TABLE NO. 2.—PORT ARTHUR, 1896–1905.

Rainfall.

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
1896	0.00	0.00	0.12	2.32	4.10	2.04	1.75	1.73	1.41	3.04	1.28	0.00	17.79
1897	0.57	0.00	0.00	0.64	2.06	3.39	6.53	4.05	1.12	1.44	0.57	0.00	20.97
1898	0.00	0.00	0.33	0.07	3.04	6.94	4.58	2.42	5.40	2.78	0.65	0.09	26.23
1899	0.00	0.00	0.00	2.57	3.40	3.84	3.52	3.76	3.65	1.79	1.34	0.78	24.65
1900	0.00	0.00	0.00	0.50	0.36	2.48	3.33	6.77	6.14	5.20	0.49	0.12	25.39
1901	0.00	0.00	0.00	1.57	0.95	3.76	6.24	2.92	1.98	2.47	0.38	0.00	20.27
1902	0.00	0.02	0.36	0.55	1.89	5.18	3.03	3.01	1.99	2.78	1.29	0.00	20.10
1903	0.00	0.00	0.14	0.23	3.14	1.60	3.29	1.97	5.56	2.61	0.27	0.00	18.81
1904	0.00	0.00	0.36	0.32	2.37	2.36	2.94	2.65	3.41	3.62	0.15	0.06	19.24
1905	0.00	0.00	0.88	0.69	2.14	2.36	7.33	1.30	4.58	2.27	2.29	0.00	23.84
Average	.057	*.002*	.22	.95	2.35	3.39	*4.25*	3.12	3.52	2.8	.87	.09	*21.73*
S. E. Michigan	*1.94*	2.16	2.42	2.27	*3.53*	3.19	2.68	2.38	2.30	2.73	2.88	2.03	*30.22*

Snowfall.

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

These climatic records are likely to mean little when taken by themselves, but when compared with the conditions found in the other extreme of the state, interesting relations become apparent. Transeau ('05 b, pp. 356-358) has summarized the temperature and precipitation means for certain localities in southeastern Michigan, and these means have been placed in the table with the Port Arthur data. The most striking difference (Table 1) is the much higher temperature throughout the year in southern Michigan; the mean July maximum is 71.9° as contrasted with 62.24° at Port Arthur; the annual mean is 47.2° as contrasted with 36.07° for Port Arthur. The northern mean is between the temperature of the maximum density of water (39.2°) and the freezing point. The precipitation presents almost equally striking differences. The rainfall instead of being largely confined to the summer months, as at Port

Arthur, is much more generally distributed throughout the year. The rainfall is also about ⅓ more in the south, the northern mean is 21.72 inches and the southern one 30.22 inches. In the north there is about 1/5 more snow than rainfall, 21.72 as contrasted with 25.44 inches; while in the south about ¼ more of the precipitation occurs as snow, 30.22 of rain as contrasted with 38.4 inches of snow. While in both regions the greater precipitation is in the form of snow, the longer growing season of the plants in the south makes more of this moisture available; but on the other hand, on account of the higher temperature, more is needed. While about one-half of the rainfall in both regions occurs during the growing season, yet the evaporation is much greater in the south so that the relative humidity is less when compared with the north. (Cf. Transeau, '05, a). It seems probable that the relative humidity of Isle Royale is greater than on the adjacent mainland on account of its insular location and imperfect drainage.

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

To one accustomed to the hot summers farther south, the cool summer of Isle Royale is very agreeable and invigorating. Moderately heavy clothing is needed for comfort except during the middle of the day when the heat at times is very oppressive. This was especially the case during our examinations of the rock ridges. Thus on July 10 on the Jack Pine Ridge (III, 5) the thermometer on a mat of Cladonia recorded 93° F. in the sun, while at the same time (2 P. M.) in the sun, but exposed to a cool breeze, it recorded 76° F. Such temperatures would not attract special attention were it not for the fact that usually the temperature is so much lower. The nights are very cool, and at Washington Harbor on Aug. 22 there was a frost in the valley along Washington Creek (II, '04). During our camp at the Light-house, when shore winds accompanied a storm, the temperature became so low that a fire in the evening was necessary for comfort. On July 15 there was a brisk east wind, with a mean temperature of about 50° so that the vapor of ones breath was visible all day. The lake breeze is at times very noticeable as one passes from Rock Harbor into the channel at Middle Islands. It is quite probable, as Jackson ('50, p. 420) suggests, that this cold lake air is a factor in the production of the stunted tree growth.

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

b. Seiches. The rapid and temporary changes of the water level in the harbors has been the basis of much comment. This was very marked at Tobin Harbor and at Washington Harbor. Its influence upon Washington Creek was quite marked, at times it would be ponded for some distance up stream while on other days it would be a briskly flowing

stream. Foster and Whitney ('50, p. 51) make the following comment upon these fluctuations at Rock Harbor; "While at Rock Harbor, Isle Royale, in the summer of 1847, we witnessed the ebbing and flowing of the water, recurring at intervals of fifteen or twenty minutes, during the entire afternoon. The variation was from twelve to eighteen inches; and we took advantage of their recession to catch some of the small lake fish which were left in the pools. The day was calm and clear but before the expiration of forty-eight hours a violent gale set in."

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

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

may have, as a rule, passed farther south than at present. If these suggestions are applied to the interpretation of the Glacial and post-Glacial history of Isle Royale, the general relations will be about as follows: Succeeding the disappearance of the ice was an arctic condition with short summers and long winters, prevailing westerly winds, and severe easterly or southeasterly moving storms. Such conditions as these would influence the direction of lake currents, wave action on the beaches, and the source and movement of the lake drift, all of which would greatly influence the biota.

If the Glacial and post-Glacial adjustment of the permanent lows was accompanied by severe storms, this would be a factor which would certainly influence the rate of formation and the distinctness of the beach lines, and it is not altogether improbable that a study of the well developed Nipissing beach, by the development of its spits and bars, may furnish data regarding the lake currents and the prevailing winds. But in order to interpret such records it will be necessary to formulate criteria by means of which duration of a beach formation may be distinguished from one of less duration but due to more severe storms and active currents.

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

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

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

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

Storms from the northwest are seldom severe; they are preceded by south or southwest winds, and after their passage the wind shifts to the west and northwest and rapidly diminishes in velocity. In winter the attending precipitation is generally light, in summer it is in the "form of thunder storms, and the high winds in squalls from the southwest

at the time the center of the storm is passing." To this class belong the majority of lake storms, but they are seldom severe.

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

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

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

e. *The Surface Currents of Lake Superior.* Mention has previously been made of the fact that in addition to the offshore winds from Canada, which accompany certain severe storms, there are other influences which have a similar effect upon drift—the lake currents. These are, in part, an expression of the same climatic trend and their direction is a resultant determined by the influence of the prevailing westerly

winds, the rotation of the earth, the form and contour of the basin, and the position of the outlet. A detailed investigation of these currents was made by Harrington and Conger (Harrington, '95) who paid particular attention to the currents about Isle Royale. As these investigations were made during the season of navigation, they are of particular interest from the standpoint of the biota, because it is during this same period that we must in general expect the most advantageous dispersal of plants and animals to take place.

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

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

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

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

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

depth of 100 feet. In other localities to the southward there is a marked difference between the surface and deep water temperatures.

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

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

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

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

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

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

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

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

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

depth of 100 feet. In other localities to the southward there is a marked difference between the surface and deep water temperatures.

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

these with the falling of the lake have migrated outward, as is suggested by the courses of the main streams occupying the rock valleys.

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

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

As the water continued to fall to lower levels, the land biota followed down the slopes behind the receding beach. By the Nipissing stage, the vegetation and many animals were probably well established and had begun to actively encroach upon the swamps and lakes and thus tended to increase the land habitat. With the tilting that followed the formation of the Nipissing beach, a readjustment must have taken place between the land and water habitats, but to what degree their relative areas were influenced is not known. During the initial elevation ponding would be expected at the northeastern end of the island, but with a greater elevation this same area would be well drained, as the divides in the valleys are low and the transverse drainage near the central part of

the island would tend to prevent extensive ponding, combined with the fact that the valleys extended in the same general direction as the uplift and not across it. It therefore appears that many processes have tended to increase the land habitats at the expense of the aquatic, such as the falling of the lake level, the encroachment of organic remains on the depressions, the perfecting of drainage lines and the tilting of the surface.

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

REFERENCES.

Bigelow, F. H.
1897. Storms, Storm Tracks, and Weather Forecasting, U. S. Dept. Agric., Weather Bureau, Bull. No. 20.

Chamberlin, T.C., and Salisbury, R. D.
1906. Geology. New York.

Coleman, A. P.
1906. Iron Ranges of Eastern Michipicoton. Report Can. Bureau of Mines for 1906, 15 (1), pp. 173-199.

Cooper, W. F.
1906. Geological Report on Bay County. Mich. Geol. Surv., Ann. Rep. for 1905, pp. 135-426.

Denison, F. N.
1898. The Great Lakes as a Sensitive Barometer. Rep. of the British Assoc. Adv. Science, 1897, pp. 567-568.

Fassig, O. L.
1899. Types of March Weather in the United States. Amer. Jour. of Sci. (4), 8, pp. 319-338.

Foster, J. W., and Whitney, J. D.
1850. Report on the Geology and Topography of a Portion of the Lake Superior Land District, in the State of Michigan. Ex. Doc., 1st Sess. 31st Cong., IX, Part 1. (Copper Lands.)
1851. Report on the Geology of the Lake Superior Land District. Part II, The Iron Region. Senate Doc. Spec'l S. 32nd Cong., Vol. 3.

Garriott, E. B.
1903. Storms of the Great Lakes. U. S. Dept. of Agr., Weather Bureau, Bull. K.

Gilman, H.
1873. The Caribou on Lake Superior. Amer. Nat., 7, p. 751.

Goldthwait, J. W.
1907. The Abandoned Shore Lines of Eastern Wisconsin. Bull. 17, Wis. Geol. and Nat. His. Survey.
1908. The Records of the Extinct Lakes. Ill. Geol. Survey, Bull. No. 7, pp. 54-68.

Harrington, M. W.
1895. Surface Currents of the Great Lakes, as Deduced from the movements of Bottle Papers during the Seasons of 1892, 1893 and 1894. U. S. Dept. of Agric., Weather Bureau, Bull. B, Revised Edition.
Hubbard, G. H., and Schwarz, E. A.
1878. List of Coleoptera in the Lake Superior Region. Trans. Amer. Phil. Soc., 17, pp. 627-666.
Jackson, C. T.
1849. Geological and Mineralogical Reports. Senate Ex. Doc., No. 1, 1st Sess. 31st Cong., 3, 371-935.
Lane, A. C.
1898. Geological Report on Isle Royale, Michigan. Mich. Geol. Survey, VI, Part I, pp. 1-281.
1900. Geological Report on Huron County, Michigan. Geol. Surv. Mich., 7, Pt. II.
Lawson, A. C.
1893. Sketch of the Coastal Topography of the North Side of Lake Superior, with Special Reference to the Abandoned Strands of Lake Warren. Twentieth Ann. Rep. Minn. Geol. and Nat. Hist. Survey for 1891.
Montgomery, T. H.
1906. The Analysis of Racial Descent in Animals. New York.
Penck, A.
1906. Climatic Features of the Pleistocene Ice Age. Geogr. Jour. 27, 182-187.
Ruthven, A. G.
1906. An Ecological Survey in the Porcupine Mountains and Isle Royale, Michigan. Mich. Geol. Survey, Ann. Rep. for 1905, pp. 17-55.
Ruthven, A. G., and Others.
1906. An Ecological Survey in Northern Michigan. Mich. Geol. Survey, Ann. Rep. for 1905, pp. 1-133.
Smith, S. I.
1874. Ann, Rep. U. S. Fish Comm. for 1872 and 1873. Pt. II. pp. 690-707.
Spencer, J. W.
1891. Deformation of the Algonquin Beach, and the Birth of Lake Huron. Amer. Jour. Sci. (3), 41, pp. 12-21.
Stupart, R. F.
1898. The Climate of Canada. Scottish Geogr. Jour., 14, 73-81.
Taylor, F. B.
1896. Preliminary Notes on Studies of the Great Lakes, Made in 1895. Amer. Geol., 17, 253-257.
1896. The Algonquin and Nipissing Beaches. Amer. Geol. 17, 397-400.
1897. Notes on the Abandoned Beaches of the North Coast of Lake Superior. Amer. Geol., 20, 111-128.
Transeau, E. N.
1905 a. Forest Centers of North America. Amer. Naturalist, 39, 879-889.
1905 b. The Bogs and Bog Flora of the Huron River Valley. Bot. Gazette, 40, 351-375.

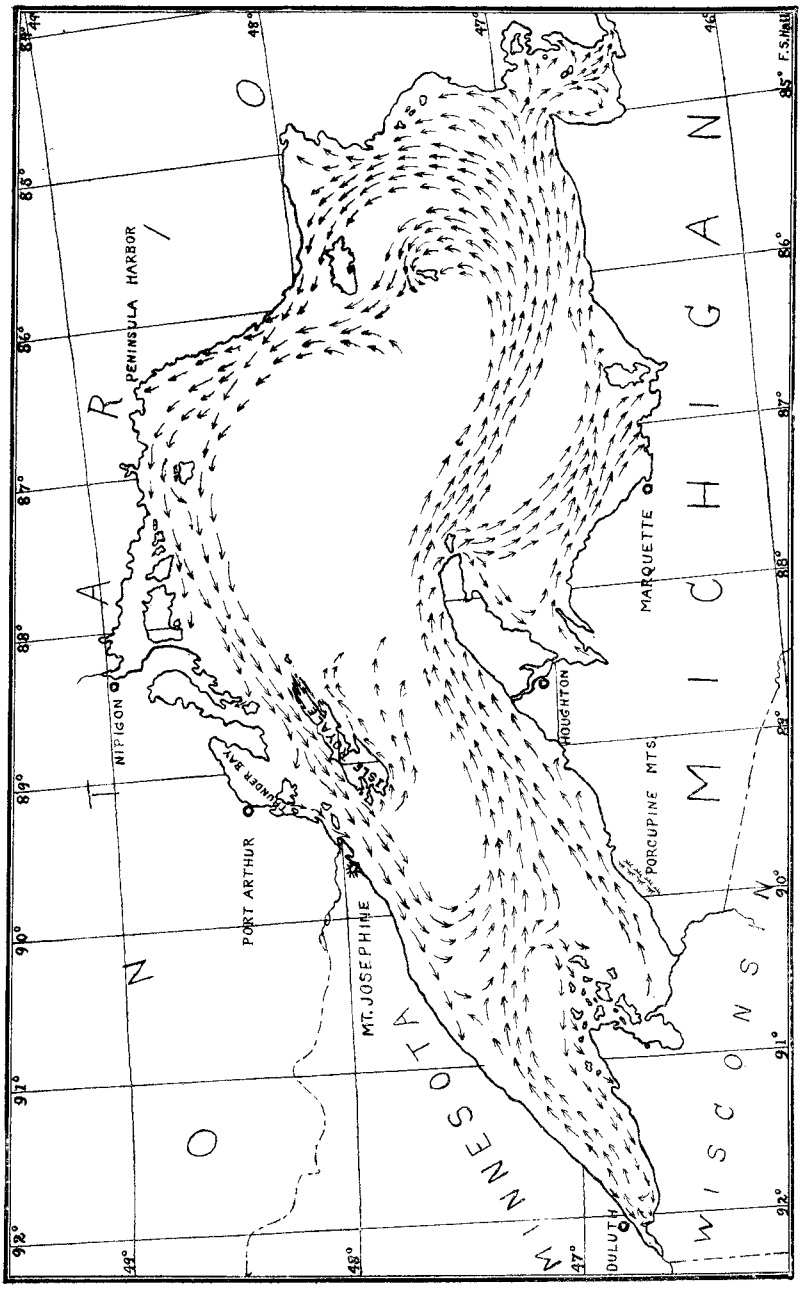


Fig. 55. Surface currents of Lake Superior. To show their possible influence on the origin of the biota. (Drawn by Hall, after Harrington.)

