.....	4.3	13.7	30.3
1905	2.2	2.9	5.5	6.3	.....	.....	.....	.....	.....	0.7	4.1	1.0	22.7
Average	4.59	3.37	5.57	7.48	0.3	.....	.....	.....	.....	.93	4.28	4.01	*25.44*
S. E. Mich. (5 years)	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	*38.4*

These climatic records are likely to mean little when taken by themselves, but when compared with the conditions found in the other extreme of the state, interesting relations become apparent. Transeau ('05 b, pp. 356-358) has summarized the temperature and precipitation means for certain localities in southeastern Michigan, and these means have been placed in the table with the Port Arthur data. The most striking difference (Table 1) is the much higher temperature throughout the year in southern Michigan; the mean July maximum is 71.9° as contrasted with 62.24° at Port Arthur; the annual mean is 47.2° as contrasted with 36.07° for Port Arthur. The northern mean is between the temperature of the maximum density of water (39.2°) and the freezing point. The precipitation presents almost equally striking differences. The rainfall instead of being largely confined to the summer months, as at Port Arthur, is much more generally distributed throughout the year. The rainfall is also about 1/3 more in the south, the northern mean is 21.72 inches and the southern one 30.22 inches. In the north there is about 1/5 more snow than rainfall, 21.72 as contrasted with 25.44 inches; while in the south about 1/4 more of the precipitation occurs as snow, 30.22 of rain as contrasted with 38.4 inches of snow. While in both regions the greater precipitation is in the form of snow, the longer growing season of the plants in the south makes more of this moisture available; but on the other hand, on account of the higher temperature, more is needed. While about one-half of the rainfall in both regions occurs during the growing season, yet the evaporation is much greater in the south so that the relative humidity is less when compared with the north. (Cf. Transeau, '05, a). It seems probable that the relative humidity of Isle Royale is greater than on the adjacent mainland on account of its insular location and imperfect drainage.

Mention should also be made of the long period of daylight in the north because this is of great importance to a vegetation whose period of growth is limited to such a short summer.

To one accustomed to the hot summers farther south, the cool summer of Isle Royale is very agreeable and invigorating. Moderately heavy clothing is needed for comfort except during the middle of the day when the heat at times is very oppressive. This was especially the case during our examinations of the rock ridges. Thus on July 10 on the Jack Pine Ridge (III, 5) the thermometer on a mat of *Cladonia* recorded 93° F. in

the sun, while at the same time (2 P. M.) in the sun, but exposed to a cool breeze, it recorded 76° F. Such temperatures would not attract special attention were it not for the fact that usually the temperature is so much lower. The nights are very cool, and at Washington Harbor oh Aug. 22 there was a frost in the valley along Washington Creek (II, '04). During our camp at the Light-house, when shore winds accompanied a storm, the temperature became so low that a fire in the evening was necessary for comfort. On July 15 there was a brisk east wind, with a mean temperature of about 50° so that the vapor of ones breath was visible all day. The lake breeze is at times very noticeable as one passes from Rock Harbor into the channel at Middle Islands. It is quite probable, as, Jackson ('50, p. 420) suggests, that this cold lake air is a factor in the production of the stunted tree growth.

The low temperature of the wet, densely forested cedar swamps is worthy of special mention. As Foster remarks (‘50, p. 420) "Under the shade of the crags, and among the thick evergreen swamps of white cedar, it not unfrequently happens that perennial ice is found, covered by a layer of turf. Mr. Blake discovered a considerable area of ice thus preserved in midsummer, near Bock Harbor." Unfortunately our party did not find such conditions although such "cold islands" were kept in mind with the idea that under such conditions "glacial relicts" might be expected if these areas were of sufficient extent.

b. Seiches. The rapid and temporary changes of the water level in the harbors has been the basis of much comment. This was very marked at Tobin Harbor and at Washington Harbor. Its influence upon Washington Creek was quite marked, at times it would be ponded for some distance up stream while on other days it would be a briskly flowing stream. Foster and Whitney ('50, p. 51) make the following comment upon these fluctuations at Rock Harbor; "While at Rock Harbor, Isle Royale, in the summer of 1847, we witnessed the ebbing and flowing of the water, recurring at intervals of fifteen or twenty minutes, during the entire afternoon. The variation was from twelve to eighteen inches; and we took advantage of their recession to catch some of the small lake fish which were left in the pools. The day was calm and clear but before the expiration of forty-eight hours a violent gale set in."

This phenomenon has been investigated on the Great Lakes by Denison ('98, p. 568) who states that these seiche movements are very marked preceding and during storms and are due to atmospheric pressure upon the lake.

c. Climatic Succession. From what is known of the general geological history of the Superior region, during Glacial and post-Glacial times, it is evident that there has been a great climatic change which has been of the utmost biological importance. It is therefore desirable to see what inferences will aid us in forming a general conception of the possible climatic successions. It appears to be generally conceded that at the margin of the ice sheet the conditions must have been quite arctic in character, similar to that of the "barren grounds" of the far north. Such climatic conditions might result from a permanent atmospheric low correlated with the presence of the ice sheet (Cf. Chamberlin and Salisbury, '06, 11, pp. 674-675; 111, p. 433). The prevailing westerlies, combined with a permanent low to the north would favor westerly continental winds along the margin of the ice. Perhaps a suggestive comparison can be made between the seasonal transitions from the two permanent winter lows near the Arctic regions, into the summer condition of one low with its transitional "March weather" and that of American and European glacial lows and their transformation into the present summer arctic low. In connection with this subject a paper by Fassig (‘99) is of special interest. Analogies are often dangerous but the idea is of interest because it suggests a "March weather" transformation for post-Glacial times. In this connection the formation and occurrence of the wind blown loess, with its greatest development in the west and on the east banks of certain streams, is of special interest, although these conditions did not develop in the north as they did farther south. The occurrence of the westerly winds seems to be further supported by the westerly and southwesterly extension of the ice from the centers of the accumulation (Cf. Chamberlin and Salisbury, ‘06, 111, pp. 330-333). Somewhat similar conditions in some respects obtained in Europe (Penck, ‘06, p. 183) but the dry winds were easterly rather than westerly as in North America. The European loess deposits also approached much nearer to the (western Europe) coast than in America, where they remain far to the interior. The Great Lake storm track may have been wider, but, more probably, was narrower and more intense. The northeastward retreat of the ice sheet is paralleled by the northeastward migration of spring weather conditions (Bigelow, ‘97, p. 48) and if this route of the -opening of spring was initiated at this early date it must have had important biological consequences upon the migrating animal life of the Interior. The arctic and storm track types of climate are perhaps the only ones which Isle Royale has possessed, although the storm centers may have, as a rule, passed farther south than at present. If these suggestions are applied to the Interpretation of the Glacial and post-Glacial history of Isle Royale, the general relations will be about as follows: Succeeding the disappearance of the ice was an arctic condition with short summers and long winters, prevailing westerly winds, and severe easterly or southeasterly moving storms. Such conditions as these would influence the direction of lake currents, wave action on the beaches, and the source and movement of the lake drift, all of which would greatly influence the biota.

If the Glacial and post-Glacial adjustment of the permanent lows was accompanied by severe storms, this would be a factor which would certainly influence the rate of formation and the distinctness of the beach lines, and it is not altogether improbable that a study of the well developed Nipissing beach, by the development of its spits and bars, may furnish data regarding the lake

currents and the prevailing winds. But in order to interpret such records it will be necessary to formulate criteria by means of which duration of a beach formation may be distinguished from one of less duration but due to more severe storms and active currents.

d. The Lake Storms and their Influence. The significance of lake storms is of special interest on account of the bearing of the latter upon the conditions of life upon the beach, and also upon the lake drift. That they must be reckoned as an important factor in the post-Glacial repopulation of Isle Royale is evident when we recall that during the life of the present fauna and flora the island has never been connected with the mainland except by ice. Very fortunately the subject of lake storms has been carefully investigated by Garriott ('03) because of its influence upon navigation.

The period of greatest seasonal frequency for severe storms ranges from September to December, with a November maximum, while March contains the greatest number of such storms for the remainder of the year. The smallest number occur in June, July and August.

There are several types of these storms, the most severe of which are those of southwestern origin and which occur between October and May. They are preceded by east and northeast winds which gradually become a gale; but when once the storm center has passed the wind suddenly shifts to the northwest and is an offshore wind from Canada. Such storms are frequently followed by much snow and intense cold. During the warmer months, storms from this direction are usually of tropical origin.

Less severe storms are those coming from the middle-west. These are preceded by gales, first from the south and later from the east, and after the passage of such a storm center the wind suddenly changes to the northwest and finally finishes with clearing weather, or if in winter, sometimes by a light snow. These storms are common at all seasons of the year, but the most severe ones occur during the cold months.

Storms from the northwest are seldom severe; they are preceded by south or southwest winds, and after their passage the wind shifts to the west and northwest and rapidly diminishes in velocity. In winter the attending precipitation is generally light, in summer it is in the "form of thunder storms, and the high winds in squalls from the southwest at the time the center of the storm is passing." To this class belong the majority of lake storms, but they are seldom severe.

From these relations it is seen that storms whose origin is from the south, southwest or middle-west, are preceded by east or northeast winds or (middle-west) by southern winds, and followed, after the passage of the storm center, by northwest or west winds; while storms of northwestern origin are preceded by south or southwest, and followed by west and northwest, winds. These facts show that offshore winds from the eastern and southern shores of Lake Superior are the general law for winds preceding most storms; and that after the passage of the storm center all appear to be followed by west or northwest winds. These offshore winds are likely to be onshore winds for Isle Royale. The proximity of the north shore, the frequency and magnitude of this wind phenomena, clearly suggests that these factors may largely account for the Canadian affinities of the majority of the Isle Boy ale biota. But we shall see later that there are other factors to reinforce this same tendency. It may seem unnecessary to enter these details, but it should be remembered that the conditions under which an organism may reach the island is an important factor in its survival, a relation of special importance in the migration of birds. That the majority of these storms occur in the fall and winter, at a period of relative inactivity on the part of the Isle Royale biota, is yet a condition which would be favorable for the transportation of some small hibernating invertebrates. The life histories of these storms, especially the conditions of their termination, may be expected to have an important bearing upon the survival of the drift biota.

There is still another important phase of this subject, and that is the influence which these storms have upon the life of the shore and! beaches. The fauna of the exposed shore of Isle Royale is very scanty and much inferior to that of the harbors, so that, generally speaking, up to a certain point the more protected the coast the more diversified the fauna. This was very clearly shown by the molluscan life upon the shore. These storms have a powerful scouring action with the sand, gravel and shingle on the exposed coasts, so that a rock surface or one with blocks too large for disturbance by the waves is much more favorable to life.

The relation of waves to lake currents presents a significant phase closely related not only to the occurrence and distribution of life along the beach, but also to the problem of lake drift and its biological importance. A breaking wave tends to carry forward floating objects so that when such objects are carried along by the currents and once come within the range of influence of the breaking waves of shallow water, they tend to move with these waves into the shallow water and thus shoreward and are cast upon the beach in harbors, bays or about islands (Harrington, '95, p. VI.).

e. The Surface Currents of Lake Superior. Mention has previously been made of the fact that in addition to the offshore winds from Canada, which accompany certain severe storms, there are other influences which have a similar effect upon drift—the lake currents. These are, in part, an expression of the same climatic trend and their direction is a resultant determined by the influence of the prevailing westerly winds, the rotation of the earth, the form and contour of the basin, and the position of the outlet. A detailed investigation of these currents was made by Harrington and Conger (Harrington, '95) who paid particular attention to the currents about Isle Royale. As these investigations were made during the season of navigation, they are of particular interest from the standpoint of the biota, because it is during this same period that we must in

general expect the most advantageous dispersal of plants and animals to take place.

The simplest of these factors influencing currents are: the general movement toward the outlet of a lake, the prevailing westerly winds, the deflection to the right (or southward) of the current on account of the rotation of the earth. But the general form of the lake and its shore line, the contour of the bottom and the location of islands, introduce important complexities into the problem. As may be seen in *Fig. 53* Lake Superior well illustrates the influences of all these conditions. The small size of the outlet does not allow the escape of this vast current, so that there is a return along the north shore, where islands are encountered which produce eddies; and in their shallow water and along their coasts breakers are encountered which tend to carry shoreward and lodge drift.

When the return swirl reaches Isle Royale the problem becomes complex and is of such importance that these currents were, made the subject of a special investigation by Harrington and Conger. In their study of the lake currents, bottles containing instructions were sent adrift and the finder was requested to communicate their recovery to the Weather Bureau. In this manner, supplemented by other sources of information, these currents were determined. The results of the investigations about Isle Royale are as follows:

"Not a single bottle has been recovered on the northwest coast of Lake Superior. This is not due to no bottles having been floated in that vicinity, as during the season of 1893 alone Mr. Conger floated 250 bottles between Duluth, Minn., and Thunder Bay, Ont.

"This fact was deemed of such importance that the Chief of the Bureau, accompanied by the inspector in charge of the Lake Marine Service, made a special trip from Duluth, Minn., along the northwest coast around Isle Royale to Port Arthur, Ont. Careful note was made of the entire coast, all beaches examined, and observations of water temperature made to assist in solving the direction of the current flow in this region. At French River, observations were made with special current floats, and it was discovered that the main current was to the northeast from 1 to 2 miles from shore. Inside this line was found a current flowing to the westward. This shore current evidently begins farther to the east, and continues to the west end of the lake, and is positive at or near Duluth, as is confirmed by investigation of the officials of the city of Duluth, however, narrow and does not extend far into the lake.

"Around Isle Royale there was found abundant evidence that the current flows to the west along the north shore of this island. Observations of water temperature at this point are very interesting and indicate a deep stream flowing from the eastward. There appears but little difference in the temperature of the water at the surface and at the depth of 100 feet. In other localities to the southward there is a marked difference between the surface and deep water temperatures.

"In confirmation of this current there may be mentioned the following special drifts, the numbers referring to those on the chart*: (7) Drift of the yacht Albatross in summer, during a dead calm; papers thrown overboard remained alongside of the yatch for several hours; the drift was strong and uniform to the west. (8) Track of driftwood floated by party from the boat in a calm off McCargoes Cove, Isle Royale. (9) Drift of wreckage from the Silver Islet crib and pier which was washed away in a northeast storm. (10) Record of ice floes in calm weather during winter of 1891; reported to have drifted from the northeast, to southwest at a rate of 3 miles an hour. (11) Drift of party in sailboat while becalmed on July 31, 1894. (12) Steamer Cumberland, which went to pieces on Rock of Ages, in 1877, whose wreckage was distributed along the entire south shore of Isle Royale. (13) Drift of a champagne bottle floated by Mr. W. H. Arnold, Port Arthur, Ont., on October 8, 1893; and (14) the drift of a fish barrel floated by J. H. Malone, keeper Menagerie Island Light, about August 27, 1885, and picked up twenty-six days later. The wind during this period was mostly from the south shore.

