REPORT

OF THE

STATE BOARD OF GEOLOGICAL SURVEY

OF MICHIGAN

FOR THE YEAR 1905

ALFRED C. LANE

STATE GEOLOGIST

BY AUTHORITY

LANSING, MICHIGAN
WYNKOOP HALLENBECK CRAWFORD COMPANY, STATE PRINTERS
1906

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BOARD OF GEOLOGICAL SURVEY

1905

EX OFFICIO:

THE GOVERNOR OF THE STATE,

HON. F. M. WARNER, *President.*

THE SUPERINTENDENT OF PUBLIC INSTRUCTION,

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From November 1, 1905.

AN ECOLOGICAL SURVEY

IN

NORTHERN MICHIGAN.

PREPARED UNDER THE DIRECTION OF

CHAS. C. ADAMS.

A Report from the University Museum, University of Michigan, published by the State Board of Geological Survey as a part of the Report for 1905.

LANSING, MICHIGAN
WYNKOOP HALLENBECK CRAWFORD CO., STATE PRINTERS
1906

LETTER OF TRANSMITTAL.

OFFICE OF THE STATE GEOLOGIST,
LANSING, MICH., Oct. 30, 1905.

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

Hon. Fred M. Warner, President.
Hon. L. L. Wright.
Hon. Patrick H. Kelley, Secretary.

Gentlemen:—I herewith transmit for publication, in the Annual Report of the Board for 1905, the following report. This is a contribution to the Biological Survey of the State, which the Legislature authorized you to supervise and execute by Act No. 250 of the Session of 1905. The following report is the result of a natural history survey made in the Porcupine Mountains and on Isle Royale by a party from the University Museum, University of Michigan. It is not a mere list of plants and animals, but a study of these forms in relation to their surroundings. It is thus a contribution to the natural history of the Upper Peninsula, and in addition to its scientific value will, I trust, be of use to teachers in all parts of this region and stimulate them in the study of the forms of life about them.

Very respectfully,
ALFRED C. LANE.

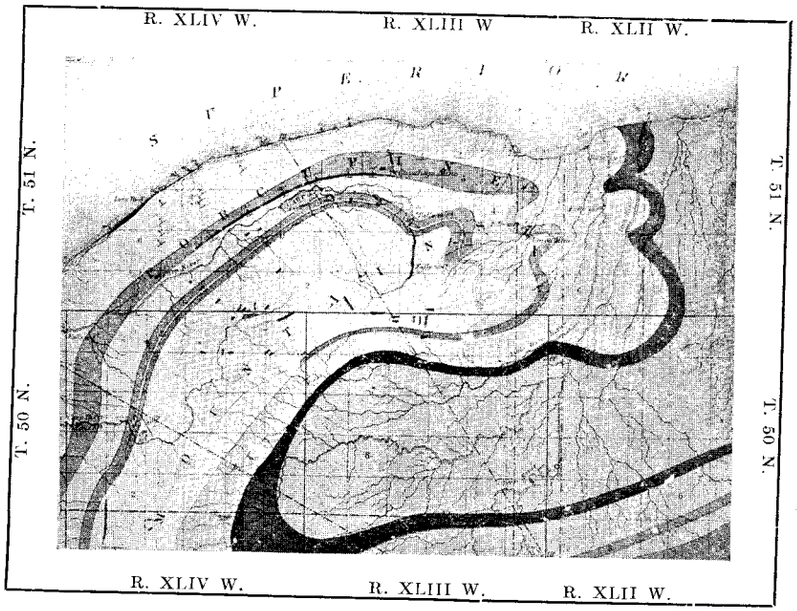

FIG. 1. Geological map of a portion of the Porcupine Mountains, Mich.

2. Quartz-porphyry. 3. Diabase. Diabase-amygdaloid ("Trap"). 4. Sandstone and Conglomerate. 5. Diabase and Diabase-amygdaloid ("Trap") 6. Sandstone with thin bands of conglomerate. 7. Dark-grey Sandstone and Black Shale.—(After Irving).

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INTRODUCTORY NOTE.

During the summer of 1904 the University Museum of the University of Michigan sent a party to Northern Michigan. The aim of the expedition was to make an ecological study of the plant and animal life of the Porcupine Mountains in Ontonagon County and on Isle Royale. The Porcupine Mountains are about 120 miles west of Marquette, on the south shore of Lake Superior; Isle Royale, an island in Lake Superior, is near the north or Canadian shore. Almost nothing has been known of the Natural History of these localities, and collections from these regions have been almost completely lacking in the Museum. Civilization has already exterminated a large number of plants and animals from parts of Lower Michigan, so that it is especially desirable that records and collections be secured from these northern regions ere it becomes too late through the encroachments of civilization.

The expedition was made possible through the generosity of certain public spirited friends of the University, as the funds of the Museum are too limited to carry on this very important line of work, without special aid. The major part of the funds were the combined gifts of Mr. Bryant Walker, of Detroit, Hon. Peter White and Mr. N. M. Kaufman, of Marquette, and to these gentlemen in particular the University Museum is under great obligation. The Board of Regents of the University generously contributed the expense of transportation, not otherwise provided. Through the efforts of Mr. White the party received transportation or special rates in the Northern Peninsula. The Duluth, South Shore & Atlantic R. R. gave a special rate to the party, and the White Line Transportation Co., through Capt. W. H. Singer, general manager, gave free transportation to the party to and from Isle Royale. Through Mr. Henry Russel, the Michigan Central R. R. also gave the party a special rate. The Washington Club of Duluth, through Mr. John Panton, provided the party with excellent field headquarters upon their private grounds on Isle Royale. The Marble Axe Co., of Gladstone, Mich., presented the party with a set of useful camp articles. In addition to the services of the volunteer members of the party and those just mentioned many others have aided in various ways. In behalf of the Museum I wish to express my sincere appreciation for this coöperation.

The field party was in charge of N. A. Wood, the Museum taxidermist. He was assisted by A. G. Ruthven, who had charge of the scientific work, and who directed it along lines outlined by the writer. The other members of the party were Messrs. Otto McCreary, N. F. Macduff, Max M. Peet and W. A. Maclean. All members of the party, except the leader, were volunteers, and thus their contribution to the success of the expedition was of a very substantial nature. Without their aid nothing could have been accomplished. Upon Messrs. Wood and Ruthven fell the responsibility of the party in the field, and to their care and foresight is due, in a large measure, the success of the expedition.

The field party left Ann Arbor, July 11, after three weeks of unfortunate and unavoidable delay, and explored the Porcupine Mountains until August 13. These mountains rise rather abruptly from the south shore of Lake Superior, and in a succession of ridges reach the height of about 1400 feet, at about two miles in the interior. The entire region is inhabited only by scattered trappers, and the forests are practically in their original condition.

From the Porcupines (August 13), the party went to Isle Royale, about 60 miles northwest of Houghton, where they made a hasty examination of the lower end of the island, the party remaining here until September 5. The lateness of the season furnished an excellent opportunity to make observations on the fall migration of the birds, and these notes are of peculiar interest on account of the insular location.

After the return of the party from the field, the preparation of the report was begun at once and has been carried on as rapidly as circumstances would permit. As the volunteer members of the party have been busy with other duties the preparation of the reports, in some cases, represents considerable sacrifice on their part. In particular this has been the case with Mr. Ruthven, upon whom naturally fell the heaviest burden.

A very pleasant feature in connection with the preparation of this report has been the generous coöperation of a large number of naturalists. In behalf of the University Museum I wish to acknowledge our indebtedness to these persons, who have, in addition to furnishing information concerning the collections, and the determination of specimens, in some cases contributed papers. The following list will show by whom the specimens have been determined.

Prof. Bruce Fink, Iowa College, Grinnell, Iowa. Lichens.
Dr. C. A. Davis, University of Michigan. Higher plants.
Mr. S. Alexander, Ann Arbor, Mich. Higher plants.
Dr. J. P. Moore, University of Pennsylvania, Philadelphia. Leeches.
Mr. Nathan Banks, U. S. Dept. of Agriculture, Washington. Spiders.
Mr. E. B. Williamson, Bluffton, Ind. Odonata.
Mr. J. R. De la Torre Bueno, New York. Hemiptera.
Mr. A. P. Morse, Wellesley College, Wellesley, Mass. Orthoptera.
Prof. A. J. Snyder, Springfield, Idaho. Lepidoptera.
Dr. W. M. Wheeler, American Museum Natural History, N. Y. Ants.
Mr. Bryant Walker, Detroit, Mich. Molluscs.
Dr. S. E. Meek, Field Columbian Museum, Chicago. Fish.
Dr. L. Stejneger, Smithsonian Institution, Washington. Amphibia.
Mr. Robert Ridgway, Smithsonian Institution, Washington. Birds.
Mr. H. C. Oberholser, Smithsonian Institution, Washington. Birds.
Dr. C. Hart Merriam, Biological Survey, U. S. Dept. Agriculture, Washington. Mammals.
Mr. W. H. Osgood, Biological Survey, U. S. Dept. Agriculture, Washington. Mammals.
Dr. Glover M. Allen, Boston Soc. Nat. History, Boston. Mammals.

This is also an appropriate place to express our obligations to Dr. A. C. Lane, State Geologist of Michigan, who furnished the party with maps and other information on Isle Royale and the Porcupine Mountains.

We are indebted to Mr. John F. Nellist for the contour map showing the location of the stations in the Porcupine Mountains, which he adapted from the map furnished by Dr. Lane.

A few remarks concerning the character of the field work, upon which the ecological reports have been based, will be of interest and also indicate the general bearing of such work. The aim of the present expedition was not directed primarily along the lines usually followed by natural history surveys. The aim was to secure *ecological facts and relations* concerning the plants and animals of the regions visited. In order to accomplish this, it was necessary not only to collect specimens but also to make observations concerning the relation of plants and animals to their environment. Mr. Ruthven was therefore instructed to run lines of survey across the region examined, in such a way as to include examples of all of the representative habitats or environments. These habitats were then to be examined in as much detail as time permitted. There is nothing unique in this method of selecting special localities, but in the detailed study of these various habitats special attention was given to the *relations of the biota* to its environment.* In this study attention was directed particularly to the forces and conditions composing the environment, in order that the dominant forces might be clearly recognized. This involved a careful analysis of the conditions, as it is only by such means that the laws of change can be recognized, and the dynamics of the habitat be understood. In this way, the habitat can be studied from the standpoint of *processes* rather than from that of the end result or effects of such forces, for it is very evident that if the habitats are to be understood it must be by a study of their laws of change.

Somewhat similar methods have been applied to special problems by a few plant ecologists, notably Cowles and his students, from whom many suggestions have been received, but such methods have not been applied to the study of both the plants and animals, and their interrelations, for any region. In the detailed application of this standpoint to the study of habitats, with its method of description in terms of *processes,* this report (Ruthven's section) is believed to be unique. That the ideal of interpretation, dynamically considered, has not been realized in the present ecological studies, will not be surprising to any one who understands the dynamic relations of ideals, or to one who has ever tried to depart from the customary static methods of working in order to think in terms of processes—dynamically.

As this method of thinking is not generally understood, it is occasionally applied in such a crude and general sense that its bearing can not be grasped when applied to special or concrete problems. There can be no question as to the general validity of this method, but what is now needed is to know how these processes are combined and related to produce particular environmental conditions or situations. It seems a very simple matter to give assent to the idea of the law of change, yet in its practical application this simplicity often vanishes at once when it is seen that it involves the relation of cause and effect. The organic environment is very complex and the ecologist, like the geologist has very frequently to deal with a complex of causes. But to be able even to refer a change to such a complex is often a distinct advance, as this involves a recognition of a problem requiring analysis, which is a further advance.

That these difficulties are not confined to the ecologist alone, but are obstacles which arise in any attempt as scientific interpretation, is worthy of special notice. We are thus able to see why certain naturalists apparently not recognizing or understanding the developmental processes which scientific ideas undergo, nor being acquainted with the tendencies of interpretation, dynamically considered, now making such rapid headway in ecological

*Biota—"the total of animal or plant life of a given region or period." Stejneger.

botany, geography, physiography, geology and psychology, are inclined to look upon such attempts in biology as merely a fad or a personal peculiarity of the student, and not of any particular consequence. Such ideas confuse the incidental with the essential and suggest a complete failure to grasp the situation or to realize the fundamental importance of stating explanations in terms of processes.

Furthermore, in several of the allied sciences, the methods of dynamical interpretation have already made considerable advance. Here then is a resource, at present largely unworked by many biologists, where a wealth of ideas and explanations lie strewn over the surface and only need to be picked up in order to be utilized by those acquainted with this method of interpretation. It is thus very apparent that as soon as ecological phenomena are investigated dynamically and expressed in terms of processes, this science will of necessity become more closely correlated with those allied sciences which have already availed themselves of such methods.

If the signs of the times are now read correctly, the most striking advance in scientific methods of thinking during the present century will be in the direction of interpretation from the standpoint of processes—dynamically.

April, 1905.

CHARLES C. ADAMS,
Curator.

University Museum,
University of Michigan.

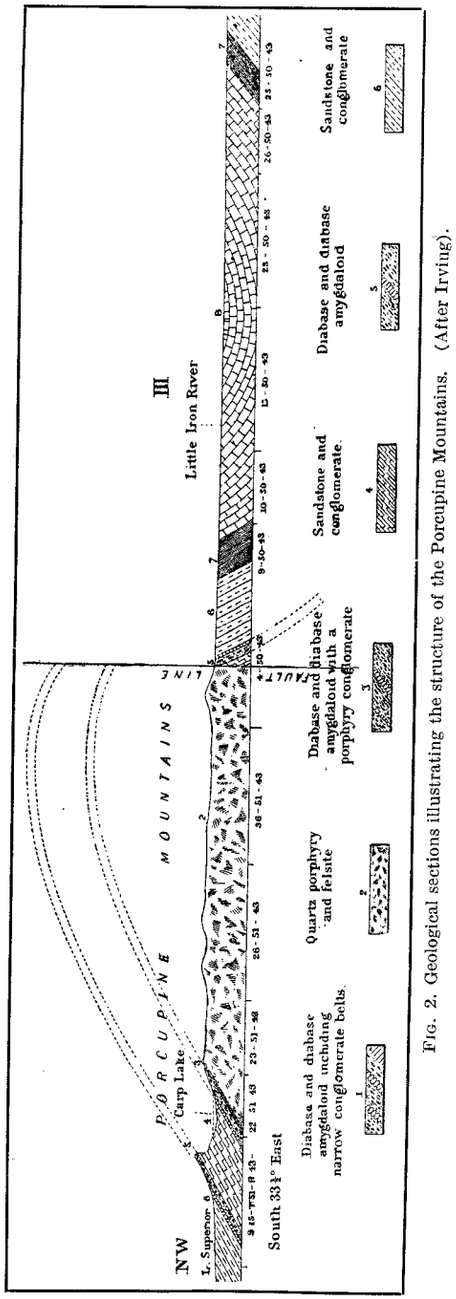

FIG. 2. Geological sections illustrating the structure of the Porcupine Mountains. (After Irving).

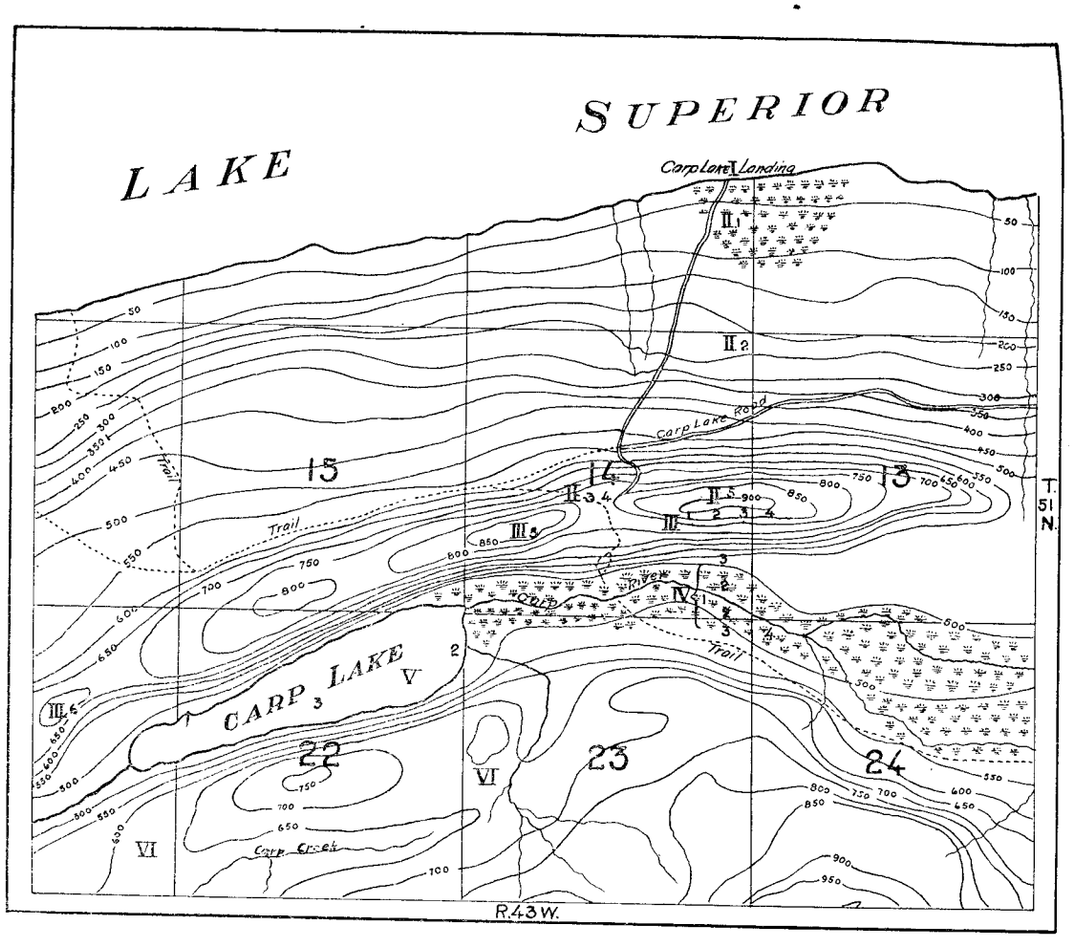

FIG. 3. Portion of the Porcupine Mountains showing location of field stations. Contour interval 50 feet. Altitudes above the level of Lake Superior, 601.19 feet.

AN ECOLOGICAL SURVEY IN THE PORCUPINE MOUNTAINS AND ISLE ROYALE, MICHIGAN.

A. G. RUTHVEN.

CONTENTS.

INTRODUCTION.

The following report is based upon the results of the University of Michigan Museum Expedition to the Northern Peninsula of Michigan. The field work covered a period from July 13 to September 5, 1904. From July 13 to August 13 was spent in the Porcupine Mountains; the remainder of the time on Isle Royale. After a short reconnaisance, a line was run through that part of the region presenting the greatest variety of habitats, and stations were established on this line at which collecting was done. This plan greatly aided keeping in mind the relation between the physical conditions and the biota, as topographic and vegetational features were made the basis for the location of stations. It also made it possible to examine a great variety of conditions and thus obtain representative collections.

There were six men in the party: Messrs N. A. Wood, Max M. Peet, N. F. Macduff, Otto McCreary, W. A. Maclean, and the writer. Having had some experience in this work, Mr. Macduff assisted the writer in running the line, and while doing this listed the flora of the stations as they were established. Mr. Wood's time was mostly spent in caring for the bird and mammal skins, and in this work he was assisted by Mr. Peet, who, in turn assisted by Mr. Wood did the trapping. Mr. Peet also spent some time

collecting birds. Mr. McCreary devoted his time to the study of the habitats of the birds and to the collecting of ants, and Mr. Maclean to collecting vertebrates alone. The invertebrates and cold blooded vertebrates were collected by the writer, with the assistance of the other members of the party.

Except in the case of the molluscs and birds, no attempt was made to make exhaustive lists of the different groups, owing to the lack of time. The collections include principally the representative forms in the different habitats, as is indicated in the description of the stations and in the annotated lists.

While running the line of survey and establishing the stations, the dependence of the biota on the environmental conditions, and the adjustment between these conditions and the plant and animal societies was given special attention. Much light was thrown on the interpretation of these interrelations by considering the physiography in its dynamic or unstable aspect. The physiography is the resultant of the geological formations and the agencies constantly at work modifying them. Since the biota is dependent on the physical conditions in the different habitats, it is also unstable. A knowledge of the present and past conditions, which can only be obtained through a knowledge of the processes involved, is therefore necessary to explain the origin and distribution of the life of this region.

Both of the localities worked are favorable for study from the ecological standpoint, for the primitive and natural order of life prevails practically free from the disturbing influences of man. The forests have not been lumbered, and, although mining has been done both in the Porcupines and on Isle Royale, the workings were all early abandoned, and the conditions of nature have reverted so nearly to their primitive order that the only evidences now remaining are caved-in shafts, and occasional growths of aspen and birch which mark the site of old clearings. The whole region is wilderness and practically uninhabited. For this reason, field headquarters were established in order to have a suitable place where provisions could be stored, and where the specimens could be properly cared for. Owing to the nature of the woods, travel was arduous and all extended trips had to be made with packs, making it difficult to care for specimens more than two days' journey from camp. This difficulty, in the Porcupine Mountains, was counterbalanced by the rough nature of the topography that made it possible to get a large variety of habitats within a comparatively small area. The territory covered by the survey was, therefore, limited to about twelve square miles, in order that representative habitats might be worked in some detail. On Isle Royale, the low relief made it necessary to extend the line much farther in order to get a variety of habitats. It was, for this reason, impossible to cover the ground in as much detail.

It is well at this time to acknowledge our indebtedness to Mr. David Allie, caretaker of the Carp Lake Mining Property in the Porcupine Mountains, who placed at our disposal a large double shack furnished with bunks, stove and dishes, and aided us in many other ways. We are also indebted to Mr. Charles Preulx and Michael Hollinger, caretakers of the grounds of the Washington Club, Isle Royale, who also assisted us in many ways.

PART I. PORCUPINE MOUNTAINS.

1. HISTORY.

The Porcupine Mountains are situated in the Northern Peninsula of Michigan, in Ontonagon County, near the west end of Lake Superior, between the Iron and Presque Isle rivers. They were acquired by the United States Government from the Mississippi and Lake Superior Chippewa Indians by virtue of a treaty concluded October 4, 1842. The territory included in this treaty was bounded on the north by Lake Superior; on the east by the Chocolate river; on the south by the Michigan-Wisconsin boundary line, and on the west by the Montreal river. Isle Royale was also included.