FIG. 56. "THE WENDIGO ROAD," FROM THE CLEARING AT THE CLUB-HOUSE TO WENDIGO, WASHINGTON HARBOR.

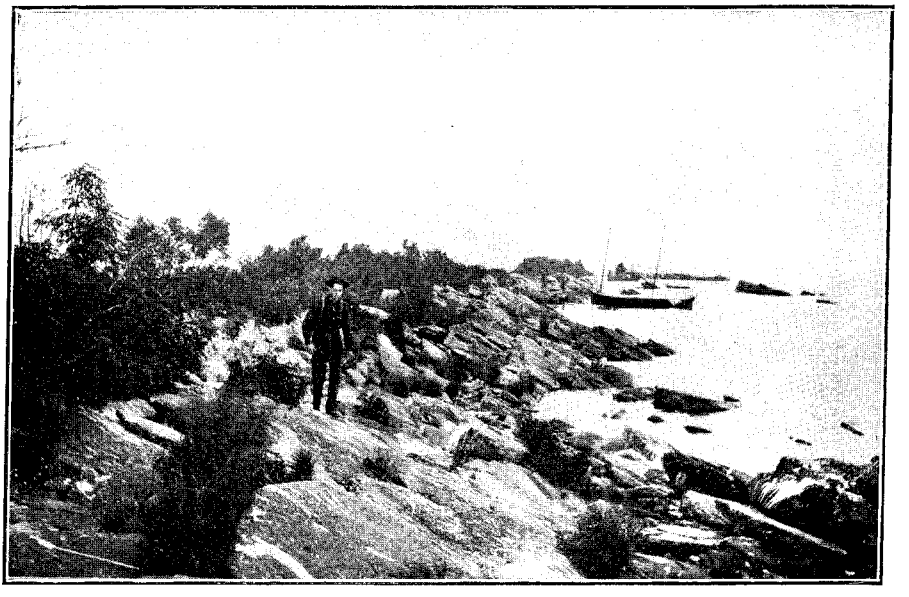


FIG. 57. LONG ISLAND (V. 10), SISKOWIT BAY, LOOKING TOWARD ISLE ROYALE LIGHT-HOUSE.

FIG. 58. GULL ROOKERY ON LONG ISLAND (V. 10), SHOWING HIDING INSTINCT OF GULL.

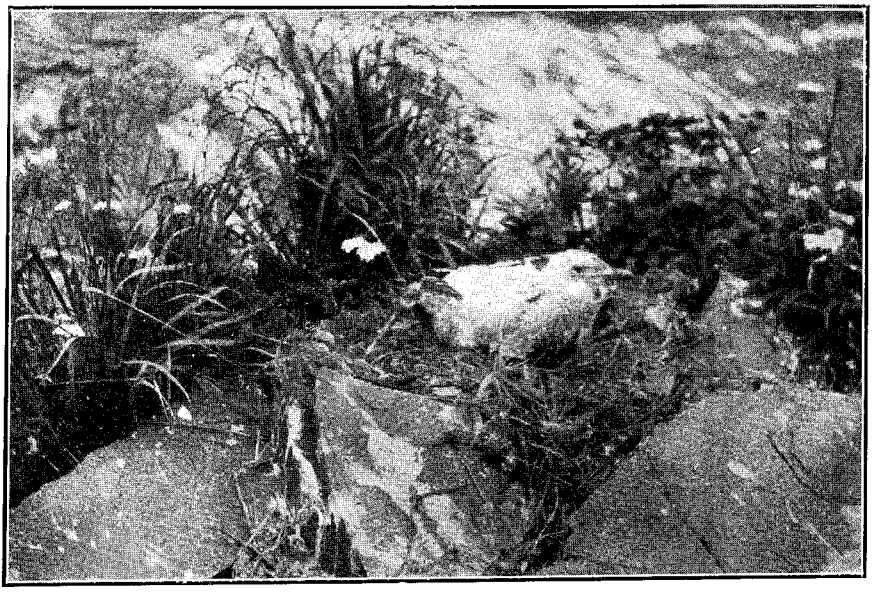


FIG. 59. GULL ROOKERY ON LONG ISLAND (V. 10).

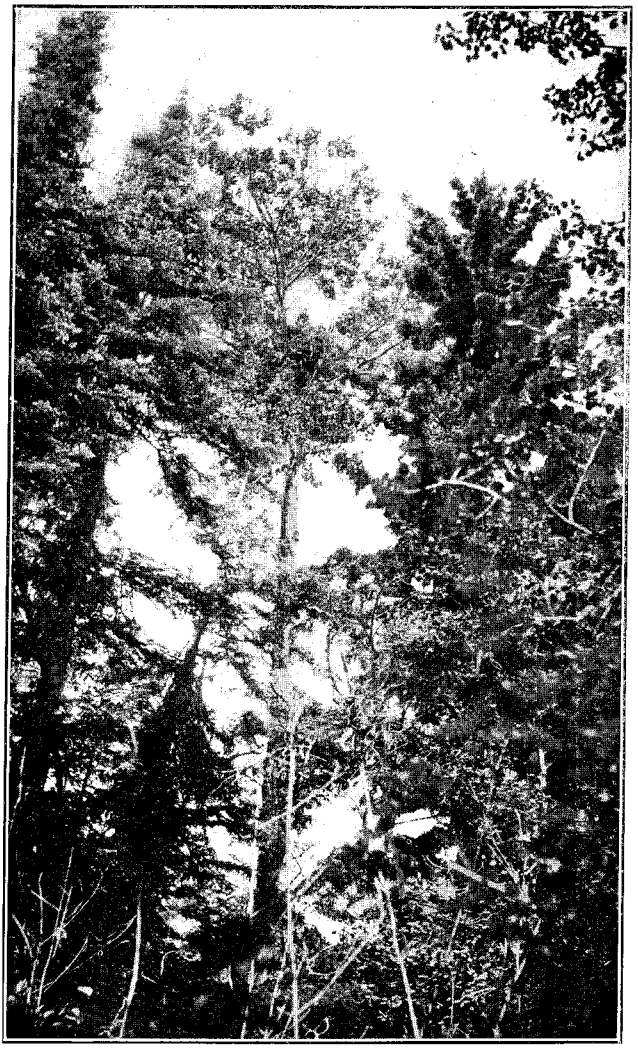


FIG. 60. EAGLE NEST AT TOBIN HARBOR (IV, S1).

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

BY DR. HENRY ALLAN GLEASON.

I. Introduction.

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

The preceding general statement rests on the assumption that the areas now occupied by the climax biotic associations have developed from the beach associations through a series of stages intermediate in time corresponding to those associations which now stand intermediate in space between the two extremes. Or briefly, as some ecologists have expressed it, the lateral distribution in space recapitulates the vertical distribution in time. Such an assumption is evidently closely akin to the recapitulation theory of the evolutionists, and just as that so-called biogenetic law has been accredited with more than its true value, so has this ecological dictum possibly much less importance than has been usually supposed. The weakness lies in too little consideration of the time element. It is certain that the higher land in Isle Royale has been submerged. This is shown by the old beach marks now many feet above the present level of the lake. Consequently by the gradual emergence all of the island has passed through a beach stage. But it is unwarranted to conclude from this that the faunal or floral associations of the former beach were similar to those of the present, or that in the intermediate stages the biota resembled that which now occupies the area between the ancient beach and the present shore. While it is likewise certain that with a continued subsidence of the lake level the present beaches will eventually be left far above the water, it must not therefore be assumed that their biota will show the same successions or reach the same climax as those of the past. Changes in the tempera-

ture or rainfall may certainly keep pace with the changes in lake level, or even be caused by it, and in either case they would exert a profound influence on the biota. Migration of species is still taking place among both plants and animals, and may introduce new or even dominating species among the present forms. The so-called equatorial pressure of southern species is fully as strong now as it was directly after the close of the glacial epoch. Lastly, and most important of all, the influence of the biota itself is always to be reckoned with. Both plants and animals are continually becoming more plastic, adapting themselves to new conditions, and extending their habitats into new associations. They push forward more rapidly than the changes in physiography, sometimes hastening and sometimes retarding physiographical action, and at all times greatly influencing the subsequent successions.

A biotic association may develop into another by a mere re-arrangement of the interrelations, numerical or otherwise, of the component species, without the necessary loss of some or addition of others. But such cases are rare, and the Isle Royale observations show that no two associations have exactly the same species, and that with each progression there has been an addition of certain forms which become the most characteristic types. The first bit of beach formed was occupied by an association possibly not unlike that of the present beaches. All the species must evidently have immigrated from beyond the island. When the soil deposits on the beach were sufficient to support a second association its species were derived partly from the beach itself and partly from new immigrants. The further development of biotic associations on the beach was then possible not only from immigrants, but also from the two associations already present. Similarly at the present time each association on the island is constantly being invaded by species from all the others, and many of them are actually able to establish themselves. This tends toward a homogeneity in the biota hardly in full accordance with the recapitulation idea. Indeed, it is very probable that independently of all physiographic agencies the whole surface of the island would eventually be occupied by the balsam-spruce forest and its attendant faunal association.

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

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

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

II. The Lake.

The lake (Superior) must obviously be regarded as the first stage in the genetic development of the faunal associations. Broadly speaking, the lake fauna is divisible into two main groups. The first is pelagic in

character and includes those species whose distribution is entirely independent of the shore, for example, most of the species of fish. The second group is littoral; the species occur along the shore in comparatively shallow water, and are to a greater or less extent dependent upon the land in its relation to the character and slope of the bottom and to the motion of the water. Members of the latter group only are considered here.

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

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

In the larger inland lakes, of which Siskowit Lake, the only one of the class studied, may be taken as an example, essentially the same conditions obtain as on Lake Superior itself. The difference in temperature and content of the water seems to be of minor importance. The waves in the larger lake can naturally reach a larger size, and their influence is felt far into the bays. Thus at the head of Rock Harbor, about six kilometers from the lake proper, the distribution of shells and the almost total absence of free forms indicate that even there wave action is of importance. In Siskowit Lake, although larger than Rock Harbor the force of the waves is so reduced by every headland or island that on the quiet water in their shelter a rich fauna of such free forms as

water-striders and whirligig beetles is found on the surface, while numerous mussel shells live on the silt or sand bottom. In Sumner Lake and others of limited area the motion of the water has no measurable effect on the biota, and they will therefore be treated under a separate heading.

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

Tonkin Bay is a small inlet about half a kilometer long, opening to the east upon the lake, and with steep, approximately parallel sides. It is narrowed half way up by two beaches lying perpendicular to its length. By this the wave action on the upper part is reduced, but still may sometimes be sufficient to wash heavy drift-wood upon the beach. In the outer half the wave action is but slightly less than on the lake itself, and no shells are found. In the inner or upper half *Limnaea stagnalis* L. (Nos. 50, 54, 57), *Limnaea emarginata* Say (Nos. 50, 57), and *Physa sayii* (Tap.) (Nos. 50, 57), live along both sides where the bottom is rock, but not across the ends. They live only on a rock substratum, which may be either horizontal or vertical, and in water up to 45 cm. in depth. The larger species, *Limnaea stagnalis*, is more abundant in the deeper water, and only the smaller species live at a depth less than 15 cm. They then prefer the vertical walls to the horizontal or flat bottom.

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

Siskowit Lake, with its rocky shores and large area, offers essentially the same condition as Lake Superior itself, and the shells have the same general distribution. Along the very gently sloping rocky shore near the outlet *Limnaea stagnalis* occurs in abundance, always at a depth

of 10-40 cm. Along the south side of a large island near the south shore, where they are sheltered from waves in every direction, the same species is abundant. They live on rocks in the full sun in water 10—45 cm. deep, with the optimum depth at 20—25 cm. They may occur on the tops or sides of rocks, but never on the sand between them. Associated with the *Limnaea*, but much less abundant, are *Planorbis bicarinatus royalensis* Walker (No. 210), *P. campanulatus* Say (Nos. 210, 211), *Lampsilis luteolus* (Lam.) (Nos. 210, 211), *Anodonta marginata* Say (No. 210), and *Anodonta grandis footiana* Lea (Nos. 210, 211).

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

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

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

hardly account for 60 of the smaller ones, however, appearing in so short a space of time. It may be taken as indicating a general and continued migration in all directions within their bathytropic limits.

It was noticeable that the large *Limnaea emarginata* and *Limnaea stagnalis*, aside from the one specimen mentioned above, live at an average depth of 3 dm. and never deeper than 4.5 or 5 dm. To test their bathytropism six of them were picked out of the deeper water by hand and held in contact with the bottom in the shallow zone until they extended their feet and attached themselves. At this time the water was very quiet, moving just enough to cause a faint sound on the beach. But the size of the shell of the two *Limnaeas* is so large that they offer considerable surface to the water and are consequently easily washed loose. Two of the six swung a little from side to side and were then washed off and carried by the undertow into water 3 dm. deep, where they again attached themselves. A third, without being shaken by the waves, clung to the rock for some time, then suddenly let go its hold and drifted over a low ledge into the deeper water. Two others immediately started to crawl down the slope, and one in about fifteen minutes, the other in about half an hour, had crawled over the ledge into water 3 dm. deep, where they both remained stationary. The sixth remained attached, and in three hours had crawled 2 dm. parallel to the shore, keeping at the same depth. The next morning, twelve hours later, it had disappeared, and of course could not be recognized in the deeper water.

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

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

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

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

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

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

But two species of insects were collected which should properly be considered here, caddice flies and stone flies. The larva cases of the caddice flies were collected only in the outlet of a small stream emptying into Rock Harbor, in 1—1.5 m. of water (No. 163 or

164), but the imagos were common all along the shore of the lake, especially on the gravel beaches. One (No. 192) was taken on the boat about 2 km. off the south shore of the island. Stone flies were also frequently collected along the beaches, where they came up to breed. They were most numerous, however, on steep or even vertical cliffs with southern exposure (Nos. 24, 80). Near the entrance to Conglomerate Bay (*Fig. 2*) they were seen collected in such a place by thousands. The water there was at least 4 m. deep.

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

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

III. The Inland Lake.

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

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

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

At the upper end of Rock Harbor some small shells, *Planorbis bicarinatus* Say (89), *Planorbis exacutus* say (89), *Planorbis parvus* Say (89, 163, 164), *Valvata tricarinata* Say (89, 163), *Valvata sincera ny-*

landeri Dall (89, 163, 164), *Amnicola lustrica* Pils. (89, 163, 164), and *Pisidium* sp. (163, 164), and Amphipods were dredged from a depth of 1.5 to 2 meters near the mouth of a small stream (*Fig. 22*) where the bottom was thickly covered with small twigs and other coarse vegetable debris. From the same place the caddice fly larvae were obtained, as mentioned previously. The same fauna was collected in the stream itself, but only near the mouth, where the water was deep, the current slow, and the conditions in general much like those of a lake. May flies probably breed in similar places. No larvae were seen, but a few imagos were collected (No. 178).

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

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

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

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

The inland lakes may be regarded as small detached portions of the main lake, cut off from it by the lowering of the level of the latter. Since they are composed of stagnant water with little or no wave action, where organic material may accumulate in quantity, they support a

different fauna and their genetic development is along a different line, culminating however in the climax type or balsam-spruce forest. The only intervening stage is the tamarack swamp.