"The confirmations indicate that the current between Isle Royale and the north shore sweeps to the west and southwest after passing the island and recurving rejoins the main easterly current to the south and west; the drift of the wreckage from the Silver Islet pier indicates that it recurves at some point to the southwest of Grand Marais, Minn.

"Special attention is called to the current between Isle Royale and the north shore. The great depths, the conformation of the bottom, and the water temperatures in this locality indicate that there is a steady and fairly strong current sweeping from the east through the narrow pathway to the west, flowing to the southwest after passing the west end of the island, and rejoining the main easterly current as mentioned above. This narrow and relatively rapid stream, like the one between the Manitou Islands and the Michigan mainland in Lake Michigan is probably the most persistent and regular to be found in this lake. * * * *

"1. Section 79.—Floated by Capt. H. O. Jackson, steamer L. Shickaluna on June 23, 1893, at 6:45 p. in., in northwest corner. Found by Charles Lesage, Lake Linden, Mich., at entrance of McCargoes Cove, Isle Royale, on October 20, 1893, on the beach."

*Not reproduced on the map or figure.

It is thus seen that drift from the north shore of Lake Superior tends to be strained from the lake currents by the various harbors of Isle Royale. It also suggests that north shore life might also reach Keweenaw Peninsula, but so far as known this has not been recognized. Drift was observed in Tonkin Bay which had evidently come from a distance and dead birds reported by Peet, as drifting into Washington Harbor, probably came in part from the north shore current. The long duration of these currents since the Ice Age seems very probable, and undoubtedly they have had an important bearing upon

the geographic origin of the Isle Royale biota, so that they cannot receive too much emphasis.

A few words may be added concerning the probable history of the lake currents. Since the location of outlets, prevailing winds, topography of the basin and rotation of the earth all influence lake currents, it is evident that any important change in these conditions will cause a modification in the currents. By means of these criteria then we may infer what currents are likely to have existed under certain conditions. Some of these conditions have had a very permanent value in the Superior basin, because the general form of the southern shore (except Keweenaw Peninsula), the earth's rotational deflection to the right, and the prevailing westerly winds, made relatively definite conditions. Thus the early Glacial lakes in this basin, which had southwestern outlets, must have had different currents, perhaps more or less against the prevailing westerly winds, and the absence of large islands would be favorable to uniformity. Later at the Algonquin stage, *Fig. 52*, there must have been a very complicated system of lake currents, perhaps a rough outline of those of the present Great Lakes, at least in the deflection toward the right shores on account of the rotation of the earth, and to the eastward on account of the prevailing westerly winds and the eastern outlets. The broad connection between the Superior and the Huron basins perhaps also favored a north shore return whirl, while at the Nipissing stage, *Fig. 54*, in the Superior basin the currents were in general quite similar to those of the present lake, but more simplified in detail by the greater depth of the lake.

If such general relations as these obtained, it will be seen that the north shore return whirl may have been of considerable duration, and that the opportunity for these currents to carry life from the south shore must have been constantly less favorable than the chances for them to effect transportation from the north shore of the Superior basin. In this basin then it seems that the currents were first relatively simple, became quite complex at the Algonquin stage and were simplified at the Nipissing stage. A detailed study of the beach lines such as those of the Nipissing, might add much positive information as to these ancient lake currents and their biological relations.

f. The Origin of the Habitats. Isle Roy ale is about 45 miles in length, has an average width of about seven or eight miles and an area of about 210 square miles. The shallow soil, rock ridges, forested swamps, lakes, small streams, rocky coast, and harbors provide a variety of conditions and furnish play for such a variety of processes that many diverse habitats are produced. Generally speaking, the island is covered with a stunted coniferous forest growth. Attention has already been called to some of the conditions and processes which have produced the major environmental regions and the general topography of the surface. If Isle Royale had high mountains and greater extent, very different habitats would be expected.

As we have seen, the entire surface of the island has been beach, and previous to that it had been a reef in the lake, so that the beach represents the original land habitat upon the island. Generally speaking this habitat has migrated from the crest of the Greenstone Range downward for about 550 feet to the present lake level. With this progressive downward movement, there has been an increasing area exposed to subaerial processes of erosion. The origin of the harbors has been a part of the beach problem, but that of the protected beach, these with the falling of the lake have migrated outward, as is suggested by the courses of the main streams occupying the rock valleys.

The very immature condition of the drainage shows that during the present post-Glacial cycle only comparatively slight changes have modified the relief from the condition in pre-Glacial times; it is thus largely an inherited topography, hence the consequent drainage. It should perhaps be added, however, that the date of the faulting is not definitely known; it may be very ancient, but the weight of the ice sheet may have had considerable influence. It thus seems probable that with the decline of the lake level there has been an increase and downward elongation of the stream environments, and that their course has been determined largely by the pre-Glacial topography, supplemented, of course, by the southward tilting of the land. The lake basins have had an origin similar to that of the streams and have tended toward extinction by tilting, inwash, organic debris and to a limited extent by the downcutting of outlets. On account of the relatively small amount of erosion by the ice sheet it is probable that the shallow swamps and the smaller streams were influenced more by the ice than those features related to the greater relief of the surface; even moderate tilting would considerably influence such an environment, because within the major valleys the divides are generally low.

The origin of certain land habitats only remains to be considered. These have undergone a complex succession of changes. The resistent lava of the Greenstone had been the least reduced by erosion so was the first to emerge from the lake level. This was first a beach, and as the water fell from its crest the upper beach migrated to lower levels and the land habitat continued to increase in area. The beach line itself expanded laterally, if not in width, as the area of the island increased. When once the exposed rocks were beyond the reach of the waves, weathering and erosive processes were initiated which tended to produce a residual soil. Plant remains from lichens were perhaps the first humus formers, and it is probable that it was not until the period of Lake Algonquin that the lake drift which was washed ashore became a source of such material; but winds, birds, lake currents and the waves may all have contributed pioneers of the higher plants. The harbors at the northeastern end of the island would tend to strain out the drift from the southwestward flowing current and the returning one along the southeastern coast of the island would tend to lodge drift in Washington Harbor and the Siskowit Bay region.

As the water continued to fall to lower levels, the land biota followed down the slopes behind the receding beach. By the Nipissing stage, the vegetation and many animals were probably well established and had begun to actively encroach upon the swamps and lakes and thus tended .to increase the land habitat. With the tilting that followed the formation of the Nipissing beach, a readjustment must have taken place between the land and water habitats, but to what degree, their relative areas were influenced is not known. During the initial elevation ponding would be expected at the northeastern end of the island, but with a greater elevation this same area would be well drained, as the divides in the valleys are low and the transverse drainage near the central part of the island would tend to prevent extensive ponding, combined with the fact that the valleys extended in the same general direction as the uplift and not across it. It therefore appears that many processes have tended to increase the land habitats at the expense of the aquatic, such as the falling of the lake level, the encroachment of organic remains on the depressions, the perfecting of drainage lines and the tilting of the surface.

With the advent of the forest a habitat differentiation developed in contrast with the natural openings. These openings were originally due to the lack of soil, as on the ridges, wave action, as on the beach, or an excess of water as in the depressions. With the accumulation of soil, the downward migration of the waves, and the filling up or draining of the depressions, the range of the forest has been extending, and is tending to completely cover the surface.

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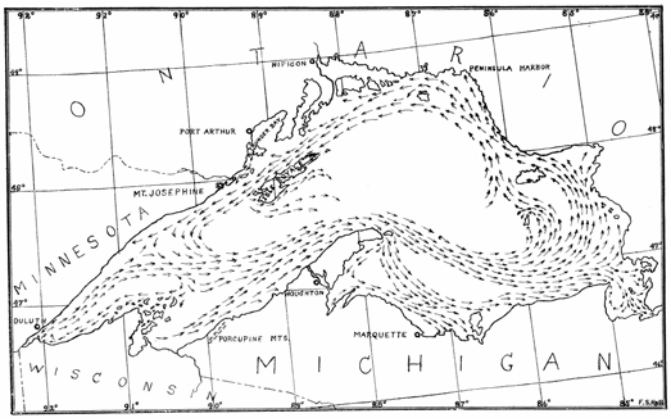


Figure 55. Surface currents of Lake Superior. To show their possible influence on the origin of the biota. (Drawn by Hall, after Harrington.)

THE ECOLOGICAL RELATIONS OF THE INVERTEBRATE FAUNA OF ISLE ROYALE, MICHIGAN.

BY DR. HENRY ALLAN GLEASON.

I. Introduction.

The most recently emerged portions of Isle Royale are the rock and gravel beaches which together constitute virtually the entire shore of the island. Animal life is found upon them almost to the edge of the water, and well within the limits of wave action. The physiographic succession in the island is such that the areas originally occupied by beach pass through a series of changes in the physical factors, a series which is accompanied., sometimes hastened, sometimes retarded, by corresponding vegetational successions, and which culminates in the final or climax plant association of balsam and spruce forest. The detail of this physiographic and vegetational succession is by no means uniform; it may proceed along either of two well-marked lines, depending on the immediate physical and biotic conditions, certain intermediate stages may be prolonged or omitted entirely, and various other deviations may occur. Nevertheless the final stage is always the same. Accompanying the changes in physiography and vegetation is a similar and dependent change in the fauna, so that there is a corresponding series of animal associations, beginning on the beaches and developing in the same direction, with the same deviations or omissions, to the final or climax association in the balsam-spruce forest.

The preceding general statement rests on the assumption that the areas now occupied by the climax biotic associations have developed from the beach associations through a series of stages intermediate in time corresponding to those associations which now stand intermediate in space between the two extremes. Or briefly, as some ecologists have expressed it, the lateral distribution in space recapitulates the vertical distribution in time. Such an assumption is evidently closely akin to the recapitulation theory of the evolutionists, and just as that so-called biogenetic law has been accredited with more than its true value, so has this ecological dictum possibly much less importance than has been usually supposed. The weakness lies in too little consideration of the time element. It is certain that the higher land in Isle Royale has been submerged. This is shown by the old beach marks now many feet above the present level of the lake. Consequently by the gradual emergence all of the island has passed through a beach stage. But it is unwarranted to conclude from this that the fauna! or floral associations of the former beach were similar to those of the present, or that in the intermediate stages the biota resembled that which now occupies the area between the ancient beach and the present shore. While it is likewise certain that with a continued subsidence of the lake level the present beaches will eventually be left far above the water, it must not therefore be assumed that their biota will show the same successions or reach the same climax as those of the past. Changes in the temperature or rainfall may certainly keep pace with the changes in lake level, or even be caused by it, and in either case they would exert a profound influence on the biota. Migration of species is still taking place among both plants and animals, and may introduce new or even dominating species among the present forms. The so-called equatorial pressure of southern species is fully as strong now as it was directly after the close of the glacial epoch. Lastly, and most important of all, the influence of the biota itself is always to be reckoned with. Both plants and animals are continually becoming more plastic, adapting themselves to new conditions, and extending their habitats into new associations. They push forward more rapidly than the changes in physiography, sometimes hastening and sometimes retarding physiographical action, and at all times greatly influencing the subsequent successions.

A biotic association may develop into another by a mere re-arrangement of the interrelations, numerical or otherwise, of the component species, without the necessary loss of some or addition of others. But such cases are rare, and the Isle Royale observations show that- no two associations have exactly the same species, and that with each progression there has been an addition of certain forms which become the most characteristic types. The first bit of beach formed was occupied by an association possibly not unlike that of the present beaches. All the species must evidently have immigrated from beyond the island. When the soil deposits on the beach were sufficient to support a

second association its species were derived partly from the beach itself and partly from new immigrants. The further development of biotic associations on the beach was then possible not only from immigrants, but also from the two associations already present. Similarly at the present time each association on the island is constantly being invaded by species from all the others, and many of them are actually able to establish themselves. This tends toward a homogeneity in the biota hardly in full accordance with the recapitulation idea. Indeed, it is very probable that independently of all physiographic agencies the whole surface of the island would eventually be occupied by the balsam-spruce forest and its attendant faunal association.

In many cases it is virtually certain that the lateral succession does faithfully repeat the vertical, and the zonation of plants around a pond may be taken as an example, but the filling of a pond is only a single step in the genetic development of the biota of an island.

With this preliminary note of warning, the truth of this recapitulation theory will be assumed for the island, and the discussion of the insect and molluscan fauna will follow the genetic lines indicated in the first paragraph.

The relationship of the various physiographic types on the island to each other may conveniently be expressed by a diagram (see end of paper), indicating the direction of the devolpment by arrows. It must be remembered that practically any one of the intermediate stages may be omitted.

II. The Lake.

The lake (Superior) must obviously be regarded as the first stage in the genetic development of the faunal associations. Broadly speaking, the lake fauna is divisible into two main groups. The first is pelagic in character and includes those species whose distribution is entirely independent of the shore, for example, most of the species of fish. The second group is littoral; the species occur along the shore in comparatively shallow water, and are to a greater or less extent dependent upon the land in its relation to the character and slope of the bottom and to the motion of the water. Members of the latter group only are considered here.

The two dynamic factors just mentioned are the most important ones that influence the biota of the lake. There are no currents of sufficient rapidity to affect the animal life. The direction of the wind, whether off-shore or on-shore, may respectively lower or raise the level a few centimeters, especially when the wind blows lengthwise of the long narrow inlets, such as Conglomerate Bay (*Fig. 11*). Some fixed or slow-moving species may accordingly be alternately submerged and exposed, while motile forms can at once adjust themselves to any change of level. Of far greater importance is the motion of the water caused by wave action. It is only on rare occasions: that the lake is quiet. Gentle waves come in nearly all the time, and after storms become of great violence. Wave action is of itself sufficient to inhibit the growth of shells along the exposed shores, where they might easily be torn loose and crushed against the rocks. Such forms are consequently restricted to the shores of the smaller bays or to the lee side of islands.

Wave action is of importance further in determining the character of the bottom. Where the shore is exposed directly to the lake it is usually of massive rock, all the fragments having been washed down to deep water. In small shallow coves, where the waves break always in one direction there is usually a sloping beach of gravel extending across the end perpendicular to the direction of the waves. Every breaker sorts over this gravel so that it is nearly impossible for a fauna to develop. In larger coves or bays, where the violence of the wave action is reduced by distance, the gravel is finer or even a beach of sand may rarely be formed. Along the steep or cliff-like sides of these coves the bottom is frequently covered with angular rock fragments too large to be moved by the water. These are frequently inhabited by shells. In general the development of a free littoral fauna demands quiet water where the animals will not be dashed on the rocks or stranded on the shore, and for attached species there is required either quiet water or a firm bottom which will not be dislodged by the waves. A more detailed discussion of this as affecting the distribution of shells will be given later.

In the larger inland lakes, of which Siskowit Lake, the only one of the class studied, may be taken as an example, essentially the same conditions obtain as on Lake Superior itself. The difference in temperature and content of the water seems to be of minor importance. The waves in the larger lake can naturally reach a larger size, and their influence is felt far into the bays. Thus at the head of Rock Harbor, about six kilometers from the lake proper, the distribution of shells and the almost total absence of free forms indicate that even there wave action is of importance. In Siskowit Lake, although larger than Rock Harbor the force of the waves is so reduced by every headland or island that on the quiet water in their shelter a rich fauna of such free forms as water-striders and whirligig beetles is found on the surface, while numerous mussel shells live on the silt or sand bottom. In Sumner Lake and others of limited area the motion of the water has no measurable effect on the biota, and they will therefore be treated under a separate heading.

