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Series XIV June, 1914 Number 2 (e)

TECHNICAL PUBLICATION No. 1

OF

THE NEW YORK STATE COLLEGE OF FORESTRY

AT

SYRACUSE UNIVERSITY

HUGH P. BAKER, Dean

PRELIMINARY REPORT

ON

DISEASES OF FISH IN THE ADIRONDACKS

A CONTRIBUTION TO THE

LIFE HISTORY OF CLINOSTOMUM MARGINATUM

BY

DR. W. M. SMALLWOOD

Professor of Comparative Anatomy in Syracuse University and
Forest Zoologist of The New York State College of Forestry in 1912 and 1913

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Am. Nat. vol. 33, No. 395, p. 861, 1899.

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Field Notes on Clinostomum marginatum with a Contribution to its Life History.

Preliminary Report — W. M. Smallwood.

It is common knowledge among those who frequent the several Adirondack Ponds during the summer months that the perch and often the bass are considered unfit for food because of the numerous parasites in their skin and in their flesh. The usual term heard from the guides is "grubby" when referring to the summer perch. A number of woodsmen have been consulted in reference to the time of the spring when they have first noticed the "grubs" in the perch and as to how long they remain. The writer has yet to find any one who knows anything definite concerning either of these important phases of the problem but all agree that in the ponds that have the worst infected fish in summer, perch free from parasites are caught in the winter and early spring.

For the past ten years the writer has usually reached the Adirondacks about the middle of June and by that time most of the perch are unfit for food as a result of parasitism. This is a condition, however, which seems to develop rather rapidly, possibly in about two weeks, for usually no trouble is experienced the last of May in securing plenty of perch entirely free from skin and flesh parasites.

Before any remedial measures of lasting benefit can be devised we must know the conditions under which these annoying parasites live and how they come to the adult stage. This is a report of a study of some of the more important biological conditions involved in an analysis of the problem. As a contribution to the life history, it is to be regarded as of a preliminary nature only.

Two species of Trematode parasites are found, the larger being the common flat-worm, Clinostomum marginatum, and the smaller one of the genus Holostomum. The phrase "grubby" perch has reference to the presence of Clinostomum which is usually imbedded in the flesh and shows as a whitish spot through the skin. Field studies covering hundreds of specimens show that these Trematodes (C. marginatum) are to be found on all parts of the body. On June 24, 1913, forty-four perch were studied with the following distribution of the parasites as seen through the skin: head, 38; gills, 5; trunk, 82; tail, 78. On August 7, 1913, one perch was taken which had over 30 fully developed Clinostoma encysted around the mouth cavity alone.

Judging from one summer's study, the number of adult parasites in a perch varies from month to month. This seemed to be noticeable early in August when a smaller average number of the "grubs" was found than late in June. Certainly the perch secured in September and especially in October were not as extensively infected as those taken early in the summer.

The ponds studied this past summer were selected because previous experience led me to believe that the perch were practically free from "grubs" in certain ponds. All of them are located in Franklin County and in Townships 19 and 20. Three pairs of ponds were selected as follows: West and East Pine Ponds; Copperas and a small mud pond; Follensby Clear and a nearby pond called Green Pond. The perch in East Pine, Copperas and Follensby Clear Ponds are and have been badly infested with Clinostoma for years, while in West Pine, in the mud pond near Copperas and in Green Pond, one may catch a fine mess of perch nearly all of which will be entirely free from parasites. All six of these ponds are practically spring-fed ponds. Copperas, Follensby Clear and East Pine each has an outlet. The water varies in depth from shoals so shallow that one must pole the boat to large areas 30 feet or more in depth. Some of the ponds are almost entirely free from weeds or lily-pads while others have many aquatic plants. The bottoms are muddy, sandy or gravelly. West Pine and East Pine Ponds are separated by a ridge some 300 feet wide; a much lower ridge of less than 250 feet separates Copperas and the mud-pond near it; while a strip of land of about 400 feet lies between Follensby Clear and Green Ponds. No constant physiographic factor was observed as belonging either to the ponds where the fish were parasitized or to those where they were non-parasitized. (Herons and Kingfishers were as frequently seen flying from one as from another). The shallow, muddy-bottomed pond near Copperas Pond contrasts strongly with the gravelly bottom and clear water in Green Pond, and yet 80 per cent to 90 per cent of the perch taken from each were free from parasites.

Where does Clinostomum spend the winter? This question cannot be definitely answered at this writing. But the fact that perch are secured during the winter free from "grubs" would indicate that they do not remain in a passive state in the perch until eaten by some bird as held by Osborne '11. Perch packed in moss and expressed from Lake Clear, N. Y., to Syracuse, in the middle of September, 1913, contained about ten parasites each, but on arrival more than two-thirds of them had escaped from the body of the dead perch and were themselves dead in most instances. They were found on the skin of the perch (completely extended). But not all of them had emerged and those still encysted in the muscles were alive when released. Examining the perch it was easy to discover where the parasite had crawled out. Those in the cyst were about ready to escape because in many instances when the whitish spot was pressed upon the parasite would emerge. The walls of the cyst and the muscles immediately in contact with it were partly dissolved indicating that Clinostomum has the power to cause the walls of the cyst, the surrounding muscles and overlying skin to disintegrate. This would seem, moreover, to be a natural process but is one that was not observed to take place during the summer when dead perch were kept several days.* This may be the normal process employed by the worms in the fall to free themselves from the perch, as fish free from parasites are found in the winter and early spring. Certainly this method of escaping throws new light on their habits and suggests that fish-eating birds are not necessary to complete their life history. For parasites probably do not make their escape in the fall until after most of the birds that feed upon perch have migrated, and even if the birds had not migrated there would be small chance of the parasites being eaten after they reach the water. But where and how the adult Clinostomum, its eggs or larvae spend the winter is unknown at present.

One often hears the guides say that the perch become "grubby" as soon as the water warms up in the spring. All of the ponds examined thus far are spring-fed and into some a cool brook empties or on the shore one or more springs are to be found. This is particularly the case at the upper end of Copperas where several springs are to be found, the water of which many campers have enjoyed. At the foot of a large tree a splendid spring runs into Copperas and some of the worst infected perch found during the summer were taken from the shore while standing beside this spring. Wells driven six or eight feet deep on the islands in Follensby Clear supply campers with plenty

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* This same phenomenon was again observed May 28, 1914. This time the parasite escaped within an hour after the fish were caught. I believe that these parasites had remained in the flesh of the perch all winter.

of very cool water and yet the perch in the surrounding ponds are badly parasitized. It is certain that these spring-fed ponds harbor parasitized perch even where the water is coolest.

The food of the perch was examined with some care on each trip in the several ponds kept under observation during the summer. The first dozen fish examined gave as much variation as was found during the entire summer. Snails, caddis-fly larvae encased in tubes of sand or sticks, an occasional dragon-fly larva and small minnows constituted the range of food for the perch as observed in these ponds. One perch was taken that had recently eaten a minnow (probably Pimephales notatus) which had a Clinostomum inbedded in the tail. The minnow was partially digested and one Clinostomum lay exposed and dead in the flesh of the minnow. It is well known that the pickerel feed upon the perch, and finally after much endeavor one was taken which had recently fed on a parasitized perch and in which the conditions were ideal for determining the fate of Clinostomum in the stomach of the pickerel. It was found on the mucous membrane of the stomach and was dead. In these two observations both parasites had the characteristic dull whitish appearance of the dead worm. The digestive tracts of several pickerel were examined critically and in no instance were any living Clinostoma found. It would seem from these two observations that the Clinostoma encysted in the flesh of fish when eaten by the perch or pickerel are quickly killed in the stomach and eventually digested.

The genus of flatworms known as Clinostomum has been familiar to American Trematode experts since Joseph Leidy in 1856 first noticed a cyst on the gills of the sunfish. Osborne, '11, summarizes the several contributions that have been made to the distribution and occurrence of Clinostomum marginatum in North America. The several observers* report the finding of this parasite in the intestine of the pike Esox, upon the gills or encysted in the muscles of the perch Perca flavescens, in two species of bass, Roccus lineatus and

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* Linton, E. R., 1910. The diagnosis of a case of parasitism in the brook trout. Proc. Seventh Internat. Zool. Congress, Boston, 1907.

* Osborne, H. L., 1911. On the distribution and mode of occurrence of Clinostomum marginatum, a trematode parasite in fishes, frogs and birds. Biol. Bul. Vol. 20.

* Cort, W. W., 1913. Notes on the Trematode genus Clinostomum. Trans. Am. Micr. Soc. Vol. 22.

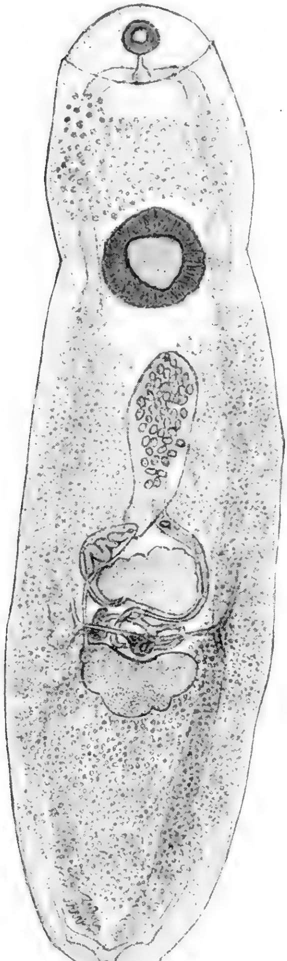


FIGURE 1. View from the ventral surface of Clinostomum marginatum, from a specimen from the throat of Ardea herodias, fixed under compression in acqueous corrosive sublimate, stained in borax-carmine, magnified twelve diameters. From Osborne. (Reproduced by permission of author and Wistar Institute of Anatomy.)

Micropterus dolomieu, in the brook trout, Salvelinus fontinalis pallidus, and in two species of sunfishes, Eupomotis pallidus and Channobryttus gulosus. I can add to this list the common bullhead, Ameiurus nebulosus, and the blunt-nosed minnow, Pimephales notatus. The perch and bass of the Adirondack ponds are usually infested with this parasitic pest throughout the summer. I have been told, but have not seen specimens as yet, that the perch in other parts of the State are parasitized with this same flatworm. The general distribution of Clinostomum, not only in New York State, but generally in the Eastern part of the United States and in many places in Canada, makes it very desirable that some means be devised for preventing

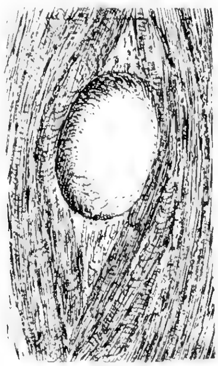


FIGURE 2. A Cyst of Clinostomum marginatum in place among the muscle fibers of the bass, from Nebish, Michigan, from a glycerine preparation after teasing off part of the muscular tissue. From Osborne. (Reproduced by permission of author and Biological Bulletin.)

its further spread and reducing its damage in such a wide extent of territory. In the Adirondacks practically all of the perch and many of the bass are rendered unfit for food. Certainly the problem is one of some economic importance.

Three observers have reported finding the adult worms in the digestive tract of the bittern, Botaurus minor, in the heron, Ardea herodias, in the herring gull, Harus argentatus, the stork, Mycteria americana, and the black-crowned night heron, Mycticorax naevius.

The encysted Clinostomum has a characteristic appearance in the muscles of the fish where it occupies a space in the endomysium. The worm fills the cyst and has a whitish appearance. Within the cyst the worm is bent twice, both times with the ventral surface outward. When the living worm is released from the cysts, it begins to crawl about on the skin of the fish or on one's hand. Osborne distinguishes two poses which he designates as the "suctorial and swimming." It does not seem to me that these are really as distinct as he points out, for when the animal is on the skin of the fish it makes a variety of movements, chiefly with the anterior end of the body, that might belong to any one of several poses. Unfortunately no experiments have ever been tried to determine just what the worm would do when brought in contact with another living fish in the water.

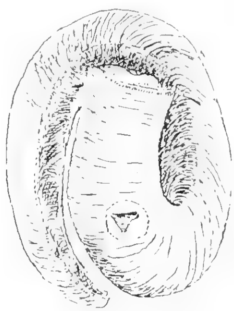


FIGURE 3. Drawn from a specimen of Clinostomum marginatum which had been removed from the cyst after fixation in alcohol and relaxed by slight maceration; from a bass taken at Nebish, Michigan. From Osborne. (Reproduced by permission of author and Biological Bulletin.)

The problem of how and at what spot these worms enter the body of the fish is still unknown.

Osborne gives a table of measurements for the adult in which the length ranges from 3 millimeters to 8 and the width from .9 to 2. millimeters. The worms that I have taken from the perch, particularly those taken in September, are much longer, some being 10 mm. long; the width, however, ranges about as given by Osborne. The most of my specimens are from 5 to 8 mm. long with several 10 mm. These long specimens were taken throughout the summer. As suggested in the early part of this study, I am inclined to believe that the small worms about 3 mm. long may be considered as young worms and that they will grow longer before making their natural escape from the body of the perch in the late fall. The mere fact that the reproductive elements have developed does not necessarily mean that the worm is full grown, because I have found the gonads differentiated in some of the smaller specimens even before the anterior sucker is well developed.

With a hand lens one can easily identify the two suckers, the oral

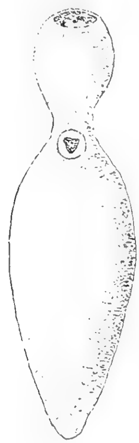


FIGURE 4. Sketch of living animal in "suctorial pose" as seen from the ventral side, from bass taken at Nebish, Michigan. From Osborne. (Reproduced by permission of author and Biological Bulletin.)

and ventral. Osborne says correctly that "the mouth opening lies in the center of the oral field and leads into the cavity of the oral sucker. The sucker is nearly spherical and is much smaller than the ventral sucker, measuring 0.28 mm. long and 0.25 mm. across. It has the usual cuticular lining and heavy muscular walls composed of fibres running in various directions."

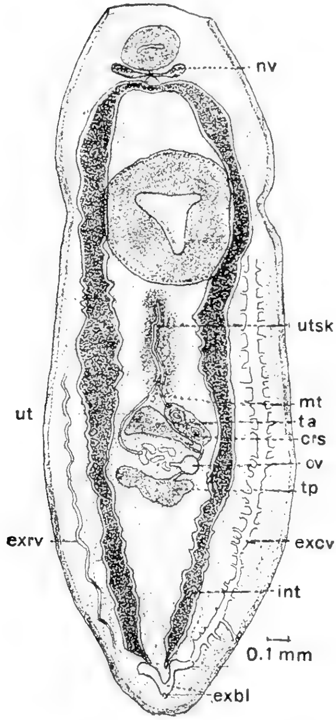


FIGURE 5. A partly schematic view from the dorsal side, combining facts from several sections of a frontal series. The vitellaria are not yet developed, the uterine sack is not dilated, the excretory collecting vessel is omitted from the right side and the recurrent vessel from the left, parts on different levels are shown on the same level. Magnified twenty-seven diameters. Crs. Cirrus sac; Exbl. excretory bladder; Excv. collecting vessel of excretory system; Exrv. recurrent vessel of excretory system; Int. intestine; mt. metraterm; nv. nerve collar; ov. ovary; ta. anterior testis; tp. posterior testis; ut. uterus; utsk. uterine sack. From Osborne. (Reproduced by permission of author and Wistar Institute of Anatomy.)

Osborne describes the several organs in the digestive system as follows:

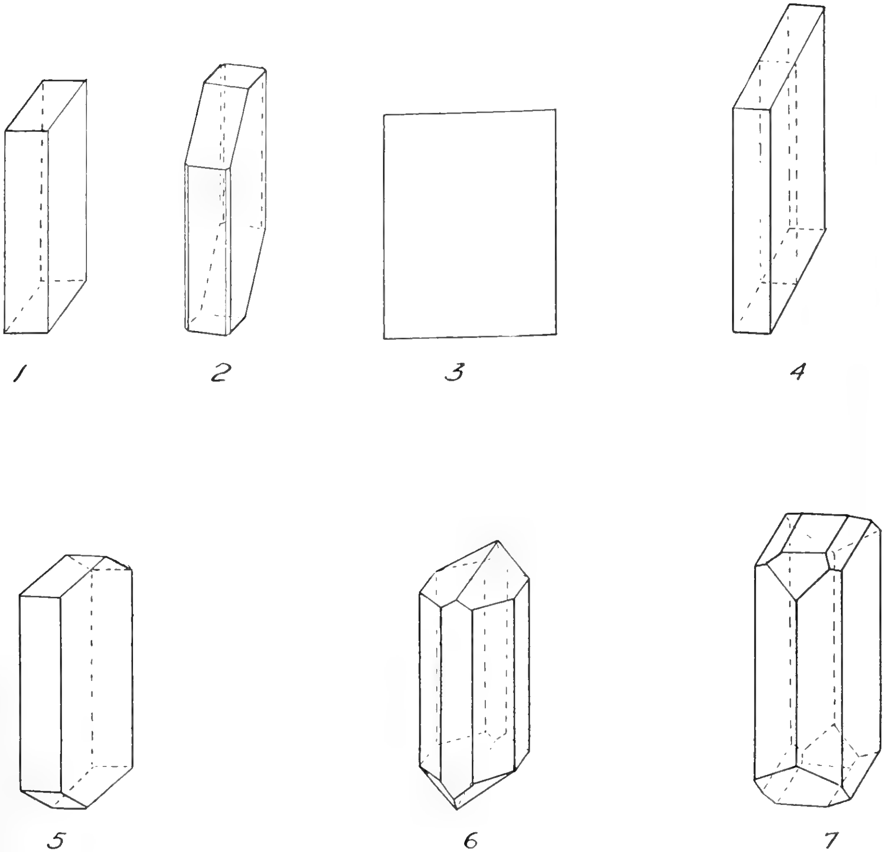
"The pharynx which is generally present in trematodes and usually follows close after the oral sucker, is entirely wanting. There is a short tube immediately behind the oral sucker which, after running ventrally a short distance, makes a dorsal bend to meet a transverse portion of the intestine. This is the esophagus. The intestine consists of a part crossing the body transversely which after bending, continues as the two long lateral coeca. The wall of the intestine is contractile; in life its movements are very conspicuous. The lumen is filled with a fine grained material lemon yellow in color. This flows back and forward, streaming, the pouches empty themselves of it or fill with it and the contractions of the wall may obliterate the intestine entirely for a moment. The cavity of the intestine of the worms obtained from the bass cysts is filled with thin, flat, four-sided crystalline bodies. As soon as the worm has escaped from its cyst the strong peristaltic contractions already mentioned force this substance backward and forward. At frequent intervals portions of it are expelled from the body through the mouth. In worms obtained from the heron this material is not found in the cavities of the intestine. In such worms on the contrary the intestine has been found to contain a coagulated fluid substance with blood corpuscles scattered through it, which upon careful examination were found to be identical with blood corpuscles taken from the heron."

The color of the fluid in the intestine is not uniformly a lemon color but may be a dark brown to almost black. The amount of substance in the two lateral coeca seems to vary in the several worms examined and in the two coeca of an individual worm. A study of the contents of the coeca in the killed specimens is not satisfactory but I am able to make out roundish bodies and a matrix which readily absorbs stain.

Sections of the intestine filled with these bodies were submitted to Dr. W. A. Groat, Professor of Microchemical Analysis of the College of Medicine, Syracuse University, and he was unable to find any evidence of hemoglobin or the products of hemoglobin in these bodies.

Professor Charles H. Richardson, of the department of mineralogy, examined this material and reports as follows:

"The stained material was uniformily dark during the complete rotation of the stage of the petrographic microscope under polarized light. No clue as to composition was afforded by this polarization. The material was then treated with water at normal temperature



Original by Richardson

FIGURE 6. 1. Composed of three sets of pinacoidal planes. 2. Composed of the same three sets of pinacoidal planes but modified by an orthodome. 3. The face of a prismatic form where the inclination of the clino axis is less than one degree. 4. Twin crystals where the twinning place is the ortho axis. 5. Composed of two sets of pinacoidal planes and two ortho domes. 6. A prismatic form terminated at either extremity by a pyramid. 7. A prismatic form terminated by a basal pinacoid, two clino domes and an ortho dome. C. H. Richardson.

and failed to pass into solution. It was further treated with concentrated nitric acid when the stained product passed immediately into solution. The nitric acid was allowed to evaporate completely. Upon a re-examination of the slide some thirty or more well defined minute crystals appeared. These were magnified 84 diameters and carefully studied under polarized light. The first six forms represented in the above legend were unquestionably present and perfectly formed. The seventh was apparently present. The forms are all simple and in the monoclinic system of crystallization. The crystals are soluble in water.

"Commercial hippuric acid is slowly soluble in water, readily soluble in concentrated nitric acid, and similar crystals form upon the evaporation of these solutions. All of the forms represented in the diagram have been duplicated with commercial hippuric acid."

The study of sections from several animals reveals the fact that these bodies exist in the tissues of the intestinal wall and adjacent cells as well as in the lumen. When the stain is extracted, there frequently remains a deeply staining center. If these bodies were crystalline as Osborne holds, the stain would appear on the edge or penetrate along the planes of cleavage. This it does not do. If it can be shown that these bodies have accumulated during the encysted period of the worm, then it will indicate an unusual amount of metabolic activity for an animal in a supposedly quiescent state.

Clinostomum marginatum possesses both organs of generation, the testes and ovary. In this sense it is to be regarded as an hermaphrodite. The question of whether the eggs are fertilized by the sperms grown in the same animal no one has attempted to answer because the facts are unknown. From figures one may see the position of the two testes and that a convoluted (much coiled) tube serves to carry the sperms to the exterior. Osborne says that the testes are made up of cells, each of which, in some bass worms, is almost completely filled by the very large nucleus. This is poor in chromatin and has a very large, readily staining nucleolus which indicates the inactive stage preceding development of the sperms. In other bass specimens are cells showing various phases of sperm transformation. In the worms from the heron the testes contain fully developed spermatozoa scattered among the active cells. The ovary is a small oval sack located between the testes. The oviduct eventually passes externally to the anterior testes on the left side and empties into a large sack termed the uterine sack. The uterine sack may be greatly distended in mature worms or as seen in optical section appear as a

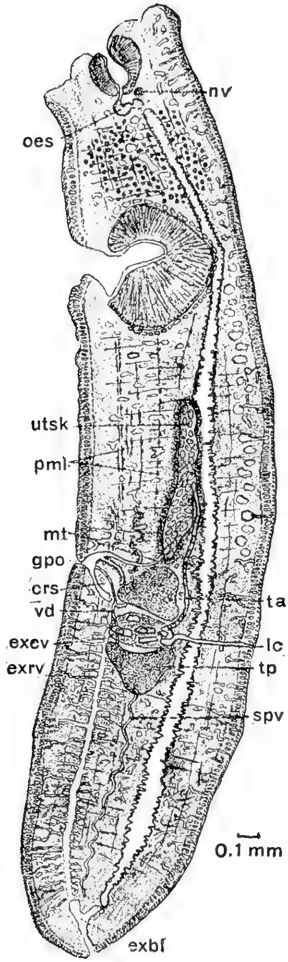


Figure 7. View combined from sections of a sagittal series, showing together organs which are on different levels, mouth, ventral sucker, genital organs and excretory pore are median while the intestine and the collecting and recurrent excretory vessels are lateral. Magnified twenty-seven diameters. Crs. cirrus sack. Exbl. excretory bladder; excv. collecting vessel of excretory system; exrv. recurrent vessel of excretory system; gpo. genital opening; lc. canal of Laurer; mt. metraterm; nv. nerve collar; oes. oesophagus; pml. longitudinal muscles of the parenchyma; ta. anterior testis; tp. posterior testis; utsk, uterine sack; vd. vas deferens. From Osborne. (Reproduced by permission of author and Wistar Institute of Anatomy.)

slit. The sack is connected with the exterior by a duct extending from its posterior end.

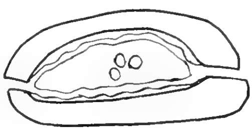
A better appreciation of the difficulties involved in unravelling the life history of Clinostomum may be had if we outline what is known about the development of some of the other distomes. This group of flatworms is exclusively parasitic throughout life in the early and mature stages. The egg is enclosed in a chitinous shell and supplied with a mass of food cells. These eggs may be attached to the host. In one species (Cryrodactylus) the eggs develop in the body of the parent. The egg of Polystomum hatches six weeks after oviposition, producing a minute larva (.3 mm. long) which swims about freely; but if in twenty-four hours it does not become attached to a tadpole, it dies. After finding a suitable host it attaches itself and eventually reaches the bladder by traveling the length of the digestive canal. Here it remains three years before attaining maturity.

The development of distomes is indirect and the life history often very complicated. From the egg a larva arises which enters a temporary host. Gamble says that "the larva gives rise by a peculiar process to numerous individuals of a second larval form, and these usually produce a third form from which the minute immature trematode is developed." Thus a large number of sexual individuals may be derived from a single egg. The larvae usually live in molluscs, the mature worm in vertebrates and the immature but metamorphosed trematode in either host.

The majority of distomes are hermaphroditic and many are capable of self-fertilization. In such cases the sperms ripen first and pass over into the uterus. The so-called egg consists of a fertilized ovum and a mass of yolk-cells. After the larva becomes attached to its host, it may degenerate into a sac-like structure full of germ cells and in this stage is designated a "sporocyst." The masses of cells in the sporocyst may give rise to another generation of larvae. Certain structures become characteristic of this larva, such as a pharynx and straight digestive sac. The name "redia" has been given to this second larva. The rediae move about in the sporocyst and eventually burst the wall, thus escaping. The free rediae may give rise to a number of new individuals, the "cercariae." Gamble* states that "the cercaria is just visible to the naked eye and has an oval or discoidal body and usually a long tail of variable form." The body of the cercaria contains in miniature all the organs of the adult.

*Gamble, F. W. 1910–11. Trematodes.
The Encyclop. Brit. 77 edition, Vol. XXVII.