IV. The Tamarack and Arbor Vitae Swamps.

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

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

As the swamps become older the water is limited to small shallow pools, seldom more than one decimeter deep or three or four decimeters wide. Their bottoms are covered with dead leaves and sphagnum, and they are usually densely shaded by the forest growth above. In them are found small bivalves, *Pisidium affine* Sterki (77A, 79A), *P. subrotundum* Sterki (116, 181, 182, 237), *P. subrotundum* Prime (116, 237), and water beetles, *Haliplus ruficollis* Deg. (No. 116, I-4) and *Scutopterus hornii* Cr. (No. 181, 144). The latter is restricted, so far as observed, to this single habitat in the pools in tamarack and arbor vitae swamps. Dragonflies are the principal aerial insects, but are not abundant. A fly (No. 240, V-5) was taken on the flowers of *Solidago neglecta.*

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

as *Formica dryas* Wheeler, suggesting a possible confusion of the numbers. No other insects were observed except the omnipresent black-flies and mosquitoes.

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

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

In connection with the swamps must be mentioned the fauna of the small rapidly flowing streams leading out of the inland lakes. The bottom is usually rock or gravel, and the swift current prevents the accumulation of organic debris. In Benson Brook on the north side of Rock Harbor in still, deeply shaded places were dredged up (No. 149) *Pallifera dorsalis* (Binn.), *Pyramidula alternata* (Say), *Pyramidula striatella* (Anth.), *Zonitoides exiguus* (Stimp.) and *Physa* sp. In the outlet from Siskowit Lake, in small pools 5-15 cm. deep with a bottom of slime covered with loose pebbles, were collected several shells (No. 238), *Physa* sp., *Pisidium medianum* Sterki, *P. subrotundum* Sterki, and *Musculium securis* (Prime). The current where these were collected was very slow. In the more swiftly flowing water nothing could be found.

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

V. The Gravel and Sand Beaches.

The gravel beaches are found in but certain places along the shore (*Fig. 1*), where the slope of the banks and the action of the waves permit the formation of the gravel deposits. Optimal conditions are found at the heads of the numerous inlets or coves; such as Conglomerate Bay (*Fig. 4*), and Tonkin Bay, already described, and many other similar places. They also occur, however, along the shore of the lake itself, where the wave action is at its minimum. Their distribution appears to be controlled principally by the slope of the bottom, since the gravel could not be piled up on slopes of too steep pitch, and they are almost

invariably in locations so bounded by rocks or shore that the waves strike them always in one direction. An instance of this was seen near the light-house. A small inlet about 5 m. in length and width opened towards an island. Waves struck it in two directions, both diagonally, but rebounding from the rocks continued into the inlet in one direction. At its back was a small but typical beach, the only one in the immediate vicinity and likewise the only spot where the waves always came in the same direction. As a consequence of this directive action the beaches always lie at right angles to the direction of wave action.

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

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

Caddice flies are rather common running about over the finer gravel just above the reach of the waves, or sometimes taking short flights (No. 10). Stoneflies are associated with them; they crawl about actively over the wet gravel near the water's edge and do not attempt to fly. They are frequently struck by waves which merely wash them a little farther up the bank. A few species of ants are also common, running over and through the gravel (No. 38). They prey on dead caddice flies or even on live ones when they succeed in capturing them. The most characteristic group, however, consists of several species of spiders, which are found in great abundance on the coarser gravel in the sun (Nos. 16, 25, 38, 39, 60), *Lycosa pratensis* Emer., *Pardosa lapidicina* Emer., *Pardosa groenlandica* Thor., *Ebo latithorax* Keys. They run with great rapidity and at the least alarm crawl under the rocks, where it is almost impossible to find them. After the first alarm they usually show themselves in 10 to 15 seconds, but being frightened again, they crawl for some distance under the gravel and are lost permanently. Many of them carry egg cases, and if forced to drop them they spin a web which they follow back in a short time. These spiders are very numerous, probably 10 or 12 to every square metre over all the gravel beaches.

Other insects observed were, a small beetle (38) crawling over the sandiest part of the beach; two species of small beetles (39) crawling through the coarse sand and fine gravel at the water's edge; a click beetle, *Corymbites medianus* Germ. (41) crawling over sand in a shaded place near a rock cliff; a Scarabaeid, *Serica vespertina* Gill. (43); a beetle, *Macropogon rufipes* Horn (60). Some fish worms (40) were also found buried 3 dm. deep in moist coarse sand under the gravel beach in front of the light-house. They were above the level of the ground water. Butterflies and wasps, which were so abundant on the

sand beaches, were collected but once. The butterfly, *Pyrameis cardui* Linn. (39) flew out of the woods, rested a moment on the gravel, and then visited a dogwood flower. The single wasp (41), *Ammophila* sp., was seen flying low over a small area of sand near the water's edge on a gravelly beach.

Some fossil beaches were observed, rising several meters above the lake. The gravel was then thinly covered with lichens, and in some cases even supported a scanty growth of flowering plants. A beetle, (37) *Leptura chrysocoma* Kby., was collected on a rose in such a place.

The contents of the drift washed up on the beaches is of some interest as indicating a possible way in which new forms might reach the island. Here were found *Limnaea stagnalis* (19); a dead butterfly, *Anosia plexippus* Linn., (19); some dead ladybugs, *Anatis 13-punctata* Oliv. (21); shells (21); butterflies (21); one snail shell, *Polygyra albolabris* (Say), badly broken but still containing part of the body (39). The vegetable drift (18, 21) included cones or fruits of jack pine, balsam, arbor vitae, and alder.

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

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

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

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

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

or two species of flies (No. 31) (*Cynomyia cadaverina* Desv.) were also common.

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

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

VI. The Rock Beach.

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

Rising directly from the water they are naturally exposed to the full force of the waves, (*Fig. 3*), which dash upon them to a considerable height, washing away all loose particles and effectually preventing even the most meager formation of soil. Beyond the reach of the waves, rains and drainage water act with greater or less effect in the same way. The vegetation is therefore limited to various species of crustaceous or foliaceous lichens, which are true lithophytes. Even they are absent from the lower portions where the wave action is more continued, and especially where the ice may scrape them off. Higher up the procumbent juniper and *Cladonia* appear and the whole eventually merges into the *Cladonia* clearing to be described next. Some idea of the zonal succession of the different plants may be gained from the following table, showing the heights of the different zones on a rock beach near the Rock Harbor light-house, *Figs. 6 and 7.*

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

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

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

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

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

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

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

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

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

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

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

VII. The Cladonia Clearing and Jack Pine Ridges.

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

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

1. *Subterranean Fauna.* In the shallow depressions and crevices of the rock (*Figs. 7, 25, 26*), are thin soil deposits supporting a dense growth of various plants, especially the Cladonia lichens, the bearberry, and dwarf juniper. Ants are frequent, running over the surface and excavating below it, but they make their nests only in the deeper crevices or under the densest growth of plants where the depth of soil is sufficient to allow them to make their excavations and to conserve the moisture supply. In the crevices they are usually 1 dm. or more below the surface. *Camponotus herculeanus* L. (22), *Myrmica rubra* L. (61), and *Leptothorax canadensis* Prov. (63) are the species generally represented. The nests are more frequent near the margin of the rock clearings,

where the soil is better shaded. A nest of *Formica sanguinea* Latr. (No. 72) was placed under a decaying limb, and the soil beneath it was largely composed of minute fragments of rotten wood. This ant has two sorts of pupa cases. Another colony, *Leptothorax canadensis* Prov. (No. 77), was also collected in Cladonia clearings.

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

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

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

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

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

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

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

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

The butterflies, *Basilarchia arthemis* Dru. and *Argynnis atlantis* Edw., are so characteristic of these clearings that we knew them by the common name of "clearing" butterflies. The blackflies are abundant, and are preyed upon by dragonflies, probably the chief reason for the occurrence of them so far from the swamps.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

nests may be built at less depth, as one of *Formica fusca* L. (No. 100) at a depth of 4 cm. These loose rocks tend to conserve the moisture just as do the crevices.

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

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

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

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

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

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

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

VIII. The Balsam-Spruce Forest.

The ultimate tendency of all plant associations on Isle Royale is toward the balsam-spruce forest. The succession is sometimes direct, sometimes indirect; sometimes rapid, as upon the smaller Cladonia

clearings; sometimes slow, as upon the jack-pine ridges. Just as all temporary plant associations are occupied by definite faunas of a composition largely dependent on the plant covering, so the climax association of plants is also accompanied by a definite fauna, which must likewise be regarded as the climax animal association.

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

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

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

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

A few species of flying insects occur, especially mosquitoes, and when

the fresh mould is turned over a few of the moisture-loving flies, *Hydrophorus philombrius* Wheeler, appear and rest on the moist exposed surface.

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

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

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

IX. Artificial Clearings.

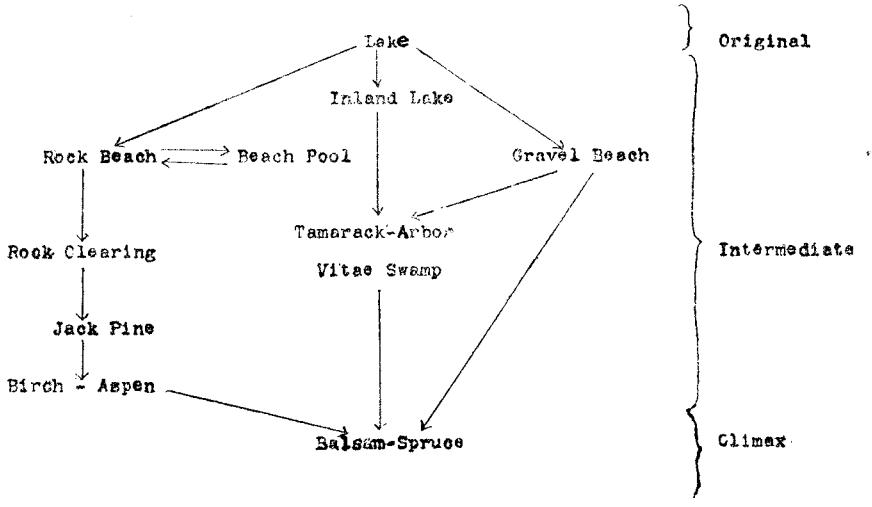
The clearing about the camps both at Rock Harbor and at Siskowit Bay attracted many species of insects, particularly strong fliers, such as Hymenoptera, Lepidoptera and Diptera. At Rock Harbor Cow-parsnip, *Heracleum lanatum,* introduced in the island some way, was in bloom and it attracted a number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

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

X. Summary.

From the lake, representing the most primitive habitat, there are three lines of development culminating in the climax association: first,

through the tamarack swamp and peat bog; second, through the gravel beach and arbor vitae swamp; third, through the rock beach and Cladonia clearings. Physiographic forces have some direct part in causing the successive changes in ecological factors, but most of them are due to the retroaction of the vegetation upon the habitat. The first stages of the series are marked by a severity of conditions which limit the fauna to a few well adapted species. The intermediate stages have generally a wide variety of conditions, leading to the development of a varied fauna. The most noteworthy in this respect is the fauna of the Cladonia clearings. The ultimate or climax stage is homogeneous because of the dominance of a few species, and the fauna is again limited to a few well adapted species.



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

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I. INTRODUCTION.

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

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

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

1. Light-house Peninsula.
2. Trail to McCargoe Cove.
3. West End of Rock Harbor and Trail to Summer Lake.
4. Siskowit Bay Region.

II. LIGHT-HOUSE PENINSULA.

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

1. Lake Superior and Beach (Station I, 1).
2. Spruce and Balsam Forest (Station I, 2 and 3).
3. Tamarack and Arbor Vitæ Swamps (Station I, 4).
4. Jack Pine Ridge (Station I, 5).
5. Sphagnum and Spruce Bog (Station I, 6).
6. Valley at Head of Conglomerate Bay (Station I, 1).

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

This station included the whole of Tonkin and Conglomerate Bays and that portion of Lake Superior and Rock Harbor which could be seen from the light-house. The water was deep, cold and contained very little vegetation. The shore bordering the lake was composed of jagged, desolate, wave-washed rocks (Figs 2, 5), and only in the

most protected portions of the bays and harbors were trees found growing near the edge of the water (Fig 4). This accounts for the fact that no shore birds or vegetable feeding water fowl were observed here.

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

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

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

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

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

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

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

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

The birds found under these conditions were as follows: Red-breasted Nuthatch, Chipping Sparrow, Nashville Warbler, Black-throated Blue Warbler, Black-throated Green Warbler, Chickadee, Flicker, Golden-crowned Kinglet, Bay-breasted Warbler, Crow, Myrtle Warbler, Sparrow Hawk, Magnolia Warbler, Wilson's Thrush, Olive-backed

Thrush, Pine Siskin, Purple Finch, White-throated Sparrow, Tree Swallow, Barn Swallow, Sharp-shinned Hawk and White-winged Crossbill.

The Purple Finch, Pine Siskin, Sparrow Hawk, Sharp-shinned Hawk, Bay-breasted Warbler, Black-throated Blue Warbler, Tree Swallow and Barn Swallow were only occasionally seen.

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

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

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

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

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

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

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

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

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

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

These two birds acted very differently when one was near their nest. The Black-throated Green would come within less than ten feet of the observer and scold while moving restlessly about among the branches. The Nashville Warbler was not as bold, for it remained up in the tree tops. It would hop on a branch, turn around a few times, turn anxiously toward the nest and then repeat the performance; but it never uttered a sound. Here was one of the difficulties in judging what localities birds preferred. These two birds nested on the slope of a rock ridge and fed in a cedar and tamarack swamp. To which did they belong? However, judging from other observations, I would say that if the natural clearing had not been here the Nashville Warbler would not have been found, while the Black-throated Green might have been.

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

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

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

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

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

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

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

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

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

III. TRIAL TO MCCARGOE COVE.

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

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

1. Ransom Clearing (Station II, 1).

This small clearing on the lowland at the mouth of Benson Brook was covered with grass and large clumps of alders, birches and aspens. These bushes scattered through the clearing formed an excellent habitat for birds, and, although the clearing was small, thirteen species were observed here. They were as follows: Black-billed Cuckoo, Canada Jay,

Song Sparrow, Alder Flycatcher, White-throated Sparrow, Redstart, Red-eyed Vireo, Cedar Waxwing, Wilson's Thrush, Olive-backed Thrush, Sparrow Hawk, Purple Finch and Pine Siskin.

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

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

2. *Benson Brook (Station II, 1).*

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

2. Small Islands (Station III, 1).

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

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

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

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

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

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

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

a. Birch Forest.

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

b. Birch and Coniferous Forest.

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

5. Sumner Lake (Station III, 5).

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

Many White-throated Sparrows were heard in the forest near the marsh, and at the foot of one of the alder bushes near the edge a nest was found hidden in a bunch of grass growing around the bush. Here in a well built nest of grass were two nearly fledged young (July 18). On the same day another nest of this bird was found on the other side of the lake, in a position similar to the one described above, but instead

of young it contained four bluish white eggs densely and irregularly variegated with brown. Out in the marsh a Bittern was flushed from the grass, and near by a deserted nest containing a bad egg and the bones of two young was found. This nest was only a depression in the tangled mat of grass in which it was situated.

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

V. SISKOWIT BAY REGION.

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

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

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

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

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

The conditions at this place were about the same as those at Rock Harbor, and almost the same species of birds were seen. Those seen here were: Herring Gull, Loon, Scaup Duck, Solitary Sandpiper, Spotted Sandpiper, Kingfisher, American Merganser and Osprey.

I cannot say with any certainty how many of these birds bred in this vicinity, but the Gull and Merganser did, as a female Merganser with a flock of very small young was seen several times, and the Herring Gulls bred on the Islands south of the bay. The Loon, Kingfisher and Spotted Sandpiper were observed nearly every day. The Solitary Sandpiper was seen only once, on August 16.