Shortly after the treaty was concluded, prospecting was begun, and during the period that followed the speculative fever ran high. The mere presence of trap rock was taken as an indication of the presence of valuable lodes of copper, and all the trap in the Porcupine Mountain region was soon secured by permits. Many shafts were sunk, especially in the first range where the junction of the trap and sandstone outcrops on the face of a cliff. It was soon found, however, that in this region there are no well defined lodes, the copper being scattered promiscuously in irregular seams through the trap. Before the expiration of the year 1848, according to Foster and Whitney ('49–'50, p. 80), nearly all of the companies had abandoned their locations, and there was scarcely a white man left in the region.

The workings, with the exception of three or four, were little more than prospect holes, and the impressions left upon the country by the presence of man have nearly all been obliterated. In this condition, the mountains have remained for fifty years. All about them the adjacent country has been lumbered, but, owing to the fact that the pines do not occur in extensive tracts, that the streams are not suitable for logging, and that up to a few years ago it was not thought worth while to lumber hardwoods and hemlock, the forests have thus far escaped destruction. With the exhaustion of the pine in Michigan, however, and the consequently increasing price of lumber, it has become profitable to lumber this timber, and the forests are being rapidly taken off of the Northern Peninsula. The lumbering about Ontonagon has nearly reached the great belt of hemlock on the east and north slopes of the first range. The extensive possessions of the mining companies will protect these forests for a time, but, with the increasing demand for lumber, it will be but a few years until these magnificant forests will be destroyed.

2. GEOLOGY.

It is not the purpose of this report to go into detailed discussion of the geology of the region in question. It is necessary, however, to have a general idea of the geological structure in order to understand the topography, for the topography is largely due to the different degrees of resistance offered by the outcropping rocks to erosion. The structural geology of this part of Michigan has been worked out in detail by several geologists, most notably

by Irving ('83), but little attempt has been made to correlate it with the topography, in which connection it chiefly concerns the distribution of animals and plants.

The rocks of this part of the Northern Peninsula belong to what is known as the Keweenawan Series, and may in a rough way be divided into three classes,—the basic or trap rocks, the porphyries or acid rocks, and the detrital rocks.

The basic rocks make up the greater part of the whole series. They are finely crystalline rocks formed by the slow cooling of molten lavas containing 45 per cent to 50 per cent of silica, and consist of a lower compact portion grading upward into a vesicular or amygdaloidal portion interstratified with bands of unaltered red sandstone and conglomerate which become more numerous near the top. These basic rocks are true eruptives and constitute successive lava overflows from fissure eruptions (Irving, '83, p. 139).

The acid rocks occur between layers of basic rocks and are in part, like the basic rocks, true eruptives. They are composed of materials which fuse with difficulty, owing to the presence of silica, and which consequently cool rapidly into rocks composed of large crystals embedded in a glassy or porcelain like matrix.

The detrital members of the series consist of sandstones, conglomerates and shales formed from acid, or less prominently basic, rocks.

The Keweenawan Series is divided by Irving into two divisions, the Upper and Lower Keweenawan. The Upper Division consists wholly of detrital material, while the Lower consists of alternating flows of lavas and sediments. Most of the Upper Division lies under Lake Superior, but it also underlies the broad plain between Portage Lake and the Porcupine Mountains. This plain is interrupted by the Porcupine Mountains but continues again to the south.

The Keweenawan rocks border nearly the entire area of the Lake Superior basin. Besides forming the larger part of Keweenaw Point and constituting the Michigan shore to the Montreal river, they occur in northern Wisconsin, eastern and northeastern Minnesota and occupy a great area about Lake Nipigon. The outcropping trap rocks in Michigan occur as a range extending from the end of Keweenaw Point southwestward into Wisconsin. From this range the detrital sandstones and conglomerates dip away toward the lake. In the vicinity of the Porcupine Mountains, an outcrop of trap, owing to a fold, leaves the main range and swings away toward the lake, in T. 50 N., R. 44 W., and returning joins the main range in T. 49 N., R. 45 W.; within this fold occur the rugged ranges of the Porcupine Mountains.

3. GENERAL TOPOGRAPHY.

The mountains rise from the south shore of Lake Superior, Fig. 1, in Township 51 North, Ranges 42, and 44 West, as a convex ridge parallel to the lake shore. Back of this ridge they extend to the south as steep ridges and knobs in T. 50 N., Rs. 42, 43, 44 and 45 W., and T. 49 N. Rs. 43, 44, and 45 W. The whole system comprises three fairly distinct parallel ridges that nowhere attain an alpine height; the highest point, according to the charts of the United States Lake Survey, being 1421 feet above the level of Lake Superior or 2022.19 feet above sea level. Unfortunately the territory covered by the topographic map of the Michigan Geological Survey does not embrace this section, so this record has not been verified. The altitudes

FIG. 4. General character of the rock beach, breaker line near shore, station I.

FIG. 5. Wave action on the Lower Beach, station I.

referred to in this report are, unless otherwise specified, above the level of Lake Superior. The elevation above sea level may be obtained by adding 601.19 feet to the given altitude (Wright, '05, p. 36).

The first ridge, rising from the shore of Lake Superior, reaches a height of 850 to 900 feet within a mile and a half. It then decends abruptly 400 feet into the valley of Carp river. This cliff consists of about 200 feet of vertical face, with a steep bare talus slope at the bottom which is composed of angular fragments of trap and sandstone rock weathered from the cliff above. As may be seen from the contour map, this talus slope grades down into the flood-plain of Carp river, except on Sections 21 and 22, T. 51 N., R. 43 W.; here the river widens out to form Carp lake and the talus decends into the lake. This great cliff extends nearly continuously across T. 51 N., R. 43 W., a distance of over six miles. Beyond Carp river the mountains rise in steep ridges and knobs, but with no precipitous cliffs, to the valley of the Little Carp river.

About three miles south of the west end of Carp Lake, on T. 50 N., R. 44 W., Section 2, Little Carp river widens out to form Little Carp Lake. This lake, which marks the end of the line of survey, is about half a mile long and a quarter of a mile in width, with very irregular shores formed by the surrounding hills.

The mountains are most easily reached from Ontonagon, Michigan. From here to Union Bay, there is a good but sandy road. After leaving Union Bay the road enters the mountains and runs along the north slope of the first ridge. This slope is terraced by old beaches which mark higher levels of Lake Superior, and the road ascends the mountains by these natural driveways, ascending from one beach to another in the less difficult places.

It is important to bear in mind that the present topography is not in a static condition but is being constantly changed by the forces acting upon it, and that it will continue to be changed and modified until the land has been reduced to base-level. It must also be borne in mind that forms of life are dependent on the environments formed by the physical conditions. These facts are as important from the ecological as from the physiographic standpoint, for with changes in the physical conditions there are associated changes in the dependent habitats. The present conditions are not sufficient, therefore, to explain the distribution of the present biota, and the past conditions can only be understood through a knowledge of the action of present forces in producing changes in the environments. It is for this reason that the present geological and topographical conditions have been considered.

4. LOCATION OF THE FIELD STATIONS.

The line of survey began at Lake Superior on the north and south line of Sections 11 and 12, Township 51 North, Range 43 West, and from here ran southwest up the north slope of the first range to a saddle in the crest at an elevation of 750 feet on Section 14. From this point a transverse line was run along the top of the range, to the west on Sections 14, 15, and 21, and to the east on Sections 14 and 13. From the saddle on Section 14, the main line was continued due south down the escarpment on the south side of the range, across the valley of Carp river to the east and west line of Sections 14 and 23. From this point it was run southwestward across the intervening ranges to the top of Government Peak on Section 27. Another line was run down the valley of Carp river from the north and south line of Sections 24 and 25 to the West end of Carp Lake on Section 21. Here it

turns to the south, crossing Sections 21 ,28, and 23, Township 51 North, Range 43 West, to Little Carp Lake on Section 2, Township 50 North, Range 44 West. It then turns to the east and follows the valley of Little Carp river about a mile and a half up stream. On these lines stations were established where different conditions prevailed. Their locations, Fig. 3, were as follows:

Station I. Beach of Lake Superior, Secs. 11 and 12, T. 51 N., R. 43 W.
Station II. North Slope of the First Range, Secs. 11, 12, 13, 14, 15, and 16, T. 51 N., R. 43 W.
- Sub. 1. Arbor Vitae Swamp at Foot of Slope, Secs. 11 and 12.
- Sub. 2. North Slope, Secs. 11, 12 and 14.
- Sub. 3. Clearing in the Saddle, Sec. 14.
- Sub. 4. Aspen Zone about Clearing, Sec. 14.
- Sub. 5. Aspen Zone at Top of Ridge bordering the Bare Mountain Top, Secs. 13, 14, 15, 21, T. 51 N., R. 43 W.

Station III. Top of the first Range and the Southern Escarpment Secs. 13, 14, 15 and 21, T. 51 N., R. 43 W.
- Sub. 1. West Slope of the Ridge on Secs. 13 and 14.
- Sub. 2. Bare Mountain Top, Secs. 13 and 14.
- Sub. 3. Zone of Pines crossing First Range, Secs. 13 and 14.
- Sub. 4. East Slope of the Ridge on Sec. 13.
- Sub. 5. Mountain Top on Secs. 14 and 15.
- Sub. 6. Mountain Top on Sec. 21.

Station IV. Carp River Valley on Secs. 13, 14, 23 and 24, T. 51 N., R. 43 W.
- Sub. 1. Carp River, Secs. 14 and 24.
- Sub. 2. Flood-plain, Sec. 14.
- Sub. 3. Valley Slopes, Secs. 14 and 23.
- Sub. 4. Peat Bog, Secs. 14, 23 and 24.

Station V. Carp Lake, Secs. 15, 21 and 22, T. 51 N., R. 43 W.
- Sub. 1. Beach at West End of Lake, Secs. 21 and 22.
- Sub. 2. Delta at East End of Lake, Sec. 22.
- Sub. 3. Carp Lake, Sec. 22.

Station VI. Mountains between the Carp and Little Carp Drainage Systems, Secs. 21, 22, 23, 27, 28, 33, and 34, T. 51 N., R. 43 W.
Station VII. Little Carp Drainage System, Sec. 2, T. 50 N., R. 44 W., and Sec. 34, T. 51 N., R. 43 W.
- Sub. 1. Little Carp Lake, Sec. 2, T. 50 N, R. 44 W.
- Sub. 2. Beaver Meadow along Little Carp River, Sec. 34, T. 51 N., R. 43 W.
- Sub. 3. Little Carp River, Sec. 34, T. 51 N., R. 43 W.

5. THE BIOTA CONSIDERED BY STATIONS.

Station I. The beach of Lake Superior at the point studied is composed of outcropping strata of sandstone tilted at a considerable angle, Fig. 4. The nature of this shore has an important effect on the conditions of the beach. The effect of the beating of the waves of a lake is to cut into the shore as a horizontal saw. If the strata of this shore were perpendicular, the material would fall away from the face of the cliff as it was undermined, and the cliff would be vertical. The strata are inclined, however, so that as the lower part of the shore is cut into, the rock is removed more slowly, in blocks determined by the joint and bedding planes, Fig. 4. The edges of the truncated

strata form the bottom of a wave cut terrace off shore and determine the breaker line, Fig. 7. The submerged edges of these strata continue to be worn off by the abrasion of the material carried by the undertow until the surface of the terrace is more or less uniform.

On account of the exposure and the difficulty of obtaining a foothold, the environmental conditions are very severe, and the biota is limited both in individuals and species. The beach has been divided by physiographers into three parts, the Upper, Middle, and Lower Beaches, according to the influence of the hydro-dynamic factors. These factors, as Cowles ('99, pp. 112-175, and '01, pp. 56-57) has shown, have an important influence upon the environment of plants, so that the beach may be divided into the same divisions for our present purpose.

The Lower Beach is that portion of the shore exposed to the action of the waves during the summer months. At the point studied, Station I, owing to the dip of the strata, the water deepens rapidly off shore, and the breaker line is brought near to the beach, the lower part of which is thus exposed to the full force of the waves, Fig. 5. Exposed as it is alternately to the pounding of the waves and dessication in the sun the conditions are so severe that very little life can exist. The only form that is found here is the snail *Limnaea decollata* that occurs occasionally behind projecting outcrops, where it is to some extent protected from the direct force of the waves. This snail seems to be adapted to habitats of this nature, for it was found elsewhere only in rapid water in the larger rivers (Ruthven, '04, p. 192).

The Middle Beach lies above the Lower Beach and differs from it in not being exposed to the summer waves. It is, however, exposed to the action of the waves during the early winter months, while during the latter part of the winter the ice is shoved upon it in great ridges. It is thus, only during the growing season free from those conditions which make the Lower Beach practically uninhabitated, but certain conditions still make the habitat unfavorrable. Owing to the difficulty in gaining and retaining a foothold, the vegetation consists principally of lichens, *Lecidea lactea* and *Parmelia conspersa*, that are not dependent upon the substratum for nourishment. Along the exposed edges of joint and bedding planes, where disintegration is more rapid, a slight soil accumulates, Fig. 6. These crevices, as may be seen from the photograph, are taken possession of by several of the higher plant forms, but, owing to the short period that this beach is not exposed to the pounding of the waves, only the hardier plants can obtain a foothold, such as the Beach Pea,* Silvery Cinquefoil, Goldenrod, Pale Spiked Lobelia, Harebell and a few grasses, Fig. 6.

The fauna, probably owing in part to the lack of food, is also limited. The insects are represented by the butterflies, *Argynnis atlantis, Phyciodes tharos, Grapta gracilis, Grapta progne, Basilarchia arthemis,* and *Colias philodice,* and the dragonflies, *Aeschna clepsydra* and *Sympetrum costiferum;* forms that also occur on the Upper Beach. The spiders are more characteristic; *Epeira trifolium* and *patagiata* and *Linyphia phrygiana* spin their webs behind the outcropping strata, while *Pardosa lapidicina* runs about over the rocks. The destruction of this rock beach will probably destroy the habitats of these spiders, especially of those that spin webs, as it would be impossible for them to attach their webs on a sandy beach. The butterflies on the other hand are dependent upon the flowering plants, which are essentially crevice forms, so that their habitats would be increased by the comminution of the beach.

*All plant names in this report follow Britton's *Manual of the Flora of the Northern States and Canada*, 1901.

There are numerous pools on this beach, Fig. 6, in the angular spaces formed by the removal, presumably by ice, of portions of rock between the joint planes. These pools are, as a rule, above the reach of the highest waves, so that during the summer they are not flooded by the cold water of the lake. Their temperature is thus higher than the lake water. In several readings taken August 6, 7 and 8, the temperature of the water in these pools varied from 60° F. to 68° which was 10° higher than the lake water as it broke on the lower beach. The vegetation in these pools is very scanty, consisting chiefly of Algae which line the sides. The small number of species is probably due to their isolation and shallowness (6 to 18 inches), and to their smooth sides which make it difficult for the plants to gain a foothold. The fauna is much better represented than the flora. Besides a number of minute forms such as Crustaceans, Hydra, etc., there are a number of the higher aquatic forms characteristic of quiet water habitats. The insects are represented by water-boatmen, water-striders, and caddis-fly larvae, and the snails by *Physa ancillaria, Limnaea desidiosa, Planorbis parvus* and occasionally, near the Lower Beach by *Limnaea decollata.* These forms are found in all of the larger pools with the exception of *Limnaea decollata* which only occurred in the lower pools that are occasionally flooded by the waves. When these pools are flooded by an exceptionally high wave, they are often temporarily united with the lake and with each other which suggests a way by which certain forms may migrate along a shore of this kind. With the destruction of this beach these pool habitats will be destroyed, as pools of this kind cannot exist on a sandy beach.

The Upper Beach is above the reach of both summer and winter waves, and the environmental conditions are consequently more favorable than those of the Lower and Middle Beaches. The principal factor that still makes the habitat an unfavorable one for plants is the poor foothold afforded by the substratum. The soil, however, increases in amount at the edges of the joint planes thus affording a foothold for small trees and shrubs, Fig. 6, and to this soil is added a small amount of humus formed by decaying logs and annuals. Owing to these conditions, the flora presents a curious assemblage of forms. It is composed of the forms of the Middle Beach, Goldenrod, Beach Pea, Vetchling, Lobelia, Hare-bells, etc.; the fern, *Polypodium vulgare;* the heaths represented by the Bearberry, Great Bilberry and Dwarf Huckleberry that constitute the next society, and a number of trees and shrubs such as the Arbor Vitae, Mountain Maple, Mountain Ash, Large-leaved and Quaking Aspens, Juneberry, Eastern Ninebark, Dwarf Cherry, Wild Raspberry and Canadian Buffalo-berry, that in this region form a transitional zone between exposed habitats and the mesophytic forest. The fauna of this beach is in many respects similar to the fauna of the Middle Beach from which it cannot be distinctly separated. The forms found here which are not, as a rule, found also on the Middle Beach are the grasshoppers *Camnula pellucida, Circotettix verruculatus, Melanoplus atlanis* and *Melanoplus femoratus,* and the Lake Superior Chipmunk. The grasshoppers, as a rule, remain closely within the limits of this beach, with the exception of the forms of *Melanoplus* which are occasionally found also on the Middle Beach. The chipmunks are also seldom observed far from the drift logs that characterize this habitat.

The beach as a whole is thus, in a general way, divided into three habitats by the dominance of different processes which bring about different enviromental conditions, but these divisions, as may be seen from the photographs, are not sharply defined. The Lower Beach in general possesses

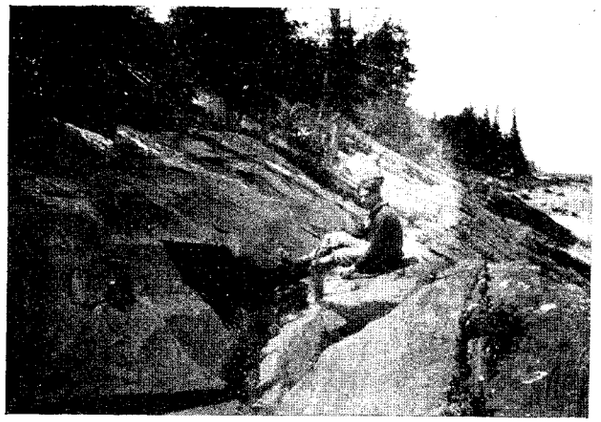

FIG. 6. Showing nature of the rock pools, crevice vegetation and lichens (white patches) of the Middle Beach, and the stunted crevice vegetation of the Upper Beach, station I.

FIG. 7. General character of the rock beach, breaker line off shore, station I.

little life, but near the upper limit of summer wave action a few straggling annuals come in that characterize the Middle Beach above, while near the upper limit reached by the winter waves and ice a few perennials of the Upper Beach occur. The biotic tension lines between these divisions also undergo occasional fluctuations, since the position of the tension line between the Lower and Middle Beaches is determined by the severity of the summer storms, while between the Middle and Upper Beaches it is determined by the height of the winter waves and ice.

Owing to the action of the waves, the beach as a whole is retreating inland, but as it retreats a wave cut and wave deposited terrace is being formed, and this by shallowing the water carries the breaker line off shore and lessens the effect of the waves, as illustrated in Fig. 7. The conditions of the Lower and Middle Beaches thus become more favorable, resulting in a progessive downward movement of the biota of the Middle and Upper Beaches respectively that decidedly narrows the beach zones.

On the other hand, the sinking of the coast in this region counteracts, in places, the tendency of the submarine terraces to decrease the efficiency of the waves. The deepening of the water near shore caused by this sinking of the coast brings the breaker line nearer shore, thus increasing the efficiency of the waves to such an extent that the beach habitats are being forced back into the adjacent swamps.

Station II. Substation 1. Back of the beach, at the foot of the first range, there often extends for considerable distances a narrow belt of arbor vitae swamp. This swamp owes its origin, according to Wright ('05, p. 37), to the general sinking of the beach of Lake Superior referred to in the discussion of the previous station. Gilbert ('97) in a discussion of this problem states that a general canting or tilting of the Great Lake Basins toward the southwest is taking place, as is indicated by the inclination of the beach lines of post-glacial lakes and by the drowned mouths of the rivers along the coast. It is evident that the rivers of the Porcupine region are drowned, as they are widened near their mouths into broad estuaries with adjacent swamps, and evidence that the tilting of the lake basin that is causing this is going on at the present time may be found in the submergence of standing trees along the lake shore, and in the discrepancy in the length of the section lines between different surveys, (Wright, '05, p. 37).

This sinking of the coast makes the conditions of a narrow zone just back of the beach too wet for some of the mesophytic forest forms that occupy the higher parts of the ridge, but at the same time it makes the conditions favorable for some of the forms of the arbor vitae swamp, so that this area is inhabited by certain forms characteristic of each of these habitats. The tree cover consists principally of the Arbor Vitae, with considerable Balsam Fir and some White Spruce and Paper Birch; the soil cover is characterized by the Running Pine, *Lycopodium clavatum,* and occasional clumps of Blue Flag. The molluscan fauna is very poorly represented, and the only shells collected were a few specimens of *Punctum pygmaeum* and *Zonitoides milium.* A single spider was taken here, *Dolomedes tenebrosus.* The mammals are those of the forest, such as the Southern Varying Hare, Southeastern Red Squirrel, etc., with the exception of the Lake Superior Chipmunk which was occasionally seen near the beach.

If the coast continues to sink, this swamp will approach more closely the conditions of the swamps of the river valleys and will become occupied more exclusively by the biota of the ordinary arbor vitae swamp, while

at the same time it will tend to retreat before the beach and invade the areas at present occupied by the mesophytic forest of the north slope.

Station II. Substation 2. Above the arbor vitae swamp, the north slope of the first range rises steeply to the top of the ridge and is covered by a dense mesophytic forest. The angle of this slope and the fact that it is formed by dipping strata, makes the drainage so rapid that the soil on the upper part tends to be washed downward and to accumulate at the bottom. The humus formed by the fallen twigs and leaves of the forest prevents in part superficial wash, and most of the water, for this reason, is conducted away under ground. The ravines are thus small and the streams transient. The lower parts of the slope support a dense hemlock forest in which there is deep shade, Fig. 8. The tree cover of this part of the forest consists principally of Hemlock associated with the Balsam Fir, Ironwood, Yellow Birch, isolated White Pines and a few Sugar Maples. The undergrowth of Ground Hemlock and Maple is very scanty, and the humus is thus composed chiefly of leaves and twigs of the Hemlock with the exception of localized accumulations of deciduous leaves from the maple underbrush. The soil cover is also scattered and is composed of the Large-leaved Aster, Wild Sarsaparilla, Twinflower, Goldthread, Maidenhair Fern, Wild Spikenard, Rattlesnake Plantain, Dwarf Dogwood, *Clintonia borealis*, and *Lycopodium lucidulum* and *clavatum*.