The distribution of shells along the shore, particularly species of *Limnaea* and *Physa*, is of especial interest. Having relatively low motility they are correspondingly limited in their distribution and the factors governing it are more readily determined. These will perhaps be made clearer by concrete illustrations.

Tonkin Bay is a small inlet about half a kilometer long, opening to the east upon the lake, and with steep, approximately parallel sides. It is narrowed half way up by two beaches lying perpendicular to its length. By this the wave action on the upper part is reduced, but still may sometimes be sufficient to wash heavy drift-wood

upon the beach. In the outer half the wave action is but slightly less than on the lake itself, and no shells are found. In the inner or upper half *Limnaea stagnalis* L. (Nos. 50, 54, 57), *Limnaea emarginata* Say (Nos. 50, 57), and *Physa sayii* (Tap.) (Nos. 50, 57), live along both sides where the bottom is rock, but not across the ends. They live only on a rock substratum, which may be either horizontal or vertical, and in water up to 45 cm. in depth. The larger species, *Limnaea stagnalis*, is more abundant in the deeper water, and only the smaller species live at a depth less than 15 cm. They then prefer the vertical walls to the horizontal or flat bottom.

Conglomerate Bay is a rocky inlet (*Fig. 11*} similar to the one just described and about 1.6 km. long. Being wider at its mouth than Tonkin Bay the force of the wave action is felt farther up the bay. Near the end the waves have little effect, as is evidenced by a sandy beach (*Fig. 4*), almost without driftwood. At the upper end of this bay along the north side *Limnaea emarginata* Say (Nos. 118, 125) and *Physa sayii* Tap. (Nos. 118, 125) are found in water 15—45 cm. deep, in the deeper water on the tops of flat rocks, in the shallower water, also on the vertical sides and in small crevices. They never occur on the sand or gravel deposited around the rocks, as is frequently the case near the sand beach at the upper end of the bay. The distance to which they extend from shore is greatest opposite the concavities of the shore line and least opposite the small rocky headlands. Their distribution in both Tonkin Bay and Conglomerate Bay seems to be regulated mostly by the wave action, since they seek the most protected places, avoid the shallow water where the waves would strike them most, and do not live on loose or small rocks, gravel, or sand, which would easily be dislodged. The fact that the smaller shells are found at the least depth, while the larger *Limnaea emarginata* inhabits the deeper water, would indicate that the small size of the former renders them less easily dislodged by the waves. Again their greater abundance on the north side suggests the possibility of a light relation.

Siskowit Lake, with its rocky shores and large area, offers essentially the same condition, as Lake Superior itself, and the shells have the same general distribution. Along the very gently sloping rocky shore near the outlet *Limnaea stagnalis* occurs in abundance, always at a depth of 10-40 cm. Along the south side of a large island near the south shore, where they are sheltered from waves in every direction, the same species is abundant. They live on rocks in the full sun in water 10-45 cm. deep, with the optimum depth at 20-25 cm. They may occur on the tops or sides of rocks, but never on the sand between them. Associated with the *Limnaea*, but much less abundant, are *Planorbis bicarinatus royalensis* Walker (No. 210), *P. campanulatus* Say (Nos. 210, 211), *Lampsilis luteolus* (Lam.) (Nos. 210, 211), *Anodonta marginata* Say (No. 210), and *Anodonta grandis footiana* Lea (Nos. 210, 211).

Opportunity was given to observe the behavior of *Limnaea stagnalis* (No. 217) in waves of some size near a small circular island half a kilometer out in the lake. The bottom was gently sloping, and either of solid rock or of large rounded fragments. There were no overhanging trees, so the shells were found in uniform abundance in the usual depth of water on all sides of the island. At the time the island was visited a strong wind was blowing, and the waves were probably nearly as high as they ever become on Siskowit Lake. One or two shells were seen which had been washed loose, and of course would be unable to re-attach themselves until the waves abated. It would be expected that in such cases the shells might be crushed or broken or the animal killed. That such may happen was evidenced by finding a few live shells which had been cracked and then healed, leaving an irregular surface. Their occurrence here and elsewhere only upon rocks of considerable size shows that they require a firm substratum, and where the rocks are free from any coating of slime they can certainly endure higher waves. Around the island under discussion the rocks were washed perfectly clean.

The beach in front of the camp at Siskowit Bay (*Fig. 29*) was inhabited by large numbers of (No. 200) *Physa sayii* Tapp., *Physa* sp., *Limnaea stagnalis* L., and *Limnaea emarginata* Say, so that more detailed observations of them could be made, and a few experiments carried out to show their sensitiveness to the depth, or bathytropism, as it has been termed. The beach here is of rock with a gentle slope of about one in five, corresponding to the dip, except where blocks have worn off, leaving low vertical walls. The wave action here is very light, its force being cut off by a series of islands lying between the beach and the main body of Siskowit Bay. This was well shown by the conditions on August 2, when there was scarcely a ripple inside the islands, although the bay outside was covered with whitecaps. The beach is covered with a thin coat of slime formed mostly of excrement from the snails.

On such a beach snails may live close to the edge of the water, but the larger *Limnaeas* still occupy their usual depth of 1.5 to 4.5 decimeters. About 10 A. M., on August 3, all the shells to a depth of about 1 decimeter were gathered from a strip of the beach about 10 meters long. They were comprised in the following species: (No. 200) *Limnaea stagnalis* L., *Limnaea emarginata* Say, *Physa sayii* Tapp., and *Physa* sp. The smaller *Physas* were especially abundant and about 200 of them were taken. Four hours later, at 2 P. M., 60 shells, all of the smaller species, had migrated upon the same strip. The only evidence concerning the way that they came is that one shell of *Limnaea stagnalis* was seen to drift up over a low wall into the shallow zone. This method could hardly account for 60 of the smaller ones, however, appearing in so short a space of time. It may be taken as indicating a general and continued migration in all directions within their bathytropic limits.

It was noticeable that the large *Limnaea emarginata* and *Limnaea stagnalis*, aside from the one specimen mentioned above, live at an average depth of 3 dm. and never deeper than 4.5 or 5 dm. To test their bathy-

tropism six of them were picked out of the deeper water by hand and held in contact with the bottom in the shallow zone until they extended their feet and attached themselves. At this time the water was very quiet, moving just enough to cause a faint sound on the beach. But the size of the shell of the two *Limnaeas* is so large that they offer considerable surface to the water and are consequently easily washed loose. Two of the six swung a little from side to side and were then washed off and carried by the undertow into water 3 dm. deep, where they again attached themselves. A third, without being shaken by the waves, clung to the rock for some time, then suddenly let go its hold and drifted over a low ledge into the deeper water. Two others immediately started to crawl down the slope, and one in about fifteen minutes, the other in about half an hour, had crawled over the ledge into water 3 dm. deep, where they both remained stationary. The sixth remained attached, and in three hours had crawled 2 dm. parallel to the shore, keeping at the same depth. The next morning, twelve hours later, it had disappeared, and of course could not be recognized in the deeper water.

On August 4 two shells of *Limnaea* appeared in the shallow zone, but it is not known whether they drifted or crawled up. They were there at least three hours. After they were last observed a fresh breeze sprang up from the east and the slight wave action caused by it probably washed them down.

The level of the lake varies somewhat with the direction and intensity of the wind, so that in front of the camp a strip of beach up to 5 dm. in width may or may not be covered with water. The smaller shells, *Physa sayii* Tapp. and *Physa* sp., live in this zone in spite of the fact that they are sometimes out of water. So far as observed they are never exposed for any considerable length of time, so that they do not become dry. Then again the weathering of the rock has left bowl-shaped hollows a centimeter or so across and about the same depth, and the snails usually get into them.

To summarize, the known facts bearing on the distribution of these four species are as follows:

1. Their lower limit is 4.5 to 5 dm. depth of water, governed possibly by the water-pressure or the food supply.

2. The upper limit is for *Limnaea stagnalis* and *Limnaea emarginata* 1.5 dm. of water, for *Physa sayii* and *Physa* sp. the shore-line. The cleaner the rock and the less the wave action the shallower the water which they may inhabit.

3. Their horizontal distribution is controlled by (a) full exposure to the sun; (b) a rock bottom; (c) a certain minimum of wave action.

But two species of insects were collected which should properly be considered here, caddice flies and stone flies. The larva cases of the caddice flies were collected only in the outlet of a small stream emptying into Rock Harbor, in, 1-1.5 m. of water (No. 163 or 164), but the imagos were common all along the shore of the lake, especially on the gravel beaches. One (No. 192) was taken on the boat about 2 km. off the south shore of the island. Stone flies were also frequently collected along the beaches, where they came up to breed. They were most numerous, however, on steep or even vertical cliffs with southern exposure (Nos. 24, 80). Near the entrance to Conglomerate Bay (*Fig. 2*) they were seen collected in such a place by thousands. The water there was at least 4 m. deep.

A few hair-worms, *Gordius aquaticus* (L.) (No. 207), were collected in 2 to 3 dm. of water on the rock beach (*Fig. 30*) in front of the camp on Siskowit Bay.

The various mussels collected in Siskowit Lake and elsewhere, even though sometimes associated with *Limnaea stagnalis*, belong rather to the associations of the smaller inland lakes.

III. The Inland Lake.

The smaller lakes are mainly surrounded by tamarack swamps, with the vegetation showing the characteristic zones, certain ones of which, as the rushes, water-lilies and pond weeds, live in the lake itself. The bottom is covered with peaty mud or with slime, and the wave action is never severe enough to interfere with the growth of either fauna or flora. In many of the smaller lakes, in fact, the water lily zone is so wide and the open water so restricted that there is practically no wave action at all (*Fig. 46*). Accordingly both fauna and flora are richly developed both in species and individuals. The fauna may be roughly classified into several groups according to their habitat in order to facilitate description. The interrelations of the different species are complex in the extreme, and of course could not be properly worked out in such a short time as the lakes were under observation.

a. The Fauna of the Bottom. In Sumner Lake (III, 5) (Figs. 18-22 and in sheltered places in Siskowit Lake several species of shells live on the bottom in sand or mud and at a depth of from 3 dm. to 1 or 2 m. *Planorbis trivolvis* Say (No. 135) lives in the shallower water, preferably in mud. It is nowhere abundant, but was collected in both lakes. One specimen only was found in Sumner Lake in a little pool with mud bottom. Shells were commoner on the shoreward side of an island in Siskowit Lake, on a bottom composed of sand and mud. They were well buried under the sand and the majority of the shells were dead.

Mussel shells, especially *Anodonta marginata* Say and *Anodonta grandis* Lea, were common in all the smaller lakes and at the upper end of Rock Harbor. They were most abundant in the deeper water with a sand bottom, particularly where there was comparatively little vegetation. In certain sheltered bays at the upper end of Siskowit Lake they were especially numerous. Muskrats carry them to the shore to eat, and leave the empty shells in heaps, which were conspicuous sights along most of the lake shores. In Sumner Lake live shells

were very scarce, but the piles of dead ones on the bank testified to their former abundance.

At the upper end of Rock Harbor some small shells, *Planorbis bicarinatus* Say (89), *Planorbis exacutus* say (89), *Planorbis parvus* Say (89, 163, 164), *Valvata tricarinata* Say (89, 163), *Valvata sincera nylanderi* Dall (80, 163, 164), *Amnicola lustrica* Pils, (89, 163, 164), and *Pisidium* sp. (163, 164), and Amphipods were dredged from a depth of 1.5 to 2 meters near the mouth of a small stream (*Fig. 22*) where the bottom was thickly covered with small twigs and other coarse vegetable debris. From the same place the caddice fly larvae were obtained, as mentioned previously. The same fauna was collected in the stream itself, but only near the mouth, where the water was deep, the current slow, and the conditions in general much like those of a lake. May flies probably breed in similar places. No larvae were seen, but a few images were collected (No. 178).

The fauna of the bottom shows a connection through the presence of *Pisidium* sp. in the last case with that of the small streams in the tamarack swamps and with that of the brooks, like the outlet of Siskowit Lake. The accumulation of vegetable debris and the more restricted amount of water are both approaches toward the conditions in the former places. In Siskowit Lake, where *Planorbis campanulatus*, *Planorbis bicarinatus royalensis* and *Anodonta grandis footiana* were associated with *Limnaea stagnalis*, another transition was shown between the faunas of the inland lakes and the larger lakes as typified by Lake Superior itself.

b. The Free Fauna of the Water. No species were observed except fishes and leeches. The latter were abundant in Sumner Lake, especially among the water lilies and in the shallow water along the shore.

c. The Fauna of the Surface. Hardly belonging properly to this group were the small shells, *Limnaea catascopium* Say (220), *Physa* sp. (220, 221), *Valvata sincera nylanderi* Dall (220), and *Amnicola limosa* Say (220), found abundantly on the under side of water lily leaves. Their distribution is directly controlled by that of the water lilies, that is, near the shore, and in the larger lakes only in the sheltered bays. Probably a third of the leaves had one or sometimes two shells attached to them. Water striders, *Gerris remigis* Say (No. 96), were abundant, usually near shore in the water lily zone, but occasionally out in the open water. Whirligig beetles, *Gyrinus minutus* Fabr. (No. 219) were also common, but not abundant on the smaller lakes. In the sheltered bays of Siskowit Lake they collected in immense swarms, keeping mostly near the shore among the water lilies and under overhanging brush. *Donacia proxima*, (Nos. 171, 184) and *Donacia cincticornis* (Nos. 171, 175) were abundant on Sumner Lake, resting on the water lily leaves. When alarmed they would fly a short distance close to the water, making a little trail behind them, and alight on another leaf.

d. The Free Aerial Fauna. Dragonflies of several species are abundant along all of the lakes. They usually keep close inshore or over the water lilies, and fly regularly in patrols around the lake, searching all the time for insects but keeping up a uniform rate of speed. *Aeschna* sp. was probably the most abundant, and associated with it were *Enallagma hageni* Walsh and *Leucorhinia proximo*, Anth. The butterfly *Argynnis atlantis* Edw. also occurs (No. 169).

The inland lakes may be regarded as small detached portions of the main lake, cut off from it by the lowering of the level of the latter. Since they are composed of stagnant water with, little or no wave action, where organic material may accumulate in quantity, they support a different fauna and their genetic development is along a different line, culminating however in the climax type or balsam-spruce forest. The only intervening stage is the tamarack swamp.

IV. The Tamarack and Arbor Vitae Swamps.

Nearly every inland lake in the Isle Royale region is wholly or partly surrounded by tamarack swamps, (*Figs. 14, 19, 22, 41, 47, 48*). It is not necessary to discuss the general structure of the vegetation, since that is described elsewhere in this report, but it may be indicated here that the ground cover is a spongy mass of sphagnum covered with a dense growth of ericaceous shrubs, such as Cassandra and Ledum, and that the trees are almost entirely tamarack and black spruce. The forest cover is open enough to allow ample illumination. Tamarack swamps may be found of all ages, from those developing at the edge of a lake to those which have completely covered the lake and are now dying as an association. Their surface is generally level, the older parts being successively somewhat higher as they are built up by the accumulations of peat.