On August 8 four young Gulls were obtained from a fisherman, and

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

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

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

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

The nests of only two birds were found here, the Chickadee and Golden-crowned Kinglet. The Chickadee's nest was in a dead birch tree about ten feet from the ground, and contained four young which were able to leave the nest August 11. The Kinglet's nest was in a spruce tree about thirty feet from the ground. Both old birds were observed carrying insects into the tree, but the top was so thick that the nest could not be seen from the ground. On August 16 the young birds were still in the nest.

The Nashville Warbler, Olive-backed Thrush, Junco, White-throated Sparrow and Chipping Sparrow frequented partial clearings or clearings in the breeding season but were found in the forests in the second week in August. On August 11 a flock of birds were seen feeding in the top of a tall tamarack. They were mistaken for warblers but on shooting one to identify it, it was found to be a Chipping Sparrow.

3. *Siskowit Lake (Station V, 6).*

This Lake was six miles long and about two miles wide at the widest part. The shores were mostly rocky, and trees grew down nearly to the waters edge. The birds found here were: Herring Gull, Osprey, Eagle, Spotted Sandpiper, American Merganser, Loon, and Kingfisher.

The Song Sparrow and Grinnel's Water Thrush were also seen along the shore.

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

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

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

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

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

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

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

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

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

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

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

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

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

XI. Summary.

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

1. *Water Birds.* The water birds found on the harbors and small lakes were the Herring Gull, Loon, American Merganser, and Hooded Merganser. Of these birds the Herring Gull was the most abundant species and could always be seen on Lake Superior and quite often on the smaller lakes on the island. The American Merganser probably ranked second in abundance. The Loon was quite numerous, and at first it seemed as if they were more abundant that the Merganser, but in time it became evident that the Merganser was the more numerous, though much less conspicuous, as they did not make any noise, while the Loon is very noisy and can often be heard a mile away. The Merganser frequented the bays, harbors and larger inland lakes. The Loon was seen very often on the larger bodies of water, but seemed to

prefer the smaller lakes more than the other water birds, as every little lake contained a pair of Loons. Young Mergansers and Gulls were often seen, but, strange as it may appear, young Loons were only seen once, August 10.

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

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

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

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

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

3. *Birds Frequenting Swamps.* The characteristic birds of the tamarack-spruce swamps were the Cedar Waxwing, Chickadee, Red-breasted Nuthatch, Golden-crowned Kinglet, White-winged Crossbill, Canada Jay, Nashville Warbler and White-throated Sparrow. Probably none of these birds were found here simply because it was a swamp, for all frequented other localities. The White-throated Sparrow, Cedar Waxwing, and Nashville Warbler are characteristic of partial clearings, and this was really a partial clearing because the trees were so far apart. The White-winged Crossbill, Red-breasted Nuthatch and Golden-crowned Kinglet are characteristic of coniferous forests, and as the trees in the swamp were nearly all coniferous trees, this would therefore be their natural habitat. The White-winged Crossbill feeds on the seeds of the tamarack trees, and during the first few weeks of July it was only seen where there were tamarack trees; during the latter part of July, when the seeds of the spruce became more mature, they were seen many times in the spruce and balsam forests.

The seeds of the tamarack mature quicker than the spruce, hence the Crossbills would prefer the tamaracks during the earlier part of the summer. The Black-throated Green Warbler was characteristic of forests where there were a number of large birch trees, and this bird was only seen in those swamps which had several of these trees around the edge. Indeed the only true swamp bird seen here was the Marsh Hawk, and that was only seen once.

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

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

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

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

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

THE FALL MIGRATION OF BIRDS AT WASHINGTON HARBOR, ISLE ROYALE, IN 1905.

BY MAX MINOR PEET.

I. INTRODUCTION.

Our observations of the fall migrations of birds at Washington Harbor extended over the period from August 18 to September 22. A hasty examination was made of the bird life here before migration had really set in (August 5 to 8), and the observations gathered at this time, together with the records obtained the previous year, gave us an insight into the conditions existing there. This was important, as migration had commenced while we were still at Siskowit Bay.

Isle Royale is situated about fifteen miles from the north shore of Lake Superior, and lies nearly northeast by southwest. Situated as it is several miles from the north shore and with an unbroken stretch of water 100 miles across lying south of it, the island makes an excellent point for the migrants to stop before crossing the lake. The birds seemed to center at Washington Harbor as if focussed there from the north shore, and in all probability the birds observed there represented the avian life of many square miles on the mainland. Records were kept of the species seen each day and are given in tabulated form at the end of this paper.

II. THE ENVIRONMENT.

1. *The Clearing.* Under the head of clearings, we include the three artificial clearings and the narrow roads connecting them. The first of these was situated on the shore of Washington Harbor, near its head and close to the mouth of Washington River. The trees had been entirely cleared away over an area of several acres, making a rectangular clearing which had been seeded to timothy and short grasses. The waves had cut away the soil along the shore leaving a nearly vertical bank two or three feet high, in some places overhanging the water. The land gradually rises from the water's edge, more rapidly at the southern end where a low bluff is formed. On this bluff the Club-house stands, and below, nearer the lake, is a little group of four small houses, the largest of which we used as a camp. Other buildings were also located in this clearing. Part of the clearing was overgrown with brush and small trees. These had been burned and the debris left where it fell. Many small bushes, weeds, and vines sprang up among the fallen logs and branches, forming on ideal retreat for the smaller birds such as warblers and sparrows. The rank growth of the vegetation made it almost impossible to penetrate any distance into it. Here the Lincoln Sparrows were most abundant during their migration. As the soil was very shallow, the timothy grew short and scattering, and probably furnished little protection for the birds, as it was cut

about the middle of August. Near the road leading to the second clearing to the north was a small spot cleared for a garden. This bare ground was the favorite feeding place of the Horned Larks. On the short, steep slope which skirted the road to the second clearing, thirty or forty stumps had been left. These were the favorite perches for the Sparrow and Sharp-shinned Hawks, and the tops of many of them were covered with the harder portions of grasshoppers, these insects forming one of the principal foods of these birds. Three narrow roads or trails left this clearing, one to the second clearing, one to the head of Siskowit Bay, and the third to Lake Desor. The first of these was kept open and had originally been much wider than at present, being narrowed by a fringe of alders, birches, and small bushes together with young balsams and spruces.

The second clearing, consisting of 3 acres, was divided into two parts, a grassy tract and a garden in which potatoes, carrots, etc., were grown. From this a road (*Fig. 56*) led to the third clearing, called Wendigo, which was about the same size, and contained two old log houses and two or three decaying sheds. Few of the stumps had been removed and hawks used them as perches. The ground was overgrown with short, nearly dead grass. White-footed mice were abundant in these clearings after nightfall, and many Northern Hares were seen along the roads just at dusk. A narrow road wound past the clearing and off along the base of the bluffs for a mile or more to several abandoned cuts made by the old mining company. It was along these roads, which ran approximately north-east and south-west, that the bulk of the migrants passed. Even during the heavy migration comparatively few birds were observed in the dense forests, although many passed along the river. It has been generally noticed that many birds, the smaller migrants in particular, as the sparrows and warblers, prefer the borders of clearings, and a long narrow road through heavy timber and bordered by bushes and small trees, appeared to be an ideal place for them. All the clearings were surrounded by the dense, coniferous forest except the first which fronted on the lake.

2. *The Forest.* The forest may be considered to consist of all that portion which has not been entirely cleared of the native trees. The major part consists of balsam and spruce with a heavy undergrowth of ground hemlock, and in places along the river there are dense thickets of alder. The soil in the depressions is damp, with small pools of water standing on the decayed leaves. Washington River flows through the lower portion of the forest. It is a stream sixty or seventy feet wide near its mouth, but it rapidly diminishes in size, so that near Wendigo is not more than five or six feet across. However it becomes much more rapid and the banks are covered with refuse and fallen logs and branches.

Few resident birds were found in the dense, dark forest, and still fewer migrants were found there. During very severe weather the Chipping Sparrow sometimes retreated to the protection of the balsams, but it never wandered far from the open. The White-throated Sparrow was quite common, breeding in the forest along the river, and even during migration it was found most abundant in the underbrush. The

Sharp-shinned and Sparrow Hawks rarely remained here, except during the night, or in very stormy weather. The warblers were scarcely ever found in the heavy timber, but along the more open part of the river and in the alder thickets they were abundant. By far the most common warbler along the river was Grinnell's Water Thrush. This bird was confined almost entirely to the forest, and especially to that portion bordering the stream where fallen logs and rubbish furnished their favorite haunt. They seemed to be migrating in pairs, but no immature birds were seen with them. During the stormy period lasting from September 2 to 5, the Water Thrush came out into the road and clearings. The Wilson and Olive-backed Thrushes bred in the forest, but during migration they preferred the open and were only occasionally found in the heavy timber. The path skirting the river was also a favorite route for them. The maple brush which bordered the forest in many places was the favorite habitat of the Hermit Thrush. This and the diminutive Winter Wren were sometimes met with among the very densest conifers. Among the other birds occurring here were the Brown Creeper, Golden-crowned Kinglet, and Red-breasted Nuthatch. Chickadees were nearly always present. This habitat was chosen by nearly all of these birds during migration, probably because it furnished the right kind of food and excellent protection. Many other species were occasionally met with, but they were only wanderers and no particular significance can be attributed to their occurrence here.

3. *Food.* The clearing afforded abundant food for nearly all species. The grassy meadows and dry hillsides were infested with great swarms of grasshoppers which rose up before one as a buzzing cloud. Nearly all the birds taken, among which might be mentioned the Sharp-shinned and Sparrow Hawks, Thick-billed Redwing, Rusty Grackle, Flicker and Nighthawk, fed to a greater or less extent on these pests, as was shown by an examination of their stomachs. Many other species of insects were abundant, blackflies, deer flies, and "no-see-ums" being at times almost unbearable. The Deer Mouse was very plentiful, and also the Northern Hare, as many as twenty or thirty of the latter being seen at one time feeding in the road between the first and second clearings. These animals together with the large number of Red Squirrels found along the edge of the road furnished abundant food for the owls and migrating hawks. Seeds were plentiful and constituted the principal food of the Savannah and other sparrows. Wild red raspberry bushes were common and these berries together with several other kinds were greedily eaten by many of the birds, especially the Cedar Waxwings. A few wild flowers grew in the clearing and these were occasionally visited by the Ruby-throated Humming Bird. Insect life characteristic of coniferous forests was probably abundant because the Brown Creeper, Chickadee, and Golden-crowned Kinglet fed here almost exclusively; otherwise this habitat did not appear to furnish much food for the migrants.

III. THE WEATHER CONDITIONS AND MIGRANTS.

1. *Weather Conditions.* Throughout the period of thirty-five days during which observations were made on migration at Washington Har-

bor, a daily record was kept of the direction of the wind, temperature, and the general weather conditions. The barometric readings, taken at Port Arthur, thirty-five miles nearly due north from the Harbor, are from the daily weather maps. A comparison of my observations on the weather with those from Port Arthur shows that the conditions at the two places were much the same, so I feel safe in assuming the barometric pressure at the island to be approximately that recorded just to the north. An examination of the daily weather maps for this period shows that the same isotherms and isobars include both localities. Unfortunately Port Arthur is the most northern station on the daily weather map that could have any appreciable effect on the bird life of Isle Royale. A reference to the areas of high and low pressure indicates that conditions similar to those on the island probably prevailed over a large area to the north of it.

The records for the entire thirty-five days are included in the following table. The readings were made between 7:30 and 8 A. M. Other readings were made during the day and where these are of importance I will give them under the particular discussion upon which they bear. All temperature readings were in Fahrenheit. The dates of the large bird waves are starred.

TABLE.

Date.	Barometer.	Temperature, F.	Wind.	Sky.
Aug. 18	29.7	62	S.	Rainy.
19	29.7	55	W.	Clear.
20	29.7	58	S. W.	Partly cloudy.
21	29.6	62	S. W.	Cloudy.
22	29.9	52	W.	Clear.
23*	29.9	58	N. W.	Clear.
24*	30.2	53	N. W.	Clear.
25*	30.3	50	None.	Clear.
26*	30.2	54	None.	Cloudy.
27	30.1	53	None.	Clear.
28	30.1	56	S. W.	Clear.
29	29.9	61	N. E.	Rain.
30*	29.8	56	N. W.	Clear.
31*	30.1	46	N.	Clear.
Sept. 1*	30.1	52	N. E.	Cloudy.
2	30	44	N. E.	Hard rain.
3	.....	40	N. E.	Hard rain.
4	.....	44	N. W.	Clear.
5*	30.1	39	N. W.	Partly cloudy.
6*	30.1	42	N. W.	Clear.
7	30.1	45	None	Rainy.
8	30.2	52	S. W.	
9	30.1	45	N. W.	
10	30	52	N. W.	
11	29.8	52	N.	Clear.
12*	30.2	42	N. W.	Clear.
13*	30.4	26	W.	Clear.
14	30.2	47	S. E.	Rain.
15	29.8	52	None	Clear.
16*	30	50	E.	Cloudy.
17	29.9	53	N. E.	Clear.
18*	29.8	52	N. E.	Clear.
19	29.4	59	N. W.	Cloudy.
20	29.8	46	W.	Clear.
21	29.5	54	W.	Clear.

*Large bird waves.

2. *The Bird Migrants.* a. *Warblers.* Many warblers nest on the island, and so the first indication of migration in this family was the tendency to flock preparatory to the trip south. At first these flocks

consisted only of the parent birds and young, but as these wandered about they were joined by other families and, impelled by the gregarious instinct which is so strong after the breeding season, kept together and formed one large flock. Beginning to feel the migratory impulse they were restless and wandered about over considerable territory, probably being joined from time to time by other families and often by other forms, for a flock of migrating warblers is rarely composed of a single species, as are the flocks of so many birds. Small bands of Myrtle Warblers were seen feeding in the balsam trees on August 18, and on August 19 the first flocks of Tennessee Warblers appeared. However, these were scattered and composed of only a few birds, mostly adults. On August 20 I saw the first Redstarts, and from then on different species were constantly making their appearance. On the 26 the bulk of the Black Poll Warblers began to arrive, only a few adults being seen among the hundreds which came to the clearing. It is a significant fact that, in all cases where the young were not in company with the adults, the latter and not the former, as some have reported, preceded. In the case of the Tennessee Warblers three days elapsed before there was any noticeable number of young, while toward the last of the migration the young greatly outnumbered the adults. Throughout the entire migration, however, the immature Blackpolls outnumbered the old birds, in fact the latter were very rarely seen. Only two Black and White Warblers were observed, and only four small flocks of Black-throated Green Warblers.

The principal feeding grounds were among the alders, birches and balsams which lined the more open parts of the road. In the narrow strips where the high conifers bordered the path, the bird life was scanty, and when these portions were encountered by the migrating warblers they were quickly passed, often in a single flight. The Myrtle Warblers were the only ones observed to linger among these large trees.

The food of the warblers consisted largely of insects, most of it being gleaned from the leaves and twigs of the bushes, but some was taken on the wing. The open area here afforded a greater supply of insects than the forest, and this may possibly have played a part in the choice of this particular habitat.

On cold mornings, when the thermometer registered about 45° F. or below, the warblers would remain hidden in the dense underbrush, not appearing until about nine o'clock, when the sun would be quite warm and the usual morning fog be dispelled. This fog hung over the harbor nearly every morning and frequently was so dense that Beaver Island, in the harbor, was almost invisible. It was often blown back over the clearings, and until it raised, the majority of the birds remained quiet. The height of the migrating movement seemed to be from the middle of the afternoon until nightfall; how far into the night it extended I was unable to ascertain, but the cries of innumerable birds could be heard until nearly morning. These cries, usually of a single faint syllable, were possibly uttered to help keep the birds together. When the migrating flock had to cross the clearing it was a noticeable fact that they rarely flew directly across, thus exposing themselves to the attack of the numerous hawks, but instead kept near to the ground, making short flights from bush to bush, and where these were scattered

they alighted directly on the ground. This was especially noticeable in the case of the Palm Warblers, which often lingered to feed in the grass.