The fauna of the hemlock forest is also rich in species. Besides many insects and other invertebrates, there are a number of birds and the toad (*Bufo americanus*). The mammals are represented by the Canadian Porcupine, Northern Virginia Deer, Northern Plains Skunk, Woodchuck, Southeastern Red and Northern Flying Squirrels, Northeastern Chipmunk, Star-nosed Mole, Large Bobtail Shrew, and the Northern and Woodland Jumping, Canadian White-footed and Red-backed Mice. Owing to the predominance of conifers, it is to be expected that few shells would occur in this forest, but the accumulated leaves of the maple underbrush counteract the unfavorable nature of the coniferous humus and support a somewhat scattered molluscan fauna composed of *Zonitoides milium, Vitrea ferrea, Euconulus fulvus, Punctum pygmaeum, Helicodiscus lineatus, Strobilops virgo, Zonitoides exigua, Sphyradium edentulum, Carychium exile,* and *Agriolimax campestris*.

On the upper parts of the slope, the soil becomes thinner, and there is a noticeable change in the character of the forest. It is still mesophytic, but the Hemlock, Balsam Fir, Ironwood and Yellow Birch give way to a forest composed of the Sugar Maple, Basswood, and Paper Birch, in which the Sugar Maple predominates. This transition is gradual and while near the top of the ridge the Ironwood and Yellow Birch are practically absent, the Hemlock and Balsam Fir may still persist. The undergrowth in this part of the forest is much better developed, Fig. 9, and consists principally of Maple, Basswood and Ground Hemlock. The ground is covered to a depth of several inches with leaves, and the soil cover, although better developed, is practically the same as in the hemlock forest except that the Large-leaved Aster, Indian Pipe and Goldthread seem to become replaced by *Cinna latifolia*, White-flowering Raspberry, Fly Honeysuckle and Brake.

The changes in the environmental conditions with which are associated the changes in the composition of the flora toward the top of the slope do not seem to influence the fauna to a marked extent. As the tree cover is principally affected, the most marked change in the fauna is seen in the case of the birds, which are more closely associated with this type of vegetation.

Another change is the occurrence, on the upper part of the slope, of the Red-bellied Snake, *Storeria occipitomaculata*, which prefers dry, rather open woods. With the coming in of the deciduous forest, the humus becomes composed of leaves, and with this change in the nature of the humus is associated an increase, at least in the number of individuals, of molluscs. When the fallen leaves are examined, they are found to be connected by a film of water. Among these leaves seemed to be the favorite habitat of all the snails collected in these woods. The forms collected are *Zonitoides exigua Zonitoides arborea, Vitrea ferrea, Euconulus chersinus polygyratus, Helicodiscus lineatus, Punctum pygmaeum, Cochlicopa lubrica morseana, Sphyradium edentulum, Pyramidula striatella catskillensis, Strobilops virgo, Polygyra albolabris, Vitrea indentata* and *multidentata*.

It has been suggested (Whitford, '01, p. 301) that the presence of isolated White Pines in the mesophytic forest indicates a former dominance of xerophytic forms. This at once suggests an explanation for the origin of the present biota that is in accordance with the observed facts. When the waters of the glacial lakes receded and left the mountains exposed to denudation, the wash on this slope must have been considerable. The vegetation that first gained a foothold was probably a society analogous to that on the Middle Beach at the present time. These forms would be followed, as the conditions became favorable, by the heath society of the Upper Beach. At the bottom of the slope where the soil was thicker and the superficial wash less, the heaths were probably soon succeeded by the conifers that usually follow the heaths in this region. With the accumulation of humus in the coniferous forest, the superficial wash would become less, while the soil formed on the higher parts of the ridge would be held in front of the forest, permitting the coniferous types to ascend the slope and restrict the area occupied by the heaths.

As the coniferous forest became well developed at the bottom of the slope, owing to the more favorable edaphic conditions brought about by the accumulation of humus, the pine seedlings which require considerable light would no longer be able to develop. The seedlings of the deciduous trees, Maple, Basswood, Hemlock, etc., which would find a favorable habitat in the increased shade and humus of this forest, would then invade the coniferous forest as underbrush, so that, as the pines died off, they would be replaced by the forms of the present forest.

The fauna of this slope would have a history similar in many respects to that of the flora. If the slope was first invaded by the heath plants, it was probably at the same time invaded by the fauna that is associated with this society; a relation which would also hold in the case of the succeeding societies.

The conditions to which the forms in the different societies are adapted, or the habitats, would thus tend to migrate up the slope from the point of invasion, and the mountain top would be the scene of the extinction of the pioneer societies, the last place where they would be found. Since the mountains were islands for some time after the retreat of the ice sheet, the level at which this invasion of life took place presents an interesting question. Evidently it must either have taken place above one of the old beach lines while the mountains were yet islands, or after they had been joined to the main land by the subsidence of the lake. In the latter case, the invasion would have come in near the base of the mountains, as they are entirely surrounded by a low plain, but in either case the succession of societies would have been much the same, with the exception that in the former

case the migration of the societies would also have taken place down the slope, following the receding lake beach.

Station II. Substations 3 and 4. These substations are located in an artificial clearing and will not be discussed. The species that occur here will be found in the annotated lists.

Station II. Substation 5; and Station III. The north slope of the first range rises directly to the top of the ridge at an elevation of about 900 feet. Over the crest there is a sharp descent of several rods to the brink of the precipitous escarpment that overlooks the valley of Carp river, Fig. 10.

The effect of the dynamics of the mountain top are very conspicuous. The exposed rock is unprotected from the forces which cause disintegration, for as fast as it is broken up the particles are washed away, and thus the first soil to accumulate is in the exposed edges of joint planes. The soil washed down the north slope on Section 21, Fig. 11, is checked and held in front of the forest, which advances as the soil becomes sufficient to support it. On Sections 13 and 14, Fig. 10, the forest has advanced to the crest so that no soil from the bald areas is washed down the north slope. The soil formed on the south side of these areas, meeting with no obstruction, is washed over the precipice and accumulates in a narrow strip along the top of the talus slope, while that which is washed laterally from the top into depressions in the crest is also checked to a certain extent by the encroaching forest. The concentration of water in these inequalities causes them to be deepened into ravines, situated at right angles to the crest, and much of the material derived in this way is carried over the cliff and deposited as alluvial cones on the talus slopes below; these alluvial cones join the ravines above forming broad saddles across the ridge, Fig. 10. The face of the cliff is also exposed to weathering agencies that tend to pry loose portions of the rock between the joint planes. The larger fragments fall to the bottom of the cliff and go bounding down the talus slope, often starting minature landslides of the talus material. The slope thus lies at the angle of repose of the material and is very unstable, Fig. 17. As a rule, the larger the fragment the farther down the slope it will go before coming to rest, and the strip of fine material at the top of the slope, which was formed partly from the soil washed over the cliff from the bald areas above, receives constant additions from the fine material that is loosened from the cliff face. Toward the bottom of the slope, the conditions become more stable, and the talus blocks are being disintegrated and decomposed into a residual soil. The mountain top, cliff, and talus slope habitats thus offer virgin conditions for plant and animal societies, and it is in localities such as these that the pioneer societies are found.

If the results of the processes at work on this ridge be summarized, it is evident that they are tending to lower the ridge toward a base leveled plain, thus changing the present conditions toward those found on the lower parts of the north slope.

Station II. Substation 5; and Station III. Substations 1 and 4. The biota of the north slope of the first range, pushes through the saddles and down the alluvial cones on the south side and mingles with the biota of the forest in the valley of Carp River, Fig. 10. From the north side and the saddles it extends upward and surrounds on three sides the bare areas of the higher parts of the ridge, but, owing to the changed environmental conditions, it becomes modified in its composition near the crest. The Hemlock and Balsam Fir and finally the Sugar Maple become replaced by a zone of aspen and oak, consisting principally of the Quaking Aspen, Paper Birch, Red and

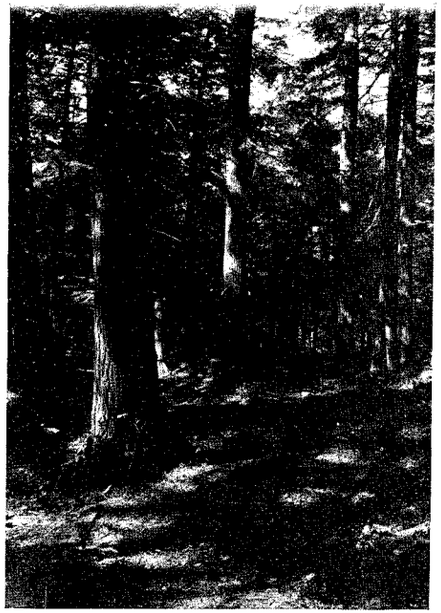

FIG. 8. Hemlock forest, showing dense shade and lack of undergrowth, station II. 2.

Burr Oaks, associated with the Mountain Maple, Large-toothed Aspen, Mountain Alder (*Alnus alnobetula*), several willows and scattered Red and White Pine. The underbrush and soil cover of this zone is composed of *Polypodium vulgare*, Juneberry, Scarlet Sumac, Bush Honeysuckle, Eastern Ninebark, Great Bilberry, Round Leaved Dogwood, Dwarf Cornel, Narrow-leaved Cow-wheat, Low Snowberry, *Polypodium vulgare*, and *Lycopodium clavatum, complanatum* and *selago*; *Linnaea americana* may also be mentioned.

Higher up the mountain the soil cover becomes replaced by the Bearberry, Dwarf and Low Black Blueberry, New Jersey Tea, and Creeping Wintergreen. The White Pines still persist, but the shrubs mostly disappear, and the oaks and aspens associated with *Juniperus nana* become very scrubby, often forming small mats on the slight soil, Fig. 12.

As in case of the vegetation, the range of many of the animals of the mesophytic forest reaches an upward limit in the aspen zone, where they occur mingled with other forms that replace them on the bald areas. Thus the molluscs become noticeably fewer in individuals in this zone; *Zonitoides exigua, Cochlicopa lubrica, Vitrea ferrea, Euconulus fulvus, Helicodiscus lineatus and Carychium exile* seem to drop out of the fauna entirely, while *Punctum pygmaeum, Sphyradium edentulum, Zonitoides milium* and *arborea*, and *Strobilops virgo*, by changing their habitats from the damp fallen leaves of the mesophytic forest to the dry soil held by the heaths, are able to persist. Mingled with these forms was found for the first time *Bifidaria curvidens*. Similarly the only grasshopper that occurs in the mesophytic forest (*Tettix*) is replaced in the aspen zone by *Melanoplus luridus, fermoratus* and *islandicus, Chloealtis abdominalis* and *conspersa*, and *Camnula pellucida*, while the Northeastern Chipmunk, Northern Plains Skunk, Woodchuck, and the woodpeckers, owls, chickadees, nuthatches, etc. are mostly replaced by the Lake Superior Chipmunk, Junco, Robin, and Bluebird. The smaller mammals such as the mice, moles and shrews seem to persist without noticeable diminution in abundance.

Station III. Substations 2, 5 and 6. On the mountain top beyond the limit of the aspens and oaks, the biota is composed almost exclusively of the forms that appear in the upper part of the aspen zone. The heaths, represented by the Bearberry and Creeping Wintergreen, with the Dwarf and Low Black Blueberry and New Jersey Tea, form a large dense mat beyond the aspen zone, that extends in long tongues along the crevices on the bare top, Fig. 11. On the denser portions of this mat occur widely scattered White and Red Pines with many dead stumps, Fig. 13.

On the bare mountain top, the flora consists only of the lichens, *Lecidea lactea, Lecanora conspersa* and *cinera, Parmelia conspersa*, and *Stereocaulon coralloides*, on the surface of the rock, and a crevice vegetation of Harebell, Three-toothed Cinquefoil, Wild Wormwood, Evening Primrose, *Panicum xanthophysum, Polypodium vulgare, Polystichium lonchitus, Asplenium trichomanes*, and *Solidago bicolor, lanceolata, juncea* and *erecta*.

The molluscs, *Punctum pygmaeum, Euconulus chersinus polygyratus, Zonitoides milium, Strobilops virgo, Vitrea indentata* and *Bifidaria curvidens*, that characterize the upper part of the aspen zone, also occur in the larger heath mats, associated with *Acanthinula harpa. Bifidaria curvidens* greatly predominates in this fauna. Dead specimens of *Helicodiscus lineatus* and *Succinea avara* are often found in the rock crevices near the brink of the cliff, but these were probably blown here as they could hardly exist in this habitat, being moisture loving forms. The characteristic insects of this station are the dragonfly, *Sympetrum obtrusum*, the butterflies, *Argynnis cybele*,

Thecla edwardsii, and the grasshoppers, *Chloealtis abdominalis* and *conspersa*, *Melanoplus fasciatus*, *amplectens* and *islandicus*, *Circotettix verruculatus*, and *Atlanticus pachymerus*.

The Cliff. Owing to the precipitous nature of the cliff, the rock fragments are removed as fast as they are split off the parent rock, and the environmental conditions of the cliff face remain uniformly severe. The only vegetation that can exist consists of the lichens, *Gyrophora (Umbilicaria) vellea*, *Amphiloma (Pannaria) languinosum*, and *Biatora lucida*, that manage to obtain a foothold on the face of the rock, but these are invariably destroyed as the rock weathers away. On the ledges, however, where the conditions are more permanent, a number of plant forms may gain a foothold, the extent of the vegetation depending upon the age and size of the ledge. On the fresher ledges the only plants are the lichens, among the representative forms of which may be mentioned *Stereocaulon coralloides*, *Parmelia conspersa* and *Lecidea lactea*. Where a slight soil has accumulated, the Harebell, *Panicum xanthophysum*, *Polystichium lonchitus*, Three-toothed Cinquefoil, and Goldenrods may occur. While on the larger ledges, which often possess several inches of soil, the Bearberry, New Jersey Tea and other forms of the heath society, together with the Juneberry, White and Red Pine, *Juniperus nana*, Arbor Vitae and Northern Poison Oak may obtain a foothold, Fig. 14.

The fauna of the cliff face is also very limited. The ledges are too small to support a characteristic fauna, but ants grasshoppers and dragon-flies are often found here. The butterfly, *Grapta gracilis*, was occasionally seen in considerable numbers on the cliff face, but the only animal that can be said to be characteristic of this habitat is the Raven which nested here.

Station III. Substation 3. Where the cliff is broken by large ledges, Fig. 15, the conditions are more stable, and the vegetation consists principally of a growth of Red and White Pine and an undergrowth of Reindeer Lichens and heath plants, that extends up the cliff and across the mountain top. Where these belts of pine join the mesophytic forests of the north slope and river valley, the undergrowth is predominated by the Sugar and Mountain Maples and Quaking Aspen. The fauna of these belts is peculiar. Although the Pine Warbler and Crossbills are often seen here, the belt is too small to support an extensive pine forest fauna, while at the same time it is, perhaps, the deposit of pine needles that excludes the molluscs of the mountain top and mesophytic forest.

Talus Slope. Where the precipice is not broken by large ledges, the fragments of rock that weather from its face fall to the talus slope below. The finer material collects along the top of the slope, at the foot of the cliff, and supports a vegetation composed of a number of species, Fig. 10. Among the more prominent of these are the Thorn Apple, Red Oak, Quaking Aspen, Wild Red Cherry, Round-leaved Dogwood, Juneberry, Bearberry, New Jersey Tea and scattered White and Red Pine. Below this zone the talus slope is strewn with dead wood and recently fallen trees, mostly pines, Fig. 16. Where the cliff is composed of trap, Substation 6, the blocks which fall from its face are large, and the talus slope is practically devoid of vegetation with the exception of scattered patches of lichens, principally *Parmelia conspersa*, Fig. 17. Where the cliff is composed of sandstone, the talus material is finer and often supports a scattered vegetation of White and Red Pine, Paper Birch, Wild Cherry, Northern Poison Oak, and Virginia Creeper. Toward the bottom of the slope, the first vegetation that occurs are the lichens, principally *Lecidea lactea* and *Parmelia conspersa*, the latter

predominating. These forms cover more or less completely the surface of the talus fragments. Farther down *Stereocaulon coralloides* and *Lecanora conspersa* are added to this society which is dominated on the lower part of the slopes by the Reindeer lichens, *Cladonia rangiferina* and *alpestris*, that often occur superimposed on the remains of the other lichens. These are replaced toward the bottom of the slope by the Bearberry, New Jersey Tea, *Polypodium vulgare*, Raspberry, Wild Red Cherry, Mountain Maple, Paper Birch, Quaking and Large-toothed Aspens, Beaked Hazelnut, Blackberry, Brake, and Bush Honeysuckle, that in turn give way to the typical mesophytic forest forms of the river bottom.

The environmental conditions as regards the fauna are more unfavorable than on the mountain top. The only forms that are found here are a few ants in the narrow zone of vegetation at the top, and occasional grasshoppers and dragon-flies on the bare slope below. Near the bottom of the slope the Lake Superior Chipmunk was often seen running about over the rocks and among the bushes that fringe the forest. Forms from the mesophytic forest of the river valley such as the Garter Snake and Northeastern Chipmunk are also occasionally seen here.

When the biota of the mountain top and north slope are listed by habitats, the genetic explanation suggested for the forest of the north slope is enforced. It is evident that certain groups of forms are, in a general way, dependent on certain environmental conditions. The action of the forces which bring about these conditions tend to modify those that exist at any one time, so that the biota must adjust itself to the new conditions or be exterminated. This is especially noticeable on an elevated area. It was shown in the discussion of the topography that the effect of physiographic processes on the ridge in question was to reduce it to a base-leveled plain. The environmental conditions are thus being changed and modified in the direction of the conditions that prevail on the lowland at the foot of the mountain. These conditions are brought about first on the lower parts of the ridge, so that the habitats of the lowland biota are extended at the expense of cliff habitats, and correlated with the changing conditions a succession of societies occurs. This may be easily seen from the top of the ridge, Fig. 11. The first plants to get a foothold on the bare rocks are those of the lichen society such as *Lecidea lactea* and *Parmelia conspersa*, that form large patches over the exposed rock surfaces. The wash and decay from these mats is at first mostly washed away down the slopes. As soon, however, as the processes of weathering have opened the edges of the joint planes, the soil accumulates in them and with it a small amount of organic material from the lichen mats. The conditions thus become favorable for a crevice vegetation consisting of certain mosses, the Harebell, Cinquefoils, Goldenrods and grasses. As the soil, held in the crevices by the plant roots, increases in amount, the conditions become still more favorable, and the crevices are invaded by the heaths from the extensive mat that surrounds the mountain top on three sides, in front of the mesophytic forest. The dense mats formed by the heaths do much to make the edaphic conditions more favorable by holding the soil as it is formed, checking that which is washed from higher areas, and by accumulating the humus formed by the decay of the vegetation.

The first society to gain a foothold on the lichen mat is represented by the White and Red Pines, and the next by the forms of the aspen zone. In many instances, the Quaking Aspen, which is one of the hardiest plants of this zone, follows the heaths along the crevices before the pines can obtain a foothold, but in any case the pine stage is but poorly represented, probably owing

largely to the exposure of this habitat to wind, Fig. 12. The aspen zone is in turn succeeded by the biota of the mesophytic forest type. This succession prevails on the north, east and west sides of the crest. On the south side, owing to the presence of the precipice, the soil accumulates only to a slight extent and the succession only progresses as far as the heath or pine stage. The biota of the cliff and upper part of the talus slopes are not in the succession, for owing to the fact that the material is removed nearly as fast as it is formed, the conditions remain practically the same, and the forms only gain a temporary foothold. It is true that on the ledges there is a more or less definite succession of societies leading up to the pine stage, but it rarely proceeds beyond this stage, while it is liable to be destroyed before this stage as is shown by the debris that accumulates on the talus below. The biota of these habitats is evidently derived from the mountain top. A large percentage of the seeds of the vegetation on the south side of the crest is washed over the cliff with the soil. Many of the ants and snails of this area probably have a similar fate, while it is a common sight to see grasshoppers on the mountain top caught by the wind, when on the wing, and carried over the precipice to light on the talus slope below. The biota of the narrow strip of finer material at the top of the talus slope, owing to the more favorable soil conditions and the shade furnished by the cliff, is composed of forms that occur in the pioneer societies both on rock and soil habitats, and it is thus a complex pioneer society. The strip of finer material is only formed at the foot of the cliff and migrates with it, leaving its lower edge to be covered by the larger talus blocks as the cliff retreats. The biota thus becomes practically destroyed, and the conditions change toward those of the talus slope. At the foot of the talus slope the conditions are nearly the same as on the mountain top. The pioneer forms are the lichens that cover the rocks and hold the material as the rocks disintegrates. The soil that is formed accumulates rapidly among the talus blocks and becomes in time sufficient to support the reindeer lichen society. As the soil continues to increase, the forms of the heath society push onto this mat, followed in turn by the climax forest society, the pioneer forms of which generally extend well up the slopes. The most prominent form among the pioneers of the climax forest on the talus slopes is the Paper Birch, broken and twisted individuals of which are often found well within the range of falling rock fragments. As Harvey ('03, p. 37) has suggested for Mt. Ktaadn, it seems to be adapted to this habitat by its flexibility.

There is thus a series of lowland societies steadily encroaching on the cliff habitats from all sides, as the physical processes reduce the ridge toward sea level. The order of succeeding societies is generally the same in a particular region. Cowles ('01) and Whitford ('01) both give the pine stage as generally following the heath society in northern Michigan, but on the cliff habitats in the Porcupine Mountains, owing to the effect of the wind and the shallow soil, the coniferous society may be nearly, if not entirely, left out of the succession. In this case, an entire stage in the order of succession is made impossible by a particular combination of the environmental conditions, and the fact is enforced that habitats are composed of a complex of physical conditions. This is further shown by the dwarfed nature of the aspens and oaks that border the "bald" areas. These trees often grow as shrubby mats, owing to the breaking off of their tops by the wind. This is undoubtedly due indirectly to the presence of the escarpment, for on higher ranges to the south, which possess no escarpment, the mesophytic forest covers the highest peaks with no noticeable decrease in the size of the trees.

FIG. 9. Deciduous forest, showing character of undergrowth, station II. 2.

The fate of the pines on the exposed top of this ridge, the scrubby nature of the aspens and oaks, and the fact that the tops of a large percentage of the living pines are dead, suggests that the timber lines on some mountains may be greatly influenced by wind.

Station IV. Substation 3. Beyond the limit of the falling rock fragments on the talus slope, where the rocks have been disintegrated and decomposed to form a soil, the Paper Birch, Mountain Maple, Aspen and Mountain Ash become mixed with the Sugar Maple, Balsam Fir and Basswood, that gradually predominate to the exclusion of the Aspen and Mountain Ash. In the forest near the bottom of the slope, Hemlock forms a part of the tree cover and occasionally predominates to such an extent that a hemlock forest results similar in composition to the hemlock forest at the foot of the north slope. More often, however, the Sugar Maple predominates in this forest, associated with the Balsam Fir, Basswood and Ironwood, with scattered Hemlocks, and White Pines, thus making it similar in composition to the mesophytic forest of the north slope with which it is connected through the saddles. The ground cover and fauna are also practically the same and need not be listed.