When the level is nearly that of the lake the beds of sphagnum are interspersed by little streams or pools of water, some of them being merely extensions of the lake itself, or some of them serving as inlet or outlet. The smaller ones have no bottom except the sphagnum itself, while the larger have a loose incoherent bottom of slime. In the larger of these streams are found small bivalve shells, *Pisidium* sp., embedded in the slime at the bottom (No. 230; V-5), and other material; and the beetles *Haliplus ruficollis* DeG., *Hydroporus tristis* Payk, and *Agabus congener* Payk. (No. 230, V-5). In the smaller ones, which are frequently only a decimeter or two wide and half as deep, there is no difference in the vegetation except for a little Utricularia in the bottom. Animal life is there very scarce (No. 237, V-5), but included *Pisidium* sp.

As the swamps become older the water is limited to small shallow pools, seldom more than one decimeter deep or three or four decimeters wide. Their bottoms are covered with dead leaves and sphagnum, and they are usually densely shaded by the forest growth above. In them are found small bivalves, *Pisidium affine* Sterki (77A, 79A), *P. subrotundum* Sterki (116, 181, 182, 237), *P. subrotundum* Prime (116, 237), and water beetles,

Haliplus ruficollis Deg. (No. 116, 14) and *Scutopterus hornii* Cr. (No. 181, 144). The latter is restricted, so far as observed, to this single habitat in the pools in tamarack and arbor vitae swamps. Dragonflies are the principal aerial insects, but are not abundant. A fly (No. 240, V-5) was taken on the flowers of *Solidago neglecta*.

In still drier swamps, where there is no longer any standing water, (*Fig. 14*). ants are a characteristic feature of the fauna. They build huge dome-shaped nests, 4 to 7 dm. high, composed within of sphagnum and other vegetable debris, and smoothly covered on the outside with leaves of Cassandra, doubtless to prevent drying. *Formica adamsii* Wheeler (No. 115, I-6) seems to be the only species concerned, and a nest from which the collection was made was photographed. No. 114, taken at the same time from a similar nest, has been identified as *Formica dryas* Wheeler, suggesting a possible confusion of the numbers. No other insects were observed except the omnipresent black-flies and mosquitoes.

At the head of the numerous fjord-like inlets along the shore there is usually a swamp tract extending for some distance inland in the same direction as the inlet itself. The level is but little above the lake itself, but there is no permanent standing water or lakes as in the tamarack swamps. The standing water is limited to small scattered pools, seldom more than a meter across, and the forest cover is prevailingly of arbor vitae. The shade is exceedingly dense, and the ground is covered with tangles of underbrush and fallen logs. The fauna is accordingly reduced to a minimum, and the few forms collected were all dredged from the leaf-covered bottoms of the small pools, and included bivalve shells, *Pyramidula striatella* (Anth.), and *Pisidium subrotundum* Sterk. (No. 182), and water beetles, *Scutopterus hornii* Cr. (No. 182). The latter were very scarce.

Faunistically the arbor vitae swamp is very closely related to the later stages of the tamarack swamp, as a comparison of the species will show. At the ends and around the sides the swamp grades imperceptibly into the balsam-spruce forest.

In connection with the swamps must be mentioned the fauna of the small rapidly flowing streams leading out of the inland lakes. The bottom is usually rock or gravel, and the swift current prevents the accumulation of organic debris. In Benson Brook on the north side of Rock Harbor in still, deeply shaded places were dredged up (No. 149) *Pallifera dorsalis* (Binn.), *Pyramidula alternata* (Say), *Pyramidula striatella* (Anth.), *Zonitoides exiguus* (Stimp.) and *Physa* sp. In the outlet from Siskowit Lake, in small pools 5-15 cm. deep with a bottom of slime covered with loose pebbles, were collected several shells (No. 288), *Physa* sp., *Pisidium medianum* Sterki, *P. subrotundum* Sterki, and *Musculium securis* (Prime). The current where these were collected was very slow. In the more swiftly flowing water nothing could be found.

Owing to the peculiar geological structure of the island the swamps have a generally oblong form with approximately parallel sides. Along the sides the swamps grade imperceptibly into the balsam-spruce forest (*Fig. 43*), and on the ends as well, though there the transition is more gradual and the facies are usually separated by an intermediate zone marked by dense thickets of alder.

V. The Gravel and Sand Beaches.

The gravel beaches are found in but certain places along the shore (*Fig. 1*), where the slope of the banks and the action of the waves permit the formation of the gravel deposits. Optimal conditions are found at the heads of the numerous inlets or coves; such as Conglomerate Bay (*Fig. 4*), and Tonkin Bay, already described, and many other similar places. They also occur, however, along the shore of the lake itself, where the wave action is at its minimum. Their distribution appears to be controlled principally by the slope of the bottom, since the gravel could not be piled up on slopes of too steep pitch, and they are almost invariably in locations so bounded by rocks or shore that the waves strike them always in one direction. An instance of this was seen near the light-house. A small inlet about 5 m. in length and width opened towards an island. Waves struck it in two directions, both diagonally, but rebounding from the rocks continued into the inlet in one direction. At its back was a small but typical beach, the only one in the immediate vicinity and likewise the only spot where the waves always came in the same direction. As a consequence of this directive action the beaches always lie at right angles to the direction of wave action.

The gravel of which they are composed varies in size from fragments as large as one's fist to mere sand, but the biota of the sand beaches is so different that it requires separate discussion. There is no vegetation, but the beaches are frequently strewn with dry drift wood in which several kinds of fruits, dead insects and shells may be found. The gravel is dry on top, but is always moist at a depth of one or two decimeters or even less. The broader beaches have full exposure to the sun, but the narrower are shaded, and all are bounded at the rear by a narrow but dense zone of alder.

The fauna of these beaches is limited in species, probably owing to the lack of food, although the number of individuals is relatively large.

Caddice flies are rather common running about over the finer gravel just above the reach of the weaves, or sometimes taking short flights (No. 10). Stoneflies are associated with them; they crawl about actively over the wet gravel near the water's edge and do not attempt to fly. They are frequently struck by waves which merely wash them a little farther up the bank. A few species of ants are also common, running over and through the gravel (No. 38). They prey on dead caddice flies or even on live ones when they succeed in capturing them. The most characteristic group, however, consists of several

species of spiders, which are found in great abundance on the coarser gravel in the sun (Nos. 16, 25, 38, 39, 60), *Lycosa pratensis* Emer., *Pardosa lapidicina* Emer., *Pardosa groenlandica* Thor., *Ebo latithorax* Keys. They run with great rapidity and at the least alarm crawl under the rocks, where it is almost impossible to find them. After the first alarm they usually show themselves in 10 to 15 seconds, but being frightened again, they crawl for some distance under the gravel and are lost permanently. Many of them carry egg cases, and if forced to drop them they spin a web which they follow back in a short time. These spiders are very numerous, probably 10 or 12 to every square metre over all the gravel beaches.

Other insects observed were, a small beetle (38) crawling over the sandiest part of the beach; two species of small beetles (39) crawling through the coarse sand and fine gravel at the water's edge; a click beetle, *Corymbites medianus* Germ. (41) crawling over sand in a shaded plaice near a rock cliff; a Scarabaeid, *Serica vespertina* Gill. (43); a beetle, *Macropogon rufipes* Horn (60). Some fish worms (40) were also found buried 3 dm. deep in moist coarse sand under the gravel beach in front of the light-house. They were above the level of the ground water. Butterflies and wasps, which were so abundant on the sand beaches, were collected but once. The butterfly, *Pyrameis cardui* Linn. (39) flew out of the woods, rested a moment on the gravel, and then visited a dogwood flower. The single wasp (41), *Ammophila* sp., was seen flying low over a small area of sand near the water's edge on a gravelly beach.

Some fossil beaches were observed, rising several meters above the lake. The gravel was then thinly covered with lichens, and in some cases even supported a scanty growth of flowering plants. A beetle, (37) *Leptura chrysocoma* Kby., was collected on a rose in such a place. The contents, of the drift washed up on the beaches is of some interest as indicating a possible way in which new forms might reach the island. Here were found *Limnaea stagnalis* (19); a dead butterfly, *Anosia plexippus* Linn., (19); some dead lady bug's, *Anatis 13-punctata* Oliv. (21); shells (21) ; butterflies (21); one snail shell, *Polygyra albo-labris* (Say), badly broken but still containing part of the body (39). The vegetable drift (18, 21) included cones or fruits of jack pine, balsam, arbor vitae, and alder.

Sand beaches are formed in the same way and under the same conditions as the gravel beaches already mentioned, but only where the wave action is much reduced by distance from the lake. The principal ecological difference between the two lies in the presence of the sand, affording a fairly uniform surface, and a finer substratum in which various species may live protected from predaceous ants and spiders.

The principal beach studied was at the head of Conglomerate Bay, (*Fig. 4*), and may be described in some detail. The beach was more than 100 meters long, and divided at the middle by a small stream running through it into the bay. One portion was only 2-6 m. wide, and overhung by alders. There the sand was always moist, and the fauna very scanty. The other portion was 10-20 m. wide, fully exposed to the sun, and sloping very gently back to the usual zone of alders. There was some drift wood scattered about over it.

A warm sunny open place like this attracts many casual visitors from the neighboring woods. Three species of butterflies were especially characteristic. *Papilio turnus* (No. 29) was the most abundant. They flew back and forth along the beach at a general height of 2-3 meters, occasionally flying out over the water and dipping into it now and then. They very seldom alighted on the sand. The red butterflies (No. 29) hovered low over the sand but when they alighted chose grass or low shrubs along the margin. No. 29 includes *Pyrameis hunteri* Fabr., *Pyrameis cardui* Linn, and *Basilarchia arthemis* Dru.

The black butterflies were not common (No. 29). They flew rapidly and irregularly over the sand and the edge of the water at a height of 1-3 m. and very rarely alighted. Two other casual visitors were observed but not caught; a redwinged grasshopper which flew over the sand at a height of 2 in., and dragonflies which hovered over the small stream. Both came from, and returned to, the woods.

Peculiar to the beach were small blue butterflies, *Phyciodes tharos* Dru. (No. 29), and two or three species of sand-wasps (No. 31), including *Diodontus* n. sp., *Ammophila* sp., and *Xanthosarus latimanus* Say, which flew rapidly over the surface at a height of about 1 dm. but very rarely alighted. When dead they were preyed upon by ants. One or two species of flies (No. 31) (*Cynomyla cadaverina* Desv.) were also common.

Crawling over the sand were ants (No. 30), spiders with eggs cases, *Pardosa groenlandica* Thor. (No. 30), and beetles, *Bembidium carinula* Chaud. (No. 30). The latter were very numerous, and included two species. They ran rapidly and irregularly over the sand, and especially the fine gravel just back of the wet margin. When alarmed they try to hide under small pebbles, or sometimes fly a short distance.

A dead shell of *Limnaea stagnalis* (No. 32) was found on the beach, and a dead *Polygyra albolabris* in the small stream (32).

VI. The Rock Beach.

Where the slope of the shore is steep or the action of the waves severe, gravel or sand cannot accumulate, and the bare rock is left exposed. The ecological conditions affecting animal life here are so different from those of the gravel beaches that they require especial mention.

Rising directly from the water they are naturally exposed to the full force of the waves, (*Fig. 3*), which dash upon them to a considerable height, washing away all loose particles and effectually preventing even the most meager formation of soil. Beyond the reach of the waves, rains and drainage water act with greater or less effect in the same way. The vegetation is therefore

limited to various species of crustaceous or foliaceous lichens, which are true lithophytes. Even they are absent from the lower portions where the wave action is more continued, and especially where the ice may scrape them off. Higher up the procumbent juniper and *Cladonia* appear and the whole eventually merges into the *Cladonia* clearing to be described next. Some idea of the zonal succession of the different plants may be gained from the following table, showing the heights of the different zones on a rock beach near the Rock Harbor light-house, *Figs. 6 and 7*.

Zone.	Height—feet.	Total height.
Crustaceous lichens	7 ft. 7 in.	7 ft. 7 in.
Foliaceous lichens	4 ft. 9 in.	12 ft. 4 in.
Juniper	4 ft. 0 in.	16 ft. 4 in.
ladonia	6 ft. 7 in.	22 ft. 11 in.
Forest	4 ft. 1 in.	27 ft. 6 in.

The first two zones, to the height of twelve feet above the lake, are Included here in the rock beach. Naturally these levels may vary with different localities, being lower in more sheltered places.

Over the lower portion of the beach the fauna is practically without shelter or protection, and in the zone of foliaceous lichens shelter is afforded only to very minute species. There are sometimes small fissures in the rock, but only two species were observed to enter them. During all or part of the day the beaches are exposed to the direct rays of the sun, and the rock consequently reaches a temperature far above that ever reached by the air.

The temperatures observed on July 11 may be given as an example.

Time.	Air at 4 ft. in sun.	Rock surface.	Rock.
9 a. m.	51 ° Fhr.	68 (sun)	88
11 a. m.	58 ° "	61 (shade)	95
1 p. m.	56 ° "	.....	100
2 p. m.	56 ° "	94 (sun)	90

The absence of plant growth also tends to limit the number and character of species to predatory forms, and the number of individuals is small.

A small rock beach jutted into the lake near the light-house, and was at most but one meter high. Although sheltered from the waves by an island, it was still completely flooded by even moderate waves. Most of the surface was accordingly without vegetation, but besides the crustaceous lichens there was one species of moss, a few plants of harebell, and several tufts of grass. Five species of insects were found on this beach, four of which were merely casual visitors. Some spiders (No. 46), *Pardosa groenlandica* Thor., wandered upon the rock from the neighboring gravel beach, but finding no rocks to hide under they soon left. Ants (No. 46), *Formica dryas* Wheeler, were rather common, but it was easy to see that they came from, and returned to, the gravel beach. The only food they obtained appeared to be the remains of dead caddice flies. A species of fly, *Hydrophorus philombrius* Wheeler (No. 46), was very common on those parts of the rock which were constantly wet by the waves. They were seldom seen over the dry portions, but remained resting on the wet rocks. This fly was of common occurrence in the uplands and will be mentioned also under other headings. A few stoneflies (No. 46) were found on the wet rocks where the waves struck. The only species confined to the beach was one species of beetle, *Bembidium grapei*, which ran over the surface, hiding from time to time in tufts of moss.

On a smaller rock beach exposed to the full force of the waves were collected a spider (No. 47) arid an ant, *Formica dryas* Wheeler (No. 47); a butterfly (No. 47), *Basilarchia arthemis* Dru., was also taken while hovering over the beach.