From the above it may be readily inferred that the task of working out the full life history of many Trematodes is beset with many difficulties. All of the stages are subject to considerable variation and in many the life history is much condensed or abbreviated. First, one must know how many hosts are necessary for the complete development of Clinostomum marginatum. The size and form of the so-called mature worms in the throat of birds does not differ from those released from the cysts in the fish. Some of those which I have taken were 10 mm. long and exceed in length those found in birds. Thus far very little information has been gained from the study of these worms in birds. This is mostly due to the irregular and in most cases to the accidental manner in which the birds have been studied so far as the problem of fish parasites is concerned. The writer hopes that permission may be obtained to make a systematic examination of the herons in the Adirondacks this coming summer. If they prove to be the real distributors of these parasites, there is

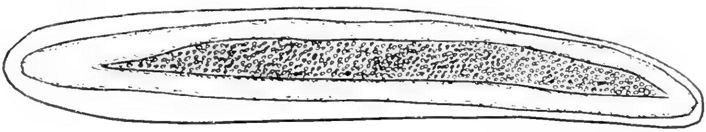


Original by W. M. Smallwood

FIGURE 8. Larval flatworm with a pair of intestinal tubes with a few round bodies forming between them. .03 mm. long; .06 mm. wide. From snail, Amnicola limosa. Original.

certainly an additional reason why the law which gives them such complete protection should be changed.

Enough observations are now on record to make it reasonably certain that Clinostomum may live for an undetermined length of time in several of the water birds. But where the early stages are passed is unknown. The wide distribution of this parasite suggests that one of several invertebrate hosts may satisfy the requirements of its larval development. The snails taken from the stomach of the perch in East Pine Pond were identified by Doctor Dall as Amnicola limosa Say. This nail is oviparous, depositing a single egg in each capsule. The snails, together with other animals, were placed in formalin to be later examined. Some of them were partly digested and no special pains were taken to insure careful fixation. When the different organs were studied for possible larval stages, some of the snails revealed the presence of a large number of brownish bodies in the liver. These bodies are elongated and in a few instances show what I believe to be a pair of intestinal tubes. The action of the digestive processes in the stomach of the perch which breaks down the tissues of the snail does not have any effect on them. The body seems to be covered with a thick cuticle and after fixation with formalin I am unable to make out any cells. This might be taken by some to argue against their being separate organisms. As further evidence of the correctness of this interpretation, three flatish worms were found .7 mm. in length while dissecting the organs of a snail preparatory to making sections. The snail which contained these three worms was so macerated as a result of the digestive changes that the organs fell to pieces when taken from the shell. I feel reasonably certain that each of these worms contains a pair of digestive tubes, while the space between the branches

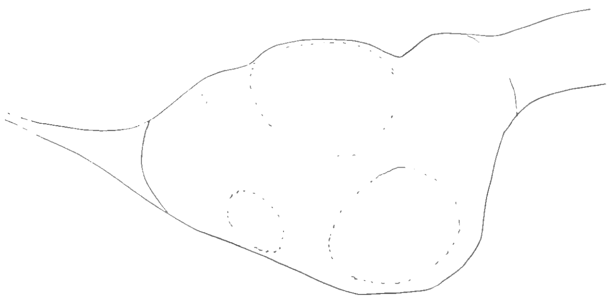


Original by W. M. Smallwood

FIGURE 9. Later larval stage of flatworm with the intestinal tubes clearly defined and the intervening space packed full of round bodies similar to those shown in figure 8. 1.2 mm. long, .2 mm. wide. From snail, Amnicola limosa. Original.

of the intestinal tract is packed full of round bodies. The color of these worms is identical with those found in the liver. Their reaction to stains is the same, so that those found in the liver impress one as being but a younger stage. The fact that these brown bodies do not occur in all of the snails and the further fact that larger specimens were secured suggests that I have part of the life history of one of the flatworms, but which one cannot be stated at present. The crucial test will come when the living tissues are examined which I plan to do next summer.

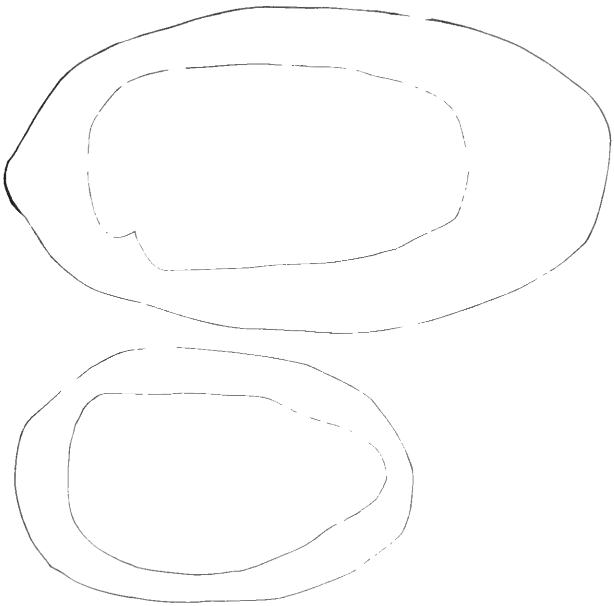
It is possible that the larval stages exist in the muscles of the perch. When the muscles of the perch are carefully examined, especially along the back, one frequently finds a number of small cysts. Osborne has given a careful description of the cysts of Clinostomum marginatum as to number of layers, the amount and arrangement of the connective tissue, etc. His account of the parts of the cyst apply to these small cysts both as to general appearance and as to structural detail. I have thus far found it very difficult to get the fixing fluids to penetrate this cyst and when I have attempted to remove the cyst, the worm has been greatly distorted and torn. These cysts are not all of the same age, for part of them are oval with a blunt process on one or each end that is in contact with the muscle. These younger cysts do not have the walls of the cyst well developed as the stain will penetrate as it will not in the older ones. I have not been able to section the latter in paraffin because the alcohol and clearing oil as well as the paraffin did not penetrate. So far as I have been able to determine with the limited amount of material at my disposal, two distinct stages are represented. In the older cysts, the young worms



Original by W. M. Smallwood

FIGURE 10. One of the smallest and youngest of the cysts found in the muscles of the perch. There are four round bodies which take a deep stain but the cells are not as yet organized into definite organs. 8 mm. long, .6 mm. wide. Original.

have a well developed oral sucker, digestive and reproductive organs. I have not been able to homologize all of the structures with those in the adult due to unsatisfactory sections but so far as I have gone the results indicate that this is a young stage of the adult. The younger cysts are filled with a mass of loose cells and connective tissue containing from one to three distinct round bodies. These round bodies take a deeper stain and vary much in size. Each is surrounded by a concentrically arranged layer of connective tissue. So far as has been determined, these bodies appear to be of growing larvae but as yet the cells are not arranged into organs. I have found these cysts in the muscles as late as October 21st. An attempt is being made to study these conditions throughout the winter and early spring. I expect to find that these cysts remain in the muscles all winter and during the early spring transform into the large worms with their well known cysts.



Original by W. M. Smallwood

FIGURE 11. Older cysts from muscles of perch in which the several layers in the wall of the cyst are present and the larval worm has a clearly defined digestive and reproductive system. The presence also of the oral and ventral suckers clearly indicates that these are early stages of Clinostomum marginatum. In the large one the cyst is 1.1 mm. long, .6 mm. wide, as compared with 3.5 mm. long for those described by Loess. The larval worm being .72 mm. long and .4 mm. wide. Small specimen has a cyst .8 mm. long, .5 mm. wide. Larval worm .65 mm. long, .35 mm. wide. Original.

Summary.

1. The physiographic conditions of the several ponds studied do not explain the distribution of parasites in the perch. The extensive distribution of Clinostomum marginatum indicates that a wide range of conditions allow the adult to reach maturity.

2. The general form and appearance of the so-called adult worm as found in birds does not differ from those taken from the cysts of the perch.

3. The brownish bodies found in the liver of the snail and the minute cysts found in the muscles of the perch suggest that this represents part of the life history of Clinostomum marginatum.

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Volume XVI November 1915 Number 1

TECHNICAL PUBLICATION NO. 2

OF

THE NEW YORK STATE COLLEGE OF FORESTRY

AT

SYRACUSE UNIVERSITY

HUGH P. BAKER, Dean

I. A New Species of Pityogenes

BY

J. M. SWAINE

II. Observations on the Life History and Habits of Pityogenes hopkinsi Swaine

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Psyche, Vol. 19, pp. 92–96, 3 fig.

A NEW SPECIES OF PITYOGENES.*

J. M. Swaine.

Pityogenes hopkinsi n. sp. Description of the female type. Length, 2 mm.; width, .75 mm.; color, black with the elytra dark reddish brown on the caudal two-thirds, the legs and antennae piceous.

The head has the front convex, moderately, closely, rather roughly punctured, with a subcircular, deep, median impression behind the epistoma, in diameter about equal to the width of the eyes, the sides of the pit clothed with minute pubescence, which forms a dense mat over a paler area between the pit and the epistomal margin; the epistoma fringed with long pale yellow hairs; the remainder of the front with slender hairs; the vertex and genae shining and transversely finely aciculate; the eyes entire; the antennal club subcircular with two strongly marked, very broadly arcuate sutures.

The pronotum slightly longer than wide, rather regularly projectile-shaped, faintly constricted before the middle; widest near the caudal margin; narrowly rounded in front; the cephalic half rather coarsely asperate in subregular rows with the apical margin serrate; coarsely, rather closely and roughly punctured behind, the punctures of varying size; with a narrow, moderately elevated median carina extending caudad of the summit and an irregular smooth space on each side behind the middle; the caudal border very finely margined; the pubescence erect, rather sparse, moderately long about the sides but much less than one-half the length of the pronotum.

The elytra are as wide as the pronotum, subparallel, faintly arcuate for nearly three-fourths the length, then broadly rounded behind as viewed from above; with the

*A Contribution from the Entomological Branch, Department of Agriculture, Ottawa, Canada.

suture slightly elevated; the sutural striae slightly impressed, the remaining striae hardly at all impressed except the last which is finely, deeply impressed; the strial punctures in fairly regular rows, deep, not close, and smaller than those of the pronotum; the interspaces uniseriately punctured, the punctures as coarse as those of the striae but more sparsely placed, particularly on the basal half; bearing long erect hairs; the punctures of the discal interspaces granulate, more strongly towards the declivity; those of the suture granulate to the base on the disc but smooth on the declivity; the declivity distinctly elevated, more strongly and widely towards the apex; the sutural striae rather deeply and widely impressed and shining, so that the declivity is moderately distinctly retuse; the interstrial punctures on the declivital prominence of each side sparse and granulate; the granules of the second interspace on the declivity represented by three conical, acute, widely separated small teeth; the last coarsest, the first two but little larger than the preceding granules; the pubescence sparse but long, stiff and erect.

The male has the front convex, coarsely granulate and closely hairy, without the median impression. The male declivity is very distinct; strongly retuse with the three teeth of the second interspace on the declivity very coarse, the first, at the top of the declivity, compressed, recurved, with the point directed caudad, the second and third regularly conical and very acute; with the second interspace smooth on the disc and the fourth and sixth smooth throughout; the granules on the outer part of the declivity coarser and the hairs longer than in the female.

This is the most abundant bark-beetle in limbs of Pine throughout the eastern part of Canada and the United States. The type is in the collection of the Entomological Branch, Department of Agriculture, Ottawa.

In 1868 Leconte described *Xyleborus sparsus* from one specimen taken at Point Kewenaw, Lake Superior. In 1878 he transferred *sparsus* to the genus *Pityophthorus,* and several authors have since placed it in the genus *Pityogenes.* The species usually discussed in literature under the name *sparsus* Lec. and usually found in collections under that name, is the common species described here as *hopkinsi.*

Many years ago Dr. A. D. Hopkins, after whom the species is named, indicated that the common *Pityogenes* in pine, probably the one discussed here, was not the true *sparsus.*

The type in the Leconte collection, now in the Agassiz Museum at Cambridge, Mass., is a male of the species now known as *balsameus* Lec.; the second specimen in the Leconte series is a male of *plagiatus* Lec.; numbers three and four are females and number five is a male of *hopkinsi;* number six is *balsameus;* numbers eight, nine and ten are *hopkinsi.*

Pityogenes lecontei n. sp. The seventh specimen in the Leconte collection, is a distinct species, a female, closely allied to *hopkinsi,* from which it is readily distinguished by the different frontal pit. The front is shining, granulate-punctuate; with two elongate, approximate foveae, with a combined outline longer than wide, situated on the median line at the base of the epistoma; the pits separated by a narrow median carina; the frontal hairs sparse and fine; the elytral pubescence is fine and very short, perhaps abraded.

Leconte's description of his type, "Head densely pilose, with long yellow hair, prothorax ——; anterior margin fringed with hairs which are half as long as the thorax;" applies well to the type, the first specimen of the series now in the Leconte collection, and to the male of *balsameus* Lec., but does not apply at all to the species described here as *lecontei,* nor to the species *hopkinsi.* It appears certain that the descriptions of *sparsus* Lec., and *balsameus* Lec., were written from the same species and since *sparsus* is the older name it must replace *balsameus.*

OBSERVATIONS ON THE LIFE HISTORY AND HABITS OF PITYOGENES HOPKINSI SWAINE

M. W. Blackman, Ph. D.

(With Six Plates)

The study of the life history and habits of the various members of the superfamily Scolytoidea offers as many points of interest either from the standpoint of pure science or from the economic aspect as does that of any other group of beetles. In spite of this, however, careful study of the biologies of this very interesting group of insects has been neglected in this country except in the case of a very few forms which are of great economic importance. Perhaps explanation of this neglect is to be found in the difficulties experienced in studying these insects consequent upon their very secluded life, as they remain either under the bark or within the wood of the host plant throughout their life, except for the short time required in finding a new host. However, by the exercise of a little ingenuity and of considerable patience, the main facts of their life histories and many of their interesting habits can be observed. This is especially true of those members of the group which habitually feed and breed in the thinner barked portions of cut trees, as the habits of these render them more easy of manipulation in the insectary and more amenable to observation in the laboratory.

Most of the observations here recorded were made upon insects in artificial cultures in the laboratory, supplemented wherever possible by observations in nature. In the laboratory the conditions of moisture, etc., were kept as near as practicable to conditions which prevailed in the field and observations upon the length of the various stages of the life history have been checked up by similar data collected in the field. Detailed study of the habits of the insect in making its burrow and in guarding it and its behavior under various controlled conditions were made in the laboratory, due to the fact that the size of the insect studied is so small that detailed observations were necessarily made at a considerable magnification.

The artificial cultures were made by placing freshly cut pieces of thin barked white pine limbs in cylindrical glass jars. These pieces were taken from living white pine and were in most cases normal in every way. The glass jars were some of them closed with a loosely fitting glass cover, while others were closed with cheese cloth tied securely over the top. Into some of the jars limbs of pine known to be infested with *P. hopkinsi* were introduced while into others were placed living adult beetles which had been removed from infested limbs. Thorough infestation of the new limbs occurred in both, but the results were more prompt in the latter case. It was necessary to add water every few days in order to keep the pine limbs in condition to furnish suitable food for the beetles and their developing brood. In the glass covered jars there was a decided tendency toward too great moisture which resulted in the development of fungi. In the cloth covered jars on the contrary the difficulty was in keeping the pine limbs in a moist enough condition. If a considerable amount of water was put in, the lower part the limb would absorb too much water while the upper part was too dry. Best results were finally obtained by alternating the two sorts of covers at intervals of several days. The occasional drying kept down the development of the fungi and also made conditions more like those occurring normally in nature where a dry period will alternate with a wet one.

The cultures were quite successful and a larger percentage of the larvae reached maturity than in nature. One interesting reason for this is that the disproportion of the sexes as they occur in the brood burrows was not so great, doubtless because the males were not subject to the dangers by which many lose their lives under natural conditions. The consequence was that each brood burrow contained the male and usually from one to three females while in nature the average number of females to the burrow is approximately three. Thus as a smaller number of egg galleries originated from each nuptial chamber there was less likelihood of many of them closely paralleling each other, and consequently fewer of the larvae in the cultures died of starvation. In nature, egg galleries which are closely parallel are very common and the engravings show that under such conditions many of the larvae do not survive to reach adult condition.

HIBERNATION.— *Pityogenes hopkinsi* hibernates in either the larval, pupal or adult condition. Burrows opened late in the fall, early in the spring or during the winter are likely to contain any or all of these stages. The author's collections include specimens taken at Syracuse, N. Y., in September, October, November, December, March, April and May, as well as during the summer months and while larvae and pupae were not present in all of the burrows they were to be found in others at the same time. However, by far the greater number of individuals pass the winter as young adults, next in number are the larvae which are usually more than half grown, while but a relatively small number spend the winter in the pupal stage.

In all stages the hibernating insects are exposed upon removing the bark although the hibernating burrow appears to groove the sapwood rather more deeply than at other seasons of the year. This is especially noticeable in the case of the larvae. Normally the young larvae burrow entirely in the bark, merely touching the surface of the sapwood, and only begin to groove the sapwood when they are nearly half grown. When taken in the late fall or winter, however, even the half grown larvae are found in burrows which are nearly entirely in the sapwood. The pupae during the winter months occupy pupal chambers (Fig. 27) apparently similar in all respects to those occupied by them at other seasons of the year. The adults pass the winter in feeding burrows in the same tree which has served them as larval food. While they have never been found hibernating in a new host, there is no reason for believing that they never do so, as at other seasons they often feed for several days or even weeks in a new host before constructing their brood burrows. The feeding burrows are a continuation of the larval and pupal burrow and at this season of the year are excavated nearly entirely from the sapwood (Figs. 27–28). Those occupied as winter quarters have never been observed to possess the so-called "ventilation" openings which are so characteristic at other seasons.

There is good reason for believing that *P. hopkinsi* hibernates in the true sense of the word only during the coldest winter weather. Burrows opened on mild days in December contained larvae and young adults which were quite active and were evidently still feeding. On being brought into a warm room from freezing winter weather, the adults show signs of life as soon as the bark is removed and become active in a very few minutes. This was shown on several occasions when beetles removed from burrows in frozen bark began creeping over fresh limbs of pine within ten minutes and several actually began new burrows within an hour. Some of these burrows were later found to be brood-burrows. Specimens of *Ips pini* Say removed from the same limbs remained torpid for a much longer time.

Emergence.—With the first warm days of spring the over-wintered larvae and adults begin feeding voraciously. For several days the adults allow their burrows to remain closed, feeding industriously in the meantime. These burdows while they still groove the sapwood include also considerable of the inner bark. After a few days of feeding they carry their mines well out into the outer bark and soon make a minute opening through this to the outside (Fig. 29). This opening is usually spoken of as a "ventilation opening." Its main purpose, however, seems to be to serve as a means of disposing of the excrement and the surplus frass produced by the adult, although it doubtless serves for ventilation also. Small hillocks of "saw-dust" soon appear in great numbers on the surface of the bark and if these are blown or brushed away it will be seen that each one has covered a small irregular opening through the bark. When first made this opening is the size of a small pin hole, but as more and more waste matter is pushed out through it, it becomes larger and more ragged.

After feeding for a variable length of time, depending doubtless largely upon the weather, the young adults choose some especially warm day for their emergence. They do not appear to emerge in swarms as has been recorded for other scolytids by Hopkins (1899) and others, but seem to leave the trees singly or possibly a few at a time. The habit possessed by some bark beetles of "swarming" during their migration from the old to the new host trees seems to be correlated with the possession of one or both of two other habits. In *Dendroctonus valens* Lec. which shows this tendency to a marked extent, the brood lives together in a common burrow during their larval and young adult existence and such a habit could develop much more readily than in a species like *P. hopkinsi* where the larvae each have a separate burrow and the feeding burrows of the young adults coalesce only occasionally and by accident. In cases where beetles attack living healthy trees, the habit of swarming is associated with the fact that a concerted attack upon the trees by a considerable number of insects is necessary in order to overcome the resistance of the tree and make it a suitable place for the development of the brood.

There seems to be good evidence for the belief that the two sexes do not leave the tree together but that the males leave the old burrow several days earlier than the females. Evidence that this is true is furnished not only by laboratory observations but also by observations made in the field. After infested limbs brought in from freezing weather conditions had remained in the laboratory for a few days, males were seen to be emerging in considerable numbers and to be attacking the fresh pine limbs, while all but a few females still remained in the old brood burrows. In the field, careful observations were made during the early spring at intervals of a few days to determine the exact date at which the adults emerge and begin to enter the new host. These observations all show that in the field just as in the laboratory, the males emerge several days earlier and the earliest males have prepared their nuptial chambers before the first females leave the larval host.

During the past spring (1915) the first record of activity of *P. hopkinsi* in the field is dated April 24th when a single male was found just completing the nuptial chamber in the bark of a white pine limb which had fallen during the winter. This was the only burrow found on a limb of two inches in diameter which was within 100 feet of a considerable quantity of pine tops and slash which had served as a breeding place during the preceding summer and which was well stocked with young adults. These infested limbs were examined and it was found that only a few specimens had emerged, although a week later nearly all, except those which from their color had transformed since the cessation of cold weather, had left. This definitely places the emergence of the overwintered adults as taking place during the last week in April for 1915. However as the past spring was considerably cooler than usual at Syracuse it is probable that emergence usually occurs somewhat earlier.

Construction of the Entrance Gallery.— In most cases where detailed observations have been made of the construction of the burrow of bark beetles, it has been reported that this work has been started by the female in the case of monogamous forms. The observations of H. A. Gossard (1913) of the habits of *Eccoptogaster regulosus* Ratz, and of *Phloeotribus liminaris* Harris, which are recorded in considerable detail establish this fact for the species he studied. In the case of polygamous forms, however, this does not appear to be true. Nüsslin (1913) says "Bei den polygamen Arten beginnt das Männchen das Brutfrassbild, indem es den Einbohrgang und die Rammelkammer nagt." My own observations upon *Pityogenes hopkinsi* agree entirely with this statement.

As has already been shown, the males emerge from their host plant slightly earlier than the females and immediately seek a suitable host and commence excavating a new burrow. They prefer to breed in recently cut limbs and tops of white pine but will attack standing, dying or dead pine provided the moisture conditions are suitable. They also quite commonly attack the trunks of weak or sickly young pines (especially in plantations) where the diameter is from one to three inches and the bark is still thin.

A considerable amount of time was spent in observing the behavior of the insects when starting their new burrows. Most of these observations were made in the laboratory upon specimens removed from their hibernating burrows and placed in a closed jar with fresh limbs. Limbs were brought into the laboratory at 11:00 A. M. on March 13, 1915 from temperature of about 20 to 22 degrees Fhr. The bark was immediately stripped from a number of limbs and the young adults of both sexes removed from their hibernating burrows. Although the burrows contained frost and frozen frass the specimens showed evidence of life by weak movement of their legs. Within ten minutes many had righted themselves and were creeping about. They were left in covered watch glasses till 2:00 P. M. at which time most of them had regained entirely their normal activity. When these were placed upon limbs of white pine freshly cut from the tree and confined in glass jars, they immediately began creeping all over the pieces of limb, carefully examining all of the crevices and roughened places on the bark.

At 4:15 one specimen, a male, was observed burrowing into the bark with its head and about one-fourth of its prothorax covered. Another one, a female, was examining the bark near and two minutes later had elevated her body nearly at right angles to the bark as if about to begin a burrow. She, however, was apparently only testing it as she abandoned work in less than a minute leaving no discernible scar. The female continued scouting about in the near vicinity of where the male was working examining the bark carefully and poking her head into all the crevices. The piece of pine limb was now placed upon the stage of a binocular microscope and observations were continued with the 32 objectives and No. 4 oculars, using the light from two tungston bulbs. The male was undisturbed and continued to work steadily and apparently with some effort, pushing his head into the burrow so that the space between prothorax and elytra was considerably lessened. Often the entire body was held at a considerable angle to the bark (Fig. 7) so that the hind legs were of no use in grasping the bark and waved about in the air. While in this position the first and second pair of legs, especially the first, were used in grasping the bark.

In working, the male continually pushed his head into the opening never taking it entirely out, and with each effort the middle legs could be seen to brace themselves just outside the edge of the hole while at times the fore legs were entirely in the hole (Fig. 7). As he worked he continually shifted his position so as gradually to encircle the opening. During this time the worker was often annoyed by other individuals, usually females. These usually, however, merely felt around with their antennae, but on one occasion a female butted into him with her head several times, causing him to back out of his burrow and move off for a short distance. The female then examined the hole rather casually and went away, whereupon the male resumed his labors.

By 4:40 P. M. the burrow had advanced till about two-thirds of the prothorax was covered. The fore legs were now entirely in the hole (Fig. 7) and were used in passing out the frass which was received by the mesothoracic legs and pushed away. At 4:45 P. M. a female again came but the male merely waved his legs and did not remove his head from the burrow. Two minutes later another male happened along. He felt about for a few seconds and then butted into the working male and appeared to grasp one of his second pair of legs in his mandibles. The worker then backed out of the hole hurriedly and began wandering about aimlessly on the bark. The disturber poked his head into the hole and likewise wandered off. Observations for the day then ceased and were not resumed till two days later.

On March 15th at 8:00 A. M. six burrows were well started in the same piece examined Saturday. All but one of the workers were buried in the bark with only the end of the abdomen showing. One specimen was about half way in and several were wandering about on the bark. Each burrow started was marked for future identification by a cross scratched in the bark with a dissecting needle. All of the workers but one were males, although several females were burrowing between the bark and sapwood at the cut ends. The one female burrowing through the bark was working, however, in the same burrow studied two days before and known to have been started by a male. This would seem to indicate that while the female of this species is perfectly able to burrow the inner bark and sapwood she seldom or never burrows through the tougher outer part of the bark, but will on occasion use burrows started by males and later abandoned.

While observing this specimen with the binocular microscope a male happened along in his wanderings and after casually examining the female, chanced to find the cross mark scratched in the bark near her burrow. He immediately began working, biting out minute bits of bark and bracing his legs against the surface of the bark. In this way he worked along one cross line till he came to the juncture of the two. There apparently finding a more suitable foothold, he elevated himself at an angle of about 45 degrees, taking the position shown in Fig. 6 and began work in earnest. Until the burrow has advanced far enough so that the front part of the prothorax is below the surface, the burrower seems to be working under considerable difficulty and it is apparent that suitable foothold is an absolute necessity. A study of Fig. 6 will make clear how these difficulties are overcome. The fore legs are placed at the sides of the hole or slightly in front with the spines at the ends of the tibiae (Fig. 18) pressed against the bark, usually in rough places, while the tarsi extend forward and the claws grasp the bark. The ends of the tibiae of the middle and hind legs are pressed against the bark. In working, the middle and hind legs are straightened more or less with each effort of the mandibles while the fore legs, gripping rough places in the bark, anchor the anterior end of the body and serve as the fulcrum of a lever formed by the rest of the body. With each elevation of the posterior end, the mandibles are pressed down into the burrow and brought into play. As he continued he gradually worked back and forth around the hole, entirely encircling it.