Station IV. Substation 2. Owing to the flat nature of its valley, Carp river above Carp Lake is a slow meandering stream that is doing practically no vertical cutting, Fig. 18. It is easily turned from side to side, and, as it is deflected toward one side of its valley, it tends to cut into it, while on the other side of the bend, owing to the decrease in the velocity of the current, part of the load is deposited to form mud flats. The river thus tends to broaden its valley at the expense of the neighboring divides and to build up its flood-plain with a part of the material derived in this way. The material that is not deposited on the mud flats is carried on until the stream reaches Carp Lake, where again owing to its diminished velocity, the stream deposits much of its load in the lake, forming a large delta at the mouth of the river. On the flood-plain of the river, Fig. 18, the deciduous forest either gives way to a coniferous society characterized by the Tamarack, Spruce, Arbor Vitae and Black and White Ash, which in turn grades toward the river into an extensive alder thicket, or, where the valley is narrow, the coniferous society may be nearly or entirely absent, and the hardwood forest grade directly into the shrub society. The shrub society is largely composed of the Hoary Alder (*Alnus incana*) associated with several willows, occasional Tamaracks, and scattered clumps of Red-osier Dogwood. The undergrowth in these thickets is not extensive; among the more noticeable forms are the Skunk Cabbage, Sensitive and Cinnamon Ferns, Skull Cap, and several species of violets.

The fauna is characterized by a great increase in the number of birds; the warblers and sparrows are especially conspicuous. This is also the habitat of the Red Backed Salamander (*Plethodon cinereus*) and the Wood Frog (*Rana sylvatica cantabrigensis*). For some undetermined reason, the molluscs seem to be very poorly represented in this society.

Between the alder thickets and the river, in the broader portions of the valley, there is often a well defined zone of vegetation characterized principally by the Dwarf Cassandra. Between the two societies the Hoary Alder and Dwarf Cassandra occur mingled with the Wax Myrtle, High Bush Blackberry, American Meadow Sweet, and Few Flowering Cranberry. Toward the river, the Hoary Alder, Willows, Red-osier Dogwood and Tamarack occur only in scattered clumps among the Cassandra that forms a low dense thicket. Less prominent but conspicuous forms in this society are the Pale

St. Johns Wort, Joe Pye Weed, Swamp Milk Weed, Running Swamp Blackberry, Marsh Cinquefoil, Ladies Tresses, Marsh Bell Flower, Creeping Snowberry, *Solidago uliginosa*, and a number of grasses and sedges among which are *Eriophorum cyperinum, Calamagrostis canadensis, Deschampsia flexusa, Panicularia canadensis, Scirpus cyperinus, Carex viridula, riparia,* and *filiformis*. Owing to the low height of these forms, the habitat is open, and the fauna is similar in many ways to the fauna of the mountain top, but, owing to its proximity to the river, several new forms are added. The more characteristic forms are the butterflies, *Argynnis cybele var.* (near *leto*), *Argynnis atlantis* and *Basilarchia arthemis;* the dragon flies, *Gomphus spicatus, Lestes unguiculatus, Calopteryx aequabilis* and *Sympetrum obtrusum*, and the grasshoppers, *Atlanticus pachymerus, Stenobothrus curtipennis, Podisma glacialis, Melanoplus islandicus* and *Scudderia pistillata*. It might be expected that this habitat would be favorable for reptiles and amphibians, but while it is the habitat of the Garter Snake, *Thamnophis sirtalis sirtalis*, the dense entangled nature of the vegetation apparently excludes the frogs.

The cassandra zone extends only to the river bank, where it generally mingles with a narrow zone of alders on the low natural levees, but a number of grasses and sedges, *Juncus effusus, Calamagrostis canadensis, Scirpus cyperinus, Dulichium arundinaceum, Carex filiformis, viridula* and *riparia*, push out on the mud flats to the edge of the water, Fig. 19, and form a transition society between the cassandra zone and the aquatic forms of the river.

The fauna of these flats is also transitional between the aquatic and terrestrial habitats. This is illustrated by the presence of the turtle, *Chrysemys marginata*, and the frogs, *Rana clamitans* and *septentrionalis*, which are amphibious and thus intermediate in habits between the two habitats. The birds are the waders and shore birds that find their food here; among these may be mentioned the sandpipers, snipes, herons, and bitterns. Although by no means limited to this habitat, and to be more properly listed with the fauna of the mesophytic forest, the Canadian Porcupine is a conspicuous form on these flats where it may often be seen, singly or in groups of two or three, feeding on the pads of the water lilies.

Owing to the steepness of the sides of the valley, the entire succession of societies is only found in the broader parts, for where the river swings toward the side of the valley the flood-plain is destroyed, and the cassandra, alder and coniferous societies are all limited to a single narrow zone between the river and the deciduous forest.

If the different flood-plain societies be compared with the succession of forms in a tamarack swamp as given by Transeau ('03, pp. 403-404), a remarkable similarity will be revealed. The societies that occur in the bogs of more southern localities are here spread out over the entire flood-plain of the river, and the tamarack swamps of Indiana, Illinois and southern Michigan are minature reproductions of the flood-plain conditions in this region.

Station IV. Substation 4. There are, however, areas where more typical bog conditions prevail, so that in the wider parts of the valley the bog types may attain a much better development. In these areas, the bog societies are not arranged in concentric zones, as in the southern bogs, but are, as the flood-plain societies, more or less parallel to the river. The succession is much the same as on the flood-plain and in the southern bogs. The sedge zone grades into a zone composed largely of Dwarf Cassandra associated with the Rose, Juneberry, High Bush Blackberry, Wax Myrtle, American Meadow Sweet, Swamp Honeysuckle, and Cranberry, that is in turn followed by a society composed largely of Balsam Fir, Tamarack and White Spruce,

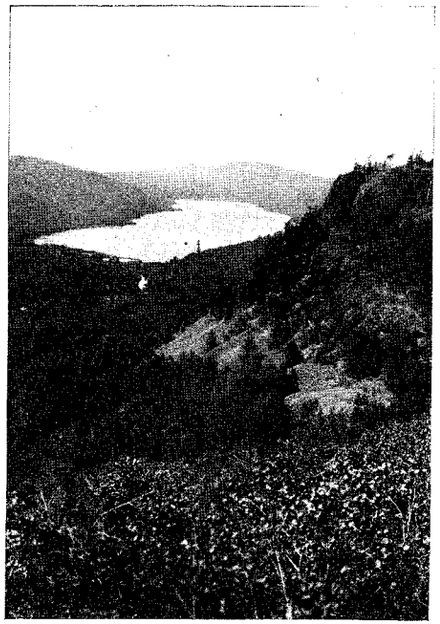

FIG. 10. Escarpment of the First Range, looking west, showing the cliff and talus slope, station III. 5, and Carp Lake, station V, in the distance.

the under growth of which consists principally of Dwarf Cornel, Creeping Snowberry, Labrador Tea, Pitcher Plant and Gold Thread on a thick carpet of Sphagnum and other mosses.

The fauna of these bogs is not characteristic. The mammals are represented by Hoy's Shrew, Southeastern Red Squirrel and Red-backed Mouse, and the molluscs by *Zonitoides arborea, Zonitoides exigua, Pyramidula striatella catskillensis, Pyramidula asteriscus, Helicodiscus lineatus, Strobilops virgo, Punctum pygmaeum, Vitrea ferrea, Sphyradium edentulum,* and *Pallifera hemphilli.* all forms that are abundant in the deciduous forest.

That certain forms, for example the Pitcher Plant and Sphagnum, that characterize the southern tamarack swamps are also restricted to the same habitat in this region, and the fact that the climax flood-plain society is evidently of the deciduous forest type, suggests that the cassandra and coniferous societies will be ultimately replaced in the flood-plain succession. But, on the other hand, the wide distribution in this region of many of the forms that are largely confined to bogs further south, such as the Balsam Fir, Dwarf Cornel and Red-backed Mouse, Starnosed Mole, and Southern Varying Hare, indicate that the conditions which permit the boreal forms to hold certain swamps to the south are here more wide spread; while the similarity between the bog and flood-plain societies indicates, as might be expected, that the more nearly related habitats are the most noticeably and probably the first to be modified by the change of conditions.

Station IV. Substation 1. The amphibious forms of the mud flats grade into the aquatic forms of the river by such marginal forms as *Dulichium arundinaceum* and *Sagittaria.* The slow current of the river is an important factor in determining the nature of this habitat, as it results in conditions similar to those that prevail in ponds, thus permitting a biota adapted to pond conditions to gain a foothold. The vegetation, although poorly represented, is decidedly of the quiet water type, being composed principally of the Yellow Pond Lily, and *Myriophyllum,* and to a small extent of the Sweet Scented White Water Lily, and *Potamogeton natans,* Fig. 19.

The fauna also shows the effect of the slow current, but, owing to lack of data on the habitats of the different forms, it is impossible to determine definitely to what extent it is modified by the changing conditions. It is, however, evident in a general way, for the forms that occur here are all forms that occur in ponds as well as streams, while the characteristic river forms that occur in the streams after they leave the mountains are apparently not represented. For example, the molluscs found here, *Amnicola limosa, Ancylus parallelus, Valvata tricarinata, Physa sp.* and *Planorbis exacuous, hirsutus* and *campanulatus,* were all found on the vegetation and are forms that, according to Baker, inhabit ponds and streams with aquatic vegetation and mud bottom, but *Limnaea decollata,* that occurs on the bare rocky bottom in the swift waters of the lower parts of the river, is apparently absent. The fish are represented by the Fine Scaled Sucker, Horned Dace, Spawn Eater, Trout Perch, Yellow Perch, and *Nototropis cayuga.* The Horned Dace is, according to Forbes, almost entirely confined to brooks and small streams. It is very abundant in Carp river, especially in the head waters, and may thus be taken to represent the stream conditions that still prevail, but in the quiet waters near the lake, there are associated with it the deeper, quiet water, bottom feeders, the Yellow Perch and Sucker, while the characteristic stream forms such as the Brook Trout and Grayling were not found. Certain other forms are so closely associated with this habitat that they must be listed here; the more conspicuous of these are the dragon flies,

Calopteryx aequabilis, *Aeschna clepsydra* and *Plathemis lydia*, and the Kingfisher, Muskrat, etc.

Station V. Substation 3. The biota of Carp Lake indicates that the environmental conditions are very similar to those that exist in the river above it but are even more pond-like. The fish are the same with the exception of the Horned Dace, which was not found here. The Sucker and Yellow Perch seem to predominate. Toward the shore the bottom becomes covered with vegetation, chiefly *Myriophyllum*, among the leaves of which, especially in the axils, occur the snails, *Amnicola limosa* and *Valvata tricarinata*. This society soon becomes mixed with *Potamogeton natans* that forms a large well defined zone. On the inner margin of this zone, the Tape Grass, *Vallisneria spiralis*, often occurs in extensive mats but does not form a definite zone. The next zone of importance is composed largely of the Yellow Pond Lily that is replaced near shore by the Canada Rush, *Juncus canadensis*, that becomes largely mixed in shallow water with the Scouring Rush, *Equisetum fluviatile*.

Station V. Substation 1. Where this marginal rush zone extends to the shore, the bivalves, *Sphaerium simile*, *Anodonta marginata*, and *Pisidium sp.*, and the univalves, *Planorbis bicarinatus*, *campanulatus* and *deflectus* are found in the silt and on the small stones.

On the fine sand of the narrow beach, *Equisetum hyemale* associated with the Horned Bladderwort (*Utricularia cornuta*), Nodding Ladies Tresses, and Seven Angled Pipewort forms a scattered vegetation behind which comes an alder thicket which is followed in turn by the mesophytic forest types.

Station V. Substation 2. The delta that is being formed by the river at the east end of the lake is similar in many ways to the mud flats along the river and presents similar but more extensive environmental conditions. On the submerged part of the delta, *Juncus canadensis* is mostly absent from the rush society which is extensive and composed principally of *Equisetum fluviatile* associated on the inner margin with *E. hyemale* and *littorale*. These forms are replaced on the area that is ordinarily unsubmerged, by *Dulichium arundinaceum*, *Carex filiformis*, *riparia* and *viridula*, associated on the dryer areas with *Calamagrostis canadensis*, *Scirpus cyperinus*, *Agrostis hyemalis*, *Eupatorium purpureum*. *Deschampsia flexusa*, *Panicularia canadensis*, *Solidago uliginosa*, Swamp Milkweed, Nodding Ladies Tresses, Pale St. Johnswort and Marsh Cinquefoil.

The fauna also shows the similarity between the conditions of this habitat and the mud flats. The dragon flies found here are *Enallagma hageni*, *Nehalennia irene*, *Enallagma carunculatum*, *Ischnura verticalis*, *Hagenius brevistylus*, *Gomphus spicatus*, *Aeschna clepsydra* and *Plathemis lydia* Of these *Enallagma hageni* is the characteristic form and occurs in considerable numbers. The birds, as on the mud flats, are the waders and shore forms such as the Carolina Rail, Great Blue Heron, American Bittern, Solitary Sandpiper and Wilson's Snipe. The nature of the habitat is also shown by the presence of most of the amphibian species of the region. The frogs are represented by *Rana pipiens brachycephala*, *clamitans*, and *septentrionalis*. No turtles were observed, but the Garter Snake, *T. sirtalis sirtalis* was taken several times.

The grass and sedge society passes directly into an alder society without an intervening cassandra zone, and the forms of the alder society are in turn followed by the forms of the deciduous forest.

It was shown in the discussion of the topography that the tendency of an

FIG 11. "Bald" on the top of the First Range, station III. 6, showing the bare rock, heath plants in crevices, scattered pines and stunted aspens that characterize this habitat.

FIG 12. The zone of stunted aspens, station II. 5, surrounding the "bald." The pine stumps show the effect of the wind.

agraded stream is to cut into the sides of its valley, and to build up a plain at its own level by the deposition in its channel of the material derived in this way. It was also pointed out that areas representing different stages in this process are characterized by different biota. Since the process is still going on it is necessary to consider the biota in reference to the changing conditions. The nature of the changes which Carp river produces on the topography is determined by its low gradient and slow current. As it meanders over its flood-plain, the mud flats that are formed on the inner side of the bends are extended into the stream by the deposition of material on their inner margin. The quiet water and favorable substratum on the submerged parts of these flats afford a favorable habitat for the pond or quiet water forms of life. As the deposition of the streams during floods builds these flats above the ordinary level of the river, the conditions become unfavorable for the aquatic forms, which are compelled to migrate outward; at the same time, however, they become favorable for the amphibious forms of the grass and sedge zone that gradually push out and occupy the flat as it becomes dry enough. The continued deposition during floods, and the accumulation of plant remains continue to raise the level of the mud flats, and, as the conditions become dryer, they support successively the cassandra, alder and the deciduous forest types of life. Where the river cuts into the sides of the valley, the flood-plain is destroyed, and its societies are limited to a single narrow zone between the deciduous forest and the river; in this zone, the littoral, cassandra and coniferous societies may be entirely lacking, but the alder society is nearly always represented.

Carp Lake may be considered as the river expanded and covering its flood-plain to the sides of the valley, and the changes that are going on are very similar to those that are being produced by the river. The conditions however, are more pond-like for the current that the river possessed above the lake is lost, so that there is no lateral corrasion. Deposition is going on all about the margin, owing to wash from the sides of the valley and the deposits made at the mouth of the river, so that the aquatic conditions are being changed into the terrestrial in a manner analagous to the development of a mud flat into a flood-plain, and the successive zones referred to in the discussion of the biota are steadily encroaching on the lake.

Different stages in the destruction of the lake may be observed nearly every where about its shores, but, owing to the dominance of different factors, the encroaching societies are not always equally developed. The extreme of this is shown on the north shore where, owing to the proximity of the cliff, the talus slope dips into the lake, the fresh talus fragments fall nearly to the water and very little soil has accumulated. There is, therefore, no shelving beach at this point, the aquatic and mud flat societies are absent while the alder zone is represented only by a few forms, the Hoary Alder more conspicuously, and is largely mixed with the Mountain Ash, White and Red Pine and Wild Cherry of the talus slope. At the east end of the lake the grass and sedge zone constitutes the principal society, for, owing to the large amount of material carried by the river, the delta is built up to the level of the lake much faster than it can be raised above it by the accumulation of plant remains and flood deposits, while at the same time owing to the shelving nature of its outer margin, the aquatic zone is also extensively developed. At the west end of the lake, however, the margin is shallow, deposition is slow, and the aquatic societies are the most prominently developed.

But, notwithstanding differences in the rapidity of the process, the lake

is undoubtedly being filled up, and the present environmental and biotic conditions are being changed toward those of the river flood-plain.

Station IV. South of Carp Lake the country is covered by the biota of the deciduous forest type which is essentially the same as on the north slope. The small spring brooks which drain the region, however, bring in a different set of conditions, and may be considered as representative of the headwater conditions of the larger streams. The two studied on Sections 23 and 28, T. 51 N., R. 43 W., are shallow, cold, swift flowing streams from 6 to 15 feet wide with a bottom composed of gravel and stones. The biota is limited in variety probably owing principally to the coldness of the water. There is practically no aquatic vegetation, and the fauna consists chiefly of the snail, *Planorbis parvus*, caddis—and stone-fly larvae, and the frogs, *Rana septentrionalis, clamitans*, and *R. sylvatica cantabrigensis*. On the banks of these streams, however, the conditions are much more favorable. The deciduous trees usually overtop them entirely, so that the humus conditions along the margin are essentially the same as in the forest with the exception of a considerable increase in the moisture content. The flora that lines the creek is composed of such forms as *Caltha palustris, Equisetum sylvaticum, Cinna latifolia, Onoclea sensibilis, Scirpus cyperinus, Osmunda claytoniana*, Skunk Cabbage, *Carex crinita* and *pubescens*, and large mats of *Conecephalus conicus* and *Endocarpon miniatum*. Behind this narrow zone occur occasional clumps of alders (*Alnus incana*), and Mountain Maple.

The molluscan fauna of the creek bank is characterized principally by an increase in the abundance of the forest forms, while among very wet leaves *Physa sayii* is occasionally found.

It will be noticed that the biota of the creek bank is composed of members of the alder, sedge and forest societies of the river valley, but that the forms of the cassandra and coniferous societies are apparently lacking.

Station VII. Practically the same conditions prevail in Little Carp Lake as in Carp Lake, although its smaller size probably affects the biota to some extent. The deciduous forest forms extend down the sides of the bordering hills nearly to the waters edge. Between the forest and the water there is a narrow zone of vegetation the most conspicuous form of which is the Hoary Alder (*Alnus incana*) which is associated with the Few Flowering Cranberry, etc. The rush society in the margin of the water and on the delta (which is mostly submerged) is composed principally of *Equisetum* (*fluviatile* where examined) but for a short distance along the south shore the Canada Rush becomes prominent. As a rule, the aquatic societies are not extensive, the vegetation of the rush societies is scattered even on the delta, while the pond lily zone is only occasionally present.

The bivalve, *Anodonta marginata*, is quite commonly found about the margin of the lake, especially on the delta. The most characteristic fish, at this time of the year, are the Sucker and Horned Dace, the latter being very abundant.

Station VII. Substation 2. Above the lake, Little Carp river is a small meandering stream about 15 feet wide and 2 feet deep. It enters the lake through a narrow valley about one-fourth of a mile long which is crossed at the east end by several beaver dams. Above these dams, the valley widens out into an amphitheater about a mile long by one-fourth mile wide. In the narrow part of the valley near the lake, the space between the river and the foot of the adjacent ridges is occupied by a dense thicket of Hoary Alder, (*Alnus incana*). As the valley widens out above the dams, this alder zone, composed now of the Hoary Alder, *Betula glandulosa*, and several willows, is

separated from the mesophytic forests of the slopes by a coniferous society of Tamarack, White Spruce, White and Black Ash, and follows closely the foot of the ridge. The floor of the valley is occupied by a broad beaver meadow, covered with a luxuriant growth of grasses, sedges and other herbaceous forms, Fig. 20.

Among the conspicuous forms in this meadow may be mentioned *Carex monile, filiformis* and *viridula, Juncus effusus* and *tenuis, Agrostis hyemale, Calamagrostis canadensis, Scirpus cyperinus, Deschampsia flexusa, Panicularia canadensis, Solidago neglecta* and *erecta*, and the Marsh Bellflower, Joe Pye Weed, Swamp Milkweed and Nodding Ladies Tresses. The fauna is composed chiefly of the butterflies, *Basilarchia arthemis, Vanessa antiopa* and *Argynnis cybele*; the dragon-flies, *Sympetrum obtrusum* and *Aeschna clepsydra*; the grasshopper, *Camnula pellucida;* and the amphibians, *Hyla pickeringii* and *Rana clamitans*. This is also the habitat of the Song and Swamp Sparrows, and there was abundant evidence that it was a favorite feeding ground for deer.

Station VII. Substation 3. The dams at the west end of the beaver meadow are not now in repair, so that they influence but little the nature of the river, except as small pools, four or five feet deep, are formed behind them, where the current is deflected to one side. In these pools the characteristic fish is *Couesius plumbeus*, although the Sucker is sometimes found. The fauna of the river, in harmony with the conditions, is composed mostly of brook and creek forms, such as the Shiner, *Nototropis cornutus*, and the Dwarf Stickle Back, *Eucalia inconstans pygmaea*. There is very little aquatic vegetation.

The mud flats along the river are small and practically devoid of vegetation with the exception of scattered grasses, such as *Dulichium arundinaceum* and *Calamagrostis canadensis*, on the dryer portions. The birds that were observed here were the Solitary and Least Sandpipers and the Yellow-legs. On the submerged edges of these flats, the characteristic form is the mollusc *Sphaerium simile* with which is occasionally associated *Anodonta marginata*.

The meadow is the result of an extension of the conditions that normally prevail on the wetter parts of the flood-plain, and with this extension of the habitat there is associated an increase of the grass and sedge zones. When the dams, which are largely formed of Hoary Alder, were constructed, the flood-plain in the broad part of the valley was flooded, and this ponding of the stream resulted in the killing off of the dryer flood-plain flora. It is not probable that the pond covered the entire valley, but the low adjacent ground between the pond and the sides of the valley would be saturated and subjected to floods, making the conditions favorable for the grasses and sedges and an associated fauna, so that a small meadow analagous to the present one probably existed about its margin.