On a larger beach near by, the elevations of which were given in a preceding paragraph, the fauna was better developed. A jumping spider was fairly abundant, and was a fine example of protective coloration, being almost invisible against the gray rock background. Another spider (No. 48) and red mites (No. 48) hid under the foliaceous lichens. A small beetle (No. 48) was abundant, running rapidly over the rock, never attempting to fly, but hiding in the crevices. A brightly colored red and black beetle was common. It ran rather slowly but flew easily. No ants were seen. Besides the forms just mentioned, which may be considered normal members of the rock beach association, there was collected a caddice fly (No. 48) and a running spider (No. 48), undoubtedly a straggler from the Cladonia zone above.

At other times were collected on rock beaches ants, (No. 15) *Camponotus herculeanus* L., carrying away dead caddice flies, and as accidental visitors a *Cimbex americana* Leach (No. 106), a butterfly (No. 107), *Basilarchia arthemis* Dm., and a running spider (No. 103), *Lycosa pratensis* Emer.

In connection with the rock beaches may be mentioned the beach pools (*Fig. 5*), which are depressions in the rock filled with water by high waves. They are naturally most abundant on flat or gently sloping beaches, and their permanency varies with their size and depth, affecting evaporation, and with their height above the lake, affecting the frequency with which they are filled. In those which are permanent are found shells, *Limnaea emarginata* Say (No. 58), and *Planorbis parvus* Say (No. 59), and a few insects, *Rhantus binotatus* Harr. and *Corixa* sp. (73, 74, 75). The water beetles and water boatman are strongly stereotropic, staying on the bottom or in/ crevices, and leaving it only to dart quickly to the surface for air.

VII. The Cladonia Clearing and Jack Pine Ridges.

The elevated position of the rock ridges and their physiographic relation to the uplands are the two chief factors determining the succession of biota upon them. In response to the rapidity of drainage, and the slowness of soil formation the first plant life to invade the rock beaches is a lichen association composed to a large extent of *Cladonia rangiferina*, which carpets the rock to a thickness of 1 to 3 dm. With it are associated various xerophilous shrubs and herbs, but no trees. Consequently the insolation is strong, and after rains that water not removed by surface drainage is soon evaporated. The soil consists only of those thin deposits formed by the disintegration of the underlying rock and the decay of the vegetation, and is held in place by the tufts of lichens. Such natural clearings in the forest are frequent near the lake (*Figs. 6, 7, 9*), either on gentle slopes but little above the lake and consequently of late origin, or upon the elevated rock ridges (*Figs. 8, 25, 26*), where they are of much greater age. Their shape and size varies naturally with the topography.

In these Cladonia clearings has been developed a very characteristic faunal association, rich in species and in individuals, and especially distinct in the number and variety of insects. The fauna may be conveniently divided for discussion into three groups, aerial, terrestrial, and subterranean. Since the latter is the most nearly fixed in habit, it may be described first.

1. Subterranean Fauna. In the shallow depressions and crevices of the rock (*Figs. 7, 25, 26*), are thin soil deposits supporting a dense growth of various plants, especially the Cladonia lichens, the bearberry, and dwarf juniper. Ants are frequent, running over the surface and excavating below it, but they make their nests only in the deeper crevices or under the densest growth of plants where the depth of soil is sufficient to allow them to make their excavations and to conserve the moisture supply. In the crevices they are usually 1 dm. or more below the surface. *Camponotus herculeanus* L. (22), *Myrmica rubra* L. (61), and *Leptothorax canadensis* Prov. (63) are the species generally represented. The nests are more frequent near the margin of the rock clearings, where the soil is better shaded. A nest of *Formica sanguinea* Latr. (No. 72) was placed under a decaying limb, and the soil beneath it was largely composed of minute, fragments of rotten wood. This ant has two sorts of pupa cases. Another colony, *Leptothorax canadensis* Prov. (No. 77), was also collected in *Cladonia* clearings.

The largest species of ant (No. 62), *Camponotus herculeanus* L., is found always singly, and no nests were ever observed.

Spiders also occur in the looser soil deposits, but most of them probably belong to the surface, such as (No. 71) *Lycosa kochii* Keys, which had an egg case attached, although buried under two cm. of soil. The largest spider, (No. 67) *Coelotes* sp. of which only one specimen was observed, is apparently entirely subterranean. It spins a pocket just about large enough for its own body, and when uncovered does not attempt to run, but buries itself in the soil or in crevices. A third species was a mite (No. 64), *Rhyncholophus simplex* Bks.

Other species are found in fewer numbers, such as the fish worm (No. 70), in soil under bearberry at a depth of 5 cm.; a, shell, *Zonitoides arboreus* Say (No. 65) ; myriapods (No. 64), and a few other insects, including beetles, beetle larvae, and one Jassid (No. 64).

2. Terrestrial Fauna. Aside from the ants, which I have included in the first group, shells, spiders and grasshoppers are the most important members of this fauna. Of the former but one species is included, *Polygyra albolabris* Say. It was not seen alive, but their dead shells are abundant on nearly every Cladonia clearing as well as the drier forest covered ridges (Nos. 20, 33, 88, 93, 138, 145, 174, 197). The live ones are also found in damper places or even in swamps (No. 113).

Spiders were numerous especially in the clumps of *Cladonia*, where they crawled over and under the mats, frequently carrying egg cases. Three species were observed, *Gnaphosa brumalis* Th., *Pardosa sternalis* Th., and *Lycosa kochii* Keys, (all No. 22).

During the first part of July grasshoppers were infrequent, except the wingless stages, but during the last part of the month and in August they were extremely abundant. They are not confined to clearings with a copious growth of Cladonia or other vegetation, but are equally abundant on the most barren rock-ridges. Immature specimens of *Chloealtis conspersa* Harr. (No. 22) were hopping over the lichens on July 6.

Mature forms of *Melanoplus huroni* Blatchl. and *Circotettix verruculatusKby*. (No 44, 35, 108, 131, 132), were very abundant. They fly well, making a clicking noise the while, and very rarely leave the sunny open ridge. *Chloealtis conspersa* Harr. (Nos. 143, 144) was collected in similar places from *Prunus pennsylvanica*, *Diervilla*, and *Coptis trifolia*, and the grasshopper *Melanoplus alaskanus* Scudd, (Nos. 146, 147) was taken on *Gnaphalium*, *Diervilla* and grass.

3. Aerial fauna. The light and warmth of the *Cladonia* clearing attracted many flying species, including the cicada, *Tibicen rimosa* Say, var. (44, 108, 111); bees, *Monumetha albifrons* Kby. (68), *Xanthosarus latimanus* Say (68, 108), *X. melanophea Sm*. (108); the dragonflies, *Aeschna* (No. 69), *Ophiogomphus colubrinus* and *Tetragoneuria spinigera* Say (132); the butterflies, *Papilio turnus* Linn. (97), *Basilarchia arthemis* Dm. (97), *Argynnis myrina* Cramer (97), and *Argynnis atlantis* Edw. (32), and hosts of blackflies, *Simulium venustum* Say.

The butterflies, *Basilarchia arthemis* Dm. and *Argynnis atlantis* Edw., are so characteristic of these clearings

that we knew them by the common name of "clearing" butterflies. The blackflies are abundant, and are preyed upon by dragonflies, probably the chief reason for the occurrence of them so far from the swamps.

Of particular interest was the small fly, *Hydrophorus philombrius* Wheeler, mentioned before in connection with the rock beaches. They were numerous over all the clearings, but they settled in especial abundance on the moist newly exposed soil which I uncovered. It is probable that they do this only for the moisture or coolness, but in one case a number of them swarmed over the pupa case of an ant, (No. 66).

Of especial interest was the fauna of the large complex of *Cladonia* clearings just behind the camp at Siskowit Bay (V, 3), *Figs. 24, 25, 26*. There was a uniform gentle slope from the margin of the bay back some distance inland, on which large areas were occupied by the usual growth of *Cladonia*, juniper and bearberry. The whole was surrounded and intersected by balsam and spruce forest.

Shells were quite rare, although a few of the usual species, *Polygyra albolabris* (Say) (233), were collected.

The subterranean species of ants so common about Rock Harbor were not observed. They were replaced by another species, *Formica fusca* L. (223, 224, 226, 227), which built large circular flat-topped nests (*Fig. 28*), 5 to 8 dm. in diameter, composed of earth and vegetable debris and covered with debris of balsam and spruce needles. Two sizes, a larger (223) and a smaller (224), were sometimes associated in the same nest. Many nests had been almost completely destroyed by the pileated woodpeckers. Spiders, *Pardosa sternalis* Th. (No. 225), were frequently seen crawling over the ant's nests. Other spiders crawl over and through the *Cladonia*, dragging egg cases behind them, and crawling into holes and crevices.

Grasshoppers were abundant, as usual. Some short winged nymphs of *Melanoplus fasciatus* Barnst-Walk., (No. 208) were taken in thickets of *Juniperus nana*. They usually hide down in the juniper and will not jump out if frightened, but crawl down close to the ground, so that they are practically invisible. When once seen they can be picked up with the fingers. Sometimes they leave the clumps of juniper and jump or fly out over the *Cladonia* and rocks. These flights seldom exceed 1-2 m. in length, but on one occasion one flew 6 m. high and disappeared among the balsam trees. The adults of the same species (193, 201, 208, 214), with full length of wings, fly long distances at a height of 3-7 m. or more, making the usual clicking noise. They alight only on the bare rock or on short *Cladonia*, avoiding the other vegetation. One fiddling grasshopper, *Camnula pellucida* Scudd. (No. 228), was also taken from mats of the juniper.

Bumblebees, particularly *Bombus terricola* Kby. (208), visited the flowers of *Diervilla*, and *Melampyrum*.

Other bees, including *Tenthredopsis nebulloides McGill*, *Coelioxys moesta* Cr., *Xanthosarus melanophea* Sm., and *X. latimanus* Say, visited the same plants.

A small carabid beetle, *Carabus serratus* Kby. (No. 208), crawls over and through the *Cladonia*, foraging. *Leptura chrysocoma* Kby. (208) was taken in the same locality.

The yellow clearing- butterfly, *Basilarchia arthemis* Dm. (208), is very common, flying in regular paths up and clown the clearing at a height of about one meter, sometimes alighting on the ground and sometimes on the flowers of *Opulaster*.

Urocerus flavicornis Fabr. and *U. flavipennis* Kby. (208, 209, 228) were especially common. They fly low, usually 2-3 feet above the ground with a moderate but uniform velocity. They are searching for balsam trees in which they deposit their eggs, and were sometimes taken crawling over the trunks.

A small brown wasp flies low over the ground like an asilid.

Asilid flies, *Asilus annulatus* Will. (208), fly low, 1-2 ft. above the ground, alight on tufts of grass or *Cladonia* and crawl down into it. It could not be determined what they were hunting.

Three species were taken on the flowers of the harebell, *Campanula rotundifolia*. They were *Coelioxys nivesta* Cr., *Xanthosarus melanophoea* Sm. and *X. latimanns* Say. Insects were more numerous on the flowers of *Opulaster*, from which were collected *Tenthredopsis nebelloides* McGill, *Prosopis* sp., *Argynnis atlantis* Edw., *Eristalis dimidiatus* Wied., *Phormia terraenovae* Desv., *P. regina* Meis, and *Hyetodesmia serva* Meis.

A wasp, *Eutypus americanus* Cress. (235), was found backing over the ground dragging a spider, *Lycosa kochii* Keys. At brief intervals it dropped the spider and ran rapidly back and forth looking for the hole to which it was taking its capture. It seemed to have a general idea of its location, but had to crawl always exactly to it. Having found it, a similar search was begun for the spider, and then the journey was resumed in a direct line toward the hole.

The typical *Cladonia* clearings just described were almost invariably on the lower ridges or gentler slopes. They were surrounded, and eventually entirely covered, by the balsam-spruce forest. On certain of the higher or steeper ridges, there was another intermediate stage in which the clearings were covered with jack pine. This was due apparently to their position; the formation of soil was slower and the drainage better, so that, even with a considerable depth of soil they were still too dry for balsam or spruce, and were accordingly occupied by the xerophile jack pine. In general ecological conditions they were but little different from the treeless associations. The ground vegetation was, as usual, *Cladonia* or bearberry, and the forest cover was scarcely heavy enough to make much shade. But the mere presence of trees indicates that there was a greater

deposit of the soil. Under the bearberry and *Cladonia*, the soil was quite thin, but there were more loose rocks, and larger, and deeper fissures, which were filled with soil. The effect on the fauna was to increase the number of subterranean species and diminish the number of aerial forms.

In the soil deposits up to 5 cm. deep there is practically no animal life, although ants crawl over the surface. Nests of *Lasius niger* L. are common in crevices and under loose stones at a depth of 1 dm. or more (Nos. 79, 82). A nest of *Lasius niger* L. (No. 83) was excavated under and at the side of a large stone. The stone formed the roof of shallow excavations where the pupae were stored, and the vertical wall of earth, at tie side was honeycombed with rounded passages 1-2 cm. high, 2-4 cm. broad, and separated by thin partitions. Under larger stones their nests may be built at less depth; as one of *Formica fusca* L. (No. 100) at a depth of 4 cm. These loose rocks tend to conserve the moisture just as do the crevices.

Beetle larvae are rarely found, owing to the abundance of ants which feed upon them. They occur under rocks or in the deepest soil deposits where the moisture is conserved. (Nos. 80, 82, 102.) No. 102 contains two species of larvae, one a Cistelid, the other *Drasterius* sp. The latter when collected had been captured by an ant, *Formica fusca* L. (No. 102). A dead beetle, *Dipolataxis liberta* (102), was collected under a flat rock.

Spiders are abundant, especially *Drassus neglectus* Keys (No. 101), *Cicurina arcuata* Keys (No. 102), and *Lycosa pratensis* Emer. (103). The former builds a small pocket-like web 2 by 3cm. in cavities under rocks, at a depth of about 1 dm. Spider egg cases were frequently found under stones or in rotten wood (No. 102).

Myriapods were rarely seen. They seem to have regular runaways excavated through the wood or soil (No. 103). A dead caterpillar was also found under a rock (No. 102).

Besides the numerous dead shells of *Polygyra albolabris* Say (Nos. 23, 27, 81, 187) which are common on the ground, especially near dead logs, others were taken below ground. They occur at a depth of 1-2 dm. under angular rocks, or at a less depth under larger flat rocks. In either case their presence seems to be controlled by the moisture (Nos. 81, 102). Other shells were also rather common under rocks, especially flat ones at a depth of 1 dm. or less (81). This single collection included *Pyramidula cronkheitei anthonyi* Pils., *Zonitoides arboreus* Say., *Vitrea binnojana* (Nise), *Strobilops virgo* (Pils.). Under angular rocks down to a depth of 1.5 dm. *Pyramidula cronkheitei anthonyi* (Pils.) and *Zonitoides arboreus* (Say) were found. There are very rarely more than one under each stone. Most of them were dead, and the shells were frequently broken, but a few were alive. At but one place were they associated with a *Polygyra*, and in this case the *Polygyra* was sealed with a membrane across the orifice and was probably still alive. No shells were ever found under rocks with ant's nests.

One jumping spider, *Lycosa pratensis* Emer. (103), was caught on a dead jack pine tree, 6 dm. from the ground.