The Sparrow and Sharp-shinned Hawks were the principal enemies of these birds, devouring many each day. During the large bird wave of September 12, the Pigeon Hawk also played a conspicuous part in their destruction. The influence of the hawks will be taken up under the discussion of that family.

During the first days of migration the warblers moved along very leisurely, the same flocks apparently remaining about the clearings all day, but toward the latter part of the season the birds hurried forward, taking their food as they moved along. There were several warbler waves or periods of great abundance, the first occurring on August 23. This one was made up almost entirely of Tennessee Warblers, adult and young being about equal in number. For the remainder of the migration, however, the young outnumbered the adults. The second, made up largely of immature Blackpolls, arrived on August 26. The third wave, consisting principally of Palm Warblers, occurred on August 30. The last wave, and by far the largest, occurred September 12. At this time the clearings and roads were full of warblers, nearly every species observed at Isle Royale being represented to a greater or less extent. These waves will be dealt with separately.

During the heavy rain and wind storms of September 1, 2 and 3, the warbler migration was at a standstill, the birds keeping under cover as much as possible. The Blackpolls and Palm Warblers were the only species which seemed to be unaffected by the weather. These beautiful warblers were observed feeding in the open clearing during the heaviest rains, but even they did not undertake to migrate against the strong wind, so far as I could determine.

b. *Sparrows.* The sparrow migration began much later in 1905 than in 1904, some of the most striking examples being Savannah, Aug. 17, White-crowned, Aug. 28 and Lincoln, Sept. 1, 1904. On August 18, (1905) the first day observations were made, Chipping and White-throated Sparrows were seen, The Chipping had gathered into flocks and roamed about the clearings, feeding near the borders, while the White-throated were still in single families hunting about among the dead leaves in the damp underbrush. Many of the White-throated Sparrows were still too young to migrate, some having a little of the first down on them. On August 22, an immature Vesper Sparrow was taken, the only one found on the island. A few Song Sparrows were present from August 21 to 24. These were the only ones seen and were probably migrating at that time. The next few days the number of both Chipping and White-throated Sparrows was materially increased, large numbers of young of both species making their appearance. Very few of these had moulted the first plumage. Not until August 31 were any other species seen, then large flocks of Savannah Sparrows, both young and adults, came to the clearings. All were in perfect fall plumage. It seems peculiar that none of these birds were seen before this date, because between August 5 and 8, I saw several, and obtained one immature barely able to leave the nest. The food was obtained along the roads, in the meadows, and about the houses, where several lost their lives by entering deserted rooms and not being able to find their

way out. The Sharp-shinned Hawks proved to be their worst enemy. The first flocks of Savannah Sparrows to arrive remained for several days, their numbers constantly increasing. On September 5 many of the Chipping, White-throated, and Savannah Sparrows left the island, and for the next two days only a comparatively few were seen, then others came in from the north and the flocks were rapidly increased.

It was noticeable that most of the birds which migrated from the island on September 5 were adults, the young remaining until a later time. The Savannahs showed the least fear of man during migration of any of the sparrows. On September 12, with the great bird wave, came the Lincoln Sparrows. Throughout this and the next three days hundreds of these birds were seen. As a rule they kept secreted in the burned brush and weeds of the first clearing, but individuals were met with all along the road, where they were seen hunting among the fallen logs and underbrush for insects.

Chipping Sparrows remained throughout the entire period during which observations were made, but probably none of the individuals first seen remained throughout that time. This seems the more likely as on several dates the bulk of the sparrows of all species left, while more came in later from the north.

c. *Hawks.* During a few days spent at Washington Harbor early in August (Aug. 5 to 8) only a few Sparrow and Sharp-shinned Hawks were seen, but by August 18, many individuals of both species had arrived. These remained here to feed on the swarms of grasshoppers infecting the meadows, and on the small birds, as warblers and sparrows, which were easily caught in the exposed clearing. The first few days the Sparrow Hawks outnumbered the Sharp-shinned about 10 to 1, but as the season advanced their numbers became more equal and toward the last the Sharp-shinned outnumbered the Sparrow Hawks, both because of a steady increase of the former and because many of the latter left the island for the south. When the observations were first made the adult Sparrow Hawks were as numerous as the immature, but toward the last of September the adults had nearly all left and many more immature had taken their places. Some idea of their number may be gained from the statement that more than thirty were counted at one time, sailing over the first clearing. Until the middle of September the immature Sharp-shinned greatly outnumbered the adults. These immature were full size, but did not have the spotted plumage of the adult. The females of both species greatly predominated. Toward the end of September many male Sharp-shinned, both immature and adult, appeared. These two species of hawks fed on grasshoppers to a considerable extent, but many crops of both species were found filled with the remains of Tennessee, Palm and Blackpoll Warblers, Savannah Sparrows and other species not determined. As a rule the older hawks were the ones which destroyed the birds, and this may account for their migration from the island at the same time that the large warbler and sparrow wave passed, while the immature hawks remained. Pigeon Hawks were recorded from time to time, but not until September 12, when the lower end of the island was suddenly flooded with bird life, did they appear in any numbers. On this date several flocks of 6 or 8 were seen in different parts of the clearing.

They were preying principally on the sparrows, and were creating great havoc among them. Coming with the great wave they remained throughout the day and passed on with it that night, only one being seen the next morning.

The migration of the hawks is thus seen to have been intimately connected with the migration of the smaller birds upon which they preyed, and seems to give at least one instance of bird migration being influenced by the food supply.

During cold, rainy mornings the hawks rarely appeared in the open, usually not until about 9 o'clock. This, however, was the time the warblers appeared on such days, and this may also have determined their appearance.

d. *Owls.* Only two species, the Great Horned and Acadian Owls, were seen. These were residents at this time and only concerned migration in that they sometimes preyed upon the migrants. Their effect was probably slight.

e. *Thrushes.* Six species were observed migrating, the Bluebird, Robin, Wilson's, Olive-backed, Gray-cheeked and Hermit Thrushes. A pair of Blue Birds nested in a dead Birch at Wendigo, and this family left the island about August 22. On the 24th a small flock probably consisting of two families appeared at the first clearing and remained about the tangled brush until August 31, when they also left. No others were seen except on September 11 and 12. Robins were seen twice during August, but on September 6, the first real migratory movement was initiated, and from then on the number rapidly increased. Small flocks numbering a dozen or so wandered about the clearings and open woodland. Many disappeared on the night of September 12, but the number was soon replenished, and at the time the observations were closed the Robins were quite abundant.

The most common of the Thrushes was the Wilson's. They bred on the island and showed no indications of the migrating spirit until the latter part of August, when they gradually increased in numbers and moved about to a greater extent. After September 6 they became rather scarce, and none were seen after the 14th. Their place was taken by the Olive-backed, and later the Gray-cheeked became abundant. Many immature Olive-backed were seen but this species had nearly disappeared when the great flocks of Gray-cheeked arrived on September 12. They showed little fear and did not seem to be frightened at the report of a gun. The flocks of the Gray-cheeked were made up of immature and adult birds, all in perfect fall plumage.

f. *Other Birds.* Following the breeding season the woodpeckers wander about the island making what might be called a local migration. Perhaps some of these birds leave the island in the fall and probably others come in from the north. In one instance, that of the Flicker, their numbers are enormously increased during the latter part of August and all through September. It is very improbable that any of these latter birds winter on the island. Flickers were seen every day, but the number greatly increased toward the last of September, and from the report of residents the number continues to increase until late October when they appear to leave the island. Many were found dead without any apparent cause, and it was reported that in the latter

part of October hundreds were found dead each year. The Downy and Hairy Woodpeckers visited the clearings occasionally, as did the Pileated Woodpecker.

Several pairs of Kingfishers frequented the river banks, and one pair nested in a sand bank, rearing 7 young. These birds gradually disappeared, until on September 15 the last ones left. Families of Redbreasted Nuthatches occasionally visited the clearings, often accompanied by Chickadees. During August, Crows were commonly seen, but by the latter part of September they had entirely disappeared, whether to the south or not it was impossible to determine. Several species of flycatchers and vireos were seen migrating, the Alder, Green-crested, and Least Flycatchers being seen several times, while only one Yellow-bellied was found. Both young and adults of the Least Flycatcher were seen, usually together.

One pair of Chimney Swifts was observed circling over the river on August 19. Whether these were migrating I do not know, but they were the only ones noted here in 1905. One of the most conspicuous species during August was the Thick-billed Redwing Blackbird which came to the clearing in flocks numbering from about 30 to 50. Flocks composed of young and adults arrived nearly every day. The proportion between the two seemed to be about equal, or if anything, in favor of the adults. None were in the black breeding dress, and only a few males had the red on the shoulders out of the pin feather stage. The majority left on August 26, a few were seen on August 29, 31, and September 2, and two young were found on the 8th, 9th and 10th. A single specimen was taken September 16 and another, partially moulted, on the 20th.

There were many instances where only an individual or a single flock of a certain species was seen. Among these might be mentioned the Catbird observed on September 12, which was the only one the expedition noted either in the Porcupine Mountains or Isle Royale during both years, the Philadelphia Vireo, Blue-headed Vireo, Chimney Swift, Vesper Sparrow, Humming Bird, Migrant Shrike, Black-throated Blue Warbler, Black-throated Green and Black and White Warblers, Yellow-bellied Flycatcher, Red-eyed Vireo, and Kingbird. Of these, only two of the Philadelphia Vireo and Chimney Swift were seen, and but single individuals of the Migrant Shrike, Black and White Warbler and Ruby-throated Humming Bird.

IV. LARGE BIRD WAVES.

During the period from August 18 to September 21, six large bird waves passed over the island. Sometimes the waves were composed principally of one species, and again several species occurred in varying numbers. These bird waves were mostly from the north, although small ones, consisting of the birds which had accumulated on the island, took place at various times.

A bird wave may be recognized, first, by a sudden increase of individuals, second, an increase of species, or, third, by a sudden decrease in the number of birds which were residents or had gradually accumulated on the island. During the large wave of September 12, all of

these evidences were present, but usually only one or two were recognized, the most pronounced of which was the great increase of birds as they passed along the roads from one clearing to another.

In some cases the bird wave marked the date of first arrival, at other times it simply marked the arrival of the bulk. The bird waves were generally sharply defined, so that their relation to the atmospheric changes could be noted to the best advantage. The bulk of the migration took place during the nights of bird waves, although there was a constant going and coming of certain species throughout the fall. Being almost constantly in the field the writer had excellent opportunities to study the migration when it was most pronounced, that is, during the large waves.

1. *First Wave.* The first wave observed occurred on August 23, and consisted principally of Tennessee Warblers, immature and adults being about equal in number. At 7:00 A. M., the temperature was 58°, a rise of 6° in the last twenty-four hours. The weather was clear, and it was in fact one of the most beautiful autumn days of the season. A light northwest wind prevailed, the barometer standing at 29.9 inches (low). This wave lasted for three days. The day previous the weather conditions had been about the same, except that the thermometer stood at 52°. An area of low pressure (29.75) was advancing towards the island and on this date was central over Assiniboia. On the 23d this area was central over Isle Royale and the area to the north and northeast of it. On August 24 a low area was centered over northeastern Missouri while the high pressure which followed it reached very nearly to Isle Royale, thus lowering the temperature to 53° with a northwest wind and barometer reading of 30.2. On the 25th of August the high (30.3 inches) included the island and the area directly south of it. The weather was clear, no wind, and a fall in temperature to 50°. On this date the beginning of the large wave of Blackpoll Warblers commenced, many large flocks appearing before nightfall. On the fourth day of the wave (August 26) the barometer fell to 30.2 with an increase to 54° in temperature. There was scarcely a breeze, and the day was for the most part humid and cloudy. The bulk of the Blackpolls arrived during the previous night and throughout the day. The wave lasted for several days, decreasing gradually in volume, so that it was difficult to tell exactly when it stopped, if in fact it did not grade off into the next one.

2. *Second Wave.* On August 30 great flocks of Palm Warblers invaded the island. On the previous day the area of low pressure was central over the region a little to the west of Isle Royale, with a barometric pressure of 29.9, a temperature of 61°, and wind northeast with rain. On the 30th the low area had passed on to the St. Lawrence Valley and the advancing high pressure was over Manitoba. The barometer stood at 29.8 with a northwest wind blowing 4 miles per hour and a temperature of 56°. This wave also lasted three days and might have continued longer but for the severe gales which set in on the night of September 1.

The second day of this wave (August 31) the area of high pressure (30.1) was central over all of Northern Michigan, a considerable area north of it, and south to southern Wisconsin. With the high pressure came a drop in temperature to 46°. The day was clear with a north

wind blowing about 4 miles per hour. The Palm Warblers continued to come in large flocks and were by far the most abundant bird at the Harbor. The vanguard of the migrating host of Savannah Sparrows appeared early on the morning of the 31st, and by evening the clearing was fairly covered with them; more came during that night and all the next day large flocks were arriving at the first clearing. There was no appreciable increase during the four succeeding days among the bird migrants. The third day of the wave (September 1) the barometer stood 30.1 inches, temperature 52°, with a northeast wind and a cloudy sky. This day marked the close of this wave both of birds coming to and leaving the island. This wave might have been checked either by the gales which followed or the change of the wind from north to northeast. A few birds attempted to cross during these succeeding days, as many were killed by striking the lighted windows, etc., or were found in an exhausted condition. These were probably part of that steady stream of migrants which continues to pass south during the fall, without any marked wave and in general disregard of the weather conditions.

3. *Third Wave.* This wave was noticed first on September 5 when the bulk of the Chipping, White-throated, and Savannah Sparrows left the island, and on September 6 the first real migration of the Robin commenced. I have considered these two days as parts of one wave, controlled by the same conditions, for probably the same influences acting at the same time caused the sparrows to leave the island and the Robins to leave their more northern home. The weather conditions were such as seem to be most favorable for fall migration. On September 5 the high pressure had advanced to an area lying from Winnipeg on the north to Memphis on the south, and extending east nearly to Duluth. The barometer stood at 30.1 (high) with a northwest wind blowing six miles per hour and a temperature of 39°. The day was partially cloudy, but no rain fell. On the 6th an area of high pressure had formed over the region directly to the north and northeast of the island. A moderate northwest wind prevailed with the barometer at 30.1 inches, and thermometer 42°, and the weather was clear. A few Robins had been noted before this, but these were only scattered individuals or pairs, but on this date a large number came to the island, both young and adults being seen, although the latter greatly predominated.