No evidence of the extent of the pond now remains, for with the trapping off of the Beaver the dams were no longer repaired and were broken through by the river. The pond was thus drained and the water resumed its former channel. This resulted in better drainage and a consequently dryer substratum in the meadow, so that the meadow forms were able to follow the water as it retreated, while the conditions are, at the present time, becoming favorable for the higher flood-plain and deciduous forest forms, that are working in about the margin. That the encroachment of the forest forms will ultimately destroy the meadow by narrowing the habitats of the grass and sedge societies, is evident from an examination of the conditions in localities where the Beaver formerly occurred. For instance, there have

been no Beaver on Carp river within the memory of several of the trappers in the region, and yet several of the bends of the river were found to be due to the remains of old dams which were once evidently of considerable size. Now a slight raising of the water level in this valley, such as would be caused by these dams if they were in repair, would cause the plain to be flooded, the trees to be killed off and either a pond or meadow would result according to the height of the dam. It thus seems probable that the present flood-plain societies of Carp river have reoccupied the flood-plain since the Beaver were killed off, which suggests that the history of the meadow on Little Carp river will be similar.

6. SUMMARY.

In order to get at the relation between the physical changes and the biota of the region as a whole, it will be necessary to summarize the present conditions, the biota, the processes that are dominant in the different habitats, and the changes which they are bringing about.

I. Beach. The beach consists of tilted strata of rock that are exposed to the forces of weathering and the action of waves. It may be divided into three parts on the basis of the processes acting upon it. The Lower Beach is exposed to the pounding of the waves, that tend to break up the rock and carry the fragments back in the undertow, building them up in a submarine terrace. The Middle Beach is exposed to the action of waves only during the winter months; during the summer months the forces of weathering predominate and tend to form a soil. This soil tends to be removed during the winter with the exception of a small amount that accumulates in the edges of the joint planes. The Upper Beach is, at present, above the reach of both summer and winter waves and is chiefly exposed to the forces of weathering, which have formed a slight residual soil.

The biota of the beach as a whole is adapted to the conditions that prevail in this habitat, and may be divided into three groups that are closely associated with the physiographic divisions. There is practically no life on the Lower Beach, owing to the pounding of the waves. The life on the Middle Beach consists for the most part of annuals that can obtain a foothold during the summer on the slight soil in the crevices, and a few associated animal forms. The flora of the Upper Beach, in response to the more favorable soil conditions and the absence of wave action, consists of a number of annuals and perennials; while the more favorable food conditions are likewise marked by an increase in the animal forms.

The changes that are taking place are due to the action of waves and weathering. The waves by cutting into the beach cause it to retreat inland, but the submarine terrace built up at the same time tends to cause this retreat to proceed more slowly in its later stages, as the growing terrace carries the breaker line off shore and tends to lessen the effect of the summer and winter waves. This is, in part, counteracted in the Porcupine Mountains by the sinking of the coast line, and the beach as a whole is moving inland. As the force of the waves is diminished, the process of weathering increases in comparative importance, the beach tends to become broken up, and the area of the habitats frequented by the crevice forms increases.

II. 1. Arbor Vitae Swamp. The narrow area back of the beach, at the foot of the north slope is not well drained, and the soil is covered by a thick layer of humus.

The forms adapted to these conditions are plants and animals found in

FIG. 13. The zone of heath plants and scattered pines, station III. 2, surrounding the bald areas, above the aspen zone, on the top of the First Range.

FIG. 14. Face of the cliff and talus slope (looking north from Carp Lake) station III. 5, showing hardwoods in the foreground on the lower part of the talus slope, the bare portion of the talus, and the belt of vegetation (pines, oaks &c.) at the foot of the cliff. The presence of the pines on the cliff show the influence of rock ledges.

swampy areas. If the undrained conditions of these areas are caused by the sinking of the coast, this habitat will tend to become destroyed by the encroachment of the beach conditions. If, on the other hand, this encroachment is relatively slow compared with other changes, the accumulation of the inwash and organic debris will tend to convert such a swamp into a dryer habitat and cause the present biota to be succeeded by a society adapted to the new conditions.

II. 2. North Slope of First Ridge. This slope on account of its relief is well exposed both to the forces of weathering and of denudation and is covered by a layer of soil that becomes thinner near the top of the ridge. Above this soil there is a layer of humus and vegetable mould that tends to conduct the water from the surface, thus greatly diminishing the effects of denudation. (It also furnishes organic constituents to the soil).

These conditions are very favorable for plant life, and the lower part of the slope is covered by a dense forest with which is associated a large number of animals. This biota is composed partly of forms whose principal distribution is in southeastern North America, and partly of those which predominate to the north of the Great Lakes and in the bogs to the south. On the thinner soil near the top of the ridge, those forms of the forest predominate that can live in the more open, poorer soil, and dryer conditions of this habitat.

The processes working on this slope tend to reduce the ridge toward base level and to increase the depth of the soil. The accumulation of humus retards the former process, while the latter proceeds more and more slowly as the soil increases in thickness. Changes are thus taking place very slowly, and the physiographic processes are evidently tending to approach an equilibrium. Near the top of the ridge, owing to thinner layers of soil and humus, the changes are more rapid but in the direction of the conditions that prevail on the lower part of the slope, and the biota adapted to these conditions is pushing up the slope.

III. Mountain Top. On the bare mountain top, the forces of weathering tend to break up the rock into a soil that is washed or blown away nearly as fast as it is formed, except along the joint planes.

The flora consists of rock inhabiting lichens and a number of crevice forms, the fauna of the types frequenting open habitats, such as the grasshoppers, etc.

The soil formed in the crevices is in part held by plant roots, and, since these soil areas are the habitats of the crevice forms of life, as they gradually spread out, the habitats of the rock inhabitating forms are restricted. At the same time, the soil washed down the slope is held at the forest margin, thus permitting the forest societies to encroach on the crevice forms which will thus in time tend to become replaced by the forest forms. This succession of forms is modified by the influence of the strong winds which tend to break down the pioneer trees on the exposed areas.

III. Cliff and Talus Slope. The cliff is constantly exposed to the forces of weathering, for as fast as the rock is broken up it is removed, exposing a fresh surface.

The fauna and flora, owing to the unstable and exposed conditions, are very poor except on the rock ledges, where a slight soil accumulates.

The talus slope at the foot of the cliff is also very unstable and is exposed to the destructive effects of falling rock fragments. Toward the bottom, beyond the limit of falling rocks, the blocks tend to become broken up into a soil.

The biota of the talus slope, on account of the unstable conditions, is also very poor. Toward the bottom of the slope the rocks become covered by a vegetation of lichens, and farther down by a slight soil and the heath and forest societies.

As the cliff is destroyed, the talus slope and the top of the ridge tend to approach. The lower part of the talus slope in time becomes broken up to form a soil, and the deciduous forest types from below tend to spread up the slope thus encroaching on the areas occupied by the cliff and talus slope forms.

IV. Carp River Valley. The sides of the valley of Carp river slope down to a low flood-plain that becomes still lower near the river, grading into mud flats along the stream. The soil is deep and contains a large amount of organic material, and there is a decrease in its moisture content from the mud flats up into the forest.

The aquatic biota is a mixture of pond and river types. The mud flats are inhabited by amphibious forms that are replaced on the dryer parts of the flood-plain by the sedge, cassandra, and alder societies, behind which usually occurs a society of Tamarack, White Spruce and White and Black Ash. On the valley slopes occurs the mesophytic forest type of biota.

The prominent forces at work in these habitats are those of denudation and deposition. The river tends to destroy the adjacent ridges and build up a part of the material derived in this way into mud flats. Deposition during high water builds these flats above the level of the water, and they come in time to form part of the flood-plain. The flood-plain is in turn built up by deposition during floods and by the accumulation of organic remains until the conditions become similar to those in the adjacent forest habitats. The effect of the processes is, therefore, to reduce the country to a level plain thus permitting the encroachment of the forest forms.

V. VII. Carp and Little Carp Lakes. These lakes on account of the similarity of conditions may be considered together. They are, for the most part, shallow throughout. At the east end of each lake, there is a broad delta formed at the mouth of the entering stream.

The aquatic biota is of the quiet water type. At the margin occur the amphibious forms that give way on the dryer ground to the flood-plain and forest forms. The deltas afford conditions similar to those on the mud flats and are occupied by a flora of grasses and sedges, and an associated fauna that is characterized by such forms as the snipes, sandpipers, etc.

The lakes are evidently being filled up, and the conditions are approaching those of the surrounding and encroaching forests.

VII. 2-3. Little Carp River. This is a small meandering stream which evidently at one time was expanded into a pond by the formation of beaver dams across it. As the Beaver were trapped off, the dams were destroyed and the pond became drained.

The biota of this stream consists of brook types. The forms on the mud flats along the stream grade into the flood-plain biota which consists principally of grasses and sedges which ordinarily inhabit the wetter parts of the flood-plain, the higher ground types being limited to a narrow zone in front of the forest.

The changes going on are evidently tending to make the flood-plain dryer, and the forest is encroaching on the meadow. The present extent of the area occupied by the meadow forms is due to the fact that they were able to push in and acquire the territory left by the receding water of the river when the dams were destroyed.

VI. Hardwood Forest. This region has been reserved to the last, for the conditions are evidently those toward which the other habitats tend to be changed under the present conditions. The conditions are similar to those on the north slope, and the whole region is covered by a similar type of biota. This society thus represents the climax society of the region. It consists of the forms that are adapted to or associated with the conditions which prevail in this region in the last stages of the mutual adjustment of all the environmental processes. As the processes become adjusted to one another, the habitat of the climax society is increased at the expense of the other habitats, and the associated biota tends to become of general geographic extent in the region.

7. INTERPRETATIONS AND CONCLUSIONS.

From the conditions of life in this region as summarized above, the following interpretations and conclusions seem justifiable.

Owing to the dependence of forms of life on their environment, biotic changes are necessarily closely related to environmental changes. These biotic changes may occur in two ways; the forms must either be able to respond to the new conditions or be supplanted by other forms. That they tend to become adjusted cannot be questioned, but in many cases at least this adjustment lags behind the changing conditions, and the forms are replaced by others from adjacent habitats which are adjusted to the conditions toward which the particular habitat is changing, thus bringing about a succession of societies.

To understand, therefore, the succession of societies in a region it is necessary to know both the environmental conditions and the processes that modify them. The environmental conditions are brought about by the association of certain environmental factors, such as the geographic, physiographic, organic, edaphic (the chemical and structural composition of the rock and the depth of the soil), time, and climatic factors. These divisions are arbitrary, for the different factors are so intimately related that they can only rarely be separated, and although certain ones may predominate in different habitats, it is impossible, owing to this interrelation, to explain the distribution of animals or plants on the basis of a single factor, for all are more or less involved in the formation of a habitat. This is one of the primary reasons for emphasizing habitat dynamics.

It will be seen by reference to Van Hise ('04, p. 40) that the environmental factors given above are the same as the geological factors in the belt of weathering. Each of these factors is the resultant of various processes (composed in turn of physical forces, heat, light, etc.) which when not in equilibrium tend to become so. The adjustment of these processes to each other brings about changes in the conditions which can only approximately cease when they approach an equilibrium, as, for example, when the topography has been reduced to a base-leveled plain covered by a layer of residual soil. The conditions in habitats where the processes are not in equilibrium are thus being constantly changed in the direction of other habitats in which they have more nearly reached an adjustment, and a succession of societies occurs that only ceases when the processes have become approximately adjusted to each other. The forms that are adapted to the adjusted conditions will constitute the climax society. It is necessary to here emphasize the importance of the organic factor; this must also become adjusted to the others for the entrance of new forms into a region may greatly change the equilibrium of its societies.

The conditions and changes that are going on in this region at the present time have been given in the discussion of the different stations, but, owing to the fact that the relation between environmental changes and the succession of societies has also prevailed in the past, the historic factor in biotic interpretation, the present conditions will not alone explain the present biotic conditions. It is therefore necessary to take into account the conditions that have prevailed in the past. This may be done by reversing the order followed in the discussion and by considering the past in the light of the action of the present processes.

The historical geology of the Lake Superior region has been worked out by Van Hise ('04), and his results are the basis of the following account. During the earliest period the oldest rocks were formed of which we have any knowledge; the crystalline schists, gneisses and granites comprising the Basement Complex (the Kewatin and Laurentian). They form in North America the broad old land area, extending, according to Wilson ('03, p. 617), from Coronation Gulf in the extreme northwest of Canada, southward around Hudson Bay, and northward through Labrador to Baffin Bay and beyond. South of Lake Superior, in Michigan and Wisconsin, there is a continuation of this area, largely buried in Michigan under later deposits but exposed in a large area in Central Wisconsin. There were at least three series of rocks formed upon the Basement Complex before the Keweenawan, but the mountains formed by the elevation and folding of these rocks were reduced to a peneplain before the Keweenawan rocks were laid down. During the period of unstable equilibrium that followed the Huronian Epoch, this peneplain was submerged, and the sediments of the Keweenawan Series were laid down. During their formation, these sediments were covered from time to time by great sheets of volcanic lavas, the products of fissure eruptions. At the close of the Keweenawan Epoch, the land was again elevated and the strata tilted to form great mountains, as is shown by the inclination of the strata in the cross section, Fig. 2. During the subsequent cycle of erosion, the entire thickness of the Keweenawan Series was greatly eroded, and the mountains together with the whole pre-Cambrian area (Wilson, '03, and Weidman, '03) were reduced nearly to sea level.

During Mesozoic times, there was a particularly well marked period of baseleveling that removed the overlying Palaeozoic sediments from the Lake Superior region and reduced the topography to a peneplain. This peneplain, the Jura-Cretaceous, extended over much of the existing land area of North America and has been recognized in Canada (Wilson, '03, p. 658), in the Ozarks (Hershey, '01, pp. 22-24), eastern (Davis, '89, p. 197) and western United States (Woodworth, '94, p. 221). At this time eastern and western North America were separated by the Cretaceous Mediterranean Sea. At the close of the Cretaceous Period, the continent was unified by an elevation of the interior which banished the Mediterranean Sea and put an end to the Jura-Cretaceous peneplain; but in the Tertiary Period that followed, another cycle of erosion occurred which, although not complete in the mountainous regions of North America, sufficed to reduce the northern part of the continent nearly to baselevel (Upham, '04). The surface of the earth in the Great Lakes region at this time probably became covered by a thick mantle of residual soil, owing to the enormous length of time during which it was subjected to disintergrating processes.

The present elevations in the Porcupine Mountain region are evidently formed by the projecting edges of the more resistant basic and acidic lava sheets, while the valleys of Carp and Union rivers are sunk by erosion into a softer inter-bedded clastic. This contrast between the resistance offered by the sandstone and trap sheets to erosion has given rise, in a small degree, to what Marbut ('96, pp. 29-32) has called step and platform topography. The cross section, Fig. 2, shows that the first ridge is formed by the projecting end of a stratum of trap; if this sheet had been vertical, erosion would have been equal on both sides and the slope on either side would have been the same. But, owing to the fact that the sheet is inclined, the outcropping edge protects the underlying sandstone and a precipitous escarpment is formed. This section also shows that the valley of Carp river is formed by the erosion of the softer stratum of sandstone lying between the escarpment and the second ridge of trap, and that the stream runs along the strike of the rocks, so that it is difficult to believe with Dr. Wright ('05, p. 38) that the valley was formed by the submarine erosion of post-glacial lakes.

If the second sheet of trap was, like the first, underlaid by a bed of detrital material, another escarpment would have been formed. But instead of overlaying an interbedded clastic, it overlies the hard resistant quartziferous porphry that constitutes the central part of the mountainous district. This results in the topography that would prevail if the resistant stratum were vertical, i. e. equal slopes on either side. The topography, however is not of recent origin, and although the physiographic history of this part of Michigan has not been worked out by geologists, one is lead to believe from the work of Wilson in Canada ('03), Weidman in Wisconsin ('03), and Van Hise in northern Michigan ('94 and '96) that the baselevel that is represented by the truncated strata, Fig. 2, probably represents a pre-Cambrian peneplain.

Prof. C. K. Leith has suggested to me in a letter that this structure possibly represents a peneplain of later age than the Wisconsin pre-Cambrian, which it probably intersects at a low angle in a manner similar to the intersection of peneplains of different ages about the Laurentian of Canada as described by Wilson ('03, p. 651). The Porcupine Mountains would thus represent the remains of a peneplain, buried since early geological time under later deposits.

But whether the topography is of pre-Cambrian or later age, it is largely determined by the geological structure and has been comparatively little modified by the ice age. Thus Van Hise ('04, p. 35) has shown that the rocks at present exposed in this part of the Lake Superior region were buried under later deposits all through the Palaeozoic Era and had probably become approximately adjusted to those conditions. Later when they were brought to the surface by the extensive denudation of Cretaceous and Tertiary Periods, and still later when the thin layer of weathered material had been removed by the ice sheets of the Glacial Epoch, this equilibrium was disturbed, and they at once began to adjust themselves to the new conditions—a process that is not yet completed.

At the close of the Tertiary Period, the Tertiary peneplain was destroyed by an elevation of 3,000 to 5,000 feet (Upham, '04, p. 244) over northern North America. Near the culmination of this uplift, three centers of ice accumulation developed in this region and gave rise to the continental ice sheets of the Glacial Epoch.

The glaciers that were formed from these three centers covered Canada and invaded the northern part of the United States at various times, but the final invasion was the most important from the standpoint of the present biota. At this time, ice sheets fed by the different centers united into a

single sheet, the Wisconsin, that covered Canada and moved southward over northern United States, forcing the biota before it. As the ice from the Labradoran center reached the Great Lake region, it was broken up into lobes, the direction of which was determined by the lake basins. The Superior Lobe traveled southwest to the end of the lake. It then spread out laterally, united with the neighboring lobes and moved southward as a continuous sheet.

Thus during the inception of the ice age, certain forces gradually became dominant, throwing the environmental processes out of adjustment, changing the conditions so that the northern forms were able to encroach on the habitats of the more southern societies, thus resulting in a general southward movement of the biota. At the same time, the habitats of the northern forms were destroyed, and their societies were forced southward beyond the limits of glaciation. It may be inferred, from the fossils of boreal forms now found in Pleistocene deposits near the margin of the ice sheet (Adams, '05, p. 55), that the societies during the ice age became adjusted, in a general way, to the conditions beyond the ice margin. But, as the glaciers finally retreated the equilibrium of environmental processes was again disturbed. The conditions changed in favor of the more southern forms which were thus able to extend their habitats into those previously occupied by the boreal types. At the same time, the habitats of the northern forms were extended by the retreat of the ice sheet and a northward migration began (Adams, '02) In this migration the extreme northern types were probably in the lead, and the barren ground left by the retreating glacier was invaded, in all probability, by the lemmings, voles, moles, ptarmigan, etc., representative of the tundra. As the glacier continued to retreat and the conditions became more favorable, the habitats of the tundral types were probably encroached upon by the hares, porcupines, chipmunks and the Lincoln's, White-throated and White-crowned Sparrows, etc., now characteristic of the northern boreal forest of Spruce, Balsam Fir and Tamarack. This biota was in turn succeeded by the deciduous forest type that includes the dominant forms of life in Indiana, Illinois and southern Michigan today. As these southern forms moved northward, they often surrounded groups of boreal plants and animals, as illustrated by tamarack swamps or bogs. These swamps are characterized by a distinctly northern biota consisting of such forms as the Southern Varying Hare, Star-nosed Mole, Red-backed Mouse, Cassandra, Tamarack, Spruce, etc., and are really boreal islands (Bailey, '96) surrounded by the deciduous forest types in the northward migration (Adams, '02, and Transeau, '03).

When the receding edge of the glacier reached the Great Lake region, it was broken into lobes that retreated up the lake basins. As soon as the lobes had retreated beyond the southern watersheds of the Great Lakes, the water accumulated in front of each lobe as an ice dammed lake which drained through the lowest point in the divide (Taylor, '05, p. 97). The lake formed in front of the Superior Lobe drained by way of the St. Croix river through the Mississippi to the Gulf, thus forming a highway for the migrating forms into the Lake Superior region. The Porcupine Mountains, however, owing to the height of the St. Croix outlet, were entirely surrounded by the lake (Wright, '05, p. 38). As the ice retreated, an eastern outlet was opened lower than the St. Croix, and the level of the lake descended; during this descent successive beach lines were cut about the Porcupines until they were finally united with the mainland.

Meanwhile, as the continental ice sheet continued to retreat north of the

Great Lakes, it was followed by plants and animals, so that when it finally disappeared the different forms of life were left distributed in a north and south direction approximately in the order of their northward migration. The wide distribution of the boreal forms in northern North America is thus seen to be very intimately related to the character and extent of the peneplained nature of the region.

Toward the south, with the retreat of the last ice sheet, the boreal forms became restricted to local areas, as in bogs for example. but further north they tend to become of wider distribution. This is shown in the Porcupine Mountains by the general distribution of forms that about Ann Arbor, Michigan are confined to the tamarack swamps, by the presence of boreal forms in the climax forest to the exclusion of more southern forms, and by the fact that there are few forms restricted to the bog societies. That this spreading out of the conditions with which the boreal forms are associated affects the more nearly related habitats first is shown by the number of boreal forms in the flood-plain biota while on the higher ground the southern forms become more numerous. When the present biotic types reached this region, the various societies took possession of the different habitats to which they were adapted, but, owing to the fact that the processes were not in equilibrium these societies could not remain fixed. This is shown, at the present time, where the changes were taking place rapidly, as for example on the mountain top, by the fact that the conditions are being changed in the direction of those that prevail on the low land, and the biota of the cliff habitats is being supplanted by the deciduous forest types which occupy the lower levels where the processes approach an equilibrium. As the processes approach an adjustment, the changes take place more slowly, and the more resistant forms may persist for a considerable time in the succeeding society, as is shown by the presence of the isolated White Pines in the deciduous forest. The deciduous forest society thus represents the climax biota in the Porcupine Mountains, as it is associated with those conditions toward which the other habitats are tending.

From the dynamic nature of the processes that give rise to the environmental factors in the different habitats, it follows that a study of the distribution of forms in a particular region should be made from the standpoint of the processes involved, and, since the conditions in particular habitats may become of geographic extent, the same methods are applicable to general distributional problems. This leads naturally to the conclusion so well expressed by H. R. Mill ('05, p. 10) for geography in general: "Geography was defined long ago as the science of distribution; but the old idea was statical distribution, the laying down on maps of where things are; now we see that we ought to go further and discuss also how the things got there, why they remain there, whether they are in transit and if so how their path is determined. We are learning to look on distribution from its dynamical side, the earth with all its activities being viewed as a machine at work."

PART II. ISLE ROYALE.

1. GENERAL GEOGRAPHY.

Isle Royale is situated in the northwestern part of Lake Superior on the junction of the 89th degree of west longitude with the 48th degree of north latitude, Fig. 21. It lies northeast and southwest nearly parallel to the north shore of the lake. The topography is striking; several nearly parallel ridges separated by broad valleys run the length of the island, and project out into the lake at either end (more conspicuously at the north) as the walls of deep fiords. These ridges are all low, the highest not exceeding 500 feet. The geology and topography have been discussed by Lane ('98) and Irving ('83), and it is sufficient for this report, to say that the topography, as in the Porcupine Mountains, is closely dependent on the geological structure. The ridges consist of the centers of outeropping sheets of lava, while the valleys between are mostly cut in the inter-bedded clastics as in the Porcupine Mountains. The dip of the rocks, is however, toward the Michigan shore, and the escarpments are thus on the north instead of the south side of the ranges. These escarpments are not precipitous in the southern part of the island. There is abundant evidence that the entire island was overridden by the ice sheets of the glacial epoch and that after the final retreat of the glacier it was entirely submerged beneath the Pleistocene Lakes (Lane, '98, pp. 183 and 184). It has not since that time been connected with the mainland, a fact to which many of the peculiarities of its biota are probably due.