The fly (*Hydrophorus philobrius* Wheeler) already observed on beaches and clearings was again common. Ordinarily they fly about near the surface in the sunniest places, alighting on the ground or on low plants. As soon as any moist soil is exposed they congregate on it in numbers, crawling over the surface, into ant burrows, and even apparently attempting to eat the ant pupae. One species of ant was seen catching them.

Among other insects were bumblebees, *Bombus* sp. (23), visiting the flowers of *Diervilla diervilla*; grasshoppers *Circotettix verruculatus* Kby. (27); cicadas, *Tibicen rimosa* Say, var. (28, 84), frequent in the pine trees.

VIII. The Balsam-Spruce Forest.

The ultimate tendency of all plant associations on Isle Royale is toward the balsam-spruce forest. The succession is sometimes direct, sometimes indirect; sometimes rapid, as upon the smaller *Cladonia* clearings; sometimes slow, as upon the jack-pine ridges. Just as all temporary plant associations are occupied by definite faunas of a composition largely dependent on the plant covering, so the climax association of plants is also accompanied by a definite fauna, which must likewise be regarded as the climax animal association.

The succession of the dense forest growth brings into play a number of new ecological factors, which are not only of the highest importance in controlling the animal life, but are also retroactive upon the plant covering itself. In all the associations heretofore described physiographic changes have been proceeding with comparative rapidity. They may be due to wave action, drainage, elevation, rock disintegration or soil formation as direct agents, or to changes in the soil composition, soil moisture, light, or heat through the indirect agency of the vegetation. Corresponding to the wide diversity in physical conditions there has been developed a fauna of many species adapted to many different modes of living. Through the agency of the forest cover the light is reduced to a constant minimum, the temperature is made more uniform, the soil becomes of uniform character throughout, and the moisture is kept nearly constant. Indirectly the diffuse light is normally too weak to allow the growth of a ground cover of herbaceous plants so that the variety of food supply is reduced. In short, the change is from heterogeneity of ecological conditions to homogeneity, and the number of species varies directly with the heterogeneity of the habitat. This is true not only for Isle Royale, but for any biotic association. Here, however, the homogeneity is especially marked, because two species alone, the balsam fir and the white spruce, are dominant throughout.

The soil in the balsam-spruce forest is a damp closely packed leaf mold, sometimes deep, sometimes shallow over the rocks, and composed of decaying balsam and spruce needles, mixed with decaying sticks and interwoven with fungus mycelium. When the forest is not so dense aspen and birch trees may be growing, and their leaves also mix in the mould. In such places there may be a very thin ground cover of *Aster macrophyllus*, *Linnaea americana*, and *Pyrola chlorantha*; otherwise the soil is without cover. Above this rises the dense growth of trees, the younger ones and the lower branches stunted or dead from lack of sufficient light.

The insect fauna is composed almost entirely of subterranean species, all few in number, and mostly colorless. A few species of spiders are seen, and a minute Collembolan, *Tomocerus niger* Bourl. (No. 140). Two species of myriapods (No. 140) are rather abundant in the mould, one other larger species was seen once (No. 140), and an *Enchytraid* earthworm (No. 140). A few species of small shells are rarely found at depths of about 5 cm. or sometimes on the surface. They are *Pyramidula striatella* (Anth.), *Zonitoides arboreus* (Say), *Vitrea binneyana* (Nise), and *Ancyclus* sp. (140).

There are no ants except a large black species which forages singly over the surface, *Camponotus herculeanus* L. (No. 140). A single black Carabid, *Calthus gregarinus* Say (No. 140, 236), also runs over the surface and hides under old balsam cones.

A few species of flying insects occur, especially mosquitoes, and when the fresh mould is turned over a few of the moisture-loving flies, *Hydrophorus philombrius* Wheeler, appear and rest on the moist ex posed surface.

The trees themselves shelter a more varied population. Most of the Buprestids and Cerambycids caught in the tent probably came from the forest. The dead trees of balsam or spruce are attacked by wood-boring larvae, which construct a network of chambers just between the wood and bark. Some of these turn into the wood and extend to the center, following a longitudinal or tangential path for most of the way. These holes may be filled with dust part of the way, but the greatest portion is empty. They are about 3 by 5 cm. in diameter, of an elliptical shape, but at the ends sometimes widen out into chambers a couple of centimeters broad. Two species of larvae occupy these burrows (No. 205), and in one was found a small spider, *Amaurobius bennetti* Blk. (No. 205).

Under the loose bark of trees which have decayed further spiders, *Amaurobius bennetti* Blk. (No. 205), frequently build their webs. A beetle, *Calathus advena* Le C. (No. 142), forages here for food, and in one case a shell (142) was taken. A nest of *Formica sanguinea* Latr. (No. 78) was found in the rotten wood of a fallen tree, but the ants probably foraged over a rock clearing near by rather than in the forest. In prostrate decaying logs the fauna is not different from that of the leaf mold, and the same species were collected.

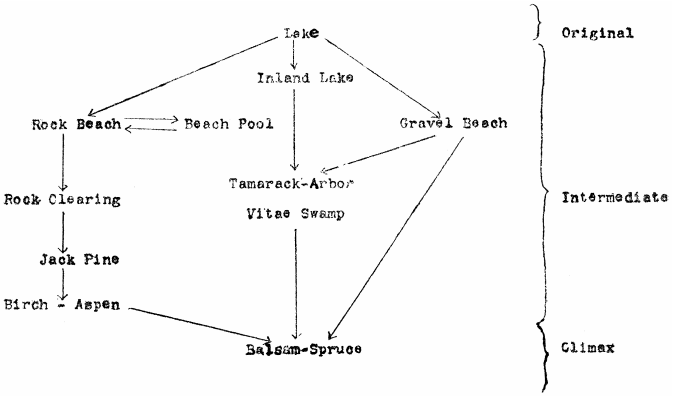
A number of the mushrooms of the genus *Pleurotus* were collected on dead trees and they were inhabited by large numbers of beetles (229) *Tritoma thoracica* Say, T. *macra* Lec., *Boletobius cincticollis* Say, and *Grophaena* sp.

IX. Artificial Clearings.

The clearing about the camps both at Bock Harbor and at Siskowit Bay attracted many species of insects, particularly strong fliers, such as Hymemoptera, Lepidoptera and Diptera. At Rock Harbor Cow-parsnip, *Heracleum lanatum*, introduced in the island some way, was in bloom and it attracted a number of species of bees and flies.

In a similar clearing on the north side of Bock Harbor a number of shells were collected from the under side of dead logs (150). Some of these were observed at no other place. They included *Polygyra albolabris* (Say), *Acanthinula harpa* (Say), *Bividaria tappaniana* (C.B. Adams), *Zonitoides arborea* (Say*), Pyramidula cronkheiti anthonyi* Pils., *Cochlicopa lubruca* (Müll), and *Vallonia costata* (Müller). A plant of *Opulaster* blooming in the same clearing attracted a multitude of insects (148), including the flies *Platychirus peltatus* Meigen, *Syrphus zennalis* Williston, *Sphaerophoria cylindrica* Say, *Eristalis dimidiatus* Weed and *Temnostoma aequalis* Loew; the bees *Halictus versans* Lowell, *Xanthosarus latimanus* Say, and *Bombus terricola* Kby; the beetle *Leptura chrysocoma* Kby. and the lepidopteron *Cupido sepiolus* Bd.

X. Summary.



From the lake, representing the most primitive habitat, there are three lines of development culminating in the climax association; first, through the tamarack swamp and peat bog; second, through the gravel beach and arbor vitae swamp; third, through the rock beach and Cladonia clearings. Physiographic forces have some direct part in causing the successive changes in ecological factors, but most of them are due to the retroaction of the vegetation upon the habitat. The first stages of the series are marked by a severity of conditions which limit the fauna to a few well adapted species. The intermediate stages have generally a wide variety of conditions, leading to the development of a

varied fauna. The most noteworthy in this respect is the fauna of the Cladonia clearings. The ultimate or climax stage is homogeneous because of the dominance of a few species, and the fauna is again limited to a few well adapted species.

THE ECOLOGICAL DISTRIBUTION OF THE BIRDS OF ISLE ROYALE, LAKE SUPERIOR.

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I. INTRODUCTION.

In this report I shall discuss the habits of the different birds and their relation to their environment as found upon Isle Royale. The different localities visited will be described, the birds listed as found in each locality, and the details of their habits and distribution described.

On account of the limited time, I was unable to examine a large part of the island, but representative localities were visited, so that a general idea of the bird life of the island can be gained from this report. For example, a number of tamarack swamps were visited and certain birds were found in each of these; it therefore seems reasonable to infer that these birds are found in the many other tamarack swamps which were not visited.

Observations were made in five different localities by members of the Museum party, but only those visited by the writer will be described. In connection with this paper the "Annotated List of Birds" should be consulted. These localities will be taken up in the following order:

1. Light-house Peninsula.

2. Trail to McCargoe Cove.

3. West End of Rock Harbor and Trail to Summer Lake.

4. Siskowit Bay Region.

II. LIGHT-HOUSE PENINSULA.

This station included the land between Conglomerate Bay and Rock Harbor. The conditions in this small strip of country varied very much, and on this account it will be divided into a number of stations as follows:

1. Lake Superior and Beach (Station I, 1).

2. Spruce and Balsam Forest (Station I, 2 and 3).

3. Tamarack and Arbor Vitae Swamps (Station I, 4).

4. Jack Pine Ridge (Station I, 5).

5. Sphagnum and Spruce Bog (Station I, 6).

6. Valley at Head of Conglomerate Bay (Station I, 1).

1. Lake Superior and Beach (Station I, 1).

This station included the whole of Tonkin and Conglomerate Bays and that portion of Lake Superior and Rock Harbor which could be seen from the light-house. The water was deep, cold and contained very little vegetation. The shore bordering the lake was composed of jagged, desolate, wave-washed rocks (Figs 2, 5), and only in the most protected portions of the bars and harbors were trees found growing near the edge of the water (Fig 4). This accounts for the fact that no shore birds or vegetable feeding water fowl were observed here.

The birds seen in this station were as follows: Herring Gull, Loon, American Merganser, Hooded Merganser, Spotted Sandpiper, Song Sparrow, Myrtle Warbler, Olive-backed Thrush, Crow and Osprey.

The Herring Gull was the only bird seen on the water in large numbers. At almost any time of the day there were fifteen or twenty in sight, and sometimes they came in large flocks to eat the refuse thrown along the shore of Rock Harbor by the fishermen. Seventy-seven were once counted, and occasionally the number was greater.

When not feeding on the water they passed the time soaring in the air or resting on the bare rocks. They seemed to prefer soaring during windy weather. With the head toward the wind they would move slowly upward and forward for some time, then turn suddenly and soar away with the wind at a rapid rate, then swing around in a graceful curve and again mount upward.

The American Merganser, Loon and Hooded Merganser were occasionally seen on the water. On July 27 and 28 a female Hooded Merganser and six young were observed. These ducklings were yet small and could be overtaken with a row boat, but when pursued they escaped by diving.

Thus it will be seen that, excepting the Gulls, water birds were scarce and the shore birds nearly lacking. Only one shore bird, the Spotted Sandpiper, was seen and that was observed two or three times; this was probably a migrant. The other birds seen on the shore, were the Crow, Myrtle Warbler, Song Sparrow, and Olive-backed Thrush. They occasionally came from the bushes and forests to feed there. Of these birds the Song Sparrow was seen the most often, and almost every morning could be heard singing on the small rocky islets partially covered with bushes, which lay just east of the light-house.

2. Spruce and Balsam Forest (Station I, 2-3).

In this forest of spruce, balsam and birches, there were many low rock ridges whose tops were almost destitute of soil and trees, thus forming a long, narrow, natural clearing of not more than two hundred yards in length and from thirty to sixty yards in width (*Fig. 8*). Near the light-house there were five of these ridges from thirty to two hundred yards apart; while farther to the west there were more of them, but they were farther apart.

On account of these openings in the forest, there were many birds here that frequented partial clearings, yet no birds that inhabit large tracts of cleared land, except the Chipping Sparrow, which occurred in the small clearing at the light-house.

The birds found under these conditions were as follows: Red-breasted Nuthatch, Chipping Sparrow, Nashville Warbler, Black-throated Blue Warbler, Black-throated Green Warbler, Chickadee, Flicker, Golden-crowned Kinglet, Bay-breasted Warbler, Crow, Myrtle Warbler, Sparrow Hawk, Magnolia Warbler, Wilson's Thrush, Olive-backed Thrush, Pine Siskin, Purple Finch, White throated Sparrow, Tree Swallow, Barn Swallow, Sharp-shinned Hawk and White-winged Crossbill. The Purple Finch, Pine Siskin, Sparrow Hawk, Sharp-shinned Hawk, Bay-breasted Warbler, Black-throated Blue Warbler, Tree Swallow and Barn Swallow were only occasionally seen.

Some of the Warblers were common, and it was interesting to note the difference in the localities which they frequented. The Myrtle Warbler was most frequently seen near the shore. The Magnolia Warbler frequented the small spruce and balsam trees but was not seen on the shore. The Black-throated Green Warbler was always observed in that part of the forest where there were many birch trees, and the Nashville kept near the partial clearings.

Nests of the Myrtle Warbler, Chickadee, Golden-crowned Kinglet, Olive-backed Thrush and Chipping Sparrow were found in this locality. The nest of the Myrtle Warbler was found July 7, on a small jack pine standing near the edge of a rocky cliff, which rose perpendicularly from the water to a height of about twenty feet. It was composed of small twigs, dried grass and pine needles, and contained four young about a week old. While we were near, the old bird approached the nest very cautiously. It would fly from tree to tree until within about fifty feet of the nest and then drop down near the ground and fly low until below the nest; when leaving it flew along the edge of the cliff.

On the same day a Golden-crowned Kinglet was seen to take a bit of moss and fly into a clump of stunted spruce trees on a rock ridge. The tops of the spruce were so thick and bushy that it was impossible to see the nest from the ground, although the tree was not more than twenty-five feet high. On climbing the tree a half finished nest was found built mostly of green moss. By July 21 the nest was finished and contained eight small eggs. This beautiful mossy cup was about four inches in diameter and of the same depth, but the cavity containing the eggs was still smaller, as the wall of the nest was about two and a half inches thick and lined with hare fur.

In front of the light-house at the edge of the beach, stood a small spruce about twenty feet high, on a horizontal limb of which was the nest of a Chipping Sparrow, composed entirely of grass. When the nest was found on July 5 it contained four young that had evidently just hatched.

An Olive-backed Thrush's nest was found July 8, in a low limb of a spruce that stood near the shore. It was found five feet from the ground, composed of grass and moss, and contained three very young birds. The old bird would not approach while I was near the nest and was so shy that the true owner of the nest was difficult to determine. Probably more nests would have been found had we arrived upon the island earlier, as many young were able to fly when we came, and several immature Magnolia Warblers were found at that time in the bushes near the light-house.

Birds were more abundant in this locality than in any other of the same size. Why this was true, I did not determine.