The freedom of movement of the head is remarkable. The juncture of the head and prothorax is practically a ball and socket joint (Figs. 1, 3, 4) which allows the greatest freedom of movement in every direction. The rapidity and range of motion of the head is also no less extraordinary. The head can move ventrally till the mandibles point nearly backward and dorsally till the mandibles extend nearly directly in front. Lateral movement of the head is no less remarkable and often this is carried so far that the greater part of the eye is covered by the side of the prothorax.

The work of making the burrow proceeds rather slowly until the hole is deep enough so that the anterior part of the prothorax extends below the margin of the opening, when it is continued more rapidly. The function of the rugosities (Figs. 1, 4, 22) on the prothorax is now quite apparent. In working, the insect now braces the dorsum of his prothorax against the side of the opening with his fore legs in the hole, his middle legs braced against the surface of the bark and his hind legs gripping the bark farther back or waving in the air (Fig. 7). The rugosities on the prothorax now serve as an anchorage and also as the fulcrum of a lever, and every push exerted by the mesothoracic legs forces the mandibles against the opposite side of the burrow. The fact that the spines on the prothorax point upward and backward (Figs. 1, 22) are of considerable advantage, as they readily allow the thorax to slip down farther into the burrow and obtain a firmer hold, but will not allow the body to slip upward as long as the prothorax is pressed firmly against the side of the burrow. The worker still continues to circle around and around the burrow while working, thus bringing his mandibles to bear upon all sides of it. His position is usually nearly perpendicular to the surface

(Fig. 7) except when gouging out the center of the bottom of the burrow, when he assumes a position as nearly parallel to the bark as the depth of the burrow will allow. As the hole became somewhat deeper, this part of his work becomes harder and this new difficulty is solved by making the burrow slightly wider a short distance below the surface (Fig. 8). It is apparently quite important that the entrance to the burrow be as small as possible. It is made just large enough to admit the insect and can then be guarded much more readily as we shall see later.

By the time the prothorax was one third submerged, the green inner bark was reached. This was quite sticky and pitchy and the borings frequently adhered to the legs, hampering them considerably. This material was passed up out of the burrow by movements of the head assisted at times by the fore legs. It was received by the middle legs which attempted to deposit it at the edge of the burrow. However, this frass often adhered and on attempting to clear it away with the hind legs both pairs soon became clogged with the sticky material. After trying in vain to free his legs of this incumbrance, he backed out of his burrow and took a short jaunt, kicking his legs and dragging them over the surface of the bark, in much the same way as a boy will free his feet of mud. This was entirely successful and he immediately returned to work.

The worker now assumed a position which allowed freer observation of the action of the mouth parts and head. With the prothorax pressed against one side of the burrow and the fore legs braced against the other side, the mandibles were pressed into the bark and by a rapid twist of the entire head a small bit was removed. The frass often adhered to the mandibles hampering them badly. The head was then turned upward to the margin of the opening and the bits of pitchy park were removed by a cleaning motion of the maxillae. These moved very freely both laterally and antero-posteriorly with a sort of plunger-like movement. The fact that the lacinal teeth or hairs are flattened (Fig. 19) must aid greatly in the performance of this function as they apparently act as scrapers. The fore legs were occasionally used in helping free the mandibles of frass but were usually not needed. Ordinarily they were braced against the sides of the burrow with the base of the femur fitting snugly in the smooth surfaced groove (Fig. 1, 2) at the ventro-lateral sides of the prothorax.

At the end of two hours work the burrow was advanced far enough so that the prothorax was two-thirds covered. The middle legs which now were nearly at the level of the surface, were still used in gripping the bark. The hind legs were flexed against the body and were used only occasionally in aiding in the disposal of the frass. At about this time the specimen was observed to defecate for the first time and this was continued at intervals of from two to thirty minutes from this time on. The foeces was cylindrical, brownish, translucent and quite sticky as was shown by the fact that it adhered to the stiff bristles surrounding the anus and later adhered to the pile of frass surrounding the entrance to the burrow.

The condition of the bark was now apparently more favorable, but the specimen experienced considerable difficulty in gouging out the bottom of the burrow. This mechanical difficulty was overcome by making the burrow wider just under the bark (Fig. 8), thus allowing space for his prothorax while his jaws were brought into play upon the center of the bottom. In this process considerable range of motion was shown at the juncture of prothorax and mesothorax. On pushing with his middle legs, the posterior part of his body was forced up so that the elytra nearly touched the prothorax and on pulling, the body was flexed so that the anterior part of the mesothorax was pulled out of the prothoracic collar to such an extent as to expose considerable of the membranous connecting part.

In order to see just the character of the burrow at this stage, the specimen was removed. The burrow was approximately the shape shown in Fig. 8. On attempting to return him to the burrow, he would not resume work but wandered off over the bark moving in a jerky way and apparently irritated at the rough handling.

On returning from dinner, however, the burrow was found to be occupied by another specimen easily distinguished by its much lighter color. Evidently he had been working some time as his prothorax was completely hidden. He continued to work steadily throughout the afternoon and when observations ceased for the day at 5 P. M., slightly over half of his body was in the burrow, the margin extending midway between the middle and hind legs. The middle legs were now in the burrow and the hind legs were braced against the surface of the bark. He apparently continued work throughout the night, as at 8 A. M. the following morning, the burrow had been extended so his hind legs were completely hidden and only the last four segments of the abdomen were visible. (Slightly farther than shown in Fig. 9.)

He now apparently began changing the course of the burrow so it gradually came to extend more and more parallel to the surface of the bark. By the time observations ceased for the day he had penetrated so far that the body was entirely below the surface, but the posterior end of his body was still visible. He again continued work all night as shown by the fact that by the next morning the burrow had advanced so far in a direction parallel to the surface that only the end of his body was visible on looking into the opening (Fig. 10). The end of the elytra, perhaps one-fourth of them, could still be seen by concentrating the light and directing it into the entrance. In burrowing he still rotated in the burrow working as well upon his back (Fig. 11) or sides as in an upright position. As the bark was burrowed out, the bits of frass were passed backward by the hind legs. As this material piled up behind him and on top of him he would back up to the entrance of the burrow, forcing it upward where it adhered to form a sort of dome over the burrow. When this was touched with a needle it would topple down upon him and he would immediately back up and force it out again. Although he was teased for five minutes or more by toppling the borings in upon him as soon as he had retired into his burrow, he always immediately backed upward until the end of his abdomen protruded slightly from the burrow. He would often partly rotate in the entrance, trying apparently to arrange the pile of frass more securely. As the specimen could not be induced to use other methods of disposing of his chips the frass was removed by blowing and other experiments were tried.

Response to Light.— Concentrated light from a tungston bulb was directed into the burrow by means of a bulls eye condenser. The specimen had been hard at work, but immediately desisted and remained motionless for half a minute, when he resumed work as before. A small ruler was then passed rather slowly back and forth between the condenser and the burrow producing a moving shadow. Only the end of his body was visible, but he immediately backed upward until the entrance was completely blocked by the ends of his elytra. For the first few times this experiment was repeated he responded in the same manner, but thereafter he would pay no attention whatever to either a moving or a stationary shadow.— In nature a passing shadow might mean danger from predaceous or parasitic enemies or it might be made by a branch waving in the wind.

Response to Mechanical Stimuli.— Response to mechanical stimuli was then tried. The entire limb was jarred by tapping it smartly. He paid no attention whatever, but continued his work. Inserting a needle into the burrow the stiff hairs at the end of the elytra were touched as gently as possible. He immediately responded by backing upward and completely blocking the entrance of the burrow with the posterior end of his body, arranging himself in such a way that the declivity of the elytra armed with the three pairs of spines was on a line with the surface of the bark as shown in Figs. 13, 14. If when stimulated he happened to be working with back downward, as in Fig. 11, he would back out as shown in Fig. 12, but would immediately revolve so that the greatest possible part of the opening was closed by the hard spiney elytral declivity (Figs. 13, 14). It is apparent that in the position shown in Fig. 12, the insect would be much more susceptible to attack than in that shown in Figs. 13 and 14. It is worthy of note that the entrance burrow always penetrates the bark at such an angle that when the insect assumes this "guarding position" the elytral declivity is on a line with the surface of the bark.

While the specimen was in the "guarding position" it was stimulated by touching the hairs very gently with a needle, first on one elytron and then on the other. It responded by crowding as close as possible to the burrow on *the side stimulated.* This response again would be most effective in guarding against small predaceous or parasitic insects. When the elytron was touched firmly with the needle the specimen immediately retreated into the burrow as far as it could go.

Response to Water.— A small drop of water was then placed over the entrance of the burrow and allowed to enter by letting out a bubble of air with the needle. The worker immediately backed upward, closing the entrance and remaining motionless, with the tip of the elytron out of the water. More water was added from time to time so that the insect and the entrance was entirely covered. While these conditions lasted he made no response to mechanical stimuli and was not induced either to leave his burrow or to retreat farther into it. The entire body of the insect was kept covered and the burrow filled with water for fifteen minutes, when it was allowed to evaporate and to seep into the wood. Very shortly after the water had sunken below the end of the abdomen slight movements were observed and on stimulating with a needle some response was obtained. Three minutes later he was quite active, moving abdomen and elytra considerably, apparently renewing the air supply and drying out the space between abdomen and wing covers. This continued for about two minutes, when he retreated into his burrow and resumed work.

Similar experiments were tried with another specimen, the burrow of which was not advanced so far, only about half of the body being covered. He seemed disturbed at first but continued to work although the hole was entirely filled with water and all of his body but the tip of the abdomen was covered. Soon he backed out bringing a considerable amount of frass and allowing the hole to fill completely with water, but resumed work immediately with most of body under water. When the entire body was covered he ceased all movement but still remained with his head and thorax in the burrow.— In nature during a rainstorm he would be more likely to survive in the burrow than he would upon the surface of the bark as he would be less likely to be washed from the limb by raindrops.

It would seem then that so long as the tip of the abdomen and elytra are not covered, water has no bad effect not even causing the insect to suspend work. When the entire body is covered, however, the air supply is shut off and all movement ceases till the opening between the end of the abdomen and the wing covers again has access to the air.

EFFECT OF TURPENTINE.— A specimen was next removed from the bark and placed in a watch glass in a drop of spirits of turpentine. It struggled violently lashing about with its legs and antennae and working its mouth parts. Within a few seconds its struggles became less violent, the head was withdrawn into prothorax nearly to the level of the base of the mandibles and the only sign of life was a spasmodic twitching of the legs. This specimen and others treated in a similar manner did not recover, showing that turpentine is quite deadly if the entire body is submerged.

A drop of turpentine was then placed in a burrow which was so far advanced that the end of the abdomen of the occupant was just visible (Fig. 10). He backed out till the end of abdomen protruded slightly, kicking vigorously, withdrew slightly with hind legs kicking and anus opening and closing. The specimen acted as if in great distress, plunging into and out of his burrow but never leaving it entirely. He would back out to level of the prothorax and immediately plunge in again till only the ends of the elytra were exposed. He was apparently not lacking in vigor as this performance was kept up almost rythmically for thirty-five minutes, this behavior being occasionally varied by his retreating to the bottom of the burrow or rotating at the entrance. At the end of forty minutes he became fairly easy in his actions but at times was still quite restless as if in some pain. At the end of an hour he was apparently normal again and was hard at work. The following few days he was very active as shown by the large quantity of frass he cast out of his burrow.

Eight days later he seemed especially solicitous in guarding his burrow, refusing to retreat even when prodded firmly with the needle, and considerable poking was necessary to make him retreat for even a short distance into his burrow. The burrow was therefore opened by turning back a flap of the bark and found to consist of a large nuptial chamber from which extended four female burrows. Two of them were only just begun while the other two were of considerable length and contained a number of egg niches. The flap of bark was replaced in its natural position without seriously disturbing either the male or his four mates. This burrow contained more females than any other in the same breeding jar although a greater number often occurs in nature. It is possible that the turpentine used in the experiment was responsible, it being a well known fact that the odor of turpentine will attract many species of bark beetles.

Disposal of Pitch.— In nature *P. hopkinsi* will often attack living white pine which is unhealthy, but which still contains a considerable amount of liquid pitch. Several young white pine trees about five feet high which were sickly, but on which the leaves were still partly green were found at Great Bear Springs near Fulton, N. Y., on May 8th. These were just being attacked by the beetles and the trunk of one of them was brought to the laboratory. The bark on one side of this was dead, while that on the other side was alive, green and quite pitchy. The dead side contained no beetles, but the pitchy side was riddled with their burrows in all stages from that in which the beetle had penetrated only about one-third of his length into the bark, to burrows containing females, egg burrows and eggs. Many of these burrows had tapped pitch ducts and typical pitch tubes (Fig. 24) consisting of frass excrement and pitch had been constructed at the entrance. Several burrows were observed which had been carried just the length of the beetle and into which so great a quantity of pitch had exuded that the worker had been unable to dispose of it and had been embedded in it and killed.

Still other burrows were found in which only the ends of the abdomen were visible, the rest of the beetle's body being in the hole surrounded by pitch. The most pitchy of these was chosen for study. When it was placed upon the stage of the binocular microscope and the light condensed upon it, the pitch flowed even more freely than before, completely enveloping the body of the beetle. He backed part way out of the entrance and tried to free his body of the sticky liquid by violent movements of the legs and abdomen, at the same time opening and closing the space between elytra and abdomen in an apparent endeavor to get air. For ten minutes he continued to work in his burrow covered with liquid pitch with only the end of his abdomen and elytra protruding and even these were often submerged momentarily. At the end of this time he backed out with only his head in the burrow and his body nearly parallel to the bark and kicked violently, trying to force the sticky pitch to one side. As the burrow was still full he backed entirely out and plunged violently back into it, repeating this a number of times. The hardening resin was forming a bank about the entrance making the burrow deeper and rendering it impossible for him to get to the bottom of the burrow without the body being completely submerged. After trying several times to resume work and being submerged each time, he backed entirely out of the hole and with his forelegs grasping the margin of the entrance, he sidled about half-way round the hole and in this way spread the adhering pitch to a distance of several millimeters.

However, the burrow was still full of pitch and the specimen after trying in vain to resume work, again backed out of the hole and leaving it entirely, sidled off kicking violently. He proceeded for a distance of 6 mm. spreading the pitch as he went, and then turned toward the burrow again. As he approached the entrance he came into contact with a small pile of frass and partly dried pitch and immediately paused and began " rooting about ", apparently seeking the opening of the burrow. When this obstruction was removed with a needle he continued onward and found the entrance. After examining the brink carefully he plunged in until only the end of the elytra protruded from the liquid resin. Apparently by trying several methods he had succeeded in disposing of enough of the pitch so that the end of his abdomen would remain unsubmerged and he could resume work. On the following day the burrow was still occupied but was little if any deeper than when last seen. All of the worker's efforts seemed to be needed in keeping the hole from closing, with his body, and in arranging the hardening pitch into a "chimney" around the entrance. Four days later the burrow had been carried no deeper and the specimen was found dead in the hole embedded in hardened pitch.

It would appear to be established then that after the burrow is well started, *P. hopkinsi* will not be driven from it by being submerged either in water or in pitch, and that it will continue working in either of these, so long as the breathing opening between the ends of the elytra and abdomen is not covered. When this is covered with water the beetle immediately becomes motionless and remains so until this subsides below the level of the end of the abdomen. When submerged entirely in pitch it attempts to dispose of this in several different ways. Usually as shown by examination of numerous burrows in living pine, it is successful, but occasionally it is overcome and is smothered in the sticky material. Only a very few pitchy burrows have been found which had apparently been abandoned and there is always the possibility that the insect may have been overcome by a predaceous enemy or that the body may have been removed by a scavenger after death. In several cases evidence of this was found in the form of portions of the head and legs still embedded in the hardened resin of apparently abandoned burrows.

Construction of the Nuptial Chamber.— It has already been shown that by the time the burrow is deep enough to cover about half of the body, the burrowing beetle begins to widen it somewhat. It is thereafter continued at such an angle that when it is completed and the insect in the guarding position, his elytral declivity will be parallel with the surface of the bark (Fig. 13). As soon as the entrance burrow reaches such a depth that the declivity is even with the bark, it is continued at a sharp angle to its original course (Fig. 10) so that it nearly immediately becomes parallel with the surface of the bark. If the burrow under construction be one intended for breeding purposes, as most of those entering through the surface of the bark are, the male constructing it soon begins widening it out to form a nuptial chamber. The length of the entrance burrows varies in different brood burrows. In some it is little more than the length of the individual building it, i. e. the nuptial chamber is excavated as soon as a position parallel with the surface is reached, while in other cases the entrance gallery may be carried horizontally for a distance of several millimeters before it is widened out to form the nuptial chamber (Fig. 15).

The nuptial chamber is a cavity of irregular shape and variable size (Fig. 23, a, b, c, d). It is a flat chamber just high enough to accommodate the body of *P. hopkinsi.* It may be constructed upon the surface of the sapwood, may even grove the sapwood, or may be entirely in the bark. The depth at which it occurs does not depend upon the thickness of the bark but is determined by the length of the specimen constructing it. The size varies greatly and does not depend on the length of time the burrow has been occupied, but apparently depends upon the length of the period in which the male constructing it remains a bachelor. It is found on opening burrows started at the same time that the nuptial chamber in those occupied only by the male constructing it are larger than those containing from one to five females with radiating egg galleries. The reason for this is clear. As long as the male does not succeed in attracting one or more females, he continues working at his burrow and continues feeding upon the frass he excavates. As soon as the females share the burrows with him, his activities are changed and he now spends most of his time guarding the entrance and removing the frass excavated by the females from their egg galleries. He doubtless feeds upon this latter and therefore it is not necessary for him to enlarge the nuptial chamber. Very often the nuptial chamber is not large enough to accommodate the male and his several mates at the same time. This does not seem necessary for if the females require more than one fertilization, as the females of other bark beetles are known to do, they can be accommodated individually while the others remain in their egg galleries.

There can be no doubt whatever that the male of *P. hopkinsi* invariably begins the brood burrow by constructing the entrance gallery and nuptial chamber. The construction of many entrance burrows has been observed and this work was always started by the male. In several cases where males abandoned their work after penetrating half of their length into the bark, these burrows were found by females and carried deeper, but on opening these after several days the character of the burrow was found to be quite different from those made by the males. There was no nuptial chamber present but the entrance burrow had been continued as a simple cylindrical excavation, the female apparently using it merely as a feeding burrow (Fig. 23, e).

To determine definitely which sex constructed the nuptial chamber, burrows in a culture started March 20th were opened five days later. Of twelve thus examined seven consisted of an entrance gallery and a typical nuptial chamber and each contained a single male and no females, one contained one male and one female and four were inhabited by one male and two females in each. This evidence seemed fairly conclusive yet in order that there might be no question a new culture was started April 20th and opened two days later. The idea being to allow the work to proceed far enough to determine whether it was a brood burrow or feeding burrow and to examine them early enough (before the entrance of the other sex) to determine which sex constructed the nuptial chamber. Seventeen burrows were examined. Ten of these each contained a single male and of these ten seven showed typical nuptial chambers while three had not proceeded far enough for the character of the burrow to be certain. Five burrows were occupied by one male and one female each, one burrow by a male and two females and one burrow by a single female. This latter burrow, although longer than any of the rest, contained nothing similar to a nuptial chamber and from evidence furnished by other cases was probably a continuation of an entrance burrow made by a male and later abandoned. Newly infested limbs brought in from out doors, showed also that where nuptial chamber was occupied by only one specimen, this was invariably a male. Thus the evidence indicating that the male constructs the entrance gallery and nuptial chamber unaided seems absolutely conclusive for this species and without a reasonable doubt such is the habit in all polygamous bark beetles.

MATING HABITS.— Concerning the details of the mating habits of *P. hopkinsi* very little was learned from direct observation. Copulation was observed in only one instance although several burrows were kept under frequent observation with the view of settling several obscure points. It is therefore known that copulation occurs in the nuptial chamber, but whether or not it may also take place outside of the burrow is not known, although the tenacity with which the male remains in his burrow would seem to indicate strongly that such is not the case. It is also not certainly known whether a female must be fertilized more than once or not, although evidence that frequent copulation such as has been found to occur in *Ips typographus* by Nüsslin (1907) and in *Phloetribus liminaris* by Gossard (1913) is not necessary in *P. hopkinsi,* seems fairly conclusive.

The most complete observations upon the later history of the brood-burrow and the periods of time which the various stages last were made upon one burrow designated as "burrow H" in the writer's notes. Burrow H was started on March 15th. The male constructing it was not particularly industrious, as was shown by the small quantity of frass cast out and also by the fact that the nuptial chamber was not completed at the end of five days. At this time it was occupied by a male only and the flap of bark loosened in order to examine the progress of the work, was successfully replaced without disturbing him. Two days later, on March 22nd, the male was still the sole occupant. The nuptial chamber was then completed and he had extended this for a short distance at one angle to form a gallery, apparently starting an egg burrow.

The flap of bark covering the burrow was again lifted on March 23rd at 1.25 P. M. and found to be occupied by a male and a female in copulation. The position in which the two were found is shown in Fig. 16. The female occupied the egg gallery which had been started the day before by the male but which was now about twice the length of the female's body. The rear end of her body was at the level of the juncture of the egg gallery and nuptial chamber. The male was in the nuptial chamber his body at an angle of about 55 degrees to that of the female. What appeared most extraordinary was that the female lay with her back upward while the male was in the position shown in the figure with his right side up. Whether this is the normal position or whether the pair had been disturbed by the burrow being opened cannot be stated as this was the only copulation observed. The pair remained motionless except for slight movements of the abdomen for about one minute and a half — long enough for the completion of a sketch. They then began to pull each other, first one way and then another, evidently trying to pull apart. The male finally kicked violently with his hind legs, thus breaking loose. The male immediately turned around, apparently excited, with his antennae vibrating rapidly and followed the female which retreated into her egg burrow. At first the female kicked with her hind legs and backed out part way, causing the male to retreat. He soon returned, however, and lay perfectly still with his head against the side of the female's. After remaining thus for a full minute, the female backed up forcing the male away, whereupon she immediately resumed the work of extending the egg gallery, although the male continued to bother her for ten or fifteen minutes by occasionally butting into her. Although the burrow was frequently opened during the next two days no other copulation was observed.

The Eggs.— The first few eggs were deposited during the next twenty-four hours as several were in position when the bark was opened farther on March 24th at 2:00 p. m. It is probable the first egg was placed within a few hours of the time copulation was observed as it was about 4 mm. from the nuptial chamber, while the depth of the egg gallery at the time copulation occurred was between 4½ and 5 mm. It is known that in other cases the egg gallery extends only a half millimeter at most beyond the egg niche when the egg is laid. The eggs are placed in little hemispherical niches or depressions gouged out of the sides of the egg gallery by the female. The niches are considerably more than half in the sapwood. The egg is placed so that the center is just below the level of the juncture of bark and sapwood. Each egg is packed in with frass held together by some sticky substance, probably a secretion of the female. For several hours this substance does not harden but remains sticky and can be drawn out into a thread on the point of a needle. Later it hardens slightly and on the needle being brought into contact with the plug of frass, a portion of this will adhere. The eggs themselves are oval in shape about .537–.662 mm. in length by .400–.425 mm. in width and are usually though not invariably placed crosswise of the egg-niche with their long diameter parallel to the egg gallery (Fig. 25). When first laid and for several days afterward they are pure white in color with a pearly luster.

On March 25th at 2:00 p. m. just two days after copulation was observed the male in "burrow H" was accidentally killed while opening the burrow. The female, however, continued to lay eggs for a period of ten days in all, in spite of the absence of the male. The last few days of this period, however, her egg laying was at a diminished rate, as shown by the smaller amount of frass excavated. Finally after April 2nd no more frass was thrown out, showing that no more eggs were being laid, although the female remained in the burrow till April 8th when she left the burrow and was seen no more. During the period of ten days while the female was active, she laid in all thirty-one eggs, all of them fertile. This is considerably more than the average number. This would make an average of slightly more than three eggs per day, but it is known that she laid few eggs during the last two days of this period, and it is also known that on March 25th she oviposited six times.

The act of laying the egg and packing it in with frass was not actually observed but several observations were made which make it certain that the process does not differ materially from that observed for *Eccoptogastar rugulosus* by Gossard (1913). "A tiny egg niche had been made by the beetle before the burrow was opened. After some hesitation the beetle backed out of the burrow to the outside where she immediately turned about and backed into the brood chamber. Upon reaching the locality of the niche, she distended her abdomen and with it seemed to be feeling along the wall of the burrow as if hunting for the niche. After a few moments of exploring, the niche was located. The lip of the abdomen was then held within the niche and a single tiny, translucent egg was deposited therein and left standing at right angles or endwise to the burrow. The beetle then crawled out of the burrow and entered again, head first, and upon reaching the niche she covered the egg with fine frass." On April 1st a burrow of *Pityogenes hopkinsi* was opened just as a female was completing an egg niche. She backed out of her egg gallery to the nuptial chamber, turned around and immediately reentered the egg gallery backward. Before depositing her egg, however, she seemed to become confused, either by the light or by the absence of the bark over her, and retreated to the nuptial chamber. On March 25th "burrow H" was opened just after the female had deposited her egg as it was in position in the niche but this had not yet been plugged with frass. The female was observed to crawl along the egg gallery, head first to the nuptial chamber where she immediately went to a pile of frass, took a quantity of this in her mandibles and turning around entered the burrow head first. She was apparently intent on packing in the egg just laid, but again, doubtless the brilliant condensed light caused her to desist.