2. LOCATION OF FIELD STATIONS. (FIG. 21).

Only the southwestern end of the island was examined. Stations were established as follows:

Station I. Clearing on the Shore of Washington Harbor, Section 29, T. 64 N., R. 38 W.

Station II. Washington River, Section 29, T. 64 N., R. 38 W.

Station III. Trail along the Top of Greenstone Range, T. 64 N., R. 38 W.

Station IV. Washington Creek, Sections 28 and 32, T. 64 N., R. 38 W.

Station V. Tamarack Swamp, Section 20, T. 64 N., R. 38 W.

Station VI. North Slope of Greenstone Range, Section 32, T. 64 N., R. 38 W.

Station VII. Lake Desor, T. 64 N., R. 32 W.

Station VIII. West End of Siskowit Bay, T. 64 N., R. 32 W.

Station IX. Southwestern End of Minong Trap Range, Section 30, T. 64 N., R. 39 W.

Station X. Washington Harbor, T. 64 N., R. 38 W.

3. THE BIOTA CONSIDERED BY STATIONS.

Station I. Clearing on the Shore of Washington Harbor. This station will not be discussed as it is an artificial clearing into which cultivated species

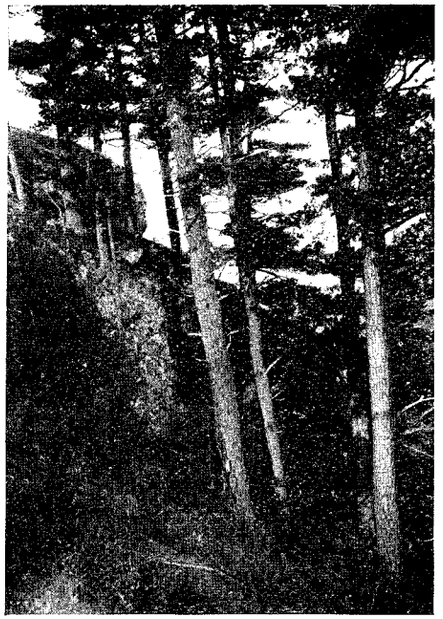

FIG. 15. Large rock ledge on the face of the cliff shown in Figure 14, illustrating the character of the vegetation on a cliff that is broken by ledges.

FIG 16. Talus slope, station III. 5, showing the nature of the talus. The influence of the unstable character of the slope upon the vegetation is indicated by the fallen pines.

have been introduced, and which is kept open, so that only in a few places can the succession of forms be observed that would occur if the clearing was left undisturbed. There is evidence, however, in several places, that the pioneer forms are the Quaking and Large-toothed Aspens, and the Paper and Yellow Birch. The animals taken here were probably all forms from adjacent habitats (see annotated lists).

Station II. Washington River. This river is a sluggish meandering stream flowing through a broad flat valley between the Greenstone and Minong Trap Ranges, and emptying into the head of Washington Harbor. The aquatic vegetation is very poor. In the quiet water near the mouth of the river, *Myriophyllum sp.* forms the principal vegetation with *Sparganium eurycarpum*, and *Phragmites communis* in the shallow water near shore. These forms are replaced on the mud flats by a zone of sedges and herbaceous forms, among the conspicuous forms of which are *Carex tribuloidea, retrorsa, intumescens* and *trisperma, Juncus effusus*, Joe Pye Weed, *Esclepias incarnata*, and *Spiraea salicifolia*. This society is not extensive but soon grades into the dense thickets of Hoary Alder (*Alnus incana*) that are characteristic of the flood plains in this region. The undergrowth in these thickets is limited to a few forms such as *Caltha palustris*, Skunk Cabbage, *Vagnera trifolia*, and several species of ferns and violets. Where the flood-plain is broad, as toward the mouth of the river, the alder thickets are followed by a society of White and Black Spruce, Tamarack, White and Yellow Birch, and Black Ash, with an undergrowth of *Taxus canadensis*, Mountain Maple, *Andromeda polyfolia, Mitella nuda*, Dwarf Dogwood, *Coptis trifolia, Chiogenes hispidula, Ledum groenlandicum, Vaccinium canadensis*, and *Viburnum opulus*, on a thick carpet of moss. As the valley narrows toward the head of the river, this zone gradually disappears.

As in the case of the flora, the aquatic fauna is limited both in individuals and species. The birds are represented by the Pied Billed Grebe, American Coot and American Merganser; the molluscs by *Planorbis exacuous* and *Physa sp.* among the leaves of aquatic plants, and *Pisidium variabile* and *Pisidium spp.* on the mud bottom. Among the alders are found the sparrows, warblers and thrushes; the toad, *Bufo americanus;* the garter snakes, *Thamnophis sirtalis sirtalis*, and *T. sirtalis parietalis*, and the molluscs, *Carychium exile, Pisidium abditum, Apecta hypnorum, Pyramidula striatella, Zonitoides arborea* and *exigua, Vitrea binneyana* and *Agriolimax campestris*. In the tamarack and spruce forest, the birds are not so numerous, and the sparrows, thrushes and warblers tend to be replaced by the Arctic Three-toed, Downy and Hairy Woodpeckers, the Crossbills and the Sharp-shinned and Sparrow Hawks. Among the molluscs, *Pisidium abditum, Apecta hypnorum* and *Carychium exile* also seem to drop out in this zone, but *Pyramidula striatella, Vitrea binneyana, Zonitoides arborea* and *exigua* were found associated with *Euconulus fulvus* and *E. chersinus polygyratus, Sphyradium edentulum, Acanthinula harpa* and *Pyramidula striatella alba*. Here also the grasshopper, *Tettix acadicus*, and the spider, *Amaurobius bennetti*, are occasionally found in the moss.

Station VI. North Slope of Greenstone Range. On account of the intermediate relation which it bears to the flood-plain of Washington river, Station II, and the top of the Greenstone Ridge, Station III, this station will be considered here. The Tamarack and Black Spruce are replaced on the sides of the valley by a forest composed principally of the Balsam Fir, White Spruce, Paper and Yellow Birch, and large isolated White Pines. The undergrowth consists principally of the Ground Hemlock associated

with the Beaked Hazel and Mountain Maple, forming dense thickets that are almost impenetrable, and in exposed situations, particularly about the shores of the island, with the Mountain Ash. Less conspicuous forms in the undergrowth are the Twin Flower, Rattle Snake Plantain, Dwarf Cornel, *Mitella nuda, Coptis trifolia, Clintonia borealis, Lycopodium annotinum* and *clavatum*, and *Chiogenes hispidula*. The birds are represented chiefly by the Nuthatch, Brown Creeper, and the Downy, Hairy, Arctic Three-toed and Pileated Woodpeckers; the molluscs by *Pyramidula striatella, Zonitoides arborea*, and *Vitrea binneyana;* the reptiles by *Storeria occipitomaculata;* the amphibians by the common toad, *Bufo americanus*, and the mammals by the Canada Lynx, Hudson Bay Red Squirrel, Canadian White-footed Mouse and Hudson Bay Varying Hare.

Station III. Top of Greenstone Range. Toward the top of the slope the White Spruce decreases in abundance and the Balsam Fir and Birches become associated on the top of the ridge with a large predominance of Sugar Maple. This forest extends as a narrow strip along the top of the ridge and contains the only Sugar Maples observed on the island. The undergrowth is essentially the same as in the Balsam Fir and Spruce forest of the slopes, and the only difference in the fauna is the greater development of molluscs; the forms collected are *Pyramidula striatella, P. striatella alba* and *alternata, Zonitoides arborea, exigua* and *milium, Vitrea binneyana, Euconulus fulvus* and *E. chersinus polygyratus*, and *Sphyradium edentulum* among the fallen leaves, and *Vertigo gouldii, Punctum pygmaeum, Carychium exile* and *Vitrina limpida* in the damp humus in the small ravines. Other forms that may be listed here, although they also occur in the Balsam Fir and Spruce forest, are Storer's Snake (*Storeria occipitomaculata*), the garter snakes, *Thamnophis sirtalis sirtalis* and *T. sirtalis parietalis*, and the grasshoppers, *Tettix acadicus* and *Ceuthophilus seclusus*.

Station IV. Washington Creek. The conditions represented here are similar to those which prevail on the head waters of the rivers and along the small streams. Where the valley is narrow (near the mouth, Section 32) the forms of the slope forest extend nearly to the waters edge, being separated from it by a narrow zone of Hoary Alder, *Equisetum arvense, Caltha palustris, Vagnera trifolia, Rhamnus alnifolia* and various grasses and sedges. Up stream, Section 28, the valley is wider, and the coniferous forest of the slope is separated from the stream by a considerable development of bog forms. The arboreal vegetation consists of the Arbor Vitae, Tamarack and Black Spruce, with an undergrowth of *Coptis trifolia, Chiogenes hispidula, Linnaea borealis, Lycopodium clavatum* and *obscurum*, and a thick carpet of *Sphagnum* and other mosses.

There is practically no aquatic flora, and the only aquatic animals found were *Pisidium*, too young to identify.

The molluscs collected in the bog society are *Pyramidula striatella, Zonitoides arborea* and *exigua, Vitrea binneyana, Acanthinula harpa, Vertigo gouldii, Agriolimax campestris* and *Pallifera hemphilli*.

Station V. Tamarack Swamp. On Section 20, T. 64 N., R. 38 W., in the valley of the small stream draining into Huginnins Cove, the bog society attains a considerable development. The Tamarack is the principal tree and is associated with the Balsam Fir, Black Spruce and Black Ash. The undergrowth consists of the Dwarf Dogwood, *Chiogenes hispidula* and *Coptis trifolia* on a thick mat of *Sphagnum* and other mosses. The molluscs found here are *Zonitoides exigua, Z. arborea* and *milium, Vitrea binneyana, Euconulus fulvus, Vertigo gouldii, Pyramidula striatella* and *Euconulus chersinus polygyratus*. A conspicuous feature of the bogs in this region is the lack of undergrowth. As may be seen from the list of species, the forms that compose the undergrowth consist only of a few herbaceous forms, which is in striking contrast to the density of the undergrowth in the surrounding forest.

Station VII. Lake Desor. This lake lies between the Greenstone and Minong Trap Ranges. Its shores are for the most part shelving and covered with a fine silt-like deposit. The islands, however, have uniformly rocky shores. The coniferous forest of the slopes comes down to the margin of the lake where it grades into a narrow zone of Hoary Alder, *Viburnum opulus* and Arbor Vitae that lines the shores. The aquatic flora and fauna is very poor. The marginal forms consist of the plants, *Equisetum sp., Phragmites communis, Sparganium eurycarpum*, and occasionally the White Water Lily (*Castalia odorata*); the frog, *Rana sylvatica cantabrigensis*, and the molluscs, *Planorbis bicarinatus striatus*, and *Anodonta marginata*. On the rocky shores of the islands, the vegetation consists of a scattered growth of *Isoetes sp.* and *Phragmites communis* in the water among the rocks, and *Equisetum arvense* on the rocks in exposed places. The animals collected here are the leeches, *Haemopis grandis* Verrill and *Nephelopsis obscura* Verrill, a number of caddis fly larvae, and the molluscs, *Planorbis hirsutus, P. exacuous* and *parvus*, and *Physa sp.*

Station VIII. Siskowit Bay. The only part of Siskowit Bay worked was the west end in T. 64 N., R. 32 W. The shore at this point consists of outcropping strata of conglomerate that dip under the bay, and are often broken up into shingle beaches. Owing to the grinding of the waves, there is practically no aquatic life, although a small *Physa* is sometimes found on the larger rocks. In the pools that occur occasionally along this beach behind the outcropping strata, the conditions are more favorable. Small mats of Algae may occur on the rocks and there is a limited fauna of which caddis fly larvae, and molluscs, *Physa sp.* and *Valvata sincera lewisii*, are the principal forms. The beach flora is also very limited, consisting chiefly of Juneberry, *Phegopteris polypodiales, Euthamia graminifolia, Campanularia rotundifolia* and *Listera convallariodes* that occur in the rock crevices and scattered over the shingle beach.

Station IX. Southwestern End of Minong Trap Range. As may be seen on the map, the Minong Trap Range on Section 30, T. 64 N., R. 39 W. projects into Lake Superior, becoming deeply submerged several hundred yards from the mainland. It is also sloping on the south side, owing to the dip of the strata, but on the north side it is precipitous. Near the outer end of the ridge, there are a number of rock pools in the angular spaces formed by the removal of portions of the rock between the joint planes. These are very similar in form and probably in origin to the beach pools in the Porcupine Mountains. The flora of these pools is very limited, but a number of animal forms are found such as the molluscs, *Limnaea sumassi* and *Planorbis parvus*, the water strider, *Gerris remigis*, and caddis-fly larvae. The flora on the outer end of the ridge consists of scattered patches of *Parmelia conspersa*, and a crevice vegetation of *Sibbaldiopsis tridentata* and *Dasiphora fruticosa Campanularia rotundifolia, Solidago sp.*, Arbor Vitae and several grasses.

Toward shore a thin soil covers the rock and supports a flora of Reindeer Lichen (*Cladonia rangiferina*), and the heaths, Bearberry, Dwarf Blueberry and New Jersey Tea that are often found growing on the remains of lichen mats. Here also are found *Empetrum nigrum*, and *Lycopodium annotinum, clavatum* and *complanatum*. The first tree is the Arbor Vitae

that grows nearly prostrate on the rock, associated with *Juniperus nana*, Mountain Ash, White Pine, and Quaking Aspen. Near the shore the White Spruce, Balsam Fir and Paper Birch come in, forming the forest of the region. The succession on these points is evidently represented by four stages, the lichen-moss, grass-sedge, heath, and coniferous societies. The history of the pools is somewhat different. There is evidence that these are being filled in places by *Sphagnum* and other mosses, and on this moss such bog forms as *Ledum groenlandicum*, Cassandra, Black Spruce and Tamarack are occasionally found. These forms must, however, in time be succeeded by the forms of the upland forest.

In listing the fauna of the outer end of the ridge, the Herring Gull should be mentioned as one of the most characteristic forms, for hundreds of individuals were often observed on this ridge during the summer. As in the Porcupine Mountains, a number of molluscs push out in advance of the forest on the heath mat. In the dry soil among the roots of these plants was found, *Pyramidula striatella, Zonitoides exigua, Vitrea binneyana* and *Acanthinula harpa.*

Station X. Washington Harbor. As may be seen from the map, Washington Harbor is a long narrow bay lying between the Minong Trap and Greenstone Ranges, on the southwest end of the island. It attains a depth of 6 to 9 fathoms and has a rocky bottom that rises nearly to the surface in places as reefs.

The fauna of the deeper waters, as represented by the collections, consists of the Lake and Brook Trout, Herring, Sucker, Muskallunge, Yellow Perch and *Couesius plumbeus.* Among the rocks near shore the Millers Thumb (*Cottus ictalops*) is found, and the molluscs, *Limnaea stagnalis var., Limnaea summassi, Physa sayii, Physa sp.* and *Planorbis exacuous.* Of these forms the two Limnaeas were the most characteristic and were particularly abundant on the northeast end of the harbor.

4. SUMMARY AND CONCLUSIONS.

On account of the preliminary nature of the work done on Isle Royale, but few conclusions will be drawn. It will be seen at once, however, that while the biota of the Porcupine Mountains possess many southern forms, the Isle Royale societies are characteristically boreal, the bog forms are less restricted, the sedge, cassandra, shrub and coniferous societies are better represented on the river flood-plains, and many of the forms of the coniferous society occur in the climax forest. This makes the climax forest society of Isle Royale, of the northeastern North American type. The bog forms are thus boreal types having the same affinities, and their spreading out in this region from the restricted habitats which they occupy to the south may be accounted for by the fact that the environmental conditions with which they are associated, toward the north tend to become of general or of geographic extent, so that these forms ultimately come to form the climax society. Thus several forms that about Ann Arbor have been recorded only from tamarack swamps, such as the snails, *Philomycus dorsalis*, and *Pallifera hemphilli* (collected by Miss Jean Dawson), and the Varying Hare, Star-nosed Mole, and Red Backed Mouse, are all boreal species (Bailey, '96), that toward the north tend to become of general distribution.

It will be noticed in the annotated lists, however, that while most of the species have northeastern affinities, a number of forms collected on Isle Royale are forms of western and northwestern distribution. There are conspicuous examples of this:

1. The snail listed as *Limnaea sumassi* Bd., according to Mr. Bryant Walker, although probably entitled to rank as a distinct variety or species, is very closely related to *L. summassi* Bd. a peculiarly western form originally described from British Columbia.
2. The range of the ant, *Camponotus herculeanus* L. var. *Whymperi* Forel, according to Dr. Wheeler, is not well known, but it has been previously found in the mountains of Colorado and Britsh Columbia.
3. The specimens of the Garter Snake, *Thamnophis sirtalis parietalis*, taken on the island strikingly resemble in coloration western forms from Washington and Colorado, and not those of southern Michigan, that are sometimes referred to this variety.
4. Although not found on the island, the Michigan Grayling, *Thymallus ontariensis*, may also be mentioned in this connection. According to Jordan and Evermann ('96, p. 518), this variety "represents a detached colony left from the post glacial extension of the range of *T. signifer*, of which it was a variety." The range of *T. signifer* is given as "Mackenzie River to Alaska and the Artic Ocean."
5. Another instance of the same nature was the finding of the Devils Club, *Echinopanax horridus* Decsene, by Wheeler ('01, p. 620) on the north end of the island in 1900. The range of this plant, as given by Macoun ('83, p. 189), is the north coast of America and in Alaska; being abundant west, but extremely rare east of the Rocky mountains.

The occurrence of these western and northwestern elements in the biota of Isle Royale is emphasized because, as was said before, the majority of the species are those of the northeastern North American type. Whatever may be the explanation of the occurrence of these western and northwestern forms this far to the east, an important factor is, no doubt, the peneplain nature of the country, which probably formed an extensive highway for boreal forms along the ice margin during the retreat of the last ice sheet.

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THE ECOLOGICAL DISTRIBUTION OF THE BIRDS IN THE PORCUPINE MOUNTAINS, MICHIGAN.

OTTO MCCREARY.

The country in which these observations were made is largely included within a narrow area about a mile wide which runs from Lake Superior almost directly south, crossing Carp river about a quarter of a mile east of Carp Lake. Few observations were made south of the Carp river valley.

On account of differences observed in the environments of the bird life of this region, it will be discussed according to the following habitats:

I. THE LAKE SUPERIOR SLOPE OF THE FIRST MOUNTAIN RIDGE.

1. Lake Superior }
2. Lake Beach... } .....Station I.
3. Cedar Swamp.....Station II. Sub. 1.
4. Hemlock Forest.....Station II. Sub. 2.
5. Hardwood Forest.....Station II. Sub. 2.
6. Camp Clearing.....Station II. Sub. 3 and 4.
7. Mountain Top and Escarpment.....Station III. Sub. 1-6.

1. Lake Superior (Station I).

This habitat includes the open water of the lake and is only a feeding place for the birds, as it is impossible for them to nest here.

The water is very cold, the temperature being about 58° F. during the latter part of July. The shores are rocky and steep, the rocks in some places making an angle of 30° with the surface of the water, and on this account, aquatic life, with the possible exception of small algae and invertebrates, was lacking along the edge of the water, so that waterfowls feeding on these would be expected to occur here only occasionally, during the migration season.

The only birds observed, were those of fish eating habits, such as mergansers, loons and gulls. On July 21 a female American Merganser with nine or ten young in the down was seen near the shore. On my approach they swam out into the lake and were soon out of sight behind some rocks that jutted into the water. Two adult Loons were seen the same day, and two days later two Herring Gulls were observed flying over the lake. These were the only birds seen in about fifteen trips made to the lake shore from July 15 to August 13.

2. Lake Beach (Station I).

At this part of the lake shore, the beach is formed by the dipping of the bed rock below the lake, thus making a barren rocky strip, almost destitute of vegetation, between the waters edge and the trees. In addition to the mosses and lichens that grew upon the rocks, the principal plants that

occurred here were goldenrods bluebells, lobelias, etc. that grow in the crevices.

The scarcity of small invertebrates and plants suitable for bird food made this a very poor feeding ground. Indeed the scarcity of bird life here was especially noticeable, as only three birds, the Spotted, Solitary and Least Sandpipers were seen, all of which are shore birds.

Ravens, Crows and Chimney Swifts were seen flying along the shore; the last was probably searching for insects and the first two for fish. Although no dead fish were seen along the shore, no doubt they are occasionally washed up, and these birds were probably patrolling the coast in search of cast up refuse.

3. Cedar Swamp (Station II. 1).

This station extended from the lake beach to the hemlock forest, a distance varying from a quarter to a half mile at different places. The trees were mostly arbor vitae, spruce, Canada balsam and birch, the principal forms being the arbor vitae and balsam. There were several clearings in this substation, and, as the bird life was different at such places than in the woodland, I shall divide this station into two parts, the Woodland and the Clearings.

Woodland.

In some places the woodland has been partially cleared, but where no lumber has been taken out the woods are very dense. The same species of birds, with one or two exceptions, were found in the dense forest as in the open woodland, only there were fewer of them in the former forest. In the very dense forest birds of all species were few and far between. The birds found here were Mangolia Warbler, Black-throated Blue Warbler, Redstart, Winter Wren, Canadian Warbler, Olive-backed Thrush, Golden-crowned Kinglet, Myrtle Warbler, White-throated Sparrow, Brown Creeper, Oven Bird, Crow, Hairy Woodpecker, Purple Finch, Red-eyed Vireo, Cedar Waxwing, Chickadee, Wood Pewee, Ruffed Grouse, Black-throated Green Warbler, Sharp-shinned Hawk, Pileated Woodpecker, Pine Siskin, Mourning Warbler, Raven, and Red-breasted Nuthatch, and Arctic Three-toed Woodpecker. The Black-throated Blue Warbler is characteristic of the undergrowth. The Pine Siskin and Purple Finch were nearly always seen in flocks and roamed about over a large expanse of territory.

The Olive-backed Thrush, Mourning Warbler, Wood Pewee and White-throated Sparrow were found in the open woods.

Clearings in the Cedar Swamp.

There were several clearings in this vicinity, most of them being near the lake. In all of them there were plenty of small trees and brush, in which the birds found favorable conditions.