3. The Tamarack and Arbor Vitae Swamps (Station I, 4).

This almost impenetrable swamp of cedar and tamarack, situated at the head of Tonkin Bay, extended back about a quarter of a mile toward the southwest. To cross this swamp was difficult on account of the fallen trees and numerous low branches, but a rock ridge extended from the bay through the middle of the swamp, almost to its western end, and furnished a convenient route into it. This ridge influenced the bird life of the vicinity because of its different ecological conditions. It was bare in places, but most of it was partially covered with birch, spruce and balsam.

The birds seen in this swamp habitat were as follows: Nashville Warbler, Red-breasted Nuthatch, Chickadee, Black-throated Green Warbler, Raven, Brown Creeper, Yellow-bellied Flycatcher, Hairy Woodpecker, Winter Wren, Black-throated Blue Warbler, Flicker and Canada Jay.

On July 11, nests of the Black-throated Green and Nashville Warblers were found on the north slope of the ridge within twenty-five yards of each other. The nests of the Black-throated Green was in a cedar tree about twenty feet from the ground. It was composed of grass, moss and twigs and contained young. The nest of the Nashville Warbler was in a cavity in a thick bed of moss which covered the face of a small cliff five or six feet high. Here, in a soft nest composed of lichens and lined with grass, were found five young in the down.

These two birds acted very differently when one was near their nest. The Black-throated Green would come within less than ten feet of the observer and scold while moving restlessly about among the branches. The Nashville Warbler was not as bold, for it remained up in the tree tops. It would hop on a branch, turn around a few times, turn anxiously toward the nest and then repeat the performance; but it never uttered a sound. Here was one of the difficulties in judging what localities birds preferred. These two birds nested on the slope of a rock ridge and fed in a cedar and tamarack swamp.

To which did they belong? However, judging from other observations, I would say that if the natural clearing had not been here the Nashville Warbler would not have been found, while the Black-throated Green might have been.

The Black-throated Green, Black-throated Blue and Nashville Warblers, Chickadee, and Red-breasted Nuthatch were nearly always found in this swamp, and these were in the more open parts where the trees were not so close together. I visited the thickest part of the swamp many times without seeing a single bird.

4. Jack Pine Ridge (Station I, 5).

This habitat was on the north side of Conglomerate Bay and composed a portion of the south side and the top of a hill about 100 feet high. The side of the hill was dry and rocky, and was partially covered with scattered aspens and clumps of jack pines (*Fig. 13*). Where there were no trees the ground was partially covered with mosses, lichens, bearberries, golden rods, etc. The top of the hill was bare rock with jack pines and a few plants growing in the crevices. Occasionally there was a small gully with other trees growing in it.

On account of the desolate character of this locality few birds were found here. A Cedar Waxwing's nest containing five eggs was found July 10. Juncos and White-throated Sparrows were occasionally heard singing among the jack pines.

5. Sphagnum and Spruce Bog. (Station I, 6).

This small bog, situated on top of the hill north of Conglomerate Bay, was covered with sphagnum moss and bushes with several black spruce trees scattered over it. There were also several tamaracks and spruce at the edge of the bog. (*Fig. 14*). The birds seen here were: Golden-crowned Kinglet, White-throated Sparrow, Cedar Waxwing, and Black-throated Green Warbler. The Oven Bird and Wilson's Thrush were heard in the forest near by.

6. Valley at Head of Conglomerate Bay (Vicinity of Station I, 1).

This location included the alders and the partial clearing at the mouth of the brook that emptied into the head of Conglomerate Bay. The partial clearing, evidently due to fire, as blackened logs were still lying around on the ground, was covered with weeds, raspberry bushes, dogwoods and clumps of small birches.

The birds seen here were: White-throated Sparrow, Canadian Warbler, Redstart, Flicker, Winter Wren, Chickadee, Nashville Warbler, Magnolia Warbler, Olive-sided Flycatcher, Olive-backed Thrush, Sparrow Hawk and Cedar Waxwing. The Redstart and Magnolia Warbler seemed to be restricted to certain parts of this locality. The Redstart was always seen among the alders, while the Magnolia Warbler kept among a patch of evergreens at the foot of the hill on the north side of the habitat.

III. TRAIL TO MCCARGOE COVE.

This station included the country along the trail which ran from Rock Harbor to McCargoe Cove. This trail started on the north side of the harbor at the mouth of Benson Brook which it followed nearly to Lake Benson, then it crossed the hills to Sargent Lake and from there it went to McCargoe Cove. As I did not make any observations north of the Greenstone Ridge, I will only describe that portion of the country between Rock Harbor and the top of the Ridge. In this portion there were several different conditions which will be described in the following order:

1. Ransom Clearing (Station II, 1).
2. Benson Brook (Station II, 1).
3. Spruce and Tamarack Swamps (Station II, 2 and 5).
4. Rock Ridge Clearings (Station II, 3).

1. Ransom Clearing (Station II, 1).

This small clearing on the lowland at the mouth of Benson Brook was covered with grass and large clumps of alders, birches and aspens. These bushes scattered through the clearing formed an excellent habitat for birds, and, although the clearing was small, thirteen species were observed here. They were as follows: Black-billed Cuckoo, Canada Jay, Song Sparrow, Alder Flycatcher, White-throated Sparrow, Redstart, Red-eyed Vireo, Cedar Waxwing, Wilson's Thrush, Olive-backed Thrush, Sparrow Hawk, Purple Finch and Pine Siskin.

Every time this station was visited there were one or two Alder Flycatchers among the alder bushes, sometimes on top of the highest bush and sometimes near the ground. They seemed to be always on the lookout for insects, and every few minutes they would fly several feet into the air and a snap of the bill told that some insect had been caught. They could often be located by their "pep" of alarm, and in the morning I frequently heard them sing a short song.

The Redstart and Nashville Warbler were often seen among the alders also. Both were always on the move. The Redstart kept flitting from branch to branch, only pausing an instant at each one to look for insects, while the Nashville Warbler would light on a limb and start to hop toward the top, looking an instant at each leaf as it passed.

2. Benson Brook (Station II, 1).

The conditions along this little brook are difficult to describe in a general way because they were so diverse; every few rods there was a change. The little stream meandered through dense forests of cedar, spruce and birch; through thickets of alders, dogwoods and small maples; rushed through narrow ravines between bare topped ridges, over rocks, through forests of birch and

aspen until it finally reached the harbor at Ransom clearing.

The birds found along this brook were the White-throated Sparrow, Redstart, Winter Wren, Red-eyed Vireo, Cedar Waxwing, Oven Bird, Sparrow Hawk, Wilson's Thrush, Olive-backed Thrush, Blue Jay, Canada Jay, Crow, Purple Finch, Sharp-tailed Grouse, Grinnell's Water Thrush, Flicker, Magnolia Warbler, Hairy Woodpecker, Nashville Warbler, Red-breasted Nuthatch, Golden-crowned Kinglet and Chickadee. The Sparrow Hawk, Blue Jay, Flicker, Sharp-tailed Grouse, Cedar Waxwing and Purple Finch were seen more often in the clearings where there were berries, grasshoppers and other insects. The Winter Wren and Water Thrush were always seen near the brook. The former frequented places where the undergrowth was thick. It was often observed flying along the brook and stopping every few yards to look under the leaves and logs for insects, and one was shot with a spider (*Amaurobius bennetti* Blk.) and two mosquitos in its mouth. Sometimes this shy bird would venture away from its damp retreat, perch upon the top of a tree and pour forth a melody that rivalled any song heard in these woods.

The Oven Bird and Red-eyed Vireo were nearly always found among the birches and aspens. The former very frequently was flushed from among the honey-suckle bushes on the ground, but the Vireo was always in the trees. The Magnolia Warbler, Red-breasted Nuthatch, and Golden-crowned Kinglet were always seen in that part of the forest where there were several spruce or cedar trees.

A large number of different species of birds was observed in this habitat, but that was because it was so large. In reality the country was rather desolate, for with the exception of some damp places along the brook, the original forest has all been burnt off and was only partially replaced by a second growth of birch and aspen.

3. Tamarack and Spruce Swamps (Station II, 2 and 5).

About a quarter of a mile north of Benson Brook there was a swamp similar to I, 5, except that, it was larger and had more spruce and tamarack trees scattered through it. The ground was covered with sphagnum, Labrador tea, pitcher plants, etc., but apparently nothing that would attract birds except the trees.

The birds seen here were the Red-breasted Nuthatch, Marsh Hawk, Juneo, Canada Jay, Black-throated Green Warbler, Black-throated Blue Warbler, Chickadee, Golden-crowned Kinglet, White-winged Crossbill, Yellow-bellied Flycatcher, and White-throated Sparrow. The Juneo probably strayed here from a large rocky clearing near by, as only one was seen in the swamp, but it was heard in the clearing every time I visited it.

About a quarter of a mile further on toward Greenstone Ridge, the trail crossed another swamp similar to this one, though it was somewhat longer. Since the conditions were the same in these two places, many of the same birds would be expected to occur in each, and this was the case as will be seen by comparing the list given above with the following: Olive-sided Flycatcher, Red-breasted Nuthatch, Nashville Warbler, Canada Jay, Chickadee, White-winged Crossbill and Golden-crowned Kinglet.

Near Forbes Lake there were two other swamps and in these the following birds were seen: White-throated Sparrow, Canada Jay, Cedar Wax wing, White-winged Crossbill, Red-breasted Nuthatch, Golden-crowned Kinglet, Chickadee, Nashville Warbler and Flicker. All these were found in both swamps with the exception of the Nashville Warbler and Flicker.

There is a marked similarity in the lists of birds seen in each of these five swamps, and five of the species were found in all of them.

4. Rock Ridge Clearings (Station II, 3).

This habitat consists of all the rock ridges which were crossed by the trail after it left Benson Brook. These ridges were nearly all bare on the top, owing to the absence of soil. They had been burnt over several years ago and the stumps that are left show that they were originally almost if not entirely covered with forests. The trees that were found in places where there was a little soil were almost entirely aspen and birch. The birds found in this habitat were the Cedar Wax-wing, Juneo, Bay-breasted Warbler, Mourning Warbler, Robin, White-throated Sparrow, Olive-backed Thrush, Sparrow Hawk and Red-eyed Vireo.

Very few birds were seen in the clearings, probably because the heat of the sun drove them to the shade, as inmost of the birds were observed at the edge of the clearings, in places where the ground was partially covered with trees.

IV. WESTERN END OF ROCK HARBOR AND TRAIL TO SUMNER LAKE.

This station comprised the western end of Rock Harbor and a portion of the adjoining land. It was divided into five habitats.

1. Harbor (Vicinity of Station III, 2).
2. Small Islands (Station III, 1).
3. Bulrush Zone and Delta (Station III, 3).
4. Trail to Sunnier Lake (Station III, 4).
    a. Birch Forest.
    b. Birch and Coniferous Forest.
5. Sumner Lake (Station III, 5).

1. The Harbor (Vicinity of Station III, 2).

In this habitat the following list of fish-eating birds were found: Loon, American Merganser, Herring Gull, Kingfisher and Bald Eagle.

An adult American Merganser and a number of young were observed about the middle of July, and about a week later another adult female and twenty-three young were seen. Although the young birds were quite small they were good swimmers, and it was impossible to get near them in a row boat, except by cornering them in a small bay or in the end of the harbor.

The Loon was often seen and heard here, and once seven were seen together. Occasionally one of the flock would swim around and around in a circle as fast as it could, splashing the water so that it could be heard for at least half a mile. It was impossible to get near these birds, not even close enough to shoot them with a shot gun, for as soon as they thought it was dangerous they would dive, to appear after a few minutes very much farther away. It is very difficult for the Loon to rise from the water, as it must fly a long distance flapping its wings and pushing the water with its feet before it can get into the air.

The Eagle was seen on a tree at the edge of the water.

2. Small Islands (Station III, 1).

Near the west end of the harbor there were two small islands partially covered with stunted cedar, spruce and birch trees, where many birds nested. The probable reason for this was that no squirrels inhabited the islands. On one island three or four rods long were found the nests of four Cedar Waxwings, two Myrtle Warblers, a White-throated Sparrow and a Song Sparrow, and on the other island which was somewhat smaller, were a number of Cedar Waxwing's nests, three containing eggs or young, and the remainder being empty, most of them last year's nests. The Waxwing's nests were from three to fifteen feet from the ground and were composed entirely of lichens (*Usnea*). These birds do not get excited as do many birds when their nests are disturbed. When I looked into these nests I did not hear a scolding note, although some of the owners were sitting on a tree not far away.

Four Myrtle Warbler's nests, two old and two new, were found. These nests were placed on spruce and cedar trees, from six to ten feet from the ground, and were composed of small twigs and grasses with a lining of feathers. One nest contained small young, July 21, and the other contained nearly fully fledged young. The White-throated Sparrow's nest was made of small sticks and grasses with a lining composed entirely of grass. It was on some bushes about a foot and a half above the ground, and contained one egg.

3. Bulrush Zone and Delta (Station III, 3).

This small grass and sedge covered marsh, was too small to attract many marsh birds, and a pair of Swamp Sparrows with two young, a pair of Kingfishers and Song Sparrows, a Red-winged Blackbird and the Lesser Yellow Legs were the only birds observed here. The last two were only observed once, and no doubt they were only stragglers here.

This small marsh was surrounded by a forest of spruce, birch and balsam, and here the Golden-crowned Kinglet, Magnolia Warbler, Chickadee and Red-breasted Nuthatch were found.

4. Trail to Sumner Lake (Station III, 4.).

Starting from the harbor this trail first went up a hill through a birch forest, then across a narrow cedar swamp into a birch, spruce and balsam forest and down the hill to Sumner Lake. As the birds found in the birch forest were not the same as those found in the birch, spruce and balsam forest, the habitats will be distinguished. The cedar swamp was too small to be of any importance, and the birds in it were nearly the same as in the birch, spruce and balsam forest of which it will be considered a part.

a. Birch Forest.

Judging from what had been observed before these birch woods were visited, I expected to find the Oven Bird and Red-eyed Vireo, and upon investigation, many of both kinds were found. A family of Black-throated Green Warblers were also seen. Several Cedar Waxwings and White-throated Sparrows were observed along the edge of Rock Harbor near the trail, but they occurred almost everywhere along the edge of the Harbor irrespective of the kind of trees. In rowing along the shore these birds were seen very much more often than any other.

b. Birch and Coniferous Forest.

This habitat was frequented by the Chickadee, Golden-crowned Kinglet, and Red-breasted Nuthatch, the three most common birds in all the coniferous forests that were visited. The Winter Wren was heard in the cedar swamp.

5. Sumner Lake (Station III, 5).

This habitat included Sumner Lake and the grassy marsh which surrounded it. Everywhere in the marsh the ground was soft, and the thick mat of grass sank under the weight of the body until the water poured into the shoe tops. The line dividing the grass and sedges from the forest was very distinct, but there were several stunted tamaracks and alders growing out in the marsh (*Figs. 18-23*).