Duties of the Male.—With the entrance of one or several females into the burrow, the duties of the male are changed. Previous to this time his main efforts have been directed toward the completion of the entrance gallery and nuptial chamber and apparently he continues to enlarge the latter until the coming of the female. He then appears to cease burrowing entirely, but his duties do not end with fertilizing the females. The females in making the egg gallery, necessarily excavate a considerable amount of frass. This they push out of their galleries into the nuptial chamber, but apparently, under no circumstances, do they cast it out of the entrance. This is the duty of the male and if he is tending from five to seven females, it is apparently no light task, especially if the frass is sticky with pitch. As a usual thing he removes this frass by backing upwards, forcing a considerable quantity out at a time. Several cases have been observed, however, where the frass was unusually sticky, where the male was forced to remove it bit by bit with his mandibles. He would come to the entrance head first, extend half of his body out of the entrance with the pitchy mass grasped in his mandibles and would press this against the pile of boring, surrounding the entrance till it adhered. He would then back down into the burrow and repeat the operation. When the male is killed or removed from the burrow, the females continue dumping their borings into the nuptial chamber till this becomes packed full, and cases were observed where part of the egg gallery had also been packed in this manner.

With the accession of females to the burrow, the male also becomes much more vigilant in guarding the entrance. He apparently spends a considerable amount of time at the entrance with his elytra forming a quite inpenetrable appearing door (Figs. 13, 14). Even sharp poking with a needle will cause him to retreat only a short distance, whereas before the entrance of the female he would retreat as far as possible if the elytra were but touched firmly.

Incubation Period.— The period of incubation of the egg of *P. hopkinsi* in the laboratory is exactly seven days. Outdoors it varies with the temperature from five to ten days according to observations made this spring (1915). Eggs laid March 24th in the laboratory, still possessed on March 27th the white color and the translucent pearly appearance characteristic of those freshly laid. Two days later they were not so transparent and were slightly yellowish in color. On March 30th, on examination with a good hand lens (X 15), a minute brown speck was just visible. On studying this at a greater magnification with a binocular microscope, it was seen that this brown spot was caused by the mandibles of the embryo larva inside. That the embryo was still alive was shown by the movement not only of the mandibles but of its entire body inside the egg membranes. The movement of the mandibles was especially strong and was continuous for the ten minutes the egg was under observation. The larval head showed a surprisingly large range of motion, moving back and forth for nearly the length of the egg, the jaws continuing to open and close. The egg membranes were still entirely intact although slightly wrinkled. It was feared the eggs might become dried so after removing one to a hollow ground slide and placing it in a moist chamber the burrow was closed. The eggs, both in the egg niches and in the moist chamber, were examined at intervals during the day, but none had hatched when work ceased for the day. One of the eggs was taken from the burrow, the outer egg membrane removed by careful manipulation with dissecting needle and the inner membrane opened so as to allow penetration. Absolute alcohol was then added and later the specimen was stained with eosin. The shape of the embryo larva is quite similar to that of the larva after hatching. A camera-lacida sketch of one of the mandibles is shown in Fig. 17. The biting edge of the mandibles is dark brown. This shades off rapidly to a tan brown and this in turn to white so that the entire outline cannot be distinguished.

On the following morning, March 31st, just seven days from the time of laying, the eggs observed the preceding day, were found with the outer end open and the larvae were busily engaged with their mandibles on the egg membranes, their heads being partly free but their bodies still in the egg. With one exception the bodies were still white and transparent. This one specimen was entirely free of its membrane and had carried its burrow nearly half the length of its own body into the bark and the contents of its digestive tract showed brown through the body wall. The incubation period seems to vary little or any in the same burrow. The eggs nearest the nuptial chamber which are laid first nearly invariably hatch first, and the burrows of the larvae arising from them are correspondingly longer. This condition is very clearly shown by Fig. 26.

The Larva.— The larva immediately after hatching is from .518 to .580 mm. long by .30 to .32 mm. broad at the broadest place which is through the head. It is a footless grub, sub-cylindrical in shape, transversely wrinkled. It is at first pure transparent whitish in color except the head which in the region of the mouth, is a light yellowish tan shading off to white at the back of the head and to a distinct brown on the mandibles. The larva is widest at the anterior part, the head being a trifle wider than through the thorax at this stage. The abdomen tapers at first gradually, but more abruptly toward the posterior end, which is reflexed ventrally.

Later, after the larvae has fed for some time, the general proportions of the body change considerably, the head remaining the same size for several days, while the thorax and abdomen increase in all three dimensions. By the time the larval burrow is one mm. in length, the thorax is usually as wide or evenly slightly wider than the head, and it so continues to be throughout larval life. At the completion of each moult the head increases in size at once and then remains without growth until the next moult. The covering of the body on the contrary seems to remain much softer and growth appears to be more of a continuous process. The reason for this doubtless is that the strongest muscles of the larvae are those used in burrowing and in chewing, and as these are located in the head, the covering of the head must necessarily be more rigid in order to afford a firm insertion for these muscles. For this reason the size of the head following each of the various moults is fairly constant and forms a reliable index by which one may ascertain the particular instar to which a larva belongs. On the other hand, the width of the thorax and the total length of the larva varies so greatly that these dimensions are practically valueless in getting at the age of a larva. These facts are shown by the accompanying table.

This table shows size and proportion of larvæ of *Pityogenes hopkinsi* Swaine at each of the various instars. As will be seen, the width of the head is fairly definite for each instar while other proportions are quite variable.

Instar.	Width of head in mm.	Width of thorax in m.m.	Length of larva in m.m.	Length of burrows in m.m.
1st	.300–.315	.250–.320	.518– .720	0 – 3
2nd...........	.345–.370	.350–.540	.680–1.20	2½– 7
3rd	.412–.450	.420–.650	.937–1.72	5 –12
4th	.475–.500	.471–.812	1.45–1.83	8 –20
5th	.520–.550	.612–.938	1.50–1.98	15 –41

The Larval Burrow.—In all cases where the act of hatching was observed, or where conditions were studied soon after hatching, the larva emerged from the egg on the side next to the bark. This would seem to be quite important as its food during the early part of the larval history consists entirely of bark. Usually approximately half of the larval burrow continues upon the surface of the wood but involves the inner bark only, while the burrow made by the older larvae grooves the sapwood deeper and deeper and the bark less and less as the larvae approaches full growth (Figs. 27, 28). Exceptions to this rule are found in broods occurring late in the fall, when the larvae show a decided tendency to groove the sapwood earlier and deeper than at other seasons. The entire larval burrow with the exception of the chamber in which pupation occurs, is always closely filled with frass excavated by the larva (Fig. 27). In the part of the burrow first excavated, this frass is brownish in color showing its origin from the bark, in the middle part it consists of a mixture of brown bark and white sapwood, and in the later part of the burrow it consists nearly entirely of the white bits of sapwood.

At the start the larval burrow is just wide enough to accommodate the larva comfortably and increases in diameter with the growth of the larva, until at the time of pupation it is of about the same width as the egg gallery. The course of the larvae burrow is at first approximately at right angles to the egg gallery from which it originates. For the greater part of its length, it is usually continued in this same general direction, provided no obstructions such as other burrows, faults in the bark, or the bases of small dead limbs lie in its course (Figs. 27, 28). Toward the end, however, the course is likely to be more tortuous (Fig. 28).

The length of the larval burrows varies considerably even in the same bark and when made by larvae from the same egg gallery (Fig. 27). Careful measurements were made of twenty larval burrows, only those being chosen which showed the entire burrow from the egg nitch to the completed pupation chamber. The measurements were taken from the egg burrow to the farther side of the pupation cavity. Of the twenty burrows measured the shortest was 18 mm., the longest 41 mm. and the average length was 31 mm. Thirteen of the twenty were between 28 mm. and 34 mm. long.

The rate at which the larvae bore their burrows might be of interest. While no study was made with special reference to this matter, the very full notes on observations made from day to day furnish some instructive data. On the third day after hatching the burrow was 1.5 mm. long, on the seventh day 4.5 mm., on the twelfth day 13 mm. and on the seventeenth day 20.5 mm. These observations were made upon larvae of which the time of hatching was known within a very few hours.

Length of Larval Period.— The length of the larval period in the laboratory, where conditions of temperature and moisture were fairly uniform, varied from eighteen to twenty-one days. Outdoors during May and early June, the larval period varied from eighteen to twenty-six days, there being several days when the temperature was such that little feeding was probably done. It is probable that a brood of larvae occurring in midsummer would require less than eighteen days for their complete larval history, and as we have already seen, individuals hatching in the fall may pass the entire winter as larvae, remaining in this stage for a period of eight months or more. However, a larval period of from eighteen to twenty-five days may be considered as about the normal one.

Number of Larval Moults.— Regarding the number of moults during the larval stage fairly satisfactory observations were made. It was hoped to be able to establish the facts by a very careful microscopic examination of the refuse filling the larval burrows. In some cases the remains of five larval cast skins were found, four in the larval burrow embedded in the packed frass and one in the pupal chamber with the pupa. However, in other cases only one or two such larval exuvii were found. It is possible in these later cases that the larvae may have devoured their cast-off skins, as is known to be the habit of some other insects, or it may merely have been overlooked on examination of the frass. Until better evidence is at hand then, the author is inclined to place the number of larval moults at five. In a burrow 18 mm. long the cast skins were distributed as follows: The first 2.5 mm. from the egg niche, the second 5 mm., the third 8 mm., the fourth 12.5 mm., and the fifth in the pupal chamber. As will be seen, both the conclusions regarding the number of moults and also the place in the burrow at which each moult occurs, agrees very well with the data given in the table of measurements of larvae on page 39. There seems to be no good reason for doubting that normally there are five larval instars. If the larval period in the case cited above was eighteen days the moults would occur about as follows: The first at about the fourth day, the second on the seventh day, the third on the ninth day, the fourth on the twelfth day and the fifth (pupation) on the eighteenth day. It is an interesting fact, attested to both by a study of the contents of the burrow and by measurements of larvae taken when actively engaged in burrowing, that nearly half of the length of the burrow is made during the last larval stage.

The Pupal Stage.— About a day before pupation the full-grown larva completes the pupation chamber and apparently ceases to feed hereafter. The position of the pupation chamber depends considerably on conditions of temperature and of moisture. It has already been said that larvae pupating in the late fall build their pupal chambers deep in the sapwood. Exactly the same is true at any season of the year if moisture is lacking. If conditions of temperature and moisture are favorable, however, the pupal chamber may be constructed half in the sapwood and half in the bark, or even nearly entirely in the bark if this is also quite thick.

The period of pupation was best observed in burrows extending rather deep into the sapwood so that only a small " window " was opened on stripping back the bark. A number of such burrows were exposed April 26th and found to contain full grown larvae, snowy white in color — the intestinal contents having all been expelled — which were apparently just ready to pupate. These were examined from time to time during the day, the strip of bark being replaced after each time and the larvae being prevented from drying by moistening the bark. They did not pupate during the day, but the following morning, April 27th, at 8.30 a. m., the pupal stage was fully established. The white transparent pupa was still quite soft, hardly capable of movement. On April 30th the color of the developing adult within was beginning to show through. The mandibles were brown and the rest of the body cream color. It was quite active, continually rotating in its burrow by movements of its abdomen. On May 1st the specimen was still more active and the color was still darker. The mandibles were dark brown, nearly black in color and the rest of the body a decided tan. The change to the adult condition occurred May 2d, and before the following morning the body covering had hardened sufficiently for the young beetle to begin burrowing. These and other observations established the period of pupal life in the laboratory where conditions are favorable, at five or six days. No definite data regarding the length of pupal existence under outdoor conditions was made, but judging from the similarity of the larval period under laboratory condition and in nature, it would not differ greatly from this.

The pupae vary considerably in size as do the full grown larvae and the adults. Alcoholic specimens measured show a variation in length of from 1.76 mm. to 2.25 mm., and a variation in the width through the prothorax of from .680 mm. to .910 mm. Aside from the difference in color previously mentioned there is a very noticeable difference in appearance between the newly formed pupa and one four or five days old. The most striking difference is in the wings. In the young pupa these are snowy white in color and both elytra and true wings extend backward from the thorax at an angle of from thirty to forty-five degrees to the abdomen, while in the older pupae they lie close to the sides of the body leaving the dorsal part of the abdomen uncovered, while the metathoracic wings, which are longer, nearly meet in the mid-ventral line.

The Young Adults.—On emerging from the pupal stage, the prevailing color of the young adult might be described as cream color or a very light tan. However, even at this time the tips of the mandibles are nearly black, while the body of the mandibles, the joints of the legs, the rugosities on the prothorax and the spines on the tibia and on the declivity of the elytra are light brown. The eyes also appear to be of a rather dark brown, but on examination with a microscope, it is readily seen that the color here is not due to pigments in the superficial structure, but to the pigment isolating the various omatidia making up the compound eye. The callow insect begins feeding almost immediately after emerging and its color becomes progressively darker, until at the end of from five to seven days it has usually acquired the appearance of the full fledged adult.

The manner of feeding depends upon condition of temperature and moisture. If the temperature is low and the host dry, the burrows groove the sapwood rather deeply, whereas if the weather is warm and the limb quite moist, the feeding burrows are likely to be entirely or nearly entirely in the bark, especially if this is comparatively thick. After feeding only a short time — two or three days at the most — the still callow adult bores through to the outer bark and makes a minute opening through the surface (Fig. 29). This is the so-called ventilation opening by means of which the feeding young beetle receives a better supply of air and through which he casts out the refuse from his burrow. This refuse consists largely of excrement but also contains considerable material excavated in its burrowing which has never passed through its body. This material is pushed out through the minute "ventilation openings" and collects in little hillocks over each such opening. The feeding burrows (Figs. 27, 28) of the young adults are built according to no uniform plan as are the other burrows. Some are long burrows but little greater in diameter than the insect inhabiting them, while others are short and broad or of irregular shape. Very often the feeding burrows of two or more beetles coalesce (Fig. 28) rendering the engraving still more irregular.

The length of time the young adults continue feeding in the larval host varies considerably from a week to several weeks. If the bark is allowed to dry they leave much sooner than when it is kept quite moist. Beetles have been induced to remain in their larval host for as long as five weeks by keeping this quite moist, while others sought a new host within a week after reaching adult condition if the old host was allowed to become too dry. It is worthy of note, however, that these latter on entering fresh pine limbs placed for them nearly all constructed feeding burrows, while those emerging after a longer period of feeding, immediately busied themselves making brood burrows. It would seem that several weeks of feeding, either in the old host or in a new one, is necessary before the adults can reproduce. It is apparent that temperature also aids in determining the length of time the adults remain in their larval host. If they reach adult condition in the fall they do not emerge from their feeding burrows until the following spring. As has already been stated, the time of emergence also varies with the sex, the males seeking a new host several days in advance of the females.

Proportions of the Sexes.— The two sexes as represented in the feeding burrows before any have emerged, occur in equal numbers, as has been determined by careful counts. Yet as the sexes exist in the brood-burrows there is a great preponderance of females as *Pityogenes* exhibits the polygamous habit to at least as marked a degree as any other genus of bark beetles (Figs. 26, 27, 28). Actual count of sixty brood-burrows occurring in nature, showed according to the engravings, that the parent females outnumbered the parent males in the proportion of 2.83 to 1. Of these sixty burrows only six contained a single egg gallery, seventeen had two, twenty-two had three, twelve had four, two had five and one had six egg galleries. Other brood-burrows of this same species have been observed which possessed as many as eight egg galleries.

This disproportion of the two sexes in the brood burrows may be explained by two factors. A number of males were found both in the laboratory cultures and in nature, which had completed their nuptial chambers and had evidently lived in them and fed in them for a number of days, but had not succeeded in attracting any females, although other burrows within an inch or two contained from two to five. In the material started in the laboratory, several males were still alone in their burrows, while other burrows in the same bit of wood which were started on the same day, contained nearly full grown larvae. There can be little doubt that these individuals would die bachelors, although both they themselves and their burrows seemed to conform to the same specifications as others which were occupied by growing families. But the factor which seems most important in determining the disproportion of the two sexes in the brood burrows is the greater danger to which the male is exposed before the nuptial chamber is prepared for his mates. When he is engaged in making the entrance burrow, with the forepart of his body in the bark and the rest entirely exposed, he is easy prey — although it must be confessed not exactly conspicuous prey — for all sorts of predaceous insects and birds. Then, too, many males are doubtless washed from their burrows and drowned by beating rains and we know it to be true that at least a small proportion are overcome by exuding pitch. The females, on the other hand, do not leave their larval host until several days later than the males and by that time the nuptial chambers are completed and as soon as they enter they are well protected by the burrow and well guarded by the vigilance of the male at the entrance. As the beetles fly only on warm bright days, the females would not even be exposed to the danger of a rain storm, provided they found a burrow to their liking within a reasonable length of time.

SUMMARY OF LIFE HISTORY.— The life history of *P. hopkinsi* may be summarized as follows:

Burrow started	March	15	
Nuptial chamber completed but only male present	March	21....	6 days
Female fertilized	March	23....	8 days
Several eggs already laid..........	March	24....	9 days
Male accidentally killed...........	March	25....	10 days
First eggs hatched................	March	31....	16 days
Female ceased laying.............	April	2....	18 days
Larvae transformed to pupae......	April	20....	36 days
Pupae transformed to adults.......	April	26....	42 days
New generation emerged........	May	6....	52 days
	May	30....	76 days
First brood burrows of new generation started	May	20....	66 days

The above data was all derived from a single brood burrow designated as "Burrow H" in the notes. It was, however, carefully checked up with other burrows started at the same time and at other times and represents the norm of laboratory conditions.

These observations were made upon broods started in the laboratory under somewhat unnatural conditions but an attempt was made to keep the conditions as nearly normal as possible. How successful this attempt was may be shown from the following observations in the field. On May 8th numerous brood burrows were observed in which the first few eggs had already been laid but these were still pearly white and from the length of the egg burrows had been laid within a day at most. On June 6th many full grown larvae and pupae were present and on July 8th " ventilation openings were numerous and a number of the new generation had already emerged. When these specimens were confined in a breeding jar with fresh pine limbs, they immediately started new brood burrows. If the eggs were one day old at the time they were first observed and the burrow had been started six days before (which in warm weather would be ample time) the entire life history would occupy just 68 days, or within two days of the time required in the laboratory. It would then seem safe to conclude that the life history of the spring brood from the starting of the parent brood burrow to the starting of that of the new generation, occupies from 60 to 75 days depending upon conditions of temperature and moisture.

Seasonal History.— The number of generations of *P. hopkinsi* occurring each year varies with the weather conditions. Careful study carried over three seasons leaves no doubt that in the vicinity of Syracuse, N. Y., from one and a half to two and a half generations are completed each year. Beetles reaching the adult condition in the late fall, just at the advent of cold weather, remain in their larval host throughout the winter. With the first warm days of spring they begin feeding anew and after several days of favorable weather, emerge and seek a new host for the construction of their brood burrows. This usually occurs in the latter part of April or early in May, but varies within a period of several weeks dependent upon the weather.

Most of the new generation to which these give rise, emerge during the first half of July and immediately attack a new host. Some, however, coming from the same colonies but from eggs laid later, may not emerge before August 10th. These then may be an entire month behind the earlier ones of their generation. This causes some overlapping of the broods even from the same ancestry and more than casual field study is necessary to get at the true conditions. The brood arising from the earlier individuals of the second generation, reach maturity early in September and some of them emerge and excavate new brood burrows, although the majority pass the winter as adults in the larval host. The offspring of those of the second generation which emerge, pass the winter as half-grown to full-grown larvae, while the parent beetles themselves occasionally survive the winter.

The beetles of the first generation emerging in August, attack new hosts and their offspring pass the winter as young adults, pupae or full-grown larvae. The great majority of the second generation reach maturity (by which is meant sexual maturity acquired after feeding a week or two in the larval host) so late that the weather conditions cause them to remain in their larval host all winter, thus completing exactly two generations.

Those which pass the winter as larvae or pupae either of the second or third generation, do not emerge until late in May or during June of the following season. These certainly do not produce more than two generations and most of their descendents pass the succeeding winter as adults of the first complete generation. Even in normal seasons, a considerable number do not reach maturity and these winter as full-grown larvae or pupae, while in years when the cold weather sets in earlier than usual, a large percentage hibernate in an immature condition.

No detailed observations with the special purpose of determining the per cent of each of the stages represented which pass through the rigors of winter weather successfully were made. However, data collected in a more or less casual manner would indicate that all stages beyond the half-grown larvae are about equally successful except the callow or newly emerged adults. Practically all of the adults which were still yellow or tan colored and a large per cent of those still light brown, succumbed during the winter of 1914–15, although this was not a particularly rigorous season. It would appear to be necessary that the beetle having reached the adult stage should feed for several days before it is able to undergo the rigors of winter successfully.

Study of the Engravings.— Much may be learned by a careful study of the engraving made by *P. hopkinsi* upon the surface of the wood, for the beetles there leave a faithful record of many of the activities of their lives in the form of hieroglyphics which may be readily deciphered by one at all acquainted with them. These engravings inform one at a glance of such intimate facts as how many mates each male possessed, as to how industrious and how fecund each one was. They also often show with what "wisdom of instinct," if the expression may be allowed, each egg was placed in order that the young be assured of a plentiful food supply. They give full data as to the activities of each larva, how much food he devoured, how many times he moulted his skin, how industrious he was in boring through the bark and wood, and finally whether he eventually reached maturity and succeeded in emerging as a full-grown beetle, or whether he succumbed before this goal was attained. The engravings are the records of facts of much greater interest to many than those to be gained by a study of the dead insect itself.

While the galleries of *P. hopkinsi* can usually be as readily identified as belonging to this species as can the individuals making them, no two galleries are exactly alike. They all, however, have certain definite characteristics in common. They all show an entrance burrow the characteristics of which have already been described. This leads into an irregular nuptial chamber which may be either upon the surface of the sapwood or in the inner bark depending upon the thickness of the latter. From this proceed outward a varying number of egg galleries each of which is ordinarily made by a different female.

The egg gallaries are usually transverse (Fig. 28), although this is not invariably true, as they are often diagonal (Figs. 26, 27) and occasionally, especially when the number of egg galleries is great, they may be nearly longitudinal. The diameter is just great enough to accommodate the body of the burrowing insect and never large enough to allow her to turn around. The length of the egg burrows varies greatly as does also the number and arrangement of the egg niches in the sides. Thirty egg galleries were measured, the length varying from 4 mm. to 49 m. m., the average being 23.1.

The number of egg niches in each egg gallery varies even more widely. Careful counts were made of 66 galleries brought in from nature with the following general result:

Minimum number of egg niches to an egg gallery	2.
Maximum number	60.
Average for 66 egg galleries	19.89

The number of egg niches does not vary exactly with the length of the egg gallery. The smallest number of niches (2) was found in the shortest gallery measured, which was 4 mm. long, but the greatest number of niches (60) was in a gallery 38 mm. long, while the longest gallery measured, which was 49 mm. long, had but 37 egg niches. In general, however, there is a distinct relation, although not an absolute ratio, between the length of the egg gallery and the number of egg niches.

The arrangement of the egg niches is by no means as regular as it is in many bark beetles. This regular arrangement seems to be especially characteristic of many monogamic forms such as the various species of *Eccoptogaster*. A careful study of the egg galleries gives rise to several interesting deductions regarding the arrangement of the egg niches. It is evident that the typical manner is for the female to place them alternately first on one side and then on the other side of the gallery and if conditions are entirely normal, these will be spaced evenly at a distance of from 1 mm. to 2 mm. from each other as shown in galleries *a, b, c,* in Fig. 20. In this way, if surrounding conditions are right, each larva is insured an adequate supply of food at the expense of the least exertion on the part of the mother. However, the fact that egg galleries either from the same or from different brood chambers often run closely parallel to each other, furnishes a factor which frequently alters greatly the typical arrangement.

A careful study of Fig. 20 will make this evident. Galleries *a, b,* and c, are spaced far enough apart that the typical and ideal arrangement of the egg niches is not affected. The other galleries, however, all run more or less closely parallel to each other and the result is apparent. Evidently galleries *d* and *e* were both started at about the same time and earlier than gallery *f*. The females in galleries *d* and *e* evidently being aware of the proximity of the two galleries, instinctively placed their eggs at greater distances. Apparently they extended their burrows at about the same rate. When female *e* had extended her burrow about two-thirds of its entire distance it apparently began to parallel gallery *g* coming from the opposite direction. Both females *e* and *g* then immediately began placing all of their eggs on the side of the burrow farthest from the other burrow and female *d* acted in a similar manner as if it were aware of the changed tactics of female *e*. Female *e* exhausted her supply of eggs sooner than did female *d* and ceased burrowing, whereupon the latter immediately began placing her eggs upon both sides of the gallery again. Gallery *f* was apparently started slighly later then *d* and *e* and, being aware of the nearness of the other burrow, female *f* from the start placed all of her eggs upon the side farthest from gallery *e*. The arrangement of the egg niches in galleries *h* and *i* is explained in a similar manner as they apparently started later than galleries *f* and *g*.

Another interesting fact to be observed with regard to the spacing of the egg niches is illustrated in Fig. 21. Very often the egg niches in the first two-thirds of the gallery are placed at a distance of 2 mm. or more apart, while in the latter part of the gallery they are crowded so closely that the egg niches are not entirely separate, often being as many as three to each millimeter. This is especially noticeable in egg galleries which are longer than usual. It would seem that at the beginning the physical strength of the female was greater than her egg-laying power and this strength is used up in placing the eggs an unusual distance apart. Later her strength is exhausted before the supply of eggs is and she places the eggs so closely together that many of the larvae arising from them do not survive, as may be seen by a study of the larval burrows.

The larval burrows have already been described in connection with the account of the larvae. They vary greatly in length from 18 mm. or less to over 40 mm., the average length of twenty being 31 mm. The course of the larval burrows is in general at right angles to the egg gallery, but when arising from galleries which are not transverse the larvae tend to burrow longitudinally with the fibres of the bark and wood (Fig, 26, 27). Larval burrows from egg galleries which parallel each other closely show a very tortuous course often crossing and recrossing each other many times (Fig. 28), and the engravings clearly show that a large percentage of the larvae do not succeed in completing their life history. The early part of the larval burrow is entirely in the bark but upon the surface of the sapwood, so when the bark is removed later the early burrows show the white of the sapwood while the space between them appears brown, due to the dried cambian (Fig. 28). The later larval burrow grooves the sapwood deeper and deeper and finally the pupation chamber usually lies with from one-half to all of its depth in the sapwood (Fig. 27).