4. *Fourth Wave.* On September 12 the largest wave of the season occurred. For number of species as well as individuals it could scarcely be compared to the other large waves, a total of 41 species being observed in actual migration on this day. On the previous day the low area was central over Lake Erie, and a similar area was formed over the Dakotas. The barometer stood at 29.8 inches, the temperature at 52°, with a north wind and a clear sky. It was cloudy, however, on the north shore. On the morning of the 12th the low area was central over New England, while the western one had moved south and had been followed by an area of high pressure central over the Dakotas and Western Minnesota. The island lay between the isobars of 30.1 and 30.2 inches, with a temperature of 42°, and a northwest wind averaging 8 miles per hour. The day was clear and seemed perfect in every way. The birds were so plentiful in the clearing at 6:30 A. M., as to attract my attention from the windows. Unlike the other bird waves, the

motion was continuous, scarcely a break occurring in the steady stream of migrants as they passed along the road. There was very little lingering by the way, although when the birds arrived at the first clearing they often scattered about, feeding on the myriads of insects infesting the grass and shrubbery. Many of the birds after collecting into great flocks, sometimes numbering more than a hundred, rose directly from the clearing and taking a southwesterly direction, left the island, presumably for the south shore. As a rule the birds flew directly down the Harbor and the fishermen and tourists at Washington Island reported that never before had they seen such numbers of birds except during the spring migration. These observers reported that the majority of the flocks passed at a considerable height above the island, many of them probably belonging to the same flocks that left the clearing four and one-half miles up the bay. Some species, particularly the warblers and sparrows, flew from the ground in practically the direction they took when on their way, but others as the American Pipit, Rusty Grackle, Horned Lark and Thick-billed Redwing flew around in great circles, often hanging around the border of the clearing for some time, as if not quite decided whether to go or not. No flocks of the last named bird were seen on this day, however. As I passed up the road toward Wendigo that morning I met flock after flock of Palm Warblers, Grey-cheeked Thrushes, and Savannah Sparrows. The progressive movement of the migratory birds was clearly shown as they passed in a southwesterly direction along the road from Wendigo to the clearing at the Club House.

Darting everywhere were Sharp-shinned and Sparrow Hawks, while every few minutes a Pigeon Hawk would dash by. All the birds seemed restless as if impelled by some uncontrollable spirit to keep ever on the move. Warblers, thrushes, sparrows and flycatchers were constantly crossing and recrossing the path in front of me.

During the night of September 12 nearly all the birds left the island. Towards evening the temperature gradually dropped, until at 9 P. M. it was only 38°. The morning of the 13th was one of the coldest I experienced on the island, ice remaining on the water pail until nearly noon. During the night the area of high pressure had advanced until at 7:00 A. M. it was central over Isle Royale with a barometer reading of 30.4, temperature at 26°, and a brisk west wind. The sky was clear, as is usual under high barometric pressure. Many Lincoln Sparrows remained, as well as numerous flocks of Gray-cheeked Thrushes. But the great flood of migrants had passed on the previous night. However, the wave set up by these very favorable conditions was not yet over. Large flocks of Horned Larks numbering from about 60 to 200 or more came to the clearing, feeding on the insects and seeds in the open meadow and on the cultivated ground. On this morning many dead birds were found, among which was an adult male Yellow-bellied Flycatcher, the only one of this species seen.

The following is a list of the 41 migrants which composed this remarkable wave of September 12: Chipping Sparrow, White-throated Sparrow, Sharp-shinned Hawk, Sparrow Hawk, Blue Bird, Flicker, Myrtle Warbler, Tennessee Warbler, Phoebe, Redstart, Least Flycatcher, Hermit Thrush, Spotted Sandpiper, Pigeon Hawk, Robin, Olive-backed Thrush, Golden-crowned Kinglet, Cooper's Hawk, Wilson's

Thrush, Solitary Sandpiper, Magnolia Warbler, Palm Warbler, Ovenbird, Bay-breasted Warbler, Blue Headed Vireo, Blackpoll Warbler, Savannah Sparrow, Black-throated Green Warbler, Grinnell's Water Thrush, Marsh Hawk, Catbird, Black-throated Blue Warbler, Nashville Warbler, Philadelphia Vireo, Red-eyed Vireo, Lincoln's Sparrow, Connecticut Warbler, Ruby-crowned Kinglet, Gray-cheeked Thrush, Broad-winged Hawk and White-crowned Sparrow.

The following were seen on September 13: Chipping Sparrow, White-throated Sparrow, Sharp-shinned Hawk, Sparrow Hawk, Flicker, Hermit Thrush, Pigeon Hawk, Robin, Palm Warbler, Blackpoll Warbler, Savannah Sparrow, Marsh Hawk, Lincoln's Sparrow, Gray-cheeked Thrush, White-crowned Sparrow, Horned Lark and Yellow-bellied Flycatcher.

5. *Fifth Wave.* On September 16 the bulk of the Rusty Grackles arrived. A few had been seen the day previous, but only scattered individuals composing the vanguard of the large, noisy flocks to follow. The area of highest pressure was off the New England states, while the low pressure centered in Kansas. The barometer stood 30.0 inches, temperature 50°, and an easterly wind with a cloudy sky. While this was one of the smallest of the sharply defined waves, it presents a marked contrast to most of the others. Although the area of highest pressure was not near Isle Royale, as during most waves, the barometer stood at 30.0 inches, which was higher than for the area to the west and south; the wind was from the east and the sky cloudy in contrast to the northwest wind and clear sky of the other waves.

6. *Sixth Wave.* On September 18 the high area was far to the east (Maine) and the low centered over Kansas. The barometer stood at 29.8 inches, with a clear sky, northeast wind, and a temperature of 52°. Like the last this was comparatively a small wave and only involved a single species, the American Pipit, which came in large flocks numbering from perhaps 100 to 200 birds.

V. THE RELATION OF WEATHER TO MIGRATION.

Cooke ('88, p. 16,) makes the following statement in regard to the relation of temperature and barometric pressure during migration, "The area of the lowest pressure is never stationary but constantly moving, and in an easterly direction. It may be moving northeast, east, southeast, and rarely north or south; but never northwest, west, nor southwest. The usual direction in the Mississippi Valley is a little south of east." Warm waves, which are associated with areas of low pressure, therefore begin in the northwest, and move toward the southeast. "It is a law of the movement of winds that they go toward areas of low pressure, and from an area of high pressure." "But an area of low pressure is followed by one of high pressure, producing an opposite effect, and the isotherms which bent north to welcome the coming of the low area turn rapidly southward before the icy breath which blows from an area of high pressure. Thus the cold and warm waves both come from the same quarter, and both move in the same direction; that is the direction in which the area of low pressure is advancing." It will thus be seen that the temperature and the direction of the wind over any given area are both associated with the barometric pressure

and the movement of its high and low areas, and since "low pressure is generally accompanied by clouds and rain, while areas of high pressure are cloudless" it will be seen that this important element is also associated with the barometric pressure. Thus we see that the four striking factors which influence migration, namely temperature, direction of wind, condition of the weather, and barometric pressure are correlated and work together, the same factors being always associated together and giving the same results.

To determine the true relation of these factors to migration we must discover the most favorable conditions for this movement, and then we can correlate the atmospheric changes which are taking place with the corresponding migratory movement. Of course many birds are constantly passing to the south throughout the fall, irrespective of the weather conditions, but the changes which will set great numbers moving onward simultaneously must be the ideal conditions for migration. If this be true the time to study this relation of the weather is during the great waves.

TABLE OF BIRD WAVES.

Date.	Barometer.	Temperature, F.	Wind.	Sky.
	FIRST BIRD WAVE.			
Aug. 23	29.9	58	N. W.	Clear.
24	30.2	53	N. W.	Clear.
25	30.3	50	None.	Clear.
26	30.2	54	None.	Cloudy.
	SECOND BIRD WAVE.			
Aug. 30	29.8	56	N. W.	Clear.
31	30.1	46	N.	Clear
Sept. 1	30.1	52	N. E.	Cloudy.
	THIRD BIRD WAVE.			
Sept. 5	30.1	39	N. W.	Partly cloudy.
6	30.1	42	N. W.	Clear.
	FOURTH BIRD WAVE.			
Sept. 12	30.2	42	N. W.	Clear.
13	30.4	26	W.	Clear.
	FIFTH BIRD WAVE.			
Sept. 16	30	50	E.	Cloudy.
	SIXTH BIRD WAVE.			
Sept. 18	29.8	52	N. E	Clear.

1. *Influence of Wind.* A reference to the table of bird waves shows that on six days of the thirteen during which large waves were observed, the wind was from the northwest. Two days were without appreciable wind, on two, the wind was from the northeast, and upon other days it was from the north, east, and west, but upon none of them was it from the south, southeast, or southwest. A northwest wind prevailed the first two days of the first wave, the third and fourth days being without wind. The second wave commenced with a northwest wind, which changed to north on the second, and to the north-

east on the third day. The northwest winds prevailed both days of the third wave, while the fourth started with a northwest wind, and changed to west on the succeeding day. The fifth wave was peculiar in having an east wind and the sixth a northeast one, both of which brought birds of different species, and from a different direction than those with northwest winds. These two waves were also much smaller than the preceding ones. It will thus be seen that the great bulk of migration took place with a northwest wind.

2. *Influence of Temperature.* Since fall migration prevails at a time when the temperature is gradually falling, the records for a wave near the first of the movement would be much higher than those at the last, so this factor can be considered only in a relative way, i. e., we must not compare the temperature at the first and last of the season, but simply consider the temperature immediately preceding and following a wave. The average temperature for the thirteen days was 47°. This low average was partially due to two days of very low temperature. All the waves but one were on a falling temperature, and in this case the mercury had fallen from the day previous. As a falling or low temperature is the cause of the high barometric pressure, which in turn with the passage of the high, causes the northwest winds which are so favorable to migration, it will be seen that a falling or low temperature is perhaps the first requisite for the bird wave. The low temperature also influences the food of the migrants, killing off the insects, or driving them to shelter, and in this connection may prove to be very important.

3. *Influence of Barometric Pressure.* One of the most striking conditions was the high barometric pressure under which these large waves took place. On ten of these thirteen days the barometer stood at 30 inches, or above, the average of these being 30.17. The lowest pressure was 29.8, the average for all being 30.09. None of the waves took place on a falling barometer, but where there was a change the pressure was rising as: first wave 29.9, 30.2, 30.3, 30.2; second wave 29.8, 30.1, 30.1; third, 30.1, 30.1; fourth 30.2, 30.4. As before stated the direction of the wind is due to the relation of the areas of low and high pressure to the region under consideration, and it is in this connection that it bears upon the problem of migration phenomena.

Cooke in his discussion of the effects of atmospheric changes on spring migration shows that at this season the large movements took place on low or falling barometers, and stated that it probably would be found that in fall the opposite conditions existed and migration would occur on the rising or high barometric pressures. This was found true at Isle Royale and probably is true for all fall migration.

4. *Condition of the Sky.* It will be noticed that on 9 of the 13 days of bird waves the sky was clear, and on the remaining four it was simply cloudy, no waves occurring during rainy weather. In spring the waves usually occur during cloudy nights; in the fall, as witnessed here, the opposite is the case, and the bulk of the fall migration can be said to take place on clear nights.

5. *Summary and Conclusion.* From the data submitted we see that fall migration as witnessed at Isle Royale occurs, in the majority of cases, with a northwest wind and a falling temperature with its rising

barometer, and clear sky. (Cf. Smith, '07, p. 223.) It therefore seems evident that low temperature and high barometric pressure, with the prevailing northwest winds and clear sky which accompany them furnishes the most favorable conditions for the bulk of the fall migration. It will be noticed under the head of Migration Routes that a few birds prefer northeast instead of a northwest wind. The conditions which would be favorable for the migration of these birds would occur after the passage of a high and while the approaching low was still some distance off.

It is desirable that similar observations be carried on at other favorable localities in order to further test these conclusions, and determine whether they are of general application to the fall migration.

VI. ROUTES OF MIGRATION.

From the observations made during the falls of 1904 and 1905, it seems that Isle Royale lies directly in the path of a very strong migratory movement. In the fall there was a great massing of bird life. For some unknown reason the path of densest movement was very narrow, at least appearances pointed to such a condition. This apparent narrowness of the route through the island was strikingly shown on September 9 when a trip was made across it from Washington Harbor to Siskowit Bay. About 15 miles were traversed, embracing every environment from clearings to high hardwood forests and damp cedar swamps. Nearly a day was spent hunting over the clearing and adjacent forest near the head of the bay, but scarcely any migrants were observed. A few Black-throated and Tennessee Warblers and a few sparrows were seen, while an occasional Sparrow or Sharp-shinned Hawk was met. This was not due to a lack of food, as grasshoppers and other insects were very plentiful. At Washington Harbor the reverse was the case; here on September 9 and 10 I saw many migrants, the majority of which were not seen at Siskowit at all. These observations at the harbor were made in the morning before leaving and in the late afternoon of the following day when I returned from the bay. While at Siskowit scarcely a bird was heard passing over, although at the harbor they could be heard throughout the night. The path apparently extended lengthwise of Isle Royale with Washington Harbor and the region lying between it and the north shore of the island as its diameter.

In a recent paper, Taverner ('05) makes the statement that perhaps a migration route lies between Isle Royale and Keweenaw Point. From the observations made on the island, I am led to believe that such a route does exist and also one lying much to the west of this point, perhaps to the Apostle Islands and the mainland lying Southwest of them. These conclusions were drawn from a consideration of the following facts. The route taken by the majority of the migrants, both those which passed slowly across the island and those observed flying overhead, whether by night or day, lay nearly southwest. During the latter part of August and parts of September, the nights were unusually bright, so that migrating flocks could often be seen high in the air even when not crossing the face of the moon. The cries of migrating birds, heard mostly on cloudy nights, usually came from a

northeasterly direction and died away in a southwesterly one. Certain birds, as the Thick-billed Red-wing Blackbird and Lincoln Sparrow, which were found commonly at the island, are very rare or do not occur at all in the region directly south or southeast of it. The Thick-billed Red-wing has never been taken at any point in southern Michigan. These birds, being of western origin, have gradually worked their way east where they have found suitable breeding grounds, but it seems probable that in their fall migration they move westward and join the throng passing down the migration route traversed by their ancestors. It seems probable that the greater portion of the migrants which leave Isle Royale, moving in a southwesterly direction, continue thus until they reach the Mississippi Valley, where they are joined by birds from other regions, and all move down this great highway of bird migration.

It was observed that nearly all the large bird waves were associated with northwest winds. As the birds probably take a southwest course this gives them the beam wind which seems to be most favorable for their flight. Of course it was impossible to tell from what direction the birds came to Isle Royale, but it seems reasonable that they should choose a beam wind when leaving the mainland, since they arrived shortly after at the island flying with such a wind. If this proves to be true, the majority of the birds coming to Isle Royale are from the north or northeast.

The data for the supposed route to Keweenaw Point is slight compared with that for the southwestern one. Two species, the Rusty Grackle and the American Pipit, were observed migrating in this direction. During their flight the wind was from the northeast giving them the beam wind which a number of observers have noted to be the one preferred by hawks and gulls during their migration. Under "Perils of Migration" an instance is cited where a number of birds were caught by a storm while crossing to the east of the island and were driven to Washington Harbor. These birds were possibly crossing to Keweenaw Point. Probably the majority of the birds which strike this point are from regions lying to the northeast of it, and arrive there on northwest winds as do those birds which migrate across Isle Royale. The theory that many birds skirt the Great Lakes, as brought out by Taverner, explains the absence of several species from Southern Michigan which is not done by the discussion of the routes from Isle Royale.

VII. THE PERILS OF MIGRATION.

Dixon in his "Migration of Birds," divides the perils of migration into three important classes: first, those arising from fatigue due to the mechanical part of season-flight; second, those arising from the natural enemies of each species; and third, those arising from blunders and fatalities on the way. These three classes were observed in varying degree during the fall migration at Washington Harbor.