Many White-throated Sparrows were heard in the forest near the marsh, and at the foot of one of the alder bushes near the edge a nest was found hidden in a

bunch of grass growing around the bush. Here in a well built nest of grass were two nearly fledged young (July 18). On the same day another nest of this bird was found on the other side of the lake, in a position similar to the one described above, but instead of young it contained four bluish white eggs densely and irregularly variegated with brown. Out in the marsh a Bittern was flushed from the grass, and near by a deserted nest containing a bad egg and the bones of two young was found. This nest was only a depression in the tangled mat of grass in which it was situated.

Two Loons were seen on the Lake many times, and these two birds were much tamer than Loons usually are, for they swam very close to the bank where I was standing. As soon as they saw me (me of them gave a weird and rapid "ha! ha! ha!" and on being imitated it would reply every time. A Hooded Merganser, another fish-eating bird, was also observed here.

V. SISKOWIT BAY REGION.

When I arrived here in August the breeding season was practically over. Many young birds could fly almost as well as the adults, and families were roving about the forests. Sandpipers were probably migrating then, and although many were seen here it cannot be said that they bred. In two weeks other birds began to come from the north in large flocks, so that most observations were on habits of birds during migration.

Another evidence that the breeding season was over was the decrease in the amount of singing. This was first noticed on July 20, and in the next few days some species were heard for the last time. The following is a list of birds with the last date upon which they were heard singing: Nashville Warbler, July 24; Myrtle Warbler and Olive-backed Thrush, July 25; Wilson's Thrush, July 26; Magnolia Warbler, Black and White Warbler and Redstart, Aug. 4; Winter Wren, Aug. 8.

Although birds are more apt to be found in all kinds of conditions during migration, yet many of them showed a preference for certain localities, so the localities in which the birds were seen will be given. This station has been subdivided into the following habitats:

1. Siskowit Bay and Shore (Station V, 1).
2. Trail to Siskowit Lake (Station V, 4).
3. Siskowit Lake (Station V, 6 and vicinity).
4. Burning West of Outlet to Siskowit Lake (Station, V, vicinity of 9).
5. Long and Menagerie Islands (Station V, 10).

1. Siskowit Bay and Shore (Station V, 1).

The conditions at this place were about the same as those at Rock Harbor, and almost the same species of birds were seen. Those seen here were: Herring Gull, Loon, Scaup Duck, Solitary Sandpiper, Spotted Sandpiper, Kingfisher, American Merganser and Osprey. I cannot say with any certainty how many of these birds bred in this vicinity, but the Gull and Merganser did, as a female Merganser with a flock of very small young was seen several .times, and the Herring Gulls bred on the Islands south of the bay. The Loon, Kingfisher and Spotted Sandpiper were observed nearly every day. The Solitary Sandpiper was seen only once, on August 16.

On August 8 four young Gulls were obtained from a fisherman, and we had an opportunity to study the habits of these birds. One was nearly full-grown, while the other three were just getting their wing feathers. All were quite tame and the oldest would eat from the hand and allow itself to be picked up. We were surprised to find how clean these young Gulls were, for the nests were as filthy as those of the domestic Pigeon. They all seem very fond of bathing, and the largest one took a bath several times a day. It would swim out into the bay. splash water over itself with its head and wings, dip its head under water, then shake itself; after repeating these performances several times it would come to the shore, flap the wings and jump as if trying to fly. They were very particular about keeping their bills clean, for after eating they would walk to the water, immerse the bill and shake the head.

2. Trail to Siskowit Lake (Station V, 4).

This habitat included all the forest along the trail between Siskowit Ray and Siskowit Lake. If it had been in the breeding season it might have been divided into two or three different habitats, but the migrating birds did not seem to show any preference for a particular forest.

The birds seen at this station were as follows: Golden-crowned Kinglet, Chickadee, Raven, Pigeon Hawk, Winter Wren, Red-breasted Nuthatch, Bay-breasted Warbler, Red-eyed Vireo, Hairy Woodpecker, Magnolia Warbler, Black-throated Green Warbler, Brown Creeper, White-throated Sparrow, Tennessee Warbler, Flicker, Canada Jay, Junco, Blue Jay, Pileated Woodpecker, Nashville Warbler, Sparrow Hawk, Chipping Sparrow, Grinnell's Water Thrush, Purple Finch, Pine Grosbeak, Sharp-shinned Hawk, Myrtle Warbler, Black-throated Blue Warbler, Olive-backed Thrush, Downy Woodpecker, Yellow-bellied Flycatcher, and Cape May Warbler.

The nests of only two birds were found here, the Chickadee and Golden-crowned Kinglet. The Chickadee's nest was in a dead birch tree about ten feet from the ground, and contained four young which were able to leave the nest August 11. The Kinglet's nest was in a spruce tree about thirty feet from the ground. Both old birds were observed carrying insects into the tree, but the top was so thick that the nest could not be seen from the ground. On August 10 the young birds were still in the nest.

The Nashville Warbler, Olive-backed Thrush, Junco, White-throated Sparrow and Chipping Sparrow frequented partial clearings or clearings in the breeding

season but were found in the forests in the second week in August. On August 11 a flock of birds were seen feeding in the top of a tall tamarack. They were mistaken for warblers but on shooting one to identify it, it was found to be a Chipping Sparrow.

3. Siskowit Lake (Station V, 6).

This Lake was six miles long and about two miles wide at the widest part. The shores were mostly rocky, and trees grew down nearly to the waters edge. The birds found here were: Herring Gull, Osprey, Eagle, Spotted Sandpiper, American Merganser, Loon, and Kingfisher. The Song Sparrow and Grinnel's Water Thrush were also seen along the shore.

The American Merganser, Loon, and Eagle nested in the neighborhood. Three different families of Mergansers were seen on the lake. One consisted of a female and three young, but I did not get close enough to the other two flocks to count them. When first observed, these two flocks were together, but they separated when we rowed toward them. Two young Loons in. the down were seen August 10. An Eagle's nest composed of sticks was found about 125 yards north of the lake, on top of a dead pine which was at least sixty feet high. The nest was four feet in diameter, and contained one young bird nearly ready to fly.

4. Burning West of Outlet to Siskowit Lake (Station V, 9).

Here the original forest had all been burnt away and was only partially replaced by a second growth of birch, mountain ash, aspen, wild cherry, June berry, and northern maple. Between the trees the ground was covered with grass, currants, fire weed and other plants.

The stream that formed the outlet of Siskowit Lake formed the eastern boundary of the burning. The birds found in this partial clearing were as follows: Purple Finch, Cedar Waxwing, Hawk Owl, White-throated Sparrow, Chickadee, Redstart, Myrtle Warbler, Flicker, Red-eyed Vireo, Black and White Warbler, Nashville Warbler, Sharp-tailed Grouse, Water Thrush, Olive-sided Flycatcher, Chipping Sparrow and Song Sparrow.

The Hawk Owl bred some place near here, as a young bird with only down on its head was taken August 4. This owl was seen flying around the clearing in the middle of the day and in the bright sunlight. The young bird was quite tame, or rather it was ignorant of the ways of man. It flew from one dead stub to another uttering a peculiar screech as it flew. The old bird was seen about a quarter of a mile away on the top of a dead tree, but was wary and flew away.

Along the stream there were several dead trees still standing, and on these trees eight to ten or more Myrtle Warblers were seen many times. These warblers sat on the limbs and watched for flies like flycatchers, and every few minutes the snap of a bill sounded the death note of some unfortunate insect. They did not sit in one place as long as a flycatcher does, but on the other hand they were not constantly in motion like most warblers.

Very little can be said about the other birds that were seen here. The Purple Finch and Cedar Waxwing fed on the berries here, and a Grouse was taken with berries and grasshoppers in its crop. The Water Thrush was seen near the lake and stream.

5. Long and Menagerie Islands (Station V, 10).

These two long narrow rocky islands were on the south side of Siskowit Bay about three miles from the mainland. Long Island was covered with trees except for a wide belt along the shore which was washed clean by the waters. Menagerie Island, on which the lighthouse was situated, had very few trees on it, as the top was barely out of the reach of the waves in severe storms.

Menagerie Island was visited twice, on August 6 and 16. The birds seen here were: Song Sparrow, Barn Swallow, Tree Swallow, Herring Gull, Spotted Sandpiper, and Humming Bird.

The Barn Swallow built in the boat-house and under the cliffs along the shore. On August 16 the nests under the cliffs contained young nearly ready to fly. These cup shaped homes were composed of moss and mud, lined with feathers, and placed on small projections of the rock.

The light-house keeper, Mr. J. A. Malone, told us that the Tree Swallow built in the tower; but at this time the young were probably gone as none were observed entering the light-house, although many were flying around.

Long Island was visited on August 6, but no observations were made on any birds except the Gulls. These birds nested here by the thousands. The nests were among the rocks, some being just beyond the reach of the waves of ordinary storms, and others back among the bushes. They were from one to two inches thick, and composed of grasses, sticks or moss, depending on which of these materials was found near. Most of the nests were on the south side of the island, and only a few were found on the north shore. At the approach of the boat the young Gulls that could not fly swam out into the water or hid in the bushes, while the old birds flew around overhead uttering their weird notes of alarm.

XI. Summary.

This brief review of the birds found in each of the habitats studied on Isle Royale will give an idea of the birds that should be expected to occur in similar habitats of the island which were not visited. Of course only the common birds will be mentioned, because preference cannot be determined by a few observations. The habitats of this rugged and hilly island presented a variety of conditions. There were bays, lakes and harbors, with rocky shores, wave-beaten and desolate. There were swamps that were covered with sphagnum moss and low bushes with here and there a black spruce or tamarack tree, other swamps that were covered with a dense forest of cedar and tamarack. There were clearings and partial clearings, forests of birch, containing scattered balsams and spruce, and still other forests of spruce and balsam containing a few birch trees. The characteristic birds of each of these habitats will be discussed in the order just given.

1. Water Birds. The water birds found on the harbors and small lakes were the Herring Gull, Loon, American Merganser, and Hooded Merganser. Of these birds the Herring Gull was the most abundant species and could always be seen on Lake Superior and quite often on the smaller lakes on the island. The American Merganser probably ranked second in abundance. The Loon was quite numerous, and at first it seemed as if they were more abundant that the Merganser, but in time it became evident that the Merganser was the more numerous, though much less conspicuous, as they did not make any noise, while the Loon is very noisy and can often be heard a mile away. The Merganser frequented the bays, harbors and larger inland lakes. The Loon was seen very often on the larger bodies of water, but seemed to prefer the smaller lakes more than the other water birds, as every little lake contained a pair of Loons. Young Mergansers and Gulls were often seen, but, strange as it may appear, young Loons were only seen once, August 10.

The Osprey, Eagle and Kingfisher were also seen several times, but only the latter was seen around any of the smaller lakes, and it was not often seen. These lakes abounded in small fish and would have been a good feeding ground for Kingfishers, but there were no sand banks around the small lakes where it could have nested, and this may have been the reason for its absence. There were two sand banks along the shores of Rock Harbor, and these were used as nesting sites.

2. Shore Birds. The Solitary and Spotted Sandpipers were seen along the shore, but these were probably migrants as only one or two Spotted Sandpipers were seen before August 1.

Although they were not shore birds the Cedar Waxwing, Winter Wren and White-throated Sparrows were often seen and heard while rowing along the shore. The Cedar Waxwing would sit on the tops of the dead trees and every few minutes would fly out over the water after insects.

Herring Gulls nested on the shores of the smaller islands in large numbers but very few nested on the main island. There is a reason why they choose the smaller islands instead of the mainland, and it is probably because there are no minks, lynx or other carnivors on these small islands. The Gull seems to place its nest on the shore at random, without any view to protection or secrecy, and if there were in ink or lynx about the young would soon all be killed by these animals.

The Earn Swallow nested underneath the cliffs along the shore at Menagerie Island and at Scovill Point. The Song Sparrow and Myrtle Warbler were often seen feeding on the shore, and both were found breeding near it. The Song Sparrow frequented the small rocky islands in front of the light-house, one of the islands in the west end of Rock Harbor, and also Ransom Clearing on the north side of the Harbor. Even in this clearing it was never seen far from the water. The Myrtle Warbler was found breeding on the north shore of Tonkin Bay, and on an island in the west end of Rock Harbor.

3. Birds Frequenting Swamps. The characteristic birds of the tamarack-spruce swamps were the Cedar Waxwing, Chickadee, Red-breasted Nuthatch, Golden-crowned Kinglet, White-winged Crossbill, Canada Jay, Nashville Warbler and White-throated Sparrow. Probably none of these birds were found here simply because it was a swamp, for all frequented other localities. The White-throated Sparrow, Cedar Waxwing, and Nashville Warbler are characteristic of partial clearings, and this was really a partial clearing because the trees were so far apart. The White-winged Crossbill, Red-breasted Nuthatch and Golden-crowned Kinglet are characteristic of coniferous forests, and as the trees in the swamp were nearly all coniferous trees, this would therefore be their natural habitat. The White-winged Crossbill feeds on the seeds of the tamarack trees, and during the first few weeks of July it was only seen where there were tamarack trees; during the latter part of July, when the seeds of the spruce became more mature, they were seen many times in the spruce and balsam forests. The seeds of the tamarack mature quicker than the spruce, hence the Crossbills would prefer the tamaracks during the earlier part of the summer. The Black-throated Green Warbler was characteristic of forests where there were a, number of large birch trees, and this bird was only seen in those swamps which had several of these trees around the edge. Indeed; the only true swamp bird seen here was the Marsh Hawk, and that was only seen once.

In the thickest part of the cedar swamp only a few birds were seen, and these were the Winter Wren, Chickadee, Red-breasted Nuthatch, and Brown Creeper. The Canada Jay, Nashville Warbler, Black-throated Blue Warbler and Black-throated Green Warbler were seen where the trees were tail and farther apart.

4. Birds of Clearings and Partial Clearings. The characteristic birds of the clearings were the (Shipping Sparrow, Junco, White-throated Sparrow, Flicker, Cedar Waxwing, Purple Finch and Sharp-tailed Grouse.

The Cedar Waxwing and Purple Finch Were often seen feeding on berries in the clearings, and a Flicker was observed scratching in an ant's nest and eating the ants. Many ants nests were found scratched to pieces, probably by these birds.

The characteristic birds of the partial clearings were the White-throated Sparrow, Cedar Waxwing, Chickadee, Olive-backed Thrush, Wilson's Thrush and Nashville Warbler.

5. Birds Frequenting the Forests. In the forests of birch or aspen the Red-eyed Vireo and Oven Bird were quite abundant, and in many small tracts of birch and aspens these were the only birds seen. Other birds seen many times in these forests were Wilson's Thrush, Chickadee, Black-throated Green Warbler and Canada Jay. The characteristic birds of the spruce and balsam forests were the Chickadee, Red-breasted Nuthatch, Golden-crowned Kinglet, Magnolia Warbler, Canada Jay and Wilson's Thrush. The Magnolia Warbler seemed to prefer places where the trees were not very high, for on the small rocky knolls which were covered with stunted spruce and balsam, this bird was more numerous than elsewhere.