If any large proportion of the brood succeeds in reaching adult condition, much of the engraving is sure to be ruined by their feeding burrows. This is especially true when the brood reaches the beetle stage a few weeks before the advent of cold weather, for they then feed in the larval host during the rest of the fall and also for a week or more the following spring. For this reason the engravings is much more perfect if taken when the majority of the brood is in the pupal stage.

Parasitic and Predaceous Enemies.— No special effort was made to study the parasitic and predaceous enemies of *P. hopkinsi* but several predaceous insects were incidentally collected in the field and several parasitic *Hymenoptera* were bred from material brought into the laboratory.

The most common alien insect found in the burrows is *Hypophlœus tenuis* Lec. This is a small brown beetle 2¼–3 mm. in length belonging to the family *Tenebrionidae.* This was obtained by the writer in many localities in the near vicinity of Syracuse, at Cicero Swamp and from material brought in by Prof. R. T. Gheen from East Schaghticoke, Rensselaer Co. In five cases definite observations were recorded as to the number occurring in each burrow of Pityogenes. In one burrow only one *H. tenuis* was present while the other four burrows each contained two. Specimens were taken from the nuptial chamber, egg galleries and the feeding burrows of the young adults. Apparently these beetles are predaceous upon the adults of *P. hopkinsi* rather than on the larvae or pupae.

Packard (1890) on the authority of Blanchard reports this species as being predaceous upon *Pityophthorus puberulus* Lec. and *Pityophthorus sparsus* Lec., the latter species probably being identical with *Pityogenes hopkinsi* Swaine. Hopkins (1899) records *H. tenuis* as "common in brood galleries of *Tomicus calligraphus,* feeding on adults; also with adult *Tomicus* in winter galleries in outer bark." Felt ('06) while he makes no mention of this species by name records finding an unidentified species of *Hypophloesus* associated with *Pityogenes sp. b.* It is possible that the *Pityogenes* mentioned is the same species which is here being considered.

Another predaceous beetle obtained from the burrows of *P. hopkinsi* is the clerid *Phyllobaenus dislocatus* Say.

The adult of this beetle was bred out from limbs of pine containing no other bark-beetles than *Pityogenes.* This material was brought into the laboratory in April and the adult of *P. dislocatus* emerged June 3. It is very probable that it was in the larval stage when the limbs were placed in the breeding jars.

Regarding this species, Hopkins (1893, 1899) reports the adults as predaceous upon *Polygraphus rufipennis* Kirby in black spruce and the larvae as occurring with *Pityophthorus consimilis* Lec. in sumach and with *Pityophthorus N. sp.* in Norway spruce. He also records it as occurring with *Scolytus regulosus* Ratz. in apple bark. Felt '06 (p. 449) states that LeConte reared this species from limbs of hickory infested with *Chramesus icoriae* Lec. and that it was reared by himself (p. 503) from limbs of hickory "infested with *Chyrysobothris femorata* Fabr. and *Magdalis olyra* Herbst, which were preyed on by several parasites, and this clerid may possibly have been subsisting on the latter borer."

P. dislocatus seems to be distributed throughout the eastern portion of the country. Felt ('06 p. 503) records it from New York and states that it "has been listed from the vicinity of Cincinnati O., south western Pennsylvania, various localities in New Jersey, and from West Virginia. Wolcott ('09) records this species for Pennsylvania, Wisconsin and Ohio, and ('10) lists it from five counties in Indiana.

In addition to these two predators a small, slender staphylinid beetle was found quite often in the burrows of *P. hopkinsi.* It is doubtful whether this is predaceous on any stage of the bark-beetle or whether it is merely a scavenger living on the decaying frass, bark and other matter in the burrows. Two *Hemiptera,* probably predaceous in their habits, were also taken. Neither of these were identified, one being lost in the mails while the other was immature.

Two species of predaceous mites belonging to the family *Gamasidae* were also found in the burrows and upon the bodies of *P. hopkinsi.* The smaller of these was identified as *Seius pomi* Parrott. Prof. H. E. Ewing writes as follows concerning this species. "This species — — — — is found generally throughout most of the U. S. on and under bark. It is predaceous and is one of the most important enemies we have of the pear-leaf blister-mite and the various species of spider mites." Parrott, Hodgkiss and Schœne ('06) report it as "Very abundant — upon infested trees and undoubtedly materially assisted in reducing the number of blister mites." The other mite is larger and belongs to the genus *Gamesus,* but as it was immature the species was not determined.

Both of these species were often found in considerable numbers both in the brood burrows and upon the bodies of the adult beetles, not only in the breeding jars, but also under natural conditions out of doors. In connection with his account of parasites of *Phloetribus liminaris* Harris, Gossard ('13) says: "Mites, found in considerable numbers in the burrows and clinging to the hairs of the beetle are apparently not parasites but feeders on the excrement and other decaying matter within the burrows. They attach themselves to the beetles in order to procure easy transportation from one place to another." In the case of *Seius pomi,* at least, this interpretation would hardly seem to agree with my observations. This mite seems to be an external parasite on both the adult and immature stages of *P. hopkinsi.* Adults harboring a dozen or more of these quite active little animals have been observed carefully under the microscope and there can be no doubt that the latter are injurious to their hosts. The mites appear to be successful in their attack upon the adults only when they obtain a firm hold upon the membrane at the juncture of the legs and body. When this vulnerable point is attacked the beetle makes frantic and often successful efforts to ward off the danger by threshing about violently with his legs. Without doubt, however, the eggs and young larvae of *P. hopkinsi* are the stages which suffer most frequently from the carnivorous habits of *P. pomi.* An actual attack upon either of these stages has never been observed, but in brood burrows containing many of the mites numerous shrunken or collapsed larvae and eggs may be observed. There can be little doubt that *Seius pomi* is responsible for this as in every case they were the only inhabitants of the burrows aside from the original builders.

Three species of parasitic Hymenoptera were bred from pine limbs containing only the burrows of *P. hopkinsi.* The largest of these of which there are three specimens belong to the family *Pteromalidae* and gerus *Metopon.* It is probable that these are parasitic upon the larvae of *P. hopkinsi* as it is known that closely allied species are parasitic upon bark beetles as well as upon the larvae of other insects. The other two Hymenoptera belong to the family *Mymaridae* and are both probably egg parasites. These are *Ooctonus quadrisignatus* Girault, a new species represented by three females, and *Polynema sp* (?) represented by one male. No records were found of either of these genera being parasitic upon the eggs of bark beetles and they have been most commonly bred from the eggs of jassids and membracids. It is possible that the individuals appearing in the breeding jar may have emerged from the eggs of tree hoppers or leaf hoppers deposited upon the bark and infested before the material was placed in the breeding jars. It may have been merely a coincidence that the adult mymarids emerged in considerable numbers during the height of the breeding season of *Pityogenes.*

Host Plants.— The favorite food plant of *P. hopkinsi* is the white pine, *Pinus strobus.* According to Hopkins (1893, 1893a) *Pityogenes sparsus* by which name he then called the species under discussion is also found in other pines in West Virginia. He does not, however, designate the species in which it was actually found, but in addition to *Pinus strobus* he also mentions that *P. echinata, P. rigida, P. virginiana, P. pungens* and occasionally *P. taeda* and *P. resinosa* are found in that locality. It is nearly certain that any of these would serve as a food plant for the adults and is possible that they might serve as breeding places as well. However, a distinction should be made between hosts which will serve as food and those in which the beetles will breed.

In the breeding jars in the laboratory it was found that the beetles would readily feed upon hemlock (*Pseuga canadensis*), red spruce (*Picea rubens*) balsam fir (*Abies balsameus* and Austrian pine (*Pinus austriaca*) even in the same jar with fresh white pine. They were able to maintain themselves in any of these for a period of three weeks or more, but in none of these was any brood found, and in only one — the Austrian pine — did any of the males construct the characteristic beginning of the brood burrow — the nuptial chamber.

Without a doubt the favorite host plant, both for feeding and for rearing the brood, is the eastern white pine. That several other species of pine in the northeastern United States and Eastern Canada also serve as host trees is also fairly certain, although the author has never had an opportunity of ascertaining this at first hand.

Economic Relations.— *Pityogenes hopkinsi* attacks only thin barked pine, and its favorite breeding place is in the recently cut limbs of felled white pine. To such material it is attracted in countless numbers and it is therefore very numerous following lumbering operations. It seems to have a decided preference for recently killed and *suddenly* killed limbs, and next to its preference for pine "slash" it finds most favorable conditions in lightning-killed trees. It, however, breeds very freely in limbs which are sickly or dying from other causes provided the bark upon these is not in too dry a condition. It will breed to a certain extent in limbs which are undergoing the process known as being "shaded out." However, very often limbs dying in this manner possess a very tough, hard, dry bark which adheres closely to the wood, and if such is true the beetles cannot breed in it. They prefer to attack such limbs while still green and sappy and in so doing often hasten their death. From a forestry standpoint they serve in such cases a beneficial purpose in that they aid and hasten the natural pruning which is necessary for the production of clear timber.

However, in other cases they are not beneficial in their effects. On a number of occasions they have been found attacking and killing limbs of pine which had been weakened by the earlier work of the pine bark aphis, *Chermes pinicorticis* Fitch. They seemed to find conditions here greatly to their liking, as the limbs were still alive and green, but apparently much of the sap had been extracted by the aphis and the resistance of the limbs reduced. They are also often found in great numbers in sickly small pines, especially in plantations, where they very rapidly kill small trees which would otherwise probably survive. They often attack these young trees while the foliage is still green and the bark green and sappy, and while many of the beetles succumb to the flow of pitch and die in their burrows, enough often succeed in building pitch tubes and disposing of the pitch to insure the death of the tree. Trees thus attacked are always small ones, varying in height from 4 to 15 feet, and the bark upon all or most of the trunk is still tender and it is this thin bark upon the trunk that is attacked. White pines which are weakened by transplanting are also attacked and killed in this way. In the summer of 1914 several pine from 4 ft. to 6 ft. high which had been transplanted early in the spring were observed to have been killed by the work of this little beetle. That the beetle enters the bark while it was still alive was shown by the numerous small pitch tubes at the entrance burrows, and the success of their attack was evidenced both by the death of the trees and by the presence of large numbers of larvae pupae and young adults in the inner bark.

As a usual thing then *P. hopkinsi* should be classed as neutral, but at times it is injurious in its effects. That it could under certain conditions do considerable injury there can be little doubt. But everywhere that white pine occurs there are so many recently killed, dying or sickly limbs that ample breeding places are provided. Usually the worst accusation which can be substantiated against this beetle is that it is accessory to the death of trees which have been weakened by other enemies or causes, although it is doubtless true that the trees thus attacked would often survive were it not for the activities of these little beetles. However, *P. hopkinsi* cannot be classed with the extremely injurious forms of which there are so many in the same family.

Even though this form is not usually markedly injurious, the writer believes that it is good policy to take reasonable precautions to keep down the numbers. The best way to accomplish this is to destroy its favorite breeding places or better still to allow these to remain until the brood has begun to develop and then destroy them. To accomplish the purpose most perfectly, pine "slash" from timber cut during the winter should be piled ready for burning but should not be burned until the first part of June. In this way the "slash" acts as a trap not only for *Pityogenes hopkinsi* but for other more or less injurious beetles such as various species of *Pityogenes, Pityophthorus* and *Ips* as well as numerous species of *Buprestidae, Cerambycidae* and of Ambrosia beetles which are often found in the same sort of material. Slash from timber cut during the early summer (June 15th to August 1st) should be burned during the latter half of August, while that cut between August 1 and November 1 should be disposed of before May 1 of the following spring. If this policy is consistently followed it will result in greatly reducing the numbers not only of *P. hopkinsi* but also of numerous other insects breeding in a similar situation and many sickly or weakened trees which would otherwise succumb to their attack will be saved. Danger of a more disastrous epidemic will also be overcome.

SUMMARY OF OBSERVATIONS.

Pityogenes hopkinsi passes the winter successfully in either the larval, pupal or adult condition but by far the larger number hibernate as adults.

With the advent of spring the young adults feed voraciously for several days as shown by the large amount of refuse pushed out through the newly made ventilation openings.

Emergence of the overwintered adults takes place during the latter part of April and first part of May depending upon weather conditions. They do not form into so-called "swarms" but the males emerge singly several days earlier than the females.

Both the entrance gallery and the nuptial chamber of the brood-burrow is constructed entirely by the male, this work requiring from two to six days.

The burrow is always started at some roughened or injured place in the bark, this being necessary in order that the worker may have suitable foothold. As soon as the gallery is deep enough, the beetle burrows by bracing the dorsum of his prothorax against one side of the burrow while the mandibles are brought to bear upon the other side. The rugosities upon the prothorax, which are in the form of flat spines pointing backward, anchor the body when they are pressed against the sides of the burrow and prevent it from slipping backward but readily allow the body to slip forward farther into the burrow.

The entrance burrow is carried into the bark at such an angle that, when it has been excavated far enough that the entire body of the insect is covered, the elytral declivity of the burrower lies parallel to the bark and completely closes the entrance.

As soon as the entire body of the beetle is below the surface of the bark, the direction of the entrance burrow is changed so it extends parallel with the surface. It is usually continued for about two millimeters — the length of the insect — and then is widened out to form a flat irregular chamber — the nuptial chamber.

The nuptial chamber may lie upon the surface of the sapwood, may groove the sapwood, or may lie entirely in the bark, dependent upon the thickness of the latter. The depth at which it occurs does not depend upon the thickness of the bark, but is determined by the length of the specimen constructing it. The size of the nuptial chamber does not depend upon the length of time it has been occupied, but upon the period that the male constructing it remains without a mate, as he continues burrowing until the advent of one or more females.

After the burrow has been carried below the surface of the bark it is impossible to dislodge the male by any ordinary means. He will respond to either intense light or to moving shadows by backing upward and closing the entrance of the burrow with his body with the elytral declivity level with the surface of the bark and parallel to it.

If the stiff hairs upon the elytra are gently touched while he is in this guarding position, he will respond by crowding closer to the burrow on the side stimulated. This would serve to effectively guard against the entrance of small enemies. If the elytra are firmly touched, the male will immediately retreat into the burrow if it is occupied by him alone, but if one or more mates share his burrow he can be driven from his guarding position only by vigorous prodding.

The male cannot be driven from his burrow by flooding it with either water, pitch or spirits of turpentine.

If the burrow is entirely filled with water, he will continue to work submerged in water as long as the end of his elytra is not covered. If the entire body is covered, he immediately becomes motionless and remains so at the entrance of the burrow in the guarding position until the flood subsides below the end of his abdomen.

Specimens when removed from the bark and submerged in a drop of spirits of turpentine die within a few seconds. When a burrow containing a male was filled with turpentine the occupant backed out to the entrance and although he showed evidence of great distress for nearly an hour, he did not leave the burrow and resumed work soon after the turpentine had evaporated and soaken into the bark. He was later as vigorous as any specimen under observation.

In excavating the entrance gallery the male often taps resin ducts and the burrow becomes filled with liquid resin or pitch. He usually succeeds in disposing of this by constructing a pitch tube composed of resin and frass, but sometimes is overcome by too great a flow and his body remains embedded in the hardened pitch in the entrance gallery.

The male does not leave the burrow even though it becomes brimming full of pitch but remains in this sticky liquid with only the tip of his abdomen protruding. He seeks to dispose of the material in various ways, but seldom or never abandons his burrow.

With the entrance of one or more females into the burrow the male ceases burrowing and spends most of his time at the entrance in the guarding position. It is his duty also to dispose of the frass derived from the egg galleries which the females leave in the nuptial chamber.

Copulation occurs in the burrows, the female lying in her egg gallery with the end of her abdomen at the juncture of this with the nuptial chamber, while the male lies in the nuptial chamber. It was not determined whether each female was fertilized more than once or not, but that frequent copulation is not necessary is proved by the fact that the female will continue egg laying for as many as eight days after the male has been removed from the burrow.

Egg laying begins within a few hours after copulation and continues for a period varying from several days to two weeks. Eggs are laid at the rate of from two to eight per day, the average number for a vigorous female being about four to six per day.

The incubation period varies with the temperature but the average is about seven days.

Movements of the embryo larvae may be observed through the egg membranes twenty-four hours or more before hatching. These consist not only of a movement of the entire larvae but also a continuous opening and closing of the brown mandibles.

The larva eats through the egg membranes on the side next to the bark and after devouring part of these membranes, begins its burrow. The first part of the burrow is entirely in the bark but upon the surface of the wood, while the later burrow grooves the sapwood deeper and deeper until the nearly full-grown larva excavates from one-half to more of the burrow from the wood.

The newly hatched larva is widest through the head but soon after it begins feeding, the rest of the body grows rapidly in all three dimensions while the head does not increase in width till the first moult.

Careful measurements of the heads of numerous larvae shows that the larval period comprises five instars and a careful study of the contents of the larval burrows reveals the presence of five exuvii in many burrows.

The length of the larval burrow varies from eighteen to forty-one millimeters, the average being about thirty-one millimeters.

The length of larval life varies with the temperature and moisture, but the average for spring conditions is from eighteen to twenty-five days.

Pupation occurs in the pupal chamber which lies principally in the sapwood. The pupal period under favorable conditions lasts five or six days, but may be much longer, dependent upon temperature.

The young adults on arising from the pupae, feed upon the bark and sapwood for a period varying from one week to several weeks before emerging. In favorable weather they soon make minute "ventilation openings" through the bark, from which they cast out the frass and excreta.

Males and females occur in equal numbers in the feeding burrows, but in the brood chambers each male has from one to eight mates, the average being 2.83 females to each male. This disproportion in the sexes is doubtless due to the fact that many males lose their lives when constructing the entrance gallery and nuptial chamber. At this time they are easy prey to predaceous enemies, many are overcome by pitch, and many more are doubtless washed from their burrows by rain. The females, on the contrary, may pass directly from their larval host, in which they remain longer than the males, to the already completed nuptial chamber.

From one and a half to two and a half generations of *P. hopkinsi* are completed each year. Over-wintered adults emerge in April or early in May and attack new hosts. Their offspring emerge in July and do likewise, while some adults of the second generation, if weather conditions are favorable, emerge in September and give rise to a partial third generation, which passes the succeeding winter as larvae and emerge about June 1st of the following spring.

Study of the engravings reveal several interesting facts. The egg galleries vary greatly in length, the longest observed being 49 mm. while the average was 23.1 mm. The number of egg niches also varies greatly, the largest number observed being sixty, while the average of sixty-six galleries was 18.89.

The egg niches are typically arranged alternately on opposite sides of the egg gallery and are spaced from 1.5 mm. to 2 mm. apart, but this typical arrangement is modified by several factors. Where two egg galleries closely parallel each other, the egg niches are all or most of them placed on the side farthest from the other burrow. Very often the niches in the early part of the egg gallery are placed at a considerable distance from each other, while near the end of the gallery they are made so close together that the eggs cannot be placed with their long axes parallel to the gallery as is the usual method.

P. hopkinsi breeds only in thin barked pine and prefers recently cut or suddenly killed pine limbs. It is occasionally beneficial in attacking and killing limbs weakened by shading thus hastening natural pruning. It, however, more often renders an injury by attacking either limbs of large trees or the trunks of small trees which have been rendered weak or sickly from the work of other insects or from other causes. Young trees which would otherwise recover are often killed.

Excessive multiplication of this insect following lumbering operations may be prevented by piling the slash and allowing it to remain as a trap till the beetles have constructed their brood burrows. It should then be burned before the emergence of the brood. This method will also aid in checking other more or less injurious forms breeding under similar conditions.

The writer wishes to express his obligations to several specialists for their kind and prompt assistance in identifying the parasitic and predaceous enemies mentioned in the body of the paper. Such help is indispensable and is doubly gratifying when so freely and promptly given. I am indebted to Dr. C. T. Brues and to Dr. A. A. Girault for identifying the Hymenopterous parasites, to Prof. H. E. Ewing for classifying the two predaceous mites and to Mr. A. B. Wol-

cott for identifying the clerid and tenebrionids. I wish also to thank my colleague, Dr. C. C. Adams for his kindness in carefully reading the manuscript.

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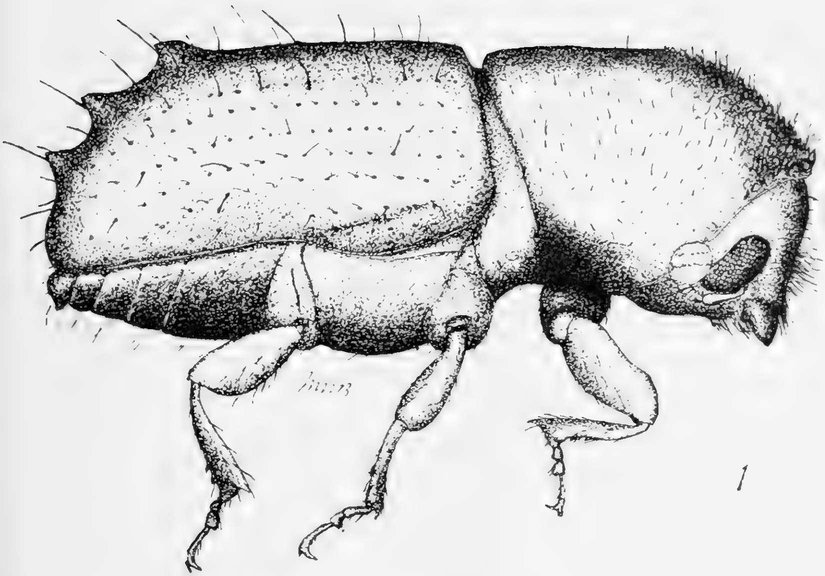
Explanation of Plates.

Figures 1, 2, 3, 4, 5, 14, 17, 18, 19 and 22 were made with the aid of a compound microscope and a camera lucida. Figures 17, 18 and 19 were made from balsam mounts with transmitted light, while the others were made with reflected light. Figures 6, 7, 8, 9, 10, 11, 12, 13, 15, 16, 20 and 21 are from sketches, made from nature. Figures 23–29 were photographed from nature with a micro-tessar lens. All drawings and photographs were made by the author.

Plate I.

Fig. 1. Adult male of *Pityogenes hopkinsi* Swaine showing the general appearance of the adult male. Especial attention is called to the rugosities on the prothorax and to the spines on the elytra. Magnified 50 dia. from a specimen exactly 2 mm. in length.

Fig. 2. Adult female of *P. hopkinsi* Swaine. Note the difference in the general shape and in the proportions of the various parts. The difference in the spines in the region of the elytral declivity is a secondary sexual characteristic of this species. Magnified 50 dia from a specimen 2.164 mm. in length. There is considerable variation in the size of the adults and this is especially true of the females. Specimens varying from 1.568 mm. to 2.18 mm. have been measured. The males appear to vary within much smaller limits.



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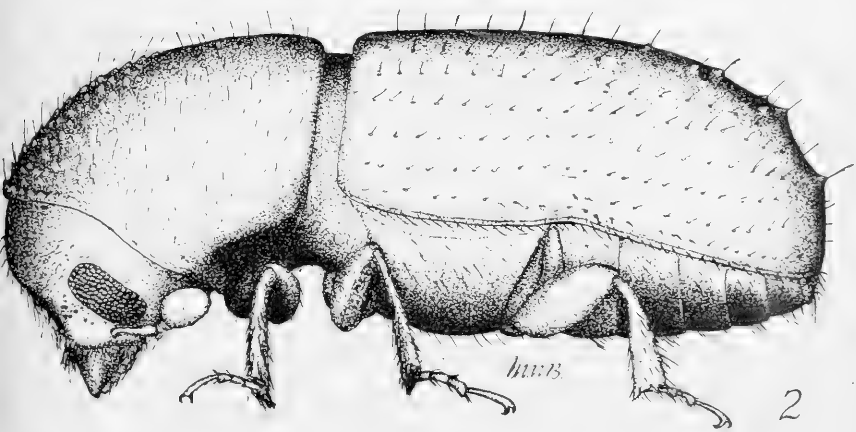

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Plate I.

Plate II.

Fig. 3. Ventral view of adult male, showing general characteristics as seen from this view, magnified 50 dia.

Fig. 4. Anterior view of adult male. Particular attention is requested here to the mandibles and the prothorax rugosities. Magnified 50 dia.

Fig. 5. Posterior view of adult male, showing the elytral declivity and the characteristic spines. Magnified 50 dia.

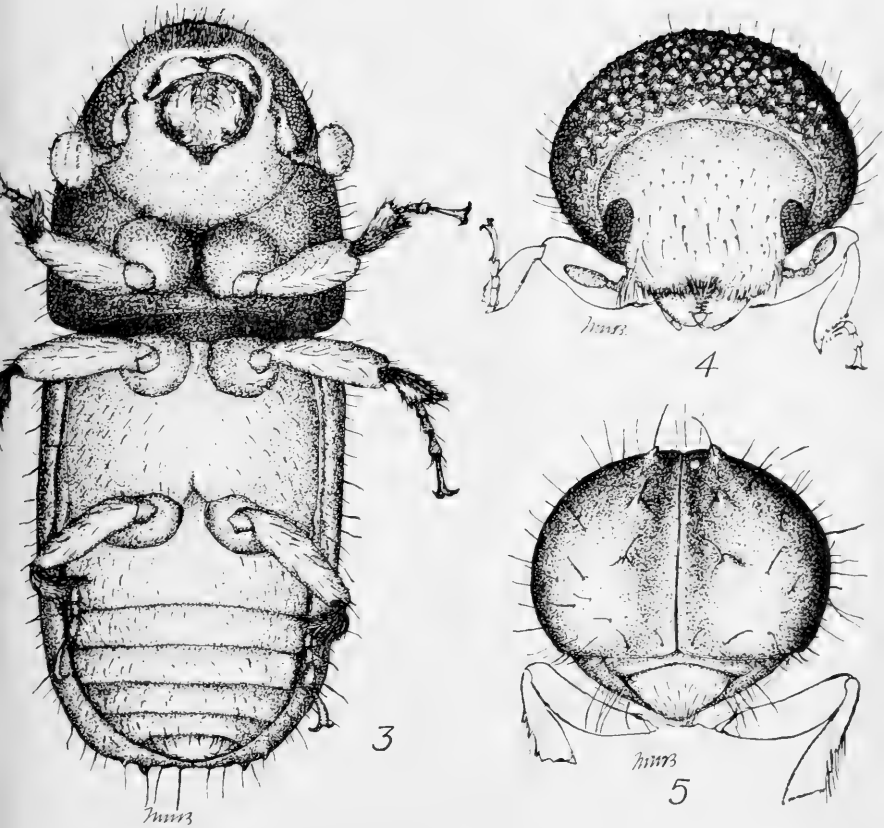


Plate II.