1. *Fatigue.* Between the north shore of Lake Superior and Isle Royale, the distance is so short that unless unfavorable winds intercept them the older birds would have little trouble from fatigue due to the simple operation of flight; but the young, which often commence migration soon after being able to fly, would experience considerable

strain on their frail bodies in even so short a flight. This was vividly shown in the number of exhausted young found after every bird wave. During September, immature warblers and sparrows were often found in the morning in an almost completely exhausted condition after their night's flight. This was especially evident among the Tennessee and Blackpoll Warblers. On the morning of September 13, following the day which witnessed the largest bird wave, I picked up many dead birds. Nearly all were warblers, the Tennessee seeming to have suffered most, although the Palm was a close second. A few immature Savannah Sparrows, one adult Yellow-bellied Flycatcher, and several young Flickers were also found dead. These dead migrants were seen in the clearing, along the roads, and on the banks of the stream. An examination of these victims showed no outward indication of the cause of their death. Only a few were emaciated to any extent. It was a noticeable fact, however, that none of the birds found dead were in the prime, fatty condition of most of the other migrants taken. The conclusion therefore seems probable, that the birds must be in the best condition possible to make a successful migration flight, and that the greatest mortality among the migrants lies in that class which for some unknown reason are not in prime condition. As there were no other reasons evident which could have brought on this high death rate, it is probable that death had been caused by severe exertion, coupled perhaps in a few instances with lack of food and unfavorable weather conditions in which to recuperate. This seemed the more plausible considering the fact that in only a comparatively few cases were the victims adult birds, while, as before stated, many of the immature warblers and sparrows had only been able to fly for a short time.

After heavy storms, especially those from the southeast, many adult as well as young birds were found in an exhausted condition, their plumage presenting a dilapidated appearance, the wing and tail feathers broken, and showing general evidence of a hard struggle with the wind. Some of these birds may have been caught by the storm while crossing from the north shore to the island, but as the birds appeared to be blown before the wind I think that at least part of them were overtaken while crossing the lake considerably to the east of Isle Royale, perhaps toward Keweenaw Point. Overtaken by the storm and with no place to take refuge they were gradually blown in the direction of the island where they were found the succeeding morning in such an exhausted condition. Some of these birds would even allow themselves to be picked up and handled without showing any fear. The birds which suffered most were the Palm and Tennessee Warblers. Michael Hollinger, a resident on the island for several years, told me that often, especially in spring, he had seen Washington Harbor "literally covered" with floating birds which had succumbed in their struggle against the storms and had drifted in from the open lake. The peculiar shape of the harbor and the lake currents tends to mass floating bodies at this point. But the loss as shown by those collected at the harbor could be but a slight proportion of the vast numbers which must have perished in the open lake.

Several fishermen said that after heavy gales in late fall and early spring, the shore at Washington Harbor would be strewn with the life-

less bodies of birds thrown up by the waves. During the fall of 1905, birds were several times reported as lighting on the ships coming into the island, and the fishermen secured several which lit on their small boats after a storm, when about two miles from land. They reported the birds as very tame and allowing themselves to be handled freely. The birds secured were several small sparrows, Tennessee and Palm Warblers, a Saw-whet Owl, and one adult Robin. These birds were all encountered near the southwestern end of the island. They had probably been blown out of their course and were striving to reach the nearest point of land, as no birds would be coming from the south at this time of year nor would any so completely exhausted have attempted to leave the island.

2. *Natural Enemies.* Without doubt the greatest natural enemies of the birds during migration were the Sharp-shinned and Sparrow Hawks. At times the Pigeon Hawk made great havoc among the smaller birds, and the Owls also played a small part. Probably weasels and minks fed to some extent on the migrants, which they caught while the birds were resting. These animals, however, only destroyed comparatively few, as remains of their victims were seldom found. Likewise the Owls probably destroyed only those which came directly in their path, the abundance of the Varying Hare furnishing a food much easier to procure. This undoubtedly saved a large number of migrants. Of the other animals, the Lynx also fed largely on the Hares and so probably molested the birds very little, while the family of house cats kept at the club-house were more than supplied by the number of small birds which met death striking against the windows, etc.

The early migrants were preyed upon very little by the hawks, principally because the Sharp-shinned Hawk had not arrived in any appreciable numbers, and secondly, the great swarms of grasshoppers furnished an abundance of appetizing food. As the season advanced and both species of hawks grew more numerous, their effect on the bird life increased. None of the smaller birds were safe, away from the protecting boughs of the conifers and alders, and therefore were confined almost exclusively to the edge of the clearings. The Sparrow Hawks fed both on grasshoppers and on warblers and sparrows, while the Sharp-shinned fed almost entirely on the latter. During the bird waves the hawks became more numerous, this being especially true for the great wave of September 12. On this date great numbers of both Sharp-shinned and Sparrow Hawks made their appearance, as well as many of the Pigeon and a few Cooper's and Broad-winged Hawks. The Pigeon Hawks in particular timed their migration to that of their victims, appearing and disappearing with each successive wave, very few remaining on the island. The majority of the Sharp-shinned also kept pace with the retreating birds and by the time the bulk of the warblers and sparrows had passed they too had gone on. Among the birds which suffered most heavily may be mentioned the Tennessee, Blackpoll, and Palm Warblers, the Wilson's, Olive-backed, and Gray-cheeked Thrushes, and the Chipping and Savannah Sparrows. Great daring was shown by the Sharp-shinned Hawks. Sometimes so eager were they in pursuit of their prey that they would dart within a few inches of one's head.

3. *Blunders and Fatalities.* A comparatively new danger which besets migratory birds on the island is the fatal attraction of the lighted windows of resorts and the light-houses. During the migration scores of warblers, chiefly Tennessee and Palm, killed themselves by striking against the lighted windows of the Club-house which stood in a clearing near the Harbor. Many also met death by the same means at Washington Island, which is situated at the entrance to the harbor. Among the species killed at the latter place were the Tennessee, Blackpoll, Myrtle, Magnolia and Palm Warblers, Gray-cheeked, Olive-backed and Hermit Thrushes, and several species of sparrows. On September 2, during a hard storm which lasted several days, five Olive-backed Thrushes were found dead by Wood beneath the windows at the hotel, and on September 5, a Gray-cheeked Thrush was found dead at the same place. This latter was the first one of this species seen, no other being observed until September 12. All the birds were killed on the north side of the buildings. Sometimes after cloudy nights numbers of small birds would be found on the north porch of the Club-house in a dazed condition, probably from striking the building the night before. Both young and adults were found, the young being the only ones killed on clear nights.

The light-house keeper at Menagerie Island in Siskowit Bay, Mr. J. H. Malone, reported that hundreds of birds lost their lives every spring and fall at his light alone. It was mainly on cloudy nights that the birds struck the lighted windows and the lantern, but some were killed on other nights.

REFERENCES.

Cooke, W. W.
1888. Report on Bird Migration in the Mississippi Valley in the years 1884 and 1885.
Bull. No. 2, Div. Economic Ornithology, U. S. Dept. Agr.

Smith, Frank.
1907. Advantages of Migration Records in Connection with Bird Study in Schools.
School Sci. and Math., 7, pp. 221-224.

Taverner, P. A.
1905. A Hyperlaken Migration Route.
Bull. Mich. Ornith. Club, VI, pp. 1-7.

Name.	August.															September.																					
	18	19	20	21	22	23	24	25	26	27	28	29	30	31		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21			
Chipping Sparrow	×	×	×	×	×	×	×	×	×	×	×	×	×	×		×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×			
White-throated Sparrow	×	×	×	×	×	×	×	×	×	×	×	×	×	×		×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×			
Chickadee	×	×	×	×	×	×	×	×	×	×	×	×	×	×		×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×			
Sharp-shinned Hawk	×	×	×	×	×	×	×	×	×	×	×	×	×	×		×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×			
Sparrow Hawk	×	×	×	×	×	×	×	×	×	×	×	×	×	×		×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×			
Great Horned Owl	×		×	×		×	×		×	×			×							×					×		×		×	×							
Herring Gull	×	×	×	×	×	×	×	×	×	×	×	×	×	×		×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×			
Thick-billed Redwing		×	×	×	×	×	×	×	×	×		×		×			×						×	×	×					×				×			
Common Redwing	×																																				
Blue Bird	×	×	×	×	×		×	×	×	×	×	×	×	×												×	×										
Flicker	×	×	×	×	×	×	×	×	×	×	×	×	×	×		×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×			
Myrtle Warbler	×				×	×								×		×					×						×										
Kingfisher	×	×	×	×	×	×	×	×	×	×	×	×	×	×		×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×							
Tennessee Warbler		×	×	×	×	×	×	×	×	×	×	×	×	×		×	×	×	×	×	×	×	×	×			×	×					×				
Canada Jay		×	×		×	×				×	×	×		×				×	×		×	×	×			×	×	×	×	×		×	×	×			
Red-breasted Nuthatch		×		×			×	×						×		×		×	×	×				×	×	×	×										
Crow		×	×		×	×	×		×	×	×			×				×	×	×				×	×	×	×	×	×	×							
Blue Jay		×		×	×		×	×	×	×		×		×		×		×	×	×		×	×	×	×	×		×		×	×	×		×		
Junco		×	×	×	×	×	×	×	×	×	×			×		×		×	×	×		×	×			×			×							
Night Hawk		×	×	×	×	×	×	×	×	×	×	×	×	×		×																					
Chimney Swift		×																																		
Pileated Woodpecker		×		×	×	×				×			×	×		×			×	×						×		×	×	×		×				
Phoebe			×		×		×							×		×				×						×										
Redstart			×	×		×	×	×		×		×				×			×		×	×	×			×										
Least Flycatcher			×	×	×	×	×	×	×	×	×	×	×	×		×		×		×			×			×	×		×							
Vesper Sparrow					×																						×									
Hermit Thrush					×	×	×		×	×	×	×	×	×				×		×	×	×	×	×		×	×	×									
Hummingbird			×		×																															
Spotted Sandpiper			×	×	×		×		×	×	×					×				×			×			×				×						
Song Sparrow				×		×	×																													
White-rumped Shrike						×																														
Cedar Waxwing						×	×			×		×	×	×				×		×	×	×			×		×		×	×	×		×	×	×		
Pigeon Hawk						×		×	×	✓	×	×				×			×			×	×				×				×					
Robin					×								×									×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	
Olive-backed Thrush			×	×			×	×	×	×		×	×	×		×	×	×	×	×	×	×		×	×		×		×	×		×					

Name.	August.															September.																				
	18	19	20	21	22	23	24	25	26	27	28	29	30	31		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Golden-crowned Kinglet					×		×	×	×	×		×	×	×		×	×	×	×	×	×		×	×	×	×	×			×	×	×	×	×	×	×
Brown Creeper					×													×						×						×	×	×	×			
Loon					×						×							×	×	×	×						×									
Winter Wren					×	×	×	×		×	×			×						×						×	×		×	×			×			
Hairy Woodpecker						×					×												×		×	×	×									
Bald Eagle							×													×					×						×	×				
Pied-billed Grebe				×	×	×	×	×	×		×	×	×	×		×	×	×	×			×					×				×	×	×	×	×	
Raven						×			×	×				×								×	×							×						
Cooper's Hawk							×																				×									
Wilson's Thrush							×	×	×	×	×	×	×	×		×		×	×		×	×		×			×		×							
Solitary Sandpiper							×					×					×	×	×	×							×		×	×						
Alder Flycatcher									×																											
Magnolia Warbler											×	×	×	×						×		×		×	×	×	×									
Palm Warbler											×	×	×	×		×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
Oven Bird											×	×	×	×									×	×	×	×	×									
Purple Finch											×																									
Bay-breasted Warbler											×	×	×	×		×	×	×	×	×	×	×					×									
Blue-headed Vireo													×														×									
Acadian Owl													×																							
Black-poll Warbler								×	×	×	×	×	×	×		×	×	×	×	×	×	×	×	×	×	×	×	×	×	×						
Black and White Warbler														×																						
Savannah Sparrow														×		×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
Black-throated Green Warbler																				×			×		×		×									
Yellow-breasted Flycatcher																												×								
Grinnell's Water Thrush											×	×	×	×		×	×	×	×	×	×	×	×			×	×									
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Green-winged Teal																			×																	
Marsh Hawk								×	×					×										×		×	×	×								
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Black-throated Blue Warbler											×																×									
Nashville								×	×	×				×		×							×			×	×									
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Red-eyed Vireo																									×									
Lincoln Sparrow																									×	×	×	×						
Connecticut Warbler																									×									
Ruby-crowned Kinglet																		×		×	×	×			×			×						
Gray-cheeked Thrush																		×							×	×	×	×	×	×	×	×	×	×
Broad-winged Hawk												×						×							×									
Wilson's Snipe									×																									×
Downy Woodpecker																	×	×		×					×			×	×	×				
Arctic Three-toed Woodpecker																				×					×									
Yellow-bellied Sapsucker																										×								
Horned Lark																										×	×	×	×	×	×	×	×	×
Rusty Grackle																												×	×	×	×	×	×	×
White-crowned Sparrow																									×	×	×	×	×	×	×		×	
Canada Goose																													×					
Yellow Legs											×				×	×												×						
Pine Siskin																															×			
Osprey																											×				×			×
American Pipit																															×	×	×	×
Sharp-tailed Grouse																							×											
American Scaup														×																				
Olive-sided Flycatcher																×																		
Northern Shrike														×								×												

THE ECOLOGICAL SUCCESSION OF BIRDS.*

BY CHARLES C. ADAMS.

"Of all truths relating to phenomena, the most valuable to us are those which relate to their order of succession. On a knowledge of these is founded every reasonable anticipation of future facts, and whatever power we possess of influencing those facts to our advantage."—JOHN STUART MILL.

"Indeed, some geologists seem to take pride in lack of knowledge of principles and of their failure to explain the facts observed in the terms of the elementary sciences. I have heard a man say: 'I observe the facts as I find them, unprejudiced by any theory.' I regard this statement as not only condemning the work of the man, but the position as an impossible one....The geologist must select the facts which he regards of sufficient note to record and describe. But such selection implies theories of their importance and significance. In a given case the problem is therefore reduced to selecting the facts for record, with a broad and deep comprehension of the principles involved, a definite understanding of the rules of the game, and appreciation of what is probable and what is not probable; or else making mere random observations. All agree that the latter alternative is worse than useless, and therefore the only training which can make a geologist safe, even in his observations, is to equip him with such a knowledge of the principles concerned as will make his observations of value."—PRESIDENT C. R. VAN HISE.

I. INTRODUCTION.

Almost every observer of animals has noted that certain kinds of birds are usually found associated in certain conditions, as, for example particular species of sandpipers and plovers upon the sandy beach, or the Meadowlark and Dickcissel upon certain prairies; but this is rarely considered a subject worthy of serious scientific study. To discuss the significance and value of such ecological study and suggest phases for investigation is the object of this paper. By the ecological distribution of birds is meant that correlation between environmental conditions and the occurrence and association of certain species of birds. In such study special attention must be devoted to the places of breeding; nevertheless the associations of birds at all seasons of the year are of importance. It is not the isolated occurrence of these species, but their relative abundance, the association of certain species, and their persistent occurrence in such conditions which is significant. In the literature of ornithology there is a vast amount of isolated data bearing on this subject, but very little of it has been organized and systematically studied.

When once the facts and general ecological relations have been determined, so that the representative bird associations or societies of given localities have been correlated with their proper environments it will then be possible to determine how one society becomes transformed into another, whether this is due primarily to other birds or to other environmental influences. A knowledge of the succession of bird societies and of the laws of change will not only lead to new ideas as to the influence of the environment, but will also have a

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marked influence upon the practical field studies of the bird student. It should lead to a more intelligent understanding of the relation of birds to the world about them, or even better, to the world of which they form a part.

Attention should further be directed to the fact that simply the occurrence of the bird in a definite habitat is not by any means the sole aim of such work. The influence of the environment should be studied in its bearing upon all phases of bird life. Not only should the most favorable habitat or optimum be recognized, but also the influence of the less favorable conditions; thus the nesting site, composition of the nest material, food, abundance, feeding grounds, migrating habits and all like relations are needed for an adequate and exhaustive study of the ecological distribution and succession of birds.