The birds seen in the clearings were, Black-throated Blue Warbler, Winter Wren, House Wren, Arctic Three-toed Woodpecker, Red-tailed Hawk, Sparrow Hawk, White-throated Sparrow, Crow, Flicker, Purple Finch, Red-eyed Vireo, Chickadee, Canadian Ruffed Grouse, Song Sparrow, Great Horned Owl, Sharp-shinned Hawk, Sparrow Hawk, Pileated Woodpecker, Pine Siskin, American Bittern, Raven, Least Fycatcher, Olive-sided Flycatcher and King Bird.

The Bittern was a straggler, observed once near the lake shore. The Red-tailed Hawk, Raven and Pine Siskins were seen flying overhead, and

the Flickers on the high dead stumps in the clearing. The Purple Finch came to the clearing to feed on the raspberries, and one was shot with part of a berry in its mouth.

Supplementary Clearing Observations.

This clearing is about two miles west of the main line of observation, and one-half mile south of Lake Superior. The conditions here were decidedly swampy, as cat-tails grew in the middle of the logging road in many places. The arbor vitae had been cleared away several years before and the second growth had become quite a factor in the conditions. This growth, together with the underbrush and tree tops, made traveling outside of the logging road very difficult. Here, among a young growth of maple about five or six feet high, was found a family of four Connecticut Warblers.

Other birds seen in this clearing are as follows: Blue-headed Vireo, Red-breasted Nuthatch, Black-throated Blue Warbler, Pileated Woodpecker and White-throated Sparrow.

4. Hemlock Forest (Station II. 2).

This habitat may be called the hemlock belt because the majority of the trees were of this species. The lower part of this station, at the edge of the cedars, was covered with a dense growth of hemlock, while farther up the side of the mountain the proportion of maples increased until finally the hemlocks were nearly all replaced by maples. In the dense hemlock forest there was very little underbrush, but where there were many maples there was always a thick underbrush of young maples and some basswood.

The birds of this Station were: Pine Siskin, Red-eyed Vireo, Cedar Waxwing, Purple Finch, Black-throated Blue Warbler, Chickadee, Hairy Woodpecker, Golden-crowned Kinglet, Brown Creeper, Blackburnian Warbler, Black-throated Green Warbler, Winter Wren, White-throated Sparrow, Oven Bird, Wilson's Thrush, Ruffed Grouse, Olive-backed Thrush, Raven, Pileated Woodpecker, Broad-winged Hawk.

Here, as in the cedars, different species of birds frequented certain places. The Pine Siskins, Purple Finches and Golden-crowned Kinglets were nearly always seen in the hemlocks. The Winter Wrens were observed mostly along streams and in damp places. The Black-throated Blue Warbler was found quite commonly in the underbrush, but where the dense shade prevented an undergrowth, none were observed. The Olive-backed Thrush and White-throated Sparrow were always found in the open woodland.

Supplementary Clearing Observations.

This was a clearing in the hemlock forest about two miles west of the main line of observation and about a quarter of a mile south of Lake Superior.

The birds seen in this clearing were the Purple Finch, Olive-sided Flycatcher, Least Flycatcher, White-throated Sparrow, Song Sparrow and Ruffed Grouse. The Olive-sided Flycatchers were seen sitting on high dead stubs making themselves conspicious by their noise.

5. Hardwood Forest (Station II. 2).

This habitat extended from the hemlock belt through the maples to the aspens about the natural clearing at the top of the cliff. This may be called the hardwood belt because the trees were mostly maple with a few scattered hemlocks, basswood, balsam, and birch. In these woods there was a very thick undergrowth composed mostly of young maples.

The birds observed in this habitat are: Black-throated Blue Warbler, Oven Bird, Black-billed Cuckoo, Cedar Waxwing, Red-tailed Hawk, Flicker, Wilson's Thrush, Red-eyed Vireo, Black-throated Green Warbler, Blackburnian Warbler, Brown Creeper, Chickadee, Pileated Woodpecker, Ruffed Grouse and Olive-backed Thrush. An Oven Bird's nest containing two eggs and one young was found along the path up the mountain on July 16. It was made of coarse grass and leaves, and was placed on the ground. The Olive-backed Thrush, Black-billed Cuckoo, and Flicker were seen near the camp, where the woods were more open.

6. Camp Clearing (Station II. 3-4).

This was the clearing around the camp. It was not more than two acres in extent and was surrounded by a zone of aspens, except on the north where the trees were mostly maple. It was situated at the crest of a low mountain pass, a little more than 750 feet above the level of Lake Superior. It was bounded on the north by Station II. 2, and on the east by II. 2, and III. 1; on the south by IV. 3, and on the west by II. 2, and III. 5; It contained many tall weeds, bushes, and several trees, principally aspen.

The birds found on this station were: Purple Finch, Mourning Warbler, Blackburnian Warbler, Red-eyed Vireo, Black-billed Cuckoo, American Crossbill, Song Sparrow, Downy Woodpecker, Pine Siskin, Sapsucker, Robin, Raven, Sparrow Hawk, Indigo Bunting, Chimney Swift and Cedar Waxwing. The Song Sparrow, Sapsucker and Indigo Bunting were probably accidental here, as only one of each was observed. The Chimney Swift was often seen flying overhead. The Purple Finches and Pine Siskins came to feed on bread crumbs and other refuse from the camp. A pair of adult Mourning Warblers and two young were taken among the bushes in the clearing, July 15.

7. Mountain Top and Escarpment (Station III. 1-6).

From the top of the mountain to the valley of Carp river, there is a precipitous descent of about 400 feet. On top of the cliff and back a few rods from the brink of the precipice, there are no trees except a few scattered pines. The chief vegetation consists of dwarf huckle and blueberries, New Jersey tea, bearberry and other heath plants. The cliff is nearly continuous, but not entirely so, being broken occasionally by gullies. Surrounding the "bald" top of the cliff is a zone of aspen which grades down into the gullies, and down the north slope into the hardwoods. At intervals, where the slope is not so steep, the pines form a narrow belt up the face of the cliff, across the top of the mountain and into the hardwoods beyond, thus surmounting the range.

It is the top of the cliff on the eastern half of Section 14 and western half of Section 13 (III.1, 2, 3) that will be described first.

The western end of the station lies in a gully in Section 14. As the top is approached the aspens become smaller and smaller and finally disappear. Toward the east end of the mountain top, on Section 13, this "bald" area is crossed by a zone of Norway and white pines, many of them being of very large size. The middle portion consists of a precipice and a narrow strip at the top. It differed from the west end in that it contained no aspens, and the pines were so far apart that they had but very little influence upon the general conditions. Probably owing to this reason the bird life on the west end and middle portion was practically identical, and I will describe them together, treating the bird life in the pines separately, as it is entirely different.

Birds were always to be found along the western slope and top (III. 1 and 2), but the small number of species was noticable. The Junco, Cedar Waxwing and Flicker were the only birds that were abundant. The Flicker was often seen on the few tall dead stumps and scattered pines that occurred here, and probably nested in these stumps, as they contained many holes. Both young and adult Juncos were found in abundance and this seemed their natural habitat. The Cedar Waxwing was attracted here by the Juneberries, upon which they were often seen feeding. Crows, Ravens, Chimney Swifts and Red-tailed Hawks were seen flying overhead. Sparrow Hawks came occasionally to feed upon the grasshoppers, but these birds seem to prefer the cliffs to the west of this location.

The birds seen in the pines (III. 3) were the Pine Warbler, Red-breasted Nuthatch, Chickadee, Chipping Sparrow and White-breasted Nuthatch. Two Pine Warblers, evidently a male and female, were seen on the tops of these pines looking for insects. Finally one caught an insect, but instead of eating it the bird perched on a limb, held the insect in its mouth, and scolded. It acted as if it had young near me and was afraid to feed them. Several Chipping Sparrows were seen on the tree tops and one was shot July 19.

The tops of the cliffs west of camp (III. 5) were similar to III. 2, except that the "bald" areas were of greater extent. The same birds that were found in III. 1 and 2 were found here and also a few additional ones.

For some reason, which I cannot explain, Robins, Bluebirds, Blue Jays and Vesper Sparrows were often found on this cliff and seldom in Station II. 1 and 2. A Bluebird's nest containing young was found in a deserted Woodpecker's hole in a Norway pine; Vesper Sparrows and a Scarlet Tanager were seen here once. The former were perhaps migrating, (August 3), while the latter was from the neighboring forest. The Ravens came here n the evening and left in the morning, when nine were counted at one time. A few could be seen about here at almost any hour of the day.

The bird life on the second cliff west of camp was somewhat different from that of the first as no Robins, Bluebirds, or Vesper Sparrows were seen here, while a Phoebe was seen here and not on the other cliffs. Two Bald Eagles were observed flying overhead.

II. CARP RIVER VALLEY.

This region extended from the foot of the talus slope south to the elevation on the other side of the river valley, a distance of about a quarter of a mile. From west to east, it extended from the outlet of Carp Lake as far up the Carp river as we could ascend in a boat, a distance of about one and a quarter miles.

Within this area are included several different varieties of conditions, and these furnish the basis for the following habitats:

1. Carp Lake.....Station V. 1, and 3.
2. Grassy Marshes.....Station V. 2, and IV. 2.
3. Alders.....Station IV. 2.
4. Damp Woodland.....Station IV. 3.
5. Tamarack Swamp.....Station IV. 4.
6. Carp River.....Station IV. 1.
7. Dry Woodland.....Station IV. 3.
   a. Western End.
   b. Eastern End.

FIG. 17. Upper portion of the talus slope, station III. 6, showing the angle of slope, and the lichens (light colored patches) on the rocks. The birches in the background are on the lower part of the slope.

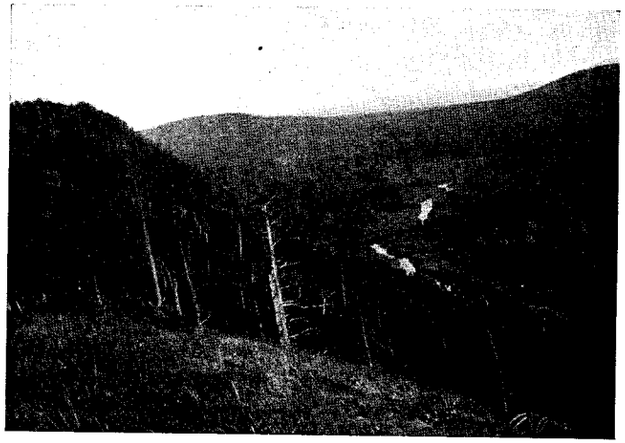

FIG. 18. General view of Carp river valley, looking up stream and southeast from station III. 5. Note the alder and cassandra vegetation bordering the river, station IV. 2.

1. Carp Lake (Station V. 1 and 3).

The lake is about a mile long, a quarter of a mile wide, and comprised, in extent, about one-half of the station. The western half of the lake extended from the foot of the talus slope to the foot of the ridge on the other side, while the eastern half differed from it principally in having a narrow strip of land between the waters edge and the foot of the talus slope on the north side.

Bordering most of the lake there is just enough beach to walk on, except on the northwest shore where it is somewhat wider. On the southwest and southeast shores of the lake, there are small grassy marshes, and at such places bulrushes and sedges grow along the edge of the water.

On the south side arbor vitae, maples, alders, and other trees grow along the edge of the beach. These trees were usually not more than twenty feet high and are so close together that it was almost impossible to penetrate them. At other places there is a fringe of alders along the beach.

Very few birds were seen on the lake; a Loon, was upon the water August 10; Kingfishers were often seen flying across the lake, now and then diving for a fish; an Osprey was observed several times doing the same thing, and a Great Blue Heron was twice seen flying across the lake and once in the sedges. A Swamp Sparrow, a Solitary Sandpiper and Crows were observed on the beach.

2. Grassy Marshes (Station V. 2, IV. 2).

There were two of these grassy marshes. One at the east end of Carp Lake and another a mile and a quarter up Carp river. Both were overgrown with tough marsh grass and were too small to be of any special importance as a bird habitat.

Song Sparrows and Swamp Sparrows came out of the alders to feed but the only birds taken characteristic of grassy marshes were the Wilson's Snipe and Carolina Rail. The former was taken in the marsh, up the river, and the latter in the marsh at the east end of the lake.

3. Alders (Station IV. 2).

The alders occupied the bottom land along either side of Carp river. There are many willows, dogwoods, and cassandra bushes among the alders, and together they formed a thicket so dense, that it was impossible to see more than a few yards.

The birds of this habitat were the White-throated Sparrow, Red-eyed Vireo, Black-throated Green Warbler, Redstart, Oven Bird, Swamp Sparrow, Mourning Warbler, Olive-backed Thrush, Downy Woodpecker, Kingfisher, Sharp-shinned Hawk, Cedar Waxwing, Chestnut-sided Warbler, Chickadee, Canadian Warbler, Rose-breasted Grosbeak, Wilson's Thrush, Black-billed Cuckoo, Alder Flycatcher, Song Sparrow, American Bittern, Ruffed Grouse, Least Flycatcher, Red-winged Blackbird, Water Thrush, and Black-throated Blue Warbler.

The Canadian and Chestnut-sided Warblers and Red-winged Blackbird probably did not breed in this zone, as they were not seen here until after the first of August.

The Kingfisher, American Bittern and Sharp-shinned Hawk were seen along the edge of the river. Only one of each of the last two were seen. The Hawk was on the bank eating a grouse and the Bittern was standing

on an alder that leaned out over the river. Kingfishers were often seen flying up and down the river and would alight upon the overhanging branches to watch for fish.

A Cedar Waxwing's nest was found in an alder. This nest was made of mud and dead grass and was built in the top of the shrub. The nest was found July 28, but contained no eggs.

Almost all of the birds among the alders appeared quite tame, for as soon as I would go into the bushes some bird would begin to scold, nearly always a White-throated Sparrow, and the rest of the birds would come to see what the trouble was about. Redstarts, Mourning Warblers, Black-throated Green Warblers, Oven Birds, Red-eyed Vireos, Swamp Sparrows, Song Sparrows, Wilson's Thrushes, Winter Wrens, Water Thrushes and a Rose-breasted Grosbeak came within a few feet of me. Even the shy Olive-backed Thrush would come within a rod to scold. It was very interesting to observe the marked curiosity which they showed.

4. Damp Woodland (Station IV. 3).

This was a small strip of maple and ash between the alders, and the maple forest of the slopes. The birds seen here were: Red-eyed Vireo, White-throated Sparrow, Winter Wren, Water Thrush, Black and White Warbler, and Least Flycatcher.

The trees of this piece of woodland were not very high but were so crowded that they produced a dense shade. This was perhaps the reason why there were so few birds seen here, and why those seen were near the margin.

5. Tamarack Swamp (Station IV. 4).

About a half mile east of the lake where the river turns to the south, there is, on the west bank, a tamarack swamp. The trees of this swamp are arbor vitae, and tamarack, which about the margin of the swamp grow much thicker than in the center.

The birds observed were as follows: Purple Finch, White-throated Sparrow, Magnolia Warbler, Cedar Waxwing, Red-breasted Nuthatch, Red Crossbill, White-winged Crossbill, Olive-sided Flycatcher, Pine Siskin, Golden-crowned Kinglet and Ruffed Grouse. The two species of Crossbills were probably attracted here by the seeds of the tamarack cones, as the crops of five specimens all contained tamarack seeds. The Red-breasted Nuthatch nested here, as an adult bird was seen feeding three young. The Olive-sided Flycatchers were seen on the tops of tall dead trees.

6. Carp River (Station IV. 1).

About a mile and a quarter east of Carp Lake, the river becomes so narrow that the alders which line the banks meet above the middle of the stream and obstruct further passage with a boat. Where the alders line the bank there were few places for wading birds, but where there were grassy mud flats between the water and the shrubs Solitary Sandpipers were to be seen at almost any time. The Snipe, however, was only seen July 17 and 18. The only birds seen on the river were Hooded Mergansers.

7. Dry Woodland (Station IV. 3, North of Carp River).

This is the upper part of the strip of woodland lying between the cliff and Carp Lake, on the north side of the valley, and occupies the lower part

of the talus slope. The trees here were mostly maple, birch and aspen, with a few pines scattered among them. At the eastern end the forest was open, while the trees of the western end were so close as to make a dense shade. On account of the difference of the character of the two portions, they will be taken up separately.

Western End. Here, where the trees were thick, few birds were seen. The different species noticed were as follows: Blackburnian Warbler, Kingfisher, Sparrow Hawk, Red-eyed Vireo, Wilson's Thrush, Canadian Warbler, Blue Jay and Redstart. There was a Sparrow Hawk's nest situated high up in a dead tree, in what seemed to be a deserted Woodpecker's hole. The young of the Wilson's Thrush, still unable to fly, were found here.

Eastern End. The birds found in this end of the forest were: Black-throated Blue Warbler, Robin, Ruffed Grouse, Flicker, Downy Woodpecker, Oven Bird, Olive-backed Thrush, Red-eyed Vireo, Black-billed Cuckoo, Blackburnian Warbler and White-throated Sparrow. In the evening and morning the song of the Olive-backed Thrush could be heard almost everywhere in the tree tops, and they seemed to be quite numerous, but in the daytime this bird was seldom heard. The probable explanation of this is that they went into the alder thickets to the south.

III. HARDWOOD FOREST SOUTH OF CARP RIVER (STATION VI.).

The trees along the trail to Government Peak were mostly maple, birch and hemlock, except in low places along the small streams, where there was much arbor vitae and balsam.

Observations along the trail were made July 26 and the following birds were seen in the forest: Oven Bird, Golden-crowned Kinglet, Scarles Tanager, Red-eyed Vireo, Magnolia Warbler, Black-throated Blue Warblert Wood Pewee, Winter Wren and Olive-backed Thrush. The Magnolia, Warbler, Wood Pewee and Winter Wren were seen along a stream.

An Olive-backed Thrush's nest was found on top of a small hemlock about ten feet high beneath a larger tree. The nest was composed of leaves, rootlets, and grasses, and was lined with still smaller grasses and rootlets, and contained two bluish green eggs with cinnamon brown spots.

IV. LITTLE CARP RIVER VALLEY.

1. Little Carp Lake (Station VII. 1).

This lake is small, being about one-half mile long and a quarter of a mile wide. The only observations made upon the bird life on the lake shore were in an open spot at the east end. Only one bird was seen on the water, a Pied-billed Grebe, on August 2.

The open area was at the foot of a small hill which arose precipitously out of the lake to a height of about fifty feet. There was very little soil, which accounts for the absence of an extensive vegetation. Observations were made on August 2 and 3 and the birds seen were: Blue Jay, Junco, Humming Bird, Yellow-bellied Sapsucker, Hairy Woodpecker, White-throated Sparrow, Wood Pewee, Purple Finch, Chimney Swift, Raven, Kingfisher, Cedar Waxwing, Flicker and Song Sparrow. The Chimney Swift and Raven were seen flying overhead.

2. Beaver Meadow (Station VII. 2 and 3).

This meadow was along Little Carp river, about a quarter of a mile east of Little Carp Lake. It was about a mile long and a quarter of a mile wide, the Little Carp river running through the middle of it. The ground was quite marshy in many places and was covered with grass, there being no trees in the meadow. There were several willow and alder bushes at the east end. The surrounding trees were alder, tamarack, arbor vitae, balsam and birch.

Observations were made on August 3, and the birds seen here were: Kingfisher, Solitary Sandpiper, Cedar Waxwing, Red-eyed Vireo, Swamp Sparrow, Song Sparrow, White-throated Sparrow, Marsh Hawk, Pine Siskin, Hairy Woodpecker, Tree Swallow, White-winged Crossbill, Yellow-legs, Least Sandpiper, Red-breasted Nuthatch.

The Kingfisher, Solitary Sandpiper, Least Sandpiper, and Yellow-legs were seen along Little Carp river. The Tree Swallow, Marsh Hawk and Pine Siskin were seen flying overhead, and the Song Sparrow and Swamp Sparrow were seen feeding in the grass, while the rest were seen in the trees around the edge. The Crossbills were seen in tamarack trees at the edge of the marsh. As it was August 3 when I was at the beaver meadow, I cannot say which birds bred there and which were migrants.

V. SUMMARY.

On glancing over the list of birds found at the different stations, it will be noticed that some birds were found at only one or in a few stations, while others were found in nearly all of them. At some stations a certain species of bird would be quite numerous, while another only a short distance away, would contain none of these. From such facts we must conclude that some birds are found only in certain situations which possess definite environmental conditions. There were also a number of birds observed which were too rare to determine what kind of localities they preferred; still others were only seen flying overhead. Regarding abundance, at one extreme were the rare forms and at the other those found almost everywhere. The rare birds were: Myrtle Warbler, Great Horned Owl, Black and White Warbler, Indigo Bunting, Broad-winged Hawk, Humming Bird, Arctic Three-toed Woodpecker, Connecticut Warbler, Blue-headed Vireo, Rose-breasted Grosbeak, Scarlet Tanager, House Wren, King Bird, White-breasted Nuthatch and Phoebe. The birds only seen flying overhead were: Red-tailed Hawk, Chimney Swift, Bald Eagle, Tree Swallow and Marsh Hawk. The birds of general distribution were: Ruffed Grouse, Red-eyed Vireo, Black-throated Green Warbler, Chickadee, Purple Finch, Black-throated Blue Warbler, Sharp-shinned Hawk, Cedar Waxwing, Oven Bird and Wilson's Thrush.

In the case of birds with a restricted range, the limiting area was occasionally very sharply defined, while in other cases it was difficult to recognize these limits. Examples of the former are the water and shore birds, of the latter, the Golden-crowned Kinglet and Pine Siskin. The distribution of the water and shore birds was the most sharply defined, and, as they are the simplest to place, I will begin my summary with them. In connection with these I will also mention other birds found in association with the shores of the lakes and rivers.

1. Water Birds. Of the water birds only a few species were observed. The Herring Gull, Loon and American Merganser were found on Lake

FIG. 19. Carp river, station IV, showing zones of vegetation on the mud flats

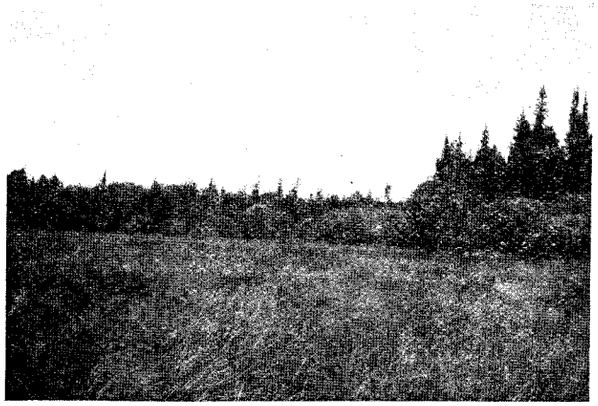

FIG. 20. Beaver meadow, station VII. 2, showing grasses and sedges bordered by encroaching willows and alders. Tamarack and spruce in the background.