Plate III.

Fig. 6. Showing the position of the male when he is just starting his burrow through the outer bark. Magnified 12 dia.

Fig. 7. Position several hours later. The spines upon the dorsum of his prothorax are pressed against the bark on one side of the burrow serving to anchor his body while the mandibles work upon the other side. Magnified 12 dia.

Fig. 8. Showing the shape of the burrow when about half of the body is covered. As soon as the outer bark is burrowed through, the burrow is widened slightly and carried downward at an angle. Magnified 12 dia.

Fig. 9. Male in position in the burrow with about two-thirds of his body covered. Magnified 12 dia.

Figs. 10 and 11. Showing male at work in his burrow, which is now being extended parallel with the surface of the bark. The beetle works as readily in the position shown in Fig. 11 as that shown in Fig. 10. It is necessary that he constantly shift his position in order to bring the mandibles into play on all sides of the burrow. Magnified 12 dia.

Fig. 12. If the male is disturbed while working in position shown in Fig. 11 he will back up to the entrance in the manner shown here, but immediately rotates and takes the position shown in Fig. 13. Magnified 12 dia.

Fig. 13. The "guarding position" assumed by the male when disturbed in any manner. In this way the opening into the burrow is effectively closed against intruders.

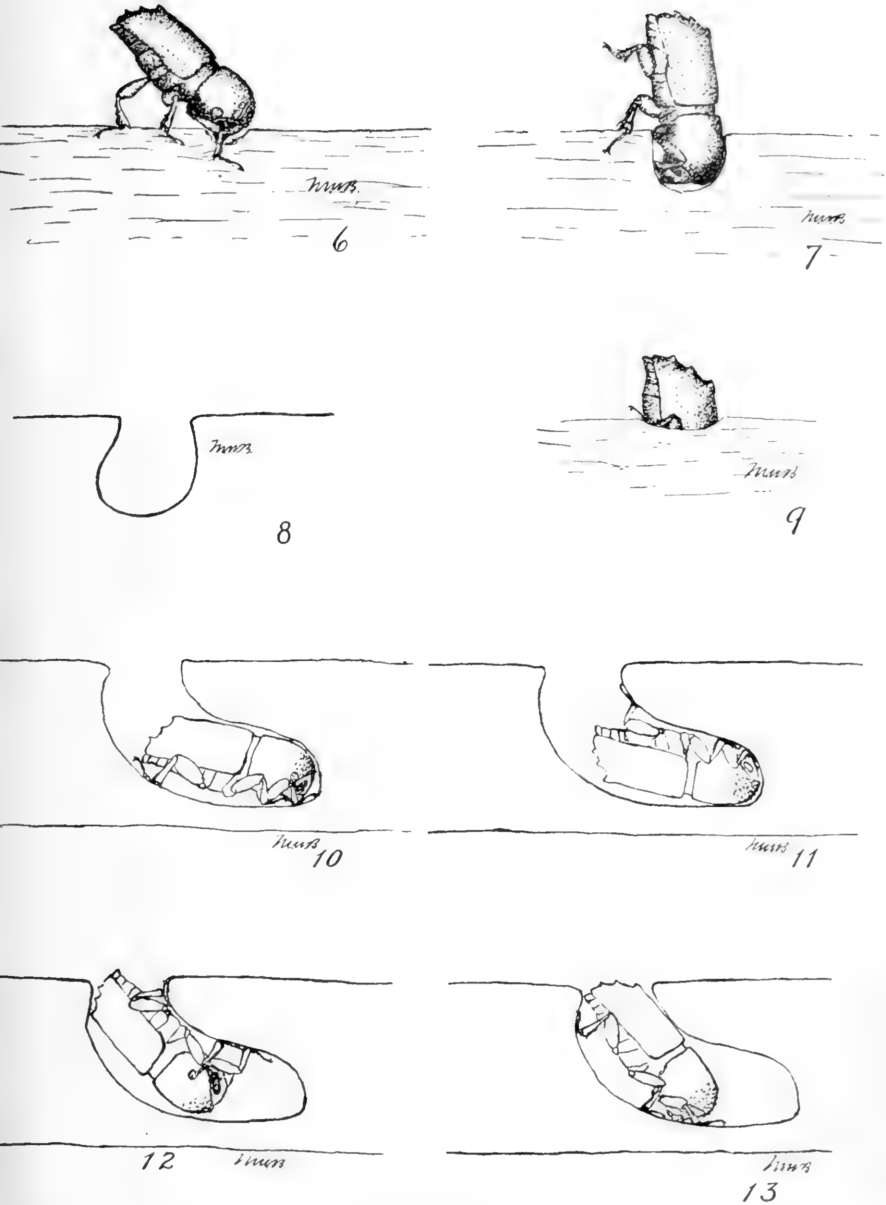


Plate III.

PLATE IV.

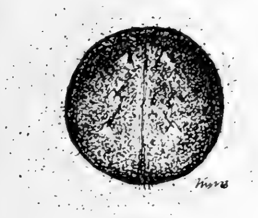
Fig. 14. Entrance to a burrow with the male in the "guarding position" as seen from without. The male's body nearly completely fills the opening, the elytral declivity lying parallel with the bark and armed with the three pairs of spines presents an impregnable appearance. Magnified 25 dia.

Fig. 15. Diagram of the entrance burrow and nuptial chamber excavated by the male. Magnified 12 dia.

Fig. 16. Male and female of *P. hopkinsi* in copulation. The female lies in the egg-gallery while the male is in the nuptial chamber. Magnified 12 dia.

Fig. 17. Mandible of embryo larva, twenty-four hours before time of hatching. Magnified 259 dia.

Fig. 18. Middle leg of adult male, intended especially to show the character of the tibia. Magnified 93 dia.



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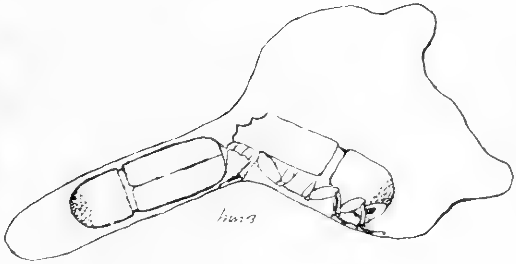

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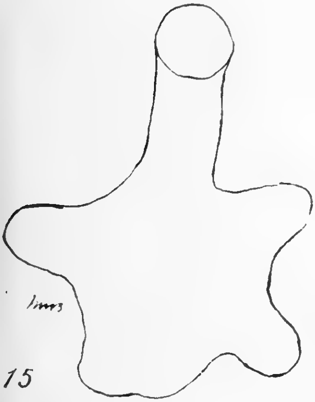

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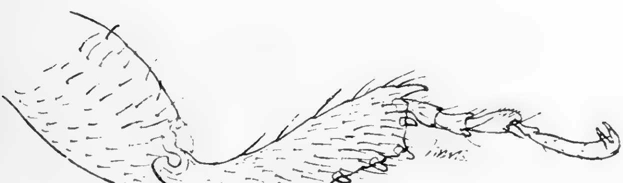


18

PLATE IV.

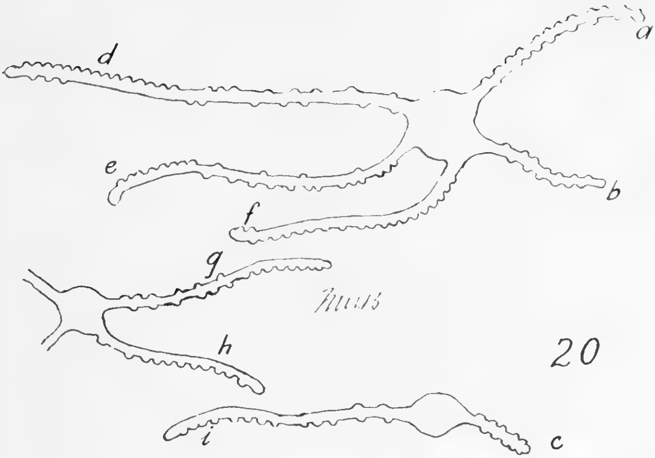
Plate V.

Fig. 19. Maxilla of adult male. Note the broad, flat lacinal teeth. These act as scrapers in removing the pitch and sticky frass from the mandibles while burrowing. Magnified 125 dia.

Fig. 20. Three brood-burrows which show modification in the manner of placing egg-niches due to the egg galleries running closely parallel. Gallaries a, b, c show typical arrangement, while d, e, f, g, h and i show modifications. This is discussed on page 51. Magnified 2 dia.

Fig. 21. Portion of a brood-burrow showing striking difference in the spacing of the egg-niches at different stages of the egg gallery. Magnified 2 dia.

Fig. 22. Dorsal view of adult male. Magnified 50 dia.



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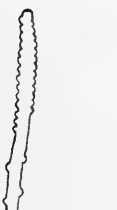

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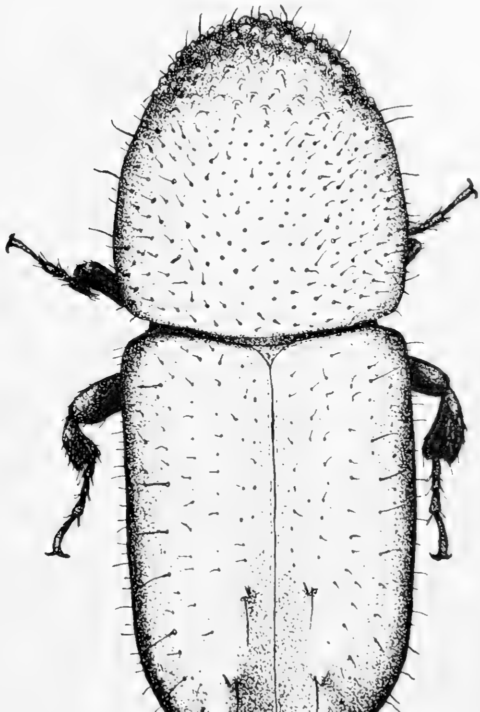

22

PLATE V.

PLATE VI.

Fig. 23. Photographs of several burrows started five days before. a and b are typical nuptial chambers. c, nuptial chamber in dried piece of pine in which the male burrowed into the sapwood. This often occurs in limbs which are too dry. d, nuptial chamber and recently started egg galleries. One of these shows 4 egg-niches. e, feeding burrow made by female extending entrance gallery started by a male. Natural size.

Fig 24. Profile view of pitch tube constructed by male of *P. hopkinsi* in making entrance burrow. Magnified about 2 dia.

Fig. 25. Photograph showing two egg galleries with egg-niches. The eggs packed in with frass are seen in most cases. Several are uncovered sufficiently to show their arrangement with long axis parallel to egg-gallery. Magnified 2 dia.

Fig. 26. Brood gallery showing nuptial chamber and four egg galleries. Two of these contain only eggs while the other two contain young larvae. The larvae nearest the nuptial chamber hatched first and their burrows are longer. Natural size.

Fig. 27. Portion of limb with bark removed showing larval burrows filled with frass, pupal chambers several of which contain pupae and feeding burrows of young adults. Natural size.

Fig. 28. Portion of limb with bark removed engraved by *P. hopkinsi* showing several brood burrows. The egg galleries are most of them transverse, several are diagonal and one is nearly directly longitudinal. Note the larval burrows. Where their course is unobstructed they are longitudinal and approximately straight but where obstructions occur (as in case of parallel egg galleries) the course is very tortuous. Feeding burrows made by the young adults are seen at each end. All frass and excreta have been removed from the burrows. About 3/5 natural size.

Fig. 29. Portion of bark of pine limb infested with *P. hopkinsi*, showing the "shot holes" which serve as exit openings for the young adults. The very small ragged holes are "ventilation openings" through which the beetle has not yet escaped. The several large holes were made by *Ips pini*. Natural size.

Plate VI.

Volume XVI November 1915 Number 2

TECHNICAL PUBLICATION NO. 3

THE NEW YORK STATE COLLEGE OF FORESTRY

AT

SYRACUSE UNIVERSITY

HUGH P. BAKER, Dean

The Development of the Vegetation of New York State

BY

DR. WILLIAM L. BRAY

Published Quarterly by the University
Syracuse, New York

Entered at the Postoffice at Syracuse as second-class mail matter

Photo by Glenn, Albany.

Kaaterskill Clove in the Catskills, looking toward the Hudson Valley. On the higher elevations, right, the forest cover is Canadian–Transition. Left, beyond the ledges, xerophytic shrub growth, notably blueberry. The rock-chestnut oak,

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A Bibliography of previous publications bearing on Plant Geography by the author of this bulletin, Dr. William L. Bray, Professor of Botany and Head of the Department of Botany in the College of Liberal Arts, Syracuse University, Special Investigator in Forest Botany during 1914–15 for the New York State College of Forestry.

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1905 The vegetation of the Sotol Country in Texas Bull. Univ. of Texas. No. 60.

1906 Distribution and adaptation of the vegetation of Texas. do. 82.

1908 The Mistletoe pest in the southwest. Bull. U. S. Dept. Agr., Bureau of Plant Industry, No. 166.

PREFACE.

In publishing this bulletin, the New York State College of Forestry at Syracuse University is carrying out a purpose announced in 1912 of presenting in a series of bulletins resulting from careful studies and extended investigations, the conditions which govern the behavior of plant life in New York State. The College was fortunate in securing Dr. Wm. L. Bray, Professor of Botany of Syracuse University and head of the Department of Botany in the College of Liberal Arts, for his sabbatical year to study the development of vegetation in New York State. Because of the work which Dr. Bray carried on in the State of Texas and elsewhere, results of which were published by the U. S. Forest Service and by the University of Texas, he brought to his studies of the vegetation of New York not only unusual previous experience, but rare insight into the many questions involved in the covering of the land surface of the state with vegetation culminating in one of the finest forests of any of the Eastern States. The purpose of the College in having a study carried on by Dr. Bray and in the publication of this report is to have a clearly defined basis upon which to add more detailed investigations, and especially a stock taking of the forest resources, all of which will lead to the establishment of definiteness and continuity of policy in the covering of the non-agricultural lands of the state with a profitable forest.

A broad analysis of the history and present aspects in the development of our native vegetation, together with some consideration of the status of vegetation as modified by human action, should serve as a good ground upon which to build detailed investigations along any phase of Forestry, and especially in such closely related lines of work as fish and game propagation and protection and control of injurious insects and fungi. The progress which our people have made in the older sciences and professions has been based upon thorough research. Little permanent progress will be made in Forestry until careful investigative work has been carried on not only to give knowledge of present conditions, but to determine principles upon which we must depend in the future in the development of the forest and all that goes with it in the way of animal life and the relation of the forest to climatic conditions.

Dr. Bray has traveled the state from North to South and East to West and has climbed the highest points and visited the most out of the way corners that he might see the dynamics which our vegetation has shown in covering the soils of the state. The College is pleased to present this bulletin by Dr. Bray because it gives a clear picture of the present status of our vegetation, and especially because it is the result of the application of a trained and keen intellect to the problem of showing the relationships of various phases of our vegetation and in interpreting the evidence of past vegetation and predicting as to future conditions.

For the unusual facilities furnished by the library and collections of the New York Botanical Garden, the College of Forestry for itself and for Dr. Bray extends its grateful thanks to the management and staff of the Garden. Throughout the bulletin, where the botanical names of plants are given, the practice in force at the Botanical Garden has been followed. That is, the name system embraced in the second edition of Britton & Brown's Flora of the Northern United States and Canada is used.

Upon the basic principles so clearly defined by Dr. Bray, the College is continuing and extending its studying and stock-taking of the forest resources of the state, and it hopes to present from time to time other reports which will be of help in a general educational way throughout the state and in the way of helping to form policies for the most satisfactory and effective utilization of the forest soils of the state especially.

HUGH P. BAKER.

CONTENTS.

ILLUSTRATIONS.

Text figures

THE DEVELOPMENT OF THE VEGETATION OF NEW YORK STATE.

Introduction.

In this bulletin emphasis is laid upon the idea of development in vegetation. I wish to bring the reader to think of vegetation at work, of its forward march and of what it is capable of doing in its course. A man who sows his field to grain may have put all his financial hopes into the development of vegetation, and it certainly is the wonder of our time to behold this unfolding of the season's planting into the fields of waving foliage and finally into fructification with a harvest so vast that a great nation's concerns center about the utilization of it. The miles of carloads of grain, the food of millions of people for the year, form some index of the energy of vegetation development as represented by the season's grain crop. But I am not writing of the season's crop development. Not even of the total of vegetation development of any one season, although the rebound of vegetation after the enforced dormancy of winter is always the great phenomenon of the year. I am thinking rather of the development of vegetation through the course of years wherein it comes to occupy the land and transform it into a new and different habitat, as when a man having abandoned a worn-out field years ago returns to find a forest there with its shade giving crown, its quiet moist air, its blanket of loose rich leaf mold, its population of forest dwellers.

In following the course of development my inclination would lead to asking whence came our vegetation? What has been its course through prehistoric ages? How is our vegetation related to the plant life of the rest of North America and of Europe–Asia? How does it behave in the presence of an environment of climatic and earth surface conditions such as New York State offers? How has the environment shaped the course and character of vegetation, and, on the other hand — and this is of particular interest to us — what changes have been wrought in the environment by vegetation? As between these two aspects of action and response — between vegetation and environment — no doubt the latter has the greater significance for us (the people of New York), for we are especially concerned for example with the character of our soils, and it is upon the soil environment that vegetation works the most profound modifications.

Landmarks of Development.

Two landmarks in history, the one geologic, the other of human history, will serve to measure the development of vegetation in the particular meaning employed in this bulletin, and equally well to show the work done by vegetation in modifying the character of the surface of this State — especially as to soil building. The first landmark covers a space of geologic time at the close of the glacial epoch, when the encroaching ice-cap having obliterated the plant life of the area covered by it (including all of New York State except a coastal strip of Long Island and a small area in the southwest), the retreating glacier — i. e., the melting of the vast ice sheet — deposited its enormous load of debris, the soils, sand, gravel, boulders, all the sediments of rock decay and fragmentation, of debris of every sort caught up in the forward flowing glaciers. The glacial waters further affected the sorting and deposition of this debris, and while this work of erosion, carrying and deposition is always going forward, still we may imagine a time when the glacial recession left its finished product — the foundation structures of our State, mountain and valley, plateau and plain covered to a greater or less depth by glacial debris, or areas of rock polished and left bare by ice action with its scouring tools, i. e., the sand, gravel, etc., held in the ice mass. As a plowed landscape lies ready for the natural reseeding by plants, so this vast and diversified terrain lay open to re-invasion by vegetation. The return of vegetation would confront the problems of establishing a plant cover upon bare rock, upon boulder strewn mountain slopes and plains, or morainic deposits, upon vast sand beds or sand plains, upon the finer glacial soils laid down in more or less level sheets or in elevated knolls and ridges (drumlins, etc.), in stream ways almost or quite obliterated or much blocked by glacial till, upon low wet lands, in kettle holes and lake basins left by glacial action. Such is in inadequate expression the terrain presented at the first landmark selected.

The second landmark by which to measure the degree and results of vegetation development is taken thousands of years later, taking the estimate, say, at twenty-five thousand years — the approximate number is of no immediate concern, so that we allow what humanly speaking would be a very long period — at a time falling within the range of the recorded history of this State. The first explorers and the pioneers of three hundred years ago found this State covered by a massive vegetation, which impressed them as being a vast forest wilderness. It appeared to the early settler as the great incubus to settlement. It took arduous labor to clear out a little farm in this forest, and once the forest was cleared away the energy of its return threatened to engulf his home as a returning tide. Early writers [1] comment on the rapidity with which the forest claimed abandoned settlements. There was forest of oak, hickory, chestnut, sweet gum and tulip in the lower Hudson region. The oak, hickory, chestnut type also extended up the Hudson and Mohawk valleys into the Iroquois–Ontario basin. Forests of sugar maple, beech, yellow birch, hemlock and white pine covered the Alleghany plateau region and much of the

[1] Van Der Donck, New Netherlands, 1656. Reprinted in Coll. N. Y. Hist. Soc. 2nd Series, Vol. I, 1841.

There is much interesting information embraced in this account of the early conditions of plant life in the vicinity of New York City. Among other things, confirmation of the dominance of oak, chestnut and hickory in the lower Hudson region. The author cites in particular an account by Indians of the rapidity with which land cleared and planted became again forested. Thus the Indians pointed out a tract of heavy young forest which twenty years previously they had planted in corn.

valleys. Forests of these species with red spruce, balsam and paper birch covered the higher Catskills and the Adirondack region. Sand plains — e. g., at Schenectady, Plattsburg and Carthage — and sand beds elsewhere had their forests of white pine. The wet lands were covered with swamp forest of soft maple, elm, basswood, black ash, or of conifers such as tamarack, arbor vitae, balsam and black spruce. Not only had vegetation reinvaded the land, but the high tide of it had been reached i. e., it had in large measure reached a stage of stability or equilibrium in which a certain permanency of forest type is maintained even in face of death and decay of the aged members of the forest society or even in the face of a calamity such as a windfall. I hope to bring out the significance of this climax or equilibrium stage more fully later, but the presence of it over so much of the State had a far greater significance than mere massiveness of forest cover. It meant that through a long course of vegetation history the soil had been prepared for this very stage. A great blanket of humus had been spread over the land and more or less incorporated with the mineral soil, much of it quite thoroughly transformed into leaf mold, much of it no doubt accumulating as forest duff. More than this, vegetation had gone far in filling shallow glacial depressions, in building up the land (by deposits of dead plants in the form of peat and muck) in the glacially filled valleys (Adirondacks, Conewango, Montezuma Marsh region). Some lakes and kettle holes had been quite filled and the site occupied by swamp forest. Cicero swamp just south of Oneida Lake represents a filled basin or streamway of large extent. Peat has accumulated there in places to a depth of thirty feet. It is suggested [1] that Flint Creek swamp south of Gorham in Ontario county is the site of one of the finger lakes which has been filled largely by vegetation remains (peat and muck).

Above all these obvious results of vegetation development —massive forest cover, blanket of leaf mold and duff, beds

[1] Soil Survey of Ontario Co., N. Y., 1910, page 7.

of peat and muck — should be placed the item of soil improvement, first in the matter of aeration, drainage and constant moisture supply and second, because of the productive energy which had been added to the soil by this age-long accumulation of the organic remains of forest life and the decomposition of them into simpler compounds capable of being absorbed by the living vegetation and of thus making the dead members contribute to the building up of new generations of the living.

A GENERAL REVIEW OF CLASSIFICATION, GROWTH FORMS AND PLANT ASSOCIATIONS.

It will not be supposed because the end of the glacial epoch was taken as a landmark in measuring vegetation development that we should consider the vegetation story as opening with that chapter. On the contrary there is ample evidence to show that before the series of ice invasions of the northern continents set in, the earth's vegetation had come to be essentially like that of the present. At any rate, the great groups of plants, algae and fungi, mosses and liverworts, ferns, scouring rushes and club mosses, seed plants, including gymnosperms of the modern conifer types and angiosperms in great abundance and diversity were present, and there is reason to think that they were represented by essentially the same types of structure as at present — trees, shrubs, annuals, bulb and tuber bearing, grass and reed types and so on with the whole range of growth forms. No doubt the vegetation formed by these associated elements was essentially of present day aspect.

But all these matters make it especially desirable for us to try to get back nearer to the beginning of the story of development of plant life and just at this point it is opportune to remind you of two or three items of current botanical doctrine which it is well to have in mind while discussing in this brief summary the history of vegetation development.

I. As To the Content of the Plant Kingdom and the Relation of Groups to Each Other.

As you know, the plant kingdom comprises a series of great groups of plants as follows: Thallophytes[1]; plants of very simple or relatively simple organization, the so-called lower or primitive forms of plant life embracing in general algae and fungi. Bryophytes, comprising liverworts and mosses. In this group the plant body is constructed on a more complex plan (is more highly differentiated) yet not possessing the characters which distinguish the higher groups. Pteridophytes, true ferns, horsetails, club mosses, etc.; plants constructed on the plan of seed plants so far as regards the possession of a differentiated body — root, stem, leaf and vascular tissue, and possibility of developing great bodies (of tree size and longevity in some cases and quite generally in the early geological history of the group) — but not seed producing plants. Spermatophytes or seed plants, differing esspecially from pteridophytes in that they do bear the structure called a seed. This group comprises the gymnosperms, a vast assemblage of forms reaching far back in geological history but whose modern forms comprise especially coniferous plants such as pines, firs, spruces, etc., and angiosperms, which as botanists say is the most recent and highly differentiated group of the plant kingdom and the one which dominates in the earth's vegetation at the present time.

Now one can scarcely define these groups without employing terms which seem to imply, first that each group has had a history of development — a racial history in fact — and second, that the development of each group is somehow linked up with the development of the other groups. The inference is that the plant kingdom as a whole tells a story of development from simple and ancient forms to modern and complex forms. We ascribe to Darwin, as you recall, the expression

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[1] This rather "old fashioned" method of sub-dividing the plant kingdom is retained here chiefly to avoid the use of a more complex and bewildering terminology.

that all these forms are bound together by ties of common descent.

From these groups our State has derived its plant population or flora. See page 45.