It is therefore not surprising that such requirements will be difficult to meet because the facts themselves are difficult to secure. Then there are further difficulties which are due to the limitations of the student himself, and are psychological in their nature. As examples of this class of difficulties two may be cited, because they are of frequent occurrence in all kinds of scientific work and not by any means confined to the study of birds. For, contrary to our youthful ideas, naturalists have the same limitations as humanity in general! We may divide naturalists into two classes, depending upon their primary type of mind. First, those who tend to see only the infinite detail of isolated facts and observations. This type of mind is particularly impressed with the multiplicity and variety in nature, and is one to which a general statement is almost a cause of irritation because there are usually exceptions to any general statement. The constructive imagination seems feebly developed in this type. To this class belongs many extremely valuable and useful students, because of the data which they, often with extreme conscientiousness, collect. They are collectors of facts rather than students of relations. To the second class belongs that type of mind whose primary interest is in generalizations, principles, relations, and which tends to neglect isolated facts and observations. The constructive imagination is liable to be developed in this type. This includes many extremely valuable and useful students on account of their tendency to condense, sift and formulate great masses of isolated facts. They are students of ideas and relations rather than collectors of "facts."

Each class, especially the well-marked types and extremes, often finds it difficult or impossible to understand the point of view of the other class. This frequently leads to misunderstandings and often to mutual contempt. Cope and Marsh clearly illustrate these two types of minds among our American naturalists.

By this time some may wonder why this subject has been introduced. It has been with a definite purpose, because frequently these opposed points of view cause delays in the development of many subjects. Thus a forewarning to students of bird ecology may produce good results if the individual student makes a conscious effort to counterbalance such deficiencies as go with his particular type of mind. In the past, details have tended to produce confusion through the neglect of general ideas. It is rarely that a word of warning on this subject is out of place, because the balanced "golden mean" investigator is never too abundant.

The quotations at the head of this article have an immediate bearing upon the subject at this point.

Not only is habitat preference, the association of avian species, their succession, and the laws expressing these relations of much interest, but they are of much importance scientifically as well as in a practical way. It is therefore desirable that naturalists realize the necessity of understanding the "rules of the game" if the true relations of birds are to be studied to the best advantage. No adequate substitute has yet been devised to replace a grasp of general principles.

Throughout this paper emphasis is placed on the *definiteness* of the dominant major environmental influences and complexes because the irregular features have apparently received undue emphasis and have retarded the recognition of certain important definite relations.

II. REPRESENTATIVE LITERATURE ON HABITATS AND SUCCESSION.

1. *Habitat Preference.* The American literature on habitat preference and succession, as a subject of special investigation, is very limited. By succession is meant the change or replacement at a given place of one or several species (an association) by others; as when a swamp is invaded by a dune and the representative swamp birds are replaced by those of the dune; or even again when the dune becomes fixed by vegetation and is inhabited by still another association of bird life. This is a much neglected subject; however, isolated observations on habitats are abundant in the biographies of the various species. The fragmentary character of these biographies tends to make them composite and they lose what pecularities they may have which are due to a response on the part of the bird to its particular conditions of life. These unfortunate limitations clearly show that here is an extensive field worthy of careful investigation. The work already done will be a useful guide in many cases, but the student who wishes to develop this subject must turn to the fields and forests rather than to the literature, both for his inspiration and his data.

Perhaps a further word should be added concerning the limitations of the *composite* life-history method, as this will aid in making clear the kind of work needed in the future. This composite or generalized method of describing habitats and life histories and the response of birds to them, tends to lay undue emphasis upon the *average* conditions of life and habits, and tends to neglect those *detailed responses* to the environment which reflect the laws of local influence. These results are similar to those produced by systematic students who are "lumpers" and who do not recognize local races or varieties. Thus a nest may be built upon the ground at the base of a shrub or bunch of grass, or in the brush, but what conditions determine such sites? In a dry meadow a Song Sparrow may build directly upon the ground, but in a swamp, in order to have a dry nesting site, it builds in a willow shrub. In many cases the causes of these differences will be difficult to determine, but in others it is a relatively simple question for any one familiar with the species to solve. There are also geographic variations of habits as well as those of habitats just cited, and for this reason it is necessary not to confuse such variations with those confined to some restricted area. These local and geographic relations are very intimately related, but they are sub-

jects which can only be worked out in detail when local studies give proper attention to local environmental responses.

In the following account of the literature no attempt is made at completeness, but the papers cited are believed to be representative. These papers will help to give some idea of the kind of observations and records already made, and will be suggestive as to future work. Mention will first be made of the literature on habitat preference, and then of that on succession.

By far the best discussion we have found on habitat preference of the birds of a given region is that by Townsend ('05) on Essex County, Massachusetts. The primary avian environments are described, the representative birds listed, and their preferred habitats are briefly discussed. Thus, the ocean and its birds, the sand beach and its birds, the sand dunes and their birds, the salt marshes and their birds, and the fresh marshes and their birds, give a general idea of the subjects treated. Regarding the birds of the sand beaches, he remarks: "Among the Plover, the Black-bellied, Semi-palmated, and Piping Plovers are above all birds of the beach, although the first two are occasionally found in the marshes, while the last-named rarely strays from the beach and the adjoining sand dunes. The Golden Plover, although at times found on the wet sands, is much more likely to hunt for food on the dry sands above the highest tides, or still farther inland, while the Killdeer generally avoids the beach altogether, preferring the fields" (p. 21). And regarding the birds of the sand dunes he remarks: "Savanna Sparrows nest in numbers at the foot of clumps of tall beach grass throughout the dunes, and on the edges of the tidal inlets from the marsh. The nests of the Red-winged Blackbirds and the Bronzed Grackles are abundant in the bogs and groves of the birches. The Crow, in the absence of tall trees, builds perforce in the stunted pines and birches, at times only ten or twelve feet from the ground" (p. 34). In the case of the Crow, note that he records the response to the dune environment.

While Townsend recognizes changes in the environment, as in the dunes and beach (pp. 21, 30), yet he does not see their relation to the bird life in the definite way in which he sees their habitat preferences, nor does he appear to clearly recognize the fundamental relation of association within the breeding habitat. To him the environment is static. However an excellent feature of his work is the record of seasonal changes in the bird life of the various habitats. In this connection attention should be called to certain papers which will greatly aid in the study of the dynamics or changing environmental factors which influence sea or lake shores bordered by dunes and swamps; conditions represented on the Massachusetts coast. Gilbert ('85) has discussed the general principles and topographic features of lake shores and Gulliver ('99) the shore line of the sea. But in addition to these physiographic forces, the vegetation also has a dominating influence upon bird life. For general principles relating to this subject Cowles ('01) should be consulted for his discussion of the vegetation of inland shores and dunes, and Ganong ('03 and '06) for his treatment of the Atlantic coastal conditions. These authors discuss

the succession of the vegetation, a factor of the utmost importance in the study of avain succession.

While considering Townsend's results, it may be well to outline briefly a general succession of bird life along the shore as indicated by his records. It is evident from the map accompanying his volume that the currents and waves are constantly modifying the coast line and forming spits, bars and islands; and that the barrier beach area is increasing, and thus tending to become continuous at the expense of some of the ocean habitat. As the continuity of the beach develops, the area of swamp land behind it tends to increase and thus to further restrict the open water and increase the swamp habitat. The beach sands, once free from the waves or ground water, are caught up by the winds to form dunes, and may migrate into the swamps and thus transform them. Thus with the extension of the beach the sea birds are replaced in dominance by the shore birds, and a succession is produced.

In a similar manner the dunes encroach upon the swamp, and swamp birds are succeeded by those of the dunes. As the wandering dunes become anchored by vegetation and forests grow upon them, still other birds will invade them. Thus all stages may be expected, from ocean to beach birds, onward to those characteristic of wandering and fixed forested dunes. These relations are outlined simply to indicate the problem and its causes, which need detailed investigation.

In Michigan a few habitat studies have been made. One in the Porcupine Mountains, on the south shore of Lake Superior, and another on Isle Royale. Both are by McCreary; the paper on the latter area is published in this volume. The summer birds of the Porcupine Mountains are listed (McCreary '06) by selected localities and the habitat preferences are discussed as follows: water birds, birds frequenting the shores and banks of streams, birds frequenting grassy meadows and alders, birds frequenting tamarack and cedar swamps, birds frequenting hemlocks and maples, and birds frequenting the cliff and mountain top. In its emphasis upon habitat preference this paper is the only one so far seen which at all approaches Townsend's discussion of this subject. McCreary's work was done without a knowledge of Townsend's.

In southeastern Michigan, Brown ('06) made a locality study and outlines the habitats as follows: birds found in orchards, birds of the open woods, birds of the open fields, birds of the thicket, and birds of the marshes and river. Brown's paper is intermediate in character between the preceding papers and those of an economic nature, to be mentioned later, because the area studied has been so much influenced by man.

There are a few papers which, although primarily faunistic or geographic, contain habitat data. Such, for example, is Ridgway's ('74) discussion of the birds of the Wabash Valley and ('89) the birds of the Illinois prairie (pp. 13-16). An exceptionally good paper of this character on the Louisiana birds is by Beyer, Allison and Kopman ('06), although its aim and method of treatment differs from that of Townsend. The bird life is, however, closely correlated with the vegetation and the physical conditions of the State.

The papers previously mentioned have been written from a regional standpoint. The study however of all the various conditions frequented

by a given species or some natural group is also an important and neglected method of ecological study which possesses certain important advantages. As an illustration of this method may be mentioned Palmer's ('00) study of the Maryland Yellow-throat. He has shown that different varieties have different habitat preferences. Jacobs ('04) has given us an interesting habitat study of a single species in Pennsylvania, the Golden-winged Warbler.

Let us now turn to another class of habitat studies, those which through man's influence throw only a subordinate light upon "natural" habitats and succession, and are primarily of economic importance but contain valuable habitat data.

An interesting and rather unique paper belonging to this class, based on observations in Southeastern Michigan, is by Watkins ('00). It is entitled 'Michigan Birds that Nest in Open Meadows.' A few of his statements explain his point of view: "To make more plain the limit and scope of this treatise, which, of necessity must be longer than I hoped, I will include in my list only such species as I have found nesting upon the ground in the open fields and meadows, excluding those found nesting upon the boundary fences or ground; also those nesting in the open marsh land which are undrained and boggy to the extent of being unfit for hay or pasture" (p. 67). The paper contains numerous notes on the habitat preference and variations in these traits.

By far the most comprehensive and thorough study of any limited farm area is that by Judd ('02) of a farm in Maryland. In this paper habitat preferences are clearly recognized, and discussed rather fully (pp. 12-20). The birds are associated thus:—birds that nest in the open fields, birds that depend on covers, birds of less limited distribution (consists largely of remarks on haunts), and birds of varied distribution. His last two sections are rather miscellaneous in character and show that the principles of classification for habitats were not clearly defined in his own mind.

The only other paper discussing habitat preference in detail is also the latest upon the subject, and is by Forbes ('07). This is a preliminary report on a bird census across the corn belt of Central Illinois in the early autumn; a study of the feeding grounds and preferences as influenced by the dominant crops of the area traversed, corn, pasture, and stubble. By means of this census, the habitat preferences for different crops and the association of species in them is statistically determined. The paper is particularly suggestive for its bearing on the subject of dominance; however, the suggested method of study has even greater significance when applied during the breeding season. Doubtless opinions will vary as to the validity of the method as applied by Forbes, even by those who would approve of it for the detailed study of a limited area, or a breeding habitat. For large areas some cooperative method may be necessary.

2. *Succession.* Turning now to the literature on succession, it is found to be extremely limited in amount. So far as known to the writer, only two American authors seem to have realized the existence of succession. In his discussion of the biotic succession in the Porcupine Mountains of Michigan, Ruthven ('06) clearly included the birds, although they did not receive separate treatment, and might for this

reason be overlooked. His position is clearly stated (p. 43) as follows: "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 supplemented 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." In speaking of the biota of the hard-wood forest he further says: "This region has been reserved for the last, for the conditions are evidently those toward which the other habitats tend to be changed under the present conditions....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."

The only other paper discussing avain succession is that by Frothingham ('06), and this is not a "natural" succession but one influenced primarily by man. He clearly expresses a bird succession correlated with the reforestation of burned lands. The area studied is the Michigan forest reserve on Higgins Lake. The region was originally covered with White and Norway pine, but repeated fires first killed off the pines, later the oak and maple; and finally the dominant vegetation is sedge, sweet fern, huckleberry and prairie willow. With the fire protection afforded by the reserve, Frothingham anticipates a reversal of the above succession of destruction, and further remarks: "With the types of vegetation which mark the different stages of the plant succession just described there seem to be correlated certain definite bird forms. These forms are for the most part such as frequent observations in northern Michigan have identified as generally characteristic of the respective environments." This is followed by lists of birds characteristic of different kinds of vegetation. While these lists do not correlate perfectly with the implied succession, yet the general statement of the problem is clearly expressed.

The burning of forests has long been known to change the character of the vegetation and fauna of areas, but this is often referred to as the change of a "life zone." Thus Merriam ('99, p. 47) states that a fire in the Canadian zone on Mt. Shasta is followed by the Transition zone and remarks: "But in the meantime a new growth of Shasta fir has started, and in ten or twenty years is likely to overtop and drown out the Transition zone species, enabling the Canadian zone to reclaim the burn....But on the steeper slopes, especially rock slopes, if the vegetable layer is burned off, the (lower) zone which creeps up to replace the (higher) one destroyed becomes permanent or nearly so....Deforestration of an area therefore tends to lower its zone position." Birds are not mentioned in this discussion nor the relation of

"zones" to the general problem of succession. Such "zones" are thus only particular phases of succession.

It is thus seen from the above outline of literature that habitat preferences have been outlined for a few widely separated localities and for some agricultural conditions, but there has been no comprehensive discussion of the problems of habitats and succession, even in a preliminary manner, either from a scientific or economic standpoint. This fact seems rather remarkable in view of the great utility of a knowledge of the general principles underlying economic practice. There are, however, certain phases of biotic succession which have been discussed by a few authors. These subjects have either been discussed in a very general manner or are detailed discussions of special regions or groups of plants and animals. For this reason, perhaps, their bearing upon other groups than those specifically mentioned are very likely to be overlooked by those who take little interest in any subject or discussion which does not specifically mention their specialty or locality. This phase is mentioned in order to show that while avain successions have been considerably neglected, advances have been made elsewhere, by means of which some general principles appear to have been fairly well established. This is particularly true of plant succession, as shown by the writings of Cowles ('01), and in considerable detail by Clements ('05). The discussion by Clements will be particularly valuable to the student of avian succession.

III. THE MAJOR AVIAN ENVIRONMENTS.

As has been seen in the preceding review of the literature on haunts, no comprehensive discussion has been given of the environmental influences or ecological distribution of (extra-tropical) North American birds. Various authors have discussed their geographic distribution, and certain geographic variations have been referred to certain environmental influences, but a general ecologic treatment, as contrasted with a primarily faunistic one, has not been made. This is remarkable when we recall the fact that the collections of North American birds are, considering the large area concerned, the best in the world both as to quality and as to quantity (Stejneger, '03). This means that there have been many trained collectors; but what has become of the notes and observations on the environments and conditions of life of these birds, which must necessarily have been known to successful collectors? Part of these observations have been published, and perhaps no one is to blame because more have not; but the point of significance is that we have, in fact, hardly made a beginning in the careful detailed study of the bird environment and its development as a distinct field of study. In common with the remainder of the North American biota, several general principles are known, but they do not appear to be current among ornithologists.

The following discussion and suggestions on the larger environmental units attempt only an outline of certain phases of the problem, in order to call attention to certain principles which seem useful as a background for the intelligent study of bird habitats and succession. From such a standpoint as this, the *dominant* influences of given areas and environments are of particular interest and of fundamental value. By focuss-