Superior. A Loon was once seen on Carp Lake and a Pied-billed Grebe was seen on Little Carp Lake. The only water bird found on the rivers was the Hooded Merganser which was taken on Carp river.

Although not an aquatic bird, I will mention the Osprey here as it was seen flying over the water. It was first seen near the mouth of Union river and afterwards over Carp Lake. It would circle around above the water until it saw a fish and then it would plunge into the water after it. As far as observed most of these efforts were successful.

2. Birds Frequenting Shores and Banks of Streams. Shore birds were most abundant along Carp and Little Carp rivers; only a few were seen on the lake beaches. The Solitary Sandpiper was the only one seen in all the places mentioned. The Lesser Yellow-legs was seen only along Little Carp river. The Least Sandpiper was seen along Little Carp river and on the Lake Superior beach. The Spotted Sandpiper was seen only on the Lake Superior beach. These birds were always seen near the waters edge except when on the wing. A Snipe was seen at the edge of the water along Carp river, in the neighborhood of a grassy marsh.

Another bird that was characteristic of the rivers and small lakes was the Kingfisher, which was nearly always seen at the edge of the water, but never on the ground. It always lit on some bush or tree, and was most frequently seen on trees overhanging the water. The Great Blue Heron was seen standing on the edge of Carp Lake once, and several times it was seen flying over.

Besides the birds characteristic of the waters edge, birds from the alders and birds of general distribution were often observed on the beach of Carp Lake and Lake Superior. This includes such birds as the Song Sparrow, Swamp Sparrow, Crow and Raven.

3. Birds Found in Grassy Marshes and in Alders. Closely associated with the birds of the water's edge were the birds of grassy marshes and alders along the streams. The birds often seen in the grassy marshes were the Wilson's Snipe, Rail, Song Sparrow, and Swamp Sparrow. The Rail was only seen once in the grassy marsh east of Carp Lake.

The Song Sparrow and Swamp Sparrow are not confined to the grassy marshes, since both were also found in the alders. The Song Sparrow was also found in the camp clearing (Station III. 3) and in one of the clearings in the arbor vitae swamp (Station II. 1), so that the Song Sparrow may be said to inhabit clearings both natural and artificial, and the Swamp Sparrow may be said to inhabit marshy clearings. In this case I have classed the alders as a natural clearing because there were no trees among the bushes.

The only bird confined to the alders was the Alder Flycatcher, but several others, of limited distribution, were found here, such as the Redstart, Swamp Sparrow, Mourning Warbler, Olive-backed Thrush, Black-billed Cuckoo, Least Flycatcher, Song Sparrow, and Water Thrush.

The Redstart was rather common here and among the cedars near the shore of Lake Superior (Station II. 1) and was also seen along Little Iron river. It seems to keep near water and near the ground, as it was very seldom seen in the high trees.

The Mourning Warbler was found here, but also in the bushes of the camp clearing, and along the path to the lake in the cedar swamp (Station II. 1). Thus it is seen that this bird is not usually found in thickly forested woodland but is more decidedly a bird of the bushes or thickets.

The Olive-backed Thrush was found on the mountain top, in the river

valley, and in the bushes around the edge of the clearings or in partially cleared woodland. In the mornings and evenings it also appeared abundant among the scattered trees at the base of the talus slope. It was never found in dense woodland.

The Black-billed Cuckoo was often seen among the alders, in the scattered trees at the foot of the talus slope, and in the aspens surrounding the camp clearing. These facts show that it was a bird of the open woodland.

The Least Flycatcher was found in the alders and in a clearing in a hemlock forest; the former a natural, and the latter an artifical clearing. It was also seen in damp woodland south of Carp river, on the edge of a clearing.

The Water Thrush was seen in two other localities, the damp woodland south of Carp river, and along the road to Ontonagon near Lake Superior.

4. Birds Frequenting Tamarack Swamps and Cedar Swamps. The lowlands have all been dealt with, with the exception of the tamarack swamps and cedar swamps. The former was not entirely true to its name, as about half of the trees were cedar. The birds of these swamps deserving mention are as follows: Magnolia Warbler, Canadian Warbler, Sparrow Hawk, and Olive-sided Flycatcher, Red-breasted Nuthatch, Red Crossbill, White-winged Crossbill, Winter Wren, White-throated Sparrow, Golden-crowned Kinglet and Pine Siskin.

The Magnolia Warbler was found only in the cedar and tamarack swamps or along small streams where the arbor vitae grew.

The Canadian Warbler was found near Lake Superior shore and near Carp Lake and always in the more or less open woods.

The Sparrow Hawk was seen in a clearing among the cedars, and had a nest just south of the cliff in a limbless tree which stood above the tops of the surrounding trees. It was also often seen on the top of the cliff and around the camp clearing.

The Olive-sided Flycatcher was found in the tamarack swamp in Carp river valley and in a hemlock clearing near Lake Superior. It was always seen on the top of a dead tree, usually on the highest perch in the neighborhood.

The Red-breasted Nuthatch was seen in the tamarack swamp, and among the pines at the top of the mountain. It can, therefore, be classed with the birds characteristic of the coniferous forests.

The Red, and White-winged Crossbills were numerous in the tamarack swamps, the White-winged Crossbill being seen only in such places. The Red Crossbill came to the camp clearing several times. The cause for their occurrence in the tamaracks is that these are the only conifers whose seeds could be obtained for food.

The Golden-crowned Kinglets and Pine Siskins were very abundant among the coniferous trees, and were seldom seen where these were lacking. The Pine Siskin occasionally came to the camp clearing.

The Winter Wren and White-throated Sparrow were found in the lowlands and about half way up the mountain side. The White-throated Sparrow frequented the open woodland and the edge of the clearings. The Winter Wren was found in the more dense parts of the forests and near streams.

5. Birds Frequenting Hemlocks and Maples. Nearly all the birds that were found in these two stations were also found in the cedar swamp to the north (II. 1) or belonged to the list of rare birds. There were a number of birds that were generally distributed in all the woodland between the Lake Superior and Carp river which, with the exception of the Blackburnian Warbler,

seemed to be more abundant in these two stations. To this class belong the following: Oven Bird, Blackburnian Warbler, Hairy Woodpecker, Brown Creeper and Pileated Woodpecker.

6. Birds Frequenting the Cliff and Mountain Top. The birds characteristic of this station were the Raven, Pine Warbler, Robin, Bluebird, Flicker, Junco and Chipping Sparrow.

The two specimens of Pine Warbler, which were observed several times, were always found among the pines that grew on the top and south slope, so it may be said to be characteristic of the pines.

The Robin and Bluebird were often observed on the bare top of the cliffs, and occasionally the Robin was seen in the camp clearing near by. The Robin and the Bluebird are early migrants and may have settled here because it was on the south side of the mountain and well exposed to the sun and protected from the north winds.

The Flicker was found here and in a clearing along the south shore of Lake Superior. The Junco was abundant here and was seen in a dry sandy clearing near Ontonagon. It was also abundant on the dry knoll at the edge of Little Carp Lake so that this bird and the Flicker may be said in this region to inhabit dry clearings. They are also examples of the tendancy of natural clearing birds to spread into the artificial clearings.

The Chipping Sparrow was found here among the pines and on the dry knoll above mentioned.

The Blue Jay was found on the south slope of the cliff from the top to the edge of Carp Lake and on the dry knoll.

I have here only attempted to give the distribution of the birds as I found them in the Porcupine Mountains. The distribution of many of these birds may be very different in other localities. This would be an interesting field for study in other regions.

I am under obligations to the University Museum for the opportunity to make these observations, and I am also much indebted to Mr. Charles C. Adams for assistance in preparing this paper for publication.

THE ECOLOGICAL RELATIONS OF THE ORTHOPTERA IN THE PORCUPINE MOUNTAINS, MICHIGAN.

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1. GENERAL REMARKS.

The Orthoptera collected by Mr. A. G. Ruthven in the Porcupine Mountains represent two families of the *Saltatoria* and comprise two species of *Locustidae* and 14 species of *Acridiidae*. The collection was made between July 13 and August 12, 1904. Though the list is far from complete, it may be said, in general, that the species obtained are representative elements of the orthopterous fauna of the Canadian and cooler parts of the Transition zones of the central portion of the continent. The commingling of species is especially interesting, and in itself would suffice to indicate, within relatively narrow limits, the locality from whence the collection was derived and the environmental conditions present.

While data in addition to those of date, locality, and general character of the station are lacking—no notes on individual captures or particular species and their relation to the environment in this instance being available—I have no doubt that the ecological relations of the species secured are essentially the same as in other quarters of the eastern section of the country. This judgment is confirmed by the careful collecting notes and discriminating observations of Mr. Morgan Hebard in reference to the Orthoptera of the Keweenaw Bay region (Rehn, Entom. News, Sept., Oct., 1904). I have elsewhere (Pub. No. 18, Carnegie Inst. of Wash., p. 15 et seq.) classified the Acridian societies of eastern North America and discussed some of their more salient features. The same classification is followed in the present paper.

The Acridians secured represent several distinct societies and habitats. These habitats, or complexes of environmental conditions, when viewed from the standpoint of locust biology, may be arranged in three major groups:

1. Bare rock and soil surfaces of the lake shore, clearing, mountain top, or talus slope, either wet or dry,—these are inhabited by campestral geophilous locusts.
2. Areas clothed with a low vegetal growth of grasses or other herbaceous plants, such as meadows, fields, clearings, etc., likewise varying greatly in moisture content of soil, and often extremely limited in size,—these are the haunts of campestral phytophilous locusts.
3. Thickets of shrubs or stunted undergrowth bordering forest edges and openings, either along the lake shore, about clearings, or on the mountain top,—here dwell the sylvan phytophilous species.

Of the Locustarians collected, one species is a bush-dwelling form, nearly related to the katydid; the other, a shield-backed grasshopper, is a typical thicket-inhabiting species.

As is evident from Mr. Ruthven's field notes on the general character of the stations, and also from a consideration of the station lists of Orthoptera, almost every station contains two or more locust societies. These societies comprise one or more characteristic species of locusts which find their preferred haunts within a relatively narrow range of physical conditions and are practically characteristic of such habitats. It should be pointed out, however, that in the heart of its range a species is usually more generally distributed, and less restricted to its special habitat, than elsewhere; furthermore, that accidental occurrences are not infrequent and can be correctly estimated as such only by careful observation or experience. "One swallow does not make a summer," and the capture of a single specimen of a locust in a given locality does not necessarily indicate either an austral or a boreal climate, a campestral or a sylvan habitat.

It is scarcely necessary to state that the abundance and extent of the area occupied by the various elements of the locust fauna will inevitably be affected by the physical and organic agencies controlling the condition of the environments they inhabit, and, other things being equal, will change as they change. On the advent of new conditions one of three things will happen: either the species will become adapted to its changed environment, will emigrate, or will die out in that particular spot—probably the latter. There is every reason to think that with increasing deforestation of the territory, the thamnophilous locusts will increase in numbers; and that, if settlements and clearings multiply, so will the campestral locusts.

The avenue of ingress of the orthopterous fanua into this territory, it is believed, was on the southwest, along the continuous land surface, following the retreat of glacial conditions. This avenue was probably the only practicable one open to the flightless thicket-dwelling forms, and was doubtless followed by most, or all, of the flying species as well.

For further information in regard to the biology of the Orthoptera herein mentioned, the following works should be consulted, in addition to those already referred to:

Blatchley, W. S.—The Orthoptera of Indiana.—27th Annual Report of the Department of Geology and Natural Resources of Indiana.

Morse, Albert P.—Notes on the Acridiidae of New England.—Psyche, vols. VII, and VIII.

The former of these contains a valuable bibliography.

2. STATION LIST.

Station I. Beach of Lake Superior. Species taken: *Chloealtis abdominalis, Camnula pellucida, Circotettix verruculatus, Melanoplus atlanis* and *Melanoplus femoratus.*

Habitats represented and characteristic species.

1. Exposed rock or soil surfaces: *Circotettix verruculatus,* (*Camnula pellucida*).
2. Grassy places—dry: *Melanoplus atlanis* and *Camnula pellucida.*
3. Grassy places—moist: *Melanoplus femoratus.*
4. Thickets—forest edge: *Chloealtis abdominalis.*

Station II. North Slope of First Range. Species taken:

Sub. 2.—Hardwood Forest.—*Tettix brunneri.*

Habitats represented and characteristic species.

The single species taken is not typical of forested environment, usually occurring on bare soil.

Sub. 3.—*Clearing in Saddle.* Species taken: *Chloealtis conspersa, Stenobothrus curtipennis, Circotettix verruculatus, Melanoplus extremus,* and *Melanoplus femoratus.*

Habitats represented and characteristic species. (No notes on conditions at this station have been submitted, but the habitats are probably the following:)

1. Exposed rock or soil surfaces: *Circotettix verruculatus.*
2. Grassy places—moist: *Stenobothrus curtipennis, Melanoplus extremus* and *Melanoplus femoratus.*
3. Thickets—edges of clearing (sometimes in dry, grassy places): *Chloealtis conspersa.*

Sub. 5.—*Aspen Zone Bordering Bare Mountain Top.* Species taken: *Melanoplus fasciatus.*

Habitats represented and characteristic species.

1. Thickets—usually xerophytic: *Melanoplus fasciatus.*

Station III. Top of First Range and Southern Escarpment. Species taken:

Sub. 1.—West Slope of Ridge (aspen zone).—*Chloealtis abdominalis, Chloealtis conspersa, Camnula pellucida, Melanoplus fasciatus, Melanoplus femoratus* and *Melanoplus luridus.*

Sub. 2.—Bare Mountain Top (heath and grass vegetation).—*Chloealtis abdominalis, Chloealtis conspersa, Circotettix verruculatus, Melanoplus fasciatus* and *Melanoplus islandicus.*

Sub. 3.—Zone of Pines crossing Mountain Top.—*Melanoplus fasciatus.*

Sub. 4.—East Slope of Ridge (aspen and scrub oak vegetation).—*Melanoplus fasciatus* and *Atlanticus pachymerus.*

Sub. 5.—Mountain Top.—*Chloealtis abdominalis, Chloealtis conspersa, Melanoplus fasciatus, Melanoplus femoratus, Circotettix verruculatus* and *Atlanticus pachymerus.*

Sub. 6.—Mountain Top.—*Melanoplus amplectens.*

Habitats represented and characteristic species.

1. Exposed rock surfaces:—*Circotettix verruculatus.*
2. Grassy places—(usually moist):—*Melanoplus femoratus.*
3. Thickets:—*Chloealtis conspersa* and *abdominalis, Melanoplus amplectens, fasciatus,* and *islandicus, Atlanticus pachymerus.*

Station IV. 2. Carp River Valley Flood-plain (characterized by cassandra thickets, grasses and sedges). Species taken: *Stenobothrus curtipennis, Podisma glacialis, Melanoplus islandicus, Atlanticus pachymerus, Scudderia pistillata.*

Habitats represented and characteristic species.

1. Grassy places—moist:—*Stenobothrus curtipennis.*
2. Thickets:—*Podisma glacialis, Melanoplus islandicus, Atlanticus pachymerus.*
3. Bushes, leafage of:—*Scudderia pistillata.*

Station VII. 2. Beaver Meadow along Little Carp River. Species taken:—*Camnula pellucida.*

Habitats represented and characteristic species.

1. Grassy places—moist. The species of locust taken here is not characteristic of such conditions, but it is a very common and widely distributed species in the boreal zones, and may occur almost anywhere, especially in grassy places. Its preferred haunts are on dry upland soils.

3. SYSTEMATIC LIST OF THE ORTHOPTERA.

Porcupine Mountains.

ACRIDIIDAE.

1.	*Tettix brunneri* Bol.	1 ♂, Station II.
2.	*Chloealtis abdominalis* Thom.	1 ♂, Station III., Substation 1.
	" "	1 ♂, III., 2.
	" "	2 ♂, 3 ♀, III., 5.
	(juv. spec. do.)	♀, juv. in the 5th stage, I.
	"	♂, juv. in the 5th stage, III., 2.
	"	2 ♀, juv. in the 5th stage, III., 2.
	"	♀, juv. in the 4th stage, III., 2.
	"	♀, juv. in the 5th stage, III., 5.
3.	*Chloealtis conspersa* Harr.	1 ♀, II., 3.
	" "	1 ♀, III., 1.
	" "	1 ♀, III., 1, long-winged.
	(juv. spec. do.)	♂, juv. in the 5th stage, III., 1.
	"	♂, juv. in the 4th stage, III., 2.
4.	*Stenobothrus curtipennis* Harr.	2 ♀, II., 3.
	" "	2 ♂, IV., 2.
	" "	1 ♀, IV., 2.
5.	*Camnula pellucida* Scudd.	1 ♀, III., 1.
	" "	1 ♂, I., beach.
	" "	1 ♀, I., beach.
	" "	2 ♀, VII., 2.
6.	*Circotettix verruculatus* Kirb.	1 ♀, II., 3.
	" "	3 ♂, III., 2.
	" "	1 ♂, III., 2.
	" "	1 ♀, III., 2.
	" "	1 ♀, III., 2.
	" "	1 ♀, III., 5.
	" "	2 ♂, I., beach.
	" "	1 ♀, I., beach.
7.	*Podisma glacialis* Scudd.	1 ♀, IV., 2.
8.	*Melanoplus amplectens* Scudd.	1 ♀, III., 6.
9.	*Melanoplus atlanis* Ril.	1 ♂, I., beach.
10.	*Melanoplus extremus* Walk.	2 ♀, II., 3.
11.	*Melanoplus fasciatus* Barnst.-Walk.	1 ♂, II., 5.
	" "	1 ♀, II., 5.
	" "	1 ♂, III., 2.
	" "	1 ♂, III., 2.
	" "	4 ♀, III., 2.
	" "	1 ♂, III., 3.
	" "	1 ♀, III., 3.
	" "	1 ♂, III., 4.
	" "	1 ♂, 4 ♀, III., 5.
12.	*Melanoplus femoratus* Burm.	4 ♂, II., 3.
	" "	8 ♀, II., 3.
	" "	1 ♀, III., 1.
	" "	1 ♂, III., 5.
	" "	2 ♀, I., beach.
	" "	1 ♂, I., beach.
	(juv. spec. do.)	2 ♀, juv. in the 5th stage, II., 3.

13. *Melanoplus islandicus* Blatchl.		1♀, II., 5.
"	"	1♂, III., 2.
"	"	1♀, IV., 2.
14. *Melanoplus luridus* Dodge.		1♂, III., 1.

LOCUSTIDAE.

15. *Scudderia pistillata* Brunn.		1♀, IV., 2.
16. *Atlanticus pachymerus* Burm.		1 juv. ♀, III., 4.
"	"	1♀, III., 4.
"	"	1♀, IV., 2.
"	"	1♂, III., 5.

Isle Royale.

The following species were identified from this locality; no field notes accompanied the specimens.

1. *Tettix acadicus* Scudd.		1♀, III.
2. *Camnula pellucida*, Scudd.		2♂, 2♀, II.
3. *Ceuthophilus seclusus* Scudd.		1♂, III.
"	"	1♀, III.

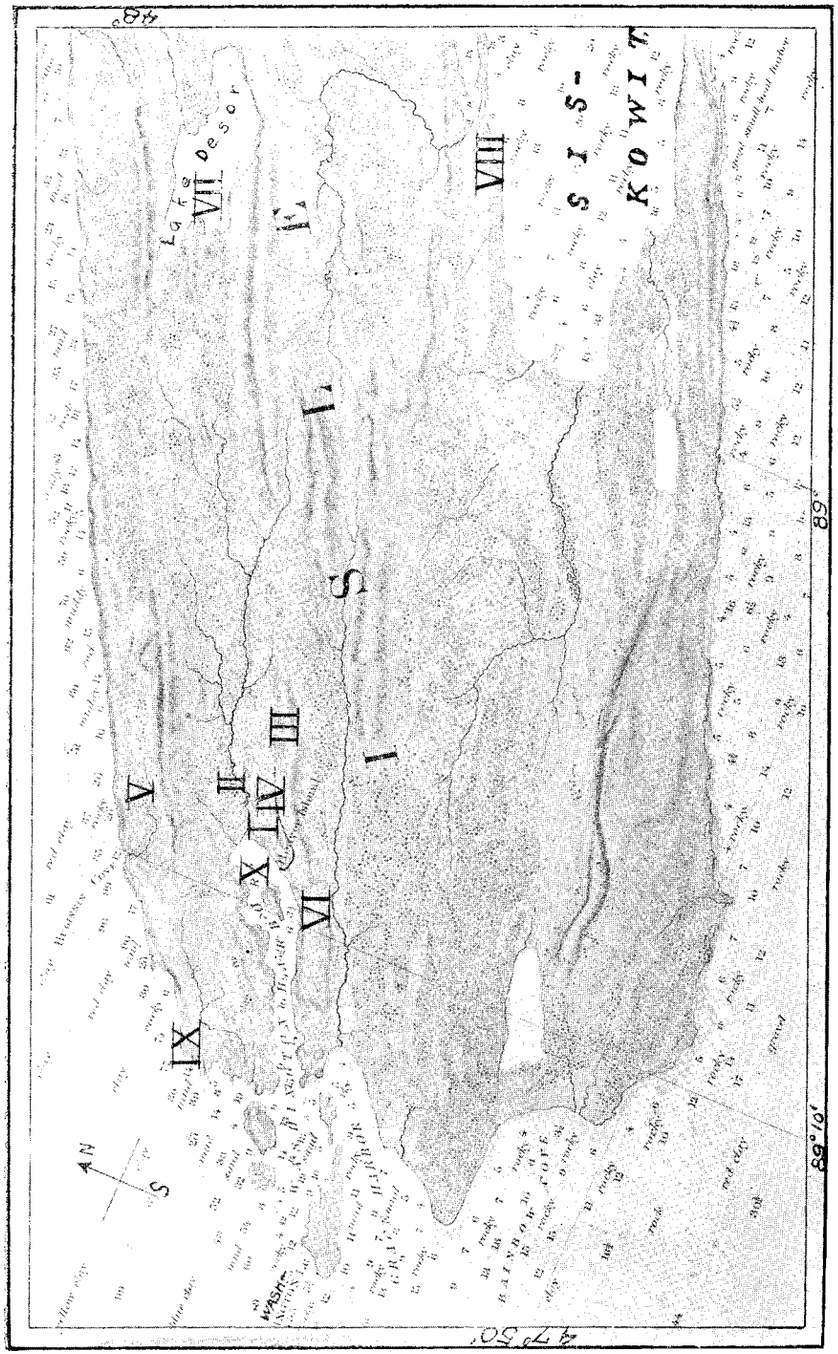

FIG. 21. Map of lower end of Isle Royale, showing the location of field stations. Scale, 2 miles to the inch. (From U. S. Lake Survey Chart).