2. As To Growth Forms or the Working Units of Vegetation and How They Work.

Recalling our idea of vegetation development as the mass movement of plant life in taking possession of the land, and bearing in mind the concrete case cited where the glacially prepared terrain comprised in New York State was invaded by vegetation and the results arising from it, it is of course trite to remark that vegetation is a very complex organization — complex in somewhat the same sense as a people or a nation. To get closer to the details of vegetation work one must consider the working units, or as one may say, the growth forms. It is sufficient characterization of some of them to mention merely the group name as bacteria, fungus, moss, liverwort, to suggest the rôle these play in vegetation work.[1] Yet of course there is differentiation of form and manner of living among these, so that with respect to fungi for example, there are those which play an indispensable rôle in the forest soil, in the disintegration of dead tree trunks as well as those which play a destructive part as parasites retarding the development of the whole vegetation community by disease. In the more highly differentiated plant groups, however, the group name — fern, club-moss, conifer — does not necessarily carry the idea of growth form (though to be sure in these special cases just cited the types in our vegetation are in each group of much the same growth form) and vastly less so do the terms angiosperm, monocotyledon, dicotyledon or even the family group name in most cases, buttercup family, rose family, legume family, etc., suggest a special type of plant structure nearer than the broad name cormo-

[1] Assuming of course that the reader has some knowledge of the structure and life habits of such plants as bacteria (of decay, of fermentation, of disease), algae (water silk, water-felt, etc.), fungi (mushroom bearing fungi, molds, rusts, smuts, etc.), lichens and so on.

phyte.[1] I have in mind such growth forms as needle-leaved evergreen tree, broad-leaved evergreen tree (scarcely represented however, in our vegetation) broad-leaved deciduous tree, evergreen shrubs (e. g. certain heaths) and deciduous shrubs; herbaceous annuals, creeping, sprawling, climbing and twining plants; plants perennial by underground stems (rhizomes, bulbs, tubers) or food storage or woody roots; grass like, weed like and rushlike growths; tussock formers like *Carex stricta,* royal fern, cinnamon fern; sod forming grasses and sedges; mat forming cat-tail and sedges; submerged pondweeds, floating leaved aquatics and so on. [2]

Looking over the world at large the range of growth forms is vastly widened beyond those represented in our vegetation. It is obvious that there is a certain relation existing between growth forms and environment. Note especially the correlation between desert environment and desert growth forms, between water habitat and aquatic plants. In reality this is no more marked than is the correlation between our local growth forms and the alternating summer–winter features of this environment. Now the compelling idea in this connection is that here, also, we have a state of things arrived at by a process of development — of evolution and adaptation, if you please. We cannot ignore the fundamental characteristics of living plants — their plastic nature, the energy which drives them into all the earth in the face of all diversity of environment, the response or outcome of this prolonged racial experience in the various growth forms or adaptation forms which we are here considering. In a subsequent paragraph reviewing the geological history of vegetation, this differentiation of growth forms will be found to be strikingly correlated with the appearance on the earth of angiosperms with their unique floral structures and with the greatly diversified features of the continents which are said to have come about

[1] That is, a plant differentiated into the well known regions of root, stem and leaf members.

[2] No attempt is here made to give a classification of growth forms on any scientific basis. As to such classification see Drude, Oscar, Die Ökologie der Pflanzen, 1913, pp. 31–112.

in that period and which made the land surface a highly differentiated habitat for plants.

3. As To the Nature of Vegetation.

The city is not merely a census figure. No more is a forest a list of plant species. The State is not merely a mass of people, far less an unorganized mob. No more is vegetation a mere mass or unorganized mob of trees, shrubs, ferns, mosses and so on. In each there is a certain biological orderliness, a biological stratification if you will, (in the State, of course, social, political, etc., as well) and especially in each is the forward mass movement or development an orderly thing and from a simple or pioneer beginning to the complex or more highly differentiated condition. When you think of it, the crowding of plastic (adaptable) organisms on the earth's surface (and consider the reproductive energy of species) must entail mutual adjustments which would ultimately mean orderly or organized association as contrasted with haphazard crowding.

Now the high forest such as we have in New York State — what we are calling here the climax forest because as a matter of fact it is the high tide of vegetation development — is an orderly thing. It is in reality a social organization or complex organism. You can't get it on bare rock nor (absurdity!) at the bottom of a lake. Not on bare sand nor in a swamp. Nevertheless, you can start the course of development at any of those stages (in the case of a lake of course only on bottom to which enough light energy penetrates for the constructive work of green plants) and arrive in the course of time at the complex stage of a forest. But the pioneer stage of the lake bottom would be a simple association of a few species of similar adaptations to the habitat — *Potamogetons, Elodea, Naias.* In the course of time, partly by the accumulation of dead vegetation, partly by mineral sediment, the lake bottom is built up to mere shallows. This permits a wider range of species and among others those like water lilies having floating leaves. Thus a new association of species supplants the pioneer one. With the further building up of the lake bed to very shallow water or marsh conditions, there follows an association of species capable of raising their stems and leaves above water and of sustaining them against the stress of rain and wind. The root system and often rhizomes build tussocks (like water-arum, *Carex stricta,* royal fern, etc.) or mats (like cat-tail flag and certain sedges) thus firming the miry uncompacted mud. Yearly accumulations of the dead members of this now quite bulky vegetation the more rapidly builds up a firmer soil to or above the water level and this condition invites an invasion of marsh-meadow vegetation, a yet more complex and varied society, to be followed later by a marsh-shrub association of alder, willows, buttonbush, sweet gale; later by swamp forest of soft maple, elm, black ash, etc., with a ground stratum of swamp fern, swamp shrubs, numerous herbaceous plants, and other growth forms among seed-plants, mosses, liverworts, lichens, wood fungi, etc. In the end when this substratum has been further built up, the soil well drained and aerated so that the organic stuff is in position to be reduced to leaf mold, the permanent or climax or high forest society becomes established. This is the most highly differentiated association of all; that is to say, it is composed of more species, a wider range of growth forms and a more perfect or at least more extended system of mutual adjustments and interdependence among species (e. g. in degrees of tolerance of shade, in moisture retaining moss cover, in diversity of forest floor species, in numbers of climbing and twining plants, in richness of forest floor fungi and wood destroying fungi, in symbiotic relation between fungi and the roots of higher plants, in the indispensable rôle of soil bacteria). See page 163 for further discussion of the climax forest.

4. As to the Static Character and Nutrition Relations of the Green Plant—Especially of the Cormophytic Plant.

The strategic fact which determines both the ground-gaining or invading power of vegetation as well as the effect it produces upon the ground which it invades lies in the sort of structure which the plant, especially the cormophytic plant erects — the machinery it sets up as one may say — to carry on its life activities, particularly of nutrition and growth. It will be recalled that with the green plant, nutrition is not a question of finding and consuming highly organized products such as carbohydrates and proteins, but literally of assembling the raw materials from soil and atmosphere and, out of these, of manufacturing organic food. Your student of the high school will demonstrate to you that the first visible product of this manufacture is starch. There is a certain aptness therefore in saying that a green plant "sets up its machinery." This is the more emphasized when you reflect that this "machinery" must include means of absorbing energy from the sun — hence, the expanse of foliage exposing the green pigment chlorophyll.[1] We have then in our ideal green plant — a great tree for example — a columnar structure of great strength and permanence, displaying through a system of branching its maximum expanse of foliage. This column rests upon the earth and is anchored in it by members massive in proportion to the stress exerted on the crown. These great anchorage and buttressing roots affect soil conditions by penetrating and loosening up the soil and by building up the soil level — notably in wet soils. (Fig. 15 shows a great pine tree which has built up, or about which has accumulated a body of soil and duff some four feet above the general swamp ground level. This "humpy" appearance of newly cleared swamp or wet lands is a familiar phenomenon in New York State.)

The capacity of chlorophyll bearing plants to transform into organic compounds certain raw materials of earth and atmosphere, means that the plant organism can invade a ter-

[1] The reader who desires to gain a more intimate knowledge of the rôle played by the green pigment of plants — chlorophyll — in the food manufacturing work of leaves will find an excellent account of this important subject in Ganong's book The Living Plant, (New York, Henry Holt & Company, 1913) chapter II, on the prevalence of green color in plants and why it exists, or chlorophyll and photosynthesis.

rain entirely destitute of organic food supply and there "set up its machinery" and start a process of food making, which food being first built up into living plant protoplasm becomes ultimately the source of food for the animal kingdom. Thus not only is the ground gaining capacity of vegetation linked up with the static character and nutrition habits of the green plant, but its invasion of the land makes possible also a corresponding development of the animal kingdom.

Now, in the case of forest trees, the plant may go on developing on the one spot for perhaps hundreds (in maximum cases thousands) of years. Not only is the soil pierced by its roots and built up about it, the ground is shaded by the crown, the movement of air is impeded, its drying out power checked and, if we have many such trees growing close together, an all-round transformation of the environment occurs.

Menacing the future welfare of this static community is the fact that all the accumulation of poisonous and waste products, all the sloughed off dead material of bark, branch, leaves, flower parts and fruits, ultimately even each whole organism, dead from disease or accident or old age, falls among the living and, by the mere volume of debris as well as by the menace of an unsanitary soil, threaten the existence of the remaining living members. More than this, and in the long run of more fundamental consequence, the renewal of the community by the development of young from the embryo of the seed (another important item in the economy of these static organisms) would be prevented if this menace of accumulating dead were continuous. As a matter of fact, in a normal, healthy climax forest it does not exist. On the contrary, the dead members are stored up energy [1] which being

[1] Wood and coal are commonly spoken of as stored up or potential energy which becomes by burning available, working energy in the form of heat which may be transformed into steam energy, electric energy, etc. In the case of soils, as pointed out by Russell, "Soil Conditions and Plant Growth," pages 53 and 66, the potential energy of dead organic stuff is liberated by bacterial activity and becomes available, productive energy in the form of nitrates, etc., which goes into the building up of new generations of living organisms.

set free by the activity of forest fungi and especially of bacteria becomes available energy for the further development of the community.

Thus we are brought again to realize that vegetation development is an orderly thing; i. e., it is development in a real sense, determined by factors quite analogous to but perhaps more vaguely defined than those which determine the course of development of the adult plant from the seed or the embryo of the seed from the fertilized egg. Also the complex character of the climax forest society is further emphasized in the contrast between those dominant members — trees — which contribute most to make the physical environment of the forest and the fungi and bacteria at the opposite end of the scale, which by regulating forest floor sanitation, make the continuance of the community possible.

LANDMARKS IN THE GEOLOGICAL HISTORY OF VEGETATION.

We may now open the geological record with the appreciation that the history of the evolution of the natural groups of the plant kingdom, the differentiation of growth forms in the vegetation and the problems of plant association were largely worked out at a period which seems very remote when measured by the relatively brief period of human history. We may not here go into the record fully but merely measure progress by selecting again periods that will serve as landmarks. I have attempted to state briefly and with a view to their bearing on our present purpose what I understand to be a fair statement of the views of geologists and paleobotanists as embraced in the current teaching of these scientists.

The Plant Life of the Coal Period. The Age of Ferns and their Allies.

The Carboniferous period, as it used to be called, makes a good beginning point because it stands out more conspicuously by reason of its popular association with the origin of the world's great coal supplies. If we regard coal as of vegetable origin chiefly, then such vast supplies imply a very massive and widely distributed vegetation. It is further unique from a modern point of view by reason of lacking the types of plants which now characterize the earth's vegetation in the large.

Several things stand out significantly for our present purpose. A practically earth-wide tropical climate permitted a massive and monotonously uniform tropical vegetation to exist in certain situations, widely distributed over the earth. Judging by conditions under which peat beds form, the heavy vegetation which built up the coal forming peat beds must have occupied swamp lands and shallow waters. The pteridophytes — ferns and their allies — constituted by far the dominant elements of the vegetation. Those branches of the pteridophytes whose modern representatives are popularly called horse-tails, or scouring rushes, and club mosses were in the Carboniferous period abundantly represented, especially by species of gigantic size and no doubt forming as conspicuous an element in the forests of that period as broad-leaved trees and conifers do at the present. There were no angiospermous plants (i. e., none of the group embracing flowering plants), no coniferous plants of the modern gymnosperm type, indeed no gymnosperms at all of any group at present living. There were very primitive forms of seed plants whose vegetative structure was so fernlike, particularly in respect to leaf form, that for long they were held to be true ferns. Such forms as these *Cycadofilices* help fill up the missing chapters in the story of descent. As before indicated, the vegetation was prevailingly heavy forest with great trees as the dominating features but with also other subordinate associates of shrub size, an undergrowth of herbaceous and woody ferns and even some ferns of climbing habit. It is interesting to note that thus early in geologic history there is shown a differentiation of growth forms in a forest. But though of arborescent size, it is not to be inferred that a tree-form of the Carboniferous period would be the biological (or ecological) equivalent of the trees which constitute our northeastern forests; for example, the deciduous foliage of maple and beech. No doubt they would seem weird, outlandish objects by contrast. So far as that goes, so do yucca trees of the dry plateaus of northern Mexico and so would many other arborescent forms of our present vegetation, e. g., the giant cactus.

The Age of Gymnosperms. Allies and Ancestral Forms of Pines, Etc.

Imagine now the passing of, let us say, millions of years since the landmark which we selected in the Paleozoic era. Our second landmark or measure of the progress of plant life lies in the Jurassic period of the Mesozoic era. Even earlier in this era, the Triassic period, seed plants had displaced "spore plants" (ferns and their allies) as the dominant vegetation of the earth. Of the Triassic, Chamberlin and Salisbury[1] Vol. III, page 38, say "The Triassic was distinctly the age of gymnosperms the world over; the supremacy of the pteridophytes had ceased though ferns, true to their persistent nature, still held an important place." "The great lycopods were almost gone." The Jurassic period is selected for our landmark rather than the Triassic because, not only did it show the same dominance of gymnosperms over pteridophytes thus marking a new era in plant life, but in this period there appeared forms of conifers of somewhat modern aspect being regarded as ancestral forms of our existing yews, cypresses, arbor vitas and pines. It was as Chamberlin and Salisbury think (Vol. III, p. 94) the climax of the "age of cycads" * * * . "The ginkgos also played a somewhat important rôle." There are a few scattered modern remnants of the cycads now living, one of which at least should be generally familiar as the "cycad palm." So also is there a single living representative of the group of gymnosperms known as ginkgos or *Ginkgoales*, the beautiful Japanese maiden-hair tree. The species is a native of Japan, though widely cultivated. The conifer group of the gymnosperms is as you well know, abundantly represented in the

[1] Chamberlin, T. C., and Salisbury, R. D. Geology. In three volumes. New York. Henry Holt & Company, 1906.

vegetation of today, if not in great numbers and diversity of forms, still as prominent forest forming species. And their segregation generally as boreal conifer forests leads to the suggestion that this segregation has been in effect from an early period in the history of modern conifers and makes it pertinent to call attention to the suggestion of Gothan [1] that in the later Jurassic there began a gradual differentiation of climate which toward the poles was manifested in alternating seasons. This condition, indicated among other evidences by the presence of true annual rings of growth in the gymnosperms of higher latitudes, resulted in a more or less obvious segregating of floral provinces, the more and more dominant gymnosperms of the group *Abietineae* (the present most numerously represented group of gymnosperms) extending into higher latitudes. At this time the cycads (as always, apparently, tropical species) reached only perhaps to 70 degrees north latitude, the approximate limit of tropical climate.

While we may at least say that at this landmark we find slight beginnings of modern types and possibly of modern climatic differentiation, still it is a distinct and remote vegetation age, made the more notably so in that no trace or forecast of our now dominant angiosperm vegetation seems to have existed.

Plant Life of the Later Cretaceous Period. Introduction of Modern Types of Broad-leaved Dicotyledonous Trees.

Let us turn next to the later or upper Cretaceous period toward the end of the Mesozoic era. Again radical and in

[1] Gothan, Die Frage der Klimadifferenzierung im Jura und in der Kreideformation. Jahrb. K. preuss. Geo. Landesanst. 19:1908, 2–220.

In this connection it is desirable to call attention to the theories of Chamberlin as to alternating periods of climate in geologic time. (Jour. Geo. vols. v–viii:1897–1901.) and to the discussion of animal evolution as determined or influenced thereby, by W. D. Matthew. (Climate and Evolution. Ann. N. Y. Acad. Sci. 24:1915, pp. 171–318). Chamberlin's theories "involve an alternation of climates through the course of geologic time from extremes of warm, moist tropical and uniform, to extremes of cold, arid, zonal climates" (Matthew, *loc. cit.*, p. 173).

this case revolutionary changes have taken place in the floristic and vegetational status. The new thing is the angiospermous type of plant which appearing suddenly (so far as geologic records show) in the lower Cretaceous, come in the upper Cretaceous to be the dominant element of the vegetation and to give it a relatively modern aspect. Some of the older types of gymnosperms remain (cycads, ginkgos) but many have become extinct. The needle-leaved or coniferous types of gymnosperms similar to those of the present day were abundant and *Podocarpus,* the present day pine type of the southern hemisphere appeared in the upper Cretaceous. There is now (in the later Cretaceous) an impressive array of genera of angiosperms made familiar by their occurrence in the earth's present vegetation. Such are *Betula* (birch), *Fagus* (beech), *Quercus* (oak), *Juglans* (walnut), *Myrica* (a type represented by sweet-gale), *Artocarpus* (breadfruit), *Platanus* (sycamore), *Liriodendron* (tulip-poplar), *Cinnamomum* (cinnamon) and other laurels, *Acer* (maple), *Ilex* (holly), *Liquidambar* (represented by our sweet-gum), *Cornus* (dogwood), *Nerium* (oleander), *Viburnum* and others dating from the lower Cretaceous (*Ficus, Sassasfras* and *Magnolia*). The list of dicotyledons is vastly larger than this. Species of the group of monocotyledons were represented also. There were palms for example, some of which were very similar to species living to-day. The appearance of grasses in this period was a matter full of significance for the on-coming wave of mammalian dominance over other groups of animals.

Climatic differentiation and consequent segregation of floral provinces appear not to have progressed notably beyond what we saw in the later Jurassic period. Approaching from the remote Carboniferous period, the prevalence of tropical conditions generally over the earth during the later Cretaceous would seem a matter of course, but from to-day's point of view it seems curious to find evidence in the form of fossil remains of familiar types of trees, of tropical or warm temperate zone plants far up in the Artic regions.

Plant Life of the Tertiary Periods. The Age of Elaboration or Differentiation of Modern Elements and Aspects of Vegetation in Response to Differentiating Environment.

It was, as others have stated, indeed a revolutionary change which, in the early Cretaceous period saw the dawn of the present in plant life when angiosperms appeared, and a forecast of wonderful possibilities of development when these became so dominantly established in the later Cretaceous. These possibilities seem to have been realized in great fullness during those periods of the Cenozoic era, known, at least to botanists, as the Tertiary.

It is always a thrilling experience to watch the bursting forth of plant life in the spring when vegetation is expressing itself in varied aspects of vital activity and in myriads of forms as it takes up its yearly active relation to the manifold aspects of its environment. There are two sides to this great process of unfolding and adjustment. On the one side, the surging energy of life in its rebound after dormancy, applied through the individuality which distinguishes every plant species and indeed every single plant. On the other side the environment, involving all the aspects of climate, of soil, of different forms of animal life impinging on plant life at every point and of the many sided relation of plants to each other.

Now this sort of thing is what I have in mind when I ask you to imagine the differentiation of plant life and of its environment as it seems to have taken place most notably during the Tertiary periods. As to the plant life, you get a partial measure of what came about when you consider (1) The apparently innumerable species of dicotyledonous and of monocotyledonous plants representing hundreds of genera and scores of families whose finer distinguishing characters are based largely upon the apparently bewildering diversity of flower structures. (2) What seems an equally bewildering diversity of growth forms already referred to on page 24. (3) The segregation of plant life into wide floral provinces from tropical to arctic divisions, and of vegetation into diverse aspects or associations of plants in harmony with the soil environment.

This fashioning of our modern, dominant, angiospermous plant life is a matter of so great consequence for us in getting the proper perspective for studies which we undertake now, that I shall single out several important features for special mention.

Climatic Differentiation and Segregation of Floral Provinces.

As late as the Miocene period of the Tertiary, warm temperate climate seems to have reached as far north as Arctic America. Thus Heer in *Flora fossilis arctica* notes the presence of forests with pines, cypresses, birches, maples, walnuts, poplars, elms, oaks, lindens, willows, hazels and even *Magnolia*, *Liriodendron* and *Sequoia* (of which there remain the "big trees" and redwoods of California) in such far northern regions as Nova Zembla, Spitzbergen, Iceland, Greenland, Grinnell Land, Bank's Land, the mouth of the McKenzie and Alaska. But through the later Tertiary, the gradual cooling of the polar regions drove the strictly warm climate plants toward the equator, and in the segregation of the floristic zones the needle-leaved gymnosperms came to occupy the sub-artic regions. Thus appears to have been formed the Arcto-Tertiary floral province of plant geographers. To the southward of the conifer forests lay a vast forest of deciduous trees embracing most of the familiar genera and in some cases, species, of the present. As a consequence of cooling of the polar regions there must have ensued a yearly fluctuation of temperature — warm and cold seasons — whose effects upon the structure and behavior of vegetation we know from long observation.

Differentiation of Land Surface and of Vegetation Aspects.

Further on in this bulletin, a good deal of space is given to the question of vegetation development as influenced by the nature of the terrain, i. e., surface features of the land.

The attempt will be made to show that diversity or variety in vegetation aspects reflects a like diversity of habitats. This idea seems to find pointed application in connection with the Tertiary elaboration of plant life now under consideration, for during that time and especially toward the close of the Tertiary, great changes took place in the surface of the land. "On the whole" (quoting Chamberlin and Salisbury, III, 316) "the close of the Pliocene must be looked upon as a time of great crustal movement, a critical period in the history of North America. New lands were made by emergence from the sea and old lands were deformed and made higher; new mountains were made and old ones rejuvenated. Streams were turned from their courses in some places and nearly everywhere started on careers of increased activity." These changes would be assumed to play a significant rôle at a time when plant life had come into the peculiarly plastic and responsive stage represented by the oncoming wave of angiosperms.

Angiosperms and the Significance of Flower Structures.

The terms "seed," "angiosperm" and "flower" are associated with revolutionary changes in the program of plant life so that, while we may not go into technical details which would suffice to distinguish, fundamentally, nonseed-bearing from seed-bearing plants and so on, it must be said that the "drift" or, biologically stated, the course of evolution was toward more certain and effective production of vigorous progeny by plants. With the coming of seed plants, a strategic point had been gained in that the origin and development of a new individual and in considerable measure, its opportunities for becoming separately established, came to be under the care and nurture of the mother plant. Nor was embryo production any longer limited to certain special conditions where sperms could reach the egg only through the agency of water, as for example in ferns, but a new process, pollination, could be effected through the air and at any height above water level.

Then the sperm could reach the egg through the pollen-tube. Now, in angiosperms, provision for the nurture and protection of the embryo went a step further in the attainment of an enclosed ovary (hence the term angiosperm), and then followed gradually the elaboration of accessory structures in connection with the stamens and pistils: a protective calyx; a colored calyx; a differentiation of protective members (calyx) and attractive members (corolla); secretion of specific odors and of nectar accompanied by special glands, containers (nectaries) and nectar guides; special forms of flowers, special times and manner of opening of the flower and so on through the whole significant field of floral adaptation in which the reproduction of a new individual (except through vegetative propagation) centers in the act of pollination and subsequent fertilization of the egg and thereby opens the way to great vigor and variability of progeny through crossing, hybridizing and so on.

It is not to be inferred that these advances took place in the Tertiary simply, for numbers of genera from the later Cretaceous period show advanced floral structures. But the presence of such qualities together with a combination of specially stimulating environmental factors, climatic, edaphic, biologic (insect pollination for example), could be made to account for the apparent energy and rapidity with which angiosperms burst into dominance in the Tertiary.

Intensified Relationship Between Animals and Plants.

Another important item of geological teaching is that "the Cretaceous revolution in vegetation was not only great as a phytological event, but was at least susceptible of profound influence on zoölogical evolution, for it brought in new and richer supplies of food in the form of seeds, fruits and fodder. " * * * The introduction therefore of dicotyledons, the great bearers of fruits and nuts, and of the monocotyledons, the greatest of grain and fodder producers, was the ground work for a profound evolution of herbivorous and frugivorous land animals" (Chamberlin and Salisbury III, pages

173 and 175). These anticipations as to the evolution of a great fauna of plant-eating animals were realized in the Tertiary. At the end of the Tertiary (the Pliocene period) "the herbivores continued to occupy the foremost as well as the fundamental place" (C. and S., III: p. 322). So also was this Tertiary elaboration of angiosperm vegetation correlated with the evolution of bird and insect life and especially must one assume, as no doubt evidence shows, the elaboration of those diversified and mutualistic relations between the specialized nectar and pollen eating insects and the floral structures of plants. Personally, no chapter in the evolution of life appeals more vividly than this parallel or, better, convergent development of the two mutually dependent relations of nectar and pollen feeding by specialized insects (and some birds) and the pollination of angiosperm flowers. To anyone who, now-a-days, observes the intimate interdependence between animal and plant life, the period of elaboration of these relations seems a necessary and vivid feature of geological history. And certainly with our present intimate knowledge of the factors which influence the behavior of living organisms can we more readily adopt this point of view in the interpretation of phenomena which have come to pass in the world of living things. That is the heart of this dynamic idea, that things come to be something. It implies the fundamental idea of development, *the coming to be something,* than which there is no more powerful idea as an inspiration for individual human conduct.

So if this preliminary review of the development of plant life seems a bit prolonged, you will recognize the more fully that this bulletin aims not so much to elaborate the plant geography of New York State as to get a proper perspective and point of view from which to go about that important work. Also that a very deep-seated conviction lies in the writer's mind that the elaboration of settled policy with respect to dealing with natural resources as represented by the productive energy of the land is, somehow, intimately linked up with the study of the dynamics of plant life.

The Glacial Period and Its Effect Upon Vegetation.

This general review of the geological history of plant life has brought us down to the geologically recent Glacial epoch, the close of which was selected as a landmark from which to measure the progress of vegetation when contrasted with the conditions found at the beginning of exploration and settlement of New York by Europeans. It will perhaps now suffice to say that by the beginning of the Glacial epoch the peculiar genius of our present vegetation had already been gained. By that I mean its method of occupying the land, considering vegetation as a working organization engaged in its march of progress or course of development. More concretely, the present floristic make-up (of great groups, families, genera and quite largely of species) the present types of adaptation (growth forms), the present segregation into floral zones or provinces and finally the present types of vegetation aspects (plant societies as regulated by soil factors) were in existence. We have then to consider what effect the glacial invasion would have on the vegetation of the areas covered by ice, and upon the fate of species generally, what effect was produced upon the land by glacial action and by the return of vegetation when the long period of arctic climate gave way once more to temperate climate. It does not affect our purpose much whether we consider a series of advances and retreats of the ice sheet or only the last one, unless we put special stress on the effects which these repeated experiences would have in trying out and fixing the qualities which our native species have come to possess. The consideration of details connected with the return and final establishment of vegetation upon this New York terrain are matters to be cleared up so far as may be, in the remaining pages of this bulletin. As preliminary we may assert:

(1) That glacial invasion would destroy the vegetation cover of our State.

(2) That species, if they did not already exist to the southward of the glacial field, would either migrate in that direction or be exterminated.

(3) That as a matter of fact the floristic stock from which our present vegetation was renewed, lay, for the most part, in regions to the southward (southern Appalachians and lands to the westward) during the glacial dominance.

(4) That these species migrated northward, falling back into their zonal positions as one may say, as these life zones expanded northward with the retreat of arctic climate.

Modern Aspects of the Plant Geography of New York.

We may now pursue the more specific purpose of this bulletin, which, in the larger view, may be said to attempt a preliminary outline of the plant geography of New York State. Our efforts to interpret the present day aspects of vegetation development will have been reinforced by the survey of the geologic aspects of it just considered. Certainly we can gain no adequate perspective without considering its remote history. On the other hand, some of the statements made with such confidence about the conditions and results of vegetation of geologic periods are largely based upon phenomena which we find presented by vegetation to-day.

Questions like the following are to be answered:

1. What does New York State offer as an environment for plants?

2. What, so far as we know, is the content of New York State flora?

3. What are the general relations of our flora to the rest of North America and to Europe–Asia?

4. What are the broad aspects of distribution or segregation as determined by climatic relations — latitude, maritime and inland lake relation, elevation, etc.?

5. What are the aspects and relationships of vegetation development as determined by the substratum — soil conditions, water level, etc.?

Aspects of the Environment.

It is a common experience that the plant life of a region is an index of the environmental conditions. Sometimes it is said that the vegetation of land — e. g. Australia — is a product of its environment. The former expression is true, the latter not necessarily so, if, for example, we should say that the vegetation of New York State is a product of the New York State environment. If we have read the geological record correctly, the floristic elements which we have in New York as well as the growth forms and the plant societies were largely products of environmental forces operating long before the post-glacial conditions of environment in our State became operative. We must recall also that the glacial invasions obliterated our vegetation, though we must suppose that many of its pre-glacial and inter-glacial floral elements, if they were not already represented south of the ice-covered region, were caused to migrate southward and so stood in a relation to permit reinvasion upon the retreat of the ice cap. So we can scarcely say that this environment moulded a vegetation product but rather that the already largely determined elements of a vegetation fell into their respective environmental relations. This statement in no wise affects the view as to what rôle environment, wherever operative, plays in determining the evolution of floral groups or the origin of growth forms and the development of plant societies, while on the other hand, it enables us to emphasize again the fact that environmental experience has become so thoroughly impressed on species that one is struck rather by their habit of falling into their environmental niches than by the tendency to get out of them. See also page 48.

Thus after repeated migrations, or at least of extinction within the area of New York — caused especially by glacial invasions — our northern conifers, which we saw were segregated in boreal regions with the gradual differentiation of polar climate, have each time fallen back into the same zonal relation.

The State of New York presents an environment of significance in determining the segregation of vegetation upon it in the following respects:

1. By reason of its geographical position, especially as to latitude, the State lies within the zone of great summer-

winter contrasts of temperature which permit plant activity (speaking generally) during certain months and bring about an enforced dormancy during other months. In our yearly experience, no fact of our vegetation stands out so prominently as this rebound into activity in spring and subsidence into dormancy in the fall. If they had not grown commonplace by being long taken for granted the adaptations in our plants to this type of climate would excite wonderment. In the zonal segregation of floral elements, manifestly there have been excluded from our region vast numbers of species whose protoplasm could not withstand the low temperature or the fluctuations of temperature, or excluded from other causes associated with our temperature conditions. On the other hand it is conceivable that others are excluded by reason of not being able to withstand the highest temperatures which we have.

2. By reason of its position with respect to the ocean and to the main continental mass and to the great inland lakes this State occupies a favorable position in regard to atmospheric moisture — relative humidity, rainfall and snowfall. Climatically it is a region in which forest vegetation naturally dominates over other types — as grass land — which is the reverse of what prevails in the middle of the continent at the same latitude. The temperature conditions are also influenced by this maritime and inland lake relation, extremes being notably reduced in territory adjacent to these waters. See page 62.

3. The general plan of relief features of the State,— low valleys and lake basin plains (the Ontario-Iroquois basin for example); elevated plateaus dissected into hill lands; mountain masses rising to noteworthy elevations (4,200 feet in the Catskills and 5,350 feet in the Adirondacks), serve to intensify climatic differences largely by influencing the temperature relation, but also through effect upon air movements, atmospheric moisture, relative humidity, clouds, fogs, dew formation, rainfall and snowfall. For example, the growing season as measured between the last spring frost and the first fall frost is more or less 90 days in the high Adiron-

dacks and 150 days in the St. Lawrence valley somewhat farther north.

4. The highly differentiated terrain or substratum for plant growth which New York State presents — a terrain which as we learned was in a great measure prepared by glacial action — is the sort of environment to call forth the widest range of vegetation aspects, a condition which might be characterized as a mosaic of plant associations — water vegetation, marsh-meadow and swamp forest, climax forest of varying composition according to zonal boundaries, and finally even a bit of arctic vegetation (as on the summit of Mt. Marcy).

5. The presence of so vast and varied a population of animals and plants crowded into an area like that of New York State becomes itself one of the most determining or most powerful groups of environmental factors. These interrelations of organisms are too complex for presentation here even if one could successfully analyze them, but one need only mention the native mammal population — deer, beaver, porcupine and the vast numbers of small rodents — and their habits with respect to plant life; the bird population especially as related to seed distribution; the insect fauna particularly as regards flower pollination and preying upon foliage; wood-boring and bark beetles, etc.; the crowding of plant species into compact formation as in a high forest with resulting adjustments in form, shade tolerance, etc.; the forest floor species; the forest soil fungi and bacteria and their relation to a sanitary soil; the wood destroying fungi, parasitic fungi, symbiotic relations, and so on.

The Content of the New York State Flora.

It may seem a bit curious in view of the advanced state of botanical knowledge, of the great activity in botanical investigation, of the extent to which botanical study is carried on in high schools and colleges, and particularly in view of the extent to which botanical knowledge is applied in exploiting and protecting crop production and forestry, that we should be so far from knowing what species of plants compose our flora. To be sure, a vast amount has been done toward gaining a knowledge of it. As early as 1843 [1] a natural history survey of New York was made in which botany was included, although the survey of the flora was confined to pteridophytes and spermatophytes. We have a number of floras of counties and more of special districts,[2] though these generally embrace only the vascular plants. The other groups have been considered, naturally, but not in a comprehensive survey of the State. The time is ripe and the need is great for a thorough-going survey of our flora. In this, we need not merely to know what species we have but their numbers and the frequency of their occurrence, where and in what environment they occur and the rôle they play in the vegetation and with respect to animal life and to human welfare. In this enterprise a proper sense of proportions is to be exercised. We have too long held the idea — really based on lack of information or on sentiment — that the only things which mattered were the conspicuous plants, notably pteridophytes and spermatophytes and, of these, especially trees and shrubs and those with conspicuous flowers. In a way this is a logical view, seeing that the earth's vegetation is so predominantly made up of angiospermous plants. But they are by no means the only ones that matter. Could we, for example, have any climax forest at all if it were not for the rôle played by fungi and bacteria? In human society, we are rapidly discovering that the upper strata, so-called, are not the only ones that matter. The welfare — moral, sanitary, etc., of the lower strata, so-called, is of fundamental concern for the whole community. We may draw a lesson if not even point an analogy in the consideration of our flora.

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[1] Torrey, John; Flora of the State of New York, 2 vols. In Nat. Hist. of New York, Division 2, Botany. Albany, 1843.

[2] I have not attempted to compile a bibliography of New York botany. This work is being done by the present State Botanist, Dr. Homer D. House, Albany. Dr. John Hendley Barnhardt of the New York Botanical Garden has made careful lists of local floras. See especially his list of local floras of the Torrey Club range in Norman Taylor's flora of the vicinity of New York, p. 38.

Following is a condensed outline of the plant kingdom giving, according to a rather old-fashioned classification, four sub-kingdoms with the larger natural groups under each. So far as data are given as to numbers of species they may indicate what the expectation may be for New York State. As a matter of fact I have not given much time to the collection of floral statistics.

General Outline of Classification.

I. *Thallophytes.*

1. Bacteria.
2. Blue-green algae.
3. Green algae.

   Dr. M. A. Howe suggests a broad estimate for blue-green and green algae together, including desmids but excluding diatoms, of 1200 species for New York.
4. Stoneworts. Chara, Nitella, etc.
5. Brown algae. Marine.
6. Red algae. Mostly marine.
7. True fungi embracing three greater and numerous lesser groups.
   - a. Alga-like fungi (water moulds, downy mildews, black moulds, etc.).
   - b. Sac fungi (blue moulds, powdery mildews, black fungi, cup fungi, morels, etc.).
   - c. Basidium-bearing fungi.
     - (1) Rusts and smuts.
     - (2) Coral fungi, polypores (bracket fungi, etc.), gill fungi (mushrooms and toadstools as gengenerally known), puff balls, etc.

   The number of gill fungi alone estimated for Michigan is 1000 species. Dr. Peck[1] de-

[1] Peck, Chas. H. List of species and varieties of fungi described by. Bull. N. Y. State Mus., 131:1909, pp. 59–189.

scribed over 2500 species of fungi not all of which, however, were New York species.

8. Lichens (included by Dr. Bruce Fink among true fungi).

The total number of species and sub-species given for Minnesota[1] is 428.

II. *Bryophytes.*

1. Liverworts. Number of Connecticut species, 107.
2. Mosses. Number of Connecticut[2] species, 280.

III. *Pteridophytes.*

1. True ferns, etc.
2. Scouring rushes.
3. Club mosses, etc.

Total number of New York Pteridophytes about 94.

IV. *Spermatophytes.*

1. Gymnosperms. Number of New York species, 19.
2. Angiosperms.

Flora of Monroe County,[3] native species and varieties, 1200.

Flora of the vicinity of New York City,[4] native species, 1930.

"	families of Angiosperms,	157
"	genera of Angiosperms,	830
"	species of monocotyledons,	663
"	species of dicotyledons,	1267

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1 Fink, Bruce. Lichens of Minnesota. Contr. U. S. Nat. Herb., vol. 14, pt. 1:1910.

2 Evans, A. W., and Nichols, G. E. The Bryophytes of Connecticut. Conn. State Geol. and Nat. Hist. Surv. Bull. 11:1906.

3 Beckwith, Florence, and Macauley, Mary E. Plants of Monroe county, N. Y. and Adjacent Territory, Proc. Roch. Acad. Sci. 3:1896, and 5:1910 (the latter a supplementary list).

4 Taylor, Norman. Flora of the Vicinity of New York, Mem. N. Y. Bot. Gard., 5:1915. The Torrey Club range includes territory within a radius of 100 miles of New York City. Possibly data from this range would equal if not exceed expectation for the whole of New York State for the groups covered.

ZONAL RELATIONS OF NEW YORK FLORA.

The presence of temperature zones about the earth has been vividly impressed upon the mind by many circumstances. It may have been first when you began the study of formal geography. The earth was found to be girdled by belts or zones from the equator to the poles. A high mountain in the tropics was shown to be similarly belted from a tropical base through temperate slopes to a frigid summit. Perhaps there were pictures showing these zones with their characteristic animals and plants or the peculiar costumes and occupations of the people.

This zonal differentiation of the earth with respect to temperature and particularly the differentiation of life zones corresponding to and indeed visibly marking the temperature zones, is fundamental elementary teaching. The vital point for our present consideration is that all this represents a history of environmental change and of adaptation of living organisms to the differentiated environments. We learned from the geological record that in the Carboniferous period for example, the climate of the earth was uniformly tropical, supporting a uniform, tropical vegetation even within the polar regions. Beginning, apparently, in the later Jurassic period, there ensued a gradual differentiation of climate marked by increasingly lower temperature toward the poles and notably by yearly fluctuations of temperature — i. e. alternating warm and cold seasons. Coincident with this there came about a segregation of species adjusted to different degrees along the temperature scale from tropical climate to arctic climate. What this means will be clear from a selection of well known or fairly well known species of plants from different latitudes along the north-south scale. Thus, mahogany, palmetto, giant magnolia, sweet gum, tulip-tree, chestnut, sugar maple, white pine, red spruce, balsam, paper birch, Bank's pine, dwarf birch, arctic willows, tundra heaths and reindeer moss.

We started out you remember, with the idea of emphasizing the developmental aspects of vegetation. We especially set forth the plant organism as having the capacity to invade unoccupied territory. Vegetation was to be regarded by us as the forward march of plant life in its occupation of the earth. We did not raise the question as to when or how plant life began to occupy the earth. We simply opened the record at a period when we found evidence of a uniformly tropical earth and of a massive tropical vegetation on at least some of the land pretty much over the whole globe. But as ages pass, the earth becomes a different earth so far as offering a plant environment is concerned. Its surface undergoes momentous changes. Its climate changes even more fundamentally. Yet we find plant life keeping up with the environment as one may say. Thus in keeping pace with temperature changes we have these antipodal conditions where, on the one hand, a species carries out its vital processes of nutrition, growth, development, reproduction, in what amounts to hothouse climate the year round while on the other hand a species carries out its life functions at temperatures from near freezing to summer heat, with daily fluctuations of temperature from below freezing to summer heat, and during nine months of the year is held dormant by freezing temperatures which fall as low as sixty, seventy and even ninety degrees below zero Fahrenheit, as in forest regions in Arctic Siberia.[1]

Now, in the long run, these temperature adjustments become so deeply impressed in the living substance or protoplasm of a species that its zonal relation is a sort of fixed habit. Thus the species which in the long run dominate our New York vegetation — tulip tree, oak, chestnut, hickory, maples, beech, birches, hemlock, white pine, spruce, balsam, and so on, may be said to have become so thoroughly identified with a climate which offers the sort of growing season and dormant season which New York does that the experience of winter is a necessary experience to them. It is, of course, a phase of environment to be endured, but on the other hand it is a necessary means of stimulating develop-

1 Warming, Ecological Plant Geography, p. 24.

mental vigor. Thus the winter is not a recurrent catastrophe for our vegetation but a stimulus to it. Indeed cases are easily cited where a period of low or even freezing temperatures is necessary to stimulate germination of spores and seeds, growth of bulbs and tubers, bud opening, etc. It seems however, necessary, in spite of this apparent zonal fixity of species, to think of them as charged with the sort of energy — variability, vigor of growth, vigor of seed, resistance to disease, etc.— which drives them toward the occupation of environments different from what they now hold, in short to burst beyond their zonal boundaries or rather to enlarge these. If this were not true, then we should have to believe that in the long run plants could not retain possession of the earth's surface. So we think of sweet gum, tulip, oaks, hickories, as exerting a pressure of distribution to the north of territory now dominated by them; so with respect to maple, beech, birch, etc. Also we think of them as exerting pressure of distribution southward.

Now it may well be — is undoubtedly — the case that a species may through age or whatever, become so fixed in its adjustment to a given environment as to have left little vigor of invasion — little competition power — or capacity to follow environmental changes; not even be able to resist the more vigorous species from invading its own zone. Possibly our conifers or some of them are in this condition. They are certainly very old species, not capable of much variation, not very vigorous in gaining new ground. Such species may be looked upon as on the road to extinction. We should expect such species from noting how whole dominant groups have disappeared from the earth. There are some to be found at the present — e. g., cycads — scattered as isolated genera of few species in widely different regions of the earth.

It is of advantage to recognize these qualities of our species, both native and cultivated. Vigor, adaptability, resistance to disease and to aggression of other species; relation to climate and soil; longevity; rapidity of growth and development; abundance of seed production or vigor of vegetative propagation; capacity to yield new variations, etc., are qualities that must be considered in this day of intensive cultivation.

But to return to the question of zonal relations; North America as a whole lies in a position with respect to latitude such that it presents a succession of life zones from tropical to arctic, the uniformity of which is of course much modified by elevation and other factors. These zones as defined by Merriam [1] are as follows:

I. The Boreal Region.

1. *The Arctic-Alpine Zone.*— The far north beyond the limit of tree growth and in the United States, high mountains above timber line. Zone of the polar bear, musk ox, reindeer and of arctic poppy, dwarf willow, etc., in north polar regions.

2. *The Hudsonian Zone.*—Includes the northern part of the boreal conifer forest stretching from Labrador to Alaska. In eastern United States it is limited to the cold summits of the highest mountains from northern New England to western North Carolina.

3. *The Canadian Zone.*— Includes the southern and most valuable part of the transcontinental boreal conifer forest in Canada and parts of Maine, New Hampshire and Michigan, extending southward along the Appalachian highlands to western North Carolina and Tennessee. Zone of red spruce, balsam fir, paper birch and mountain ash.

II. The Austral Region.

4. *The Transition Zone.*— The eastern humid area called *Alleghanian area.* Includes the northeastern states and part of the Canadian provinces and the Alleghanies from Pennsylvania to Georgia. Zone of overlap of oaks, chestnut, hickories, etc., with more northerly birches, beech, hemlock and sugar maple, etc.

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[1] Life zones and crop zones. Bull. U. S. Biol. Surv., 10:1898. Map revised to 1910. This bulletin could be profitably read in this connection.

5. *The Upper Austral Zone.*— In eastern United States, the *Carolinian area.* From the lower Hudson and coastal region of New Jersey to the mouth of Chesapeake bay and westward and southward at moderate elevations. Zone of tulip-tree, hackberry, sweet gum, red bud, persimmon, etc.

6. *The Lower Austral Zone.*— In eastern United States, the *Austroriparian area.* The coastal plain from mouth of Chesapeake bay to Florida and the other Gulf States westward. Zone of long leaf and loblolly pines, bald cypress, live oak, magnolia and tupelo.

III. The Tropical Region.

7. The Tropical Zone of southern Florida characterized by royal palm, mahogany, mangrove, etc.

Applying New York to the temperature scale and having in mind latitude only our State would fall in the region rather between the zones where southerly or austral conditions give their impress and those where northerly or boreal conditions do it — in the Transition zone of Merriam. On a theoretical latitude and sea level basis, this State would scarcely enter the boreal forest zone of spruce, balsam and paper birch. But the actual climatic situation in New York is radically different from the theoretical one based on latitude and approximate sea level. This is in part due as mentioned previously to the influence of the ocean on the one hand and to the great lakes on the other, but more especially to elevation. In order to get the effect of elevation vividly in mind let us imagine the construction of the relief features of New York on an approximately sea level foundation.[1] We construct a general plateau of say 2,000 feet elevation carried up to a maximum of 4,205 feet in the Catskills and to 5,350 feet in the Adirondacks. Next we dissect this plateau down to the aspect of a hill and mountain land,

1 Of course this imaginary construction bears no intimation of actual geological processes which have shaped the present configuration of the State.

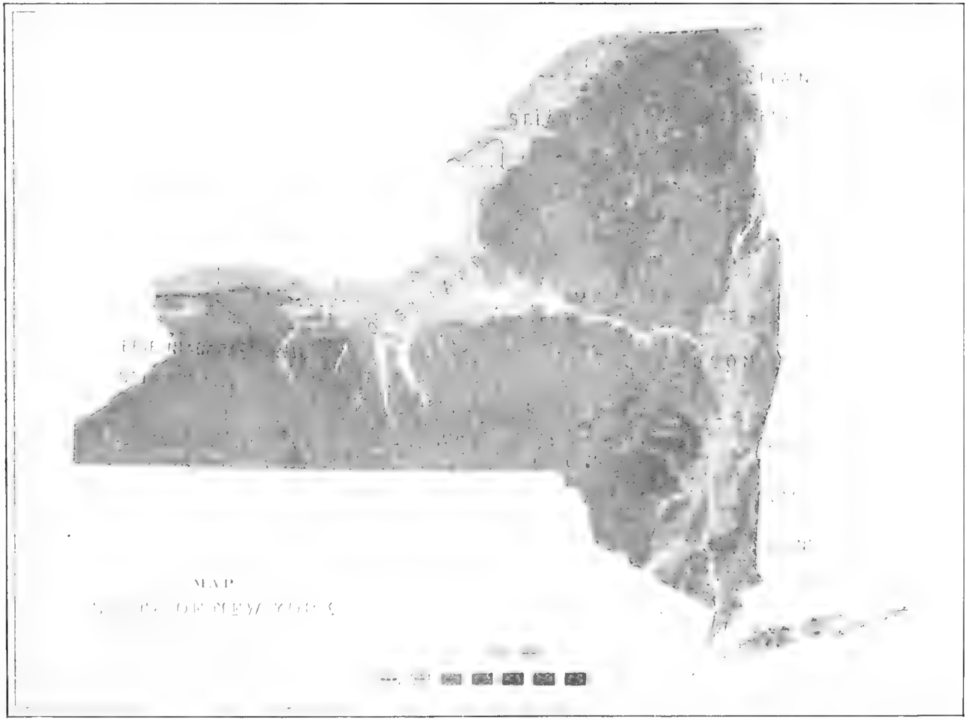

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Fig. 1. Photograph of relief map of New York. The general relief features will be found to furnish an index of the broad, zonal relations of the flora.

cutting well defined streamways which converge to form the Delaware, Susquehanna and Alleghany drainage systems cutting into the plateau from the south. The Hudson-Champlain valley is a dissection to near sea level, cutting the State across from south to north. At the northwest we should plane down to fit the Ontario Lake basin, thus constructing the low, level plain bordering that lake and extending eastward as the Iroquois basin including the Oneida Lake basin. The Mohawk is, then, a low and mostly broad valley a few hundred feet above sea level and joining the lake basin country with the Hudson valley. This cut severs the southern or Alleghany plateau from the Adirondacks. The lake basin country is continued around the north of the Adirondacks as a broad, low plain, the St. Lawrence valley. From the Iroquois-Ontario basin, cuts will be made back into the Alleghany plateau constructing the Genesee drainage and the Finger Lake region of narrow north-south valleys opening out upon the lake basin plain. Finally, dissection of the Adirondack plateau would include sharply defined channels such as the Black, Oswegatchie, Raquette, Saranac, Ausable and upper Hudson rivers and other masked or poorly established drainage features which may represent the effects of glacial filling. See Fig. 1, relief map of New York.

The extremes of climatic conditions as thus created, added to latitude and ocean influence factors, may be expressed by a contrast between Staten island and the summit of Mount Marcy. Unfortunately, actual figures are not available for Mount Marcy, but so far as growing season is concerned, where absence of frost is taken as a criterion, the summit of Marcy would scarcely have any growing period at all for warm climate plants which reach their northern limit at the mouth of the Hudson, for it is doubtful if any month is wholly free from frost. Certainly the growing season for even the cold resisting arctic flora of the summit can scarcely exceed three months, while around New York bay the frostless period covers 200 days. But this doesn't express the full force of the difference between these two extremes. One should know the daily range of temperature in summer which of course for the mountain summit would be extreme. Again the lowest winter temperatures, the duration of zero or below zero temperatures and so on.

On Staten island are found such Austral plants as sweet gum, persimmon, mistletoe, willow oak, etc. On Mount Marcy, arctic species, such as *Diapensia lapponica, Rhododendron lapponicum* and a score of other species whose distribution is throughout the arctic regions of the three northern continents extending southward only on high mountains. This is much the sort of difference that one would get as between southern Illinois and Hudson bay. It supports the suggestion that within New York State there may be recognized a right wide range of floral provinces. But I wish to caution the reader against accepting without qualification the alleged facts of temperature effect as determined by elevation. Many of the phenomena of distribution will be found correlated with soil conditions, slope and exposure, local air drainage, etc., so that in reality the local edaphic conditions must be known.

Effects of Elevation on Zonal Relations as Shown by Transects of the State.

A very instructive and in general a very effective study of the facts of plant distribution on a panoramic scale, as it were, may be made from the car window [1] while traversing the State on the various railway lines. After you have gotten the habit well formed and have learned to recognize a fairly wide range of species at a distant and rapidly passing glance, the landscape becomes a particularly entertaining "movie."

Transect from the Lower Hudson to Rouse's Point.

Thus in traveling from New York City to Rouse's Point you make a complete north-south transect at very slight elevations along the Hudson-Champlain Valley. Beginning with

[1] We are indebted to Dr. R. M. Harper of College Point, L. I., for vigorous support of projects connected with the study of the geographical distribution of plants. The "car window" method of studying plant distribution has been used and recommended by him as a valuable adjunct to more detailed studies.

a relatively mild maritime zone where willow oak, laurel magnolia, sweet gum, persimmon, etc., occur, you quickly pass from these into a dominantly chestnut, oak, hickory zone in the Highlands. This type is most intensely marked in the Palisades Park Highlands but also in the Westchester Hills and continues in strength up the Hudson well toward Albany. This element (See Zone B, p. 71) is weaker northward and by the time you reach Whitehall, chestnut has disappeared.[1] At Westport you still find some oaks (especially red oak and white oak), hickories, red juniper and others of our chestnut, oak, hickory type or Zone B; but if you thence go a few miles westward toward Elizabethtown you enter a typical maple, beech, birch, hemlock, white pine forest zone (our Zone C). This is also virtually the case on well-drained soils (not sands) at Rouse's Point and westward across the St. Lawrence Valley (not on wet lands). Thus it appears that latitude, even augmented by removal of immediate ocean influence, does not produce a very wide floristic range in New York. This would be more strikingly the case even for a transect between Binghamton (at valley level) and Massena Springs in the St. Lawrence Valley, for at Binghamton we begin with Zone B.

The Zonal differences are strikingly greater and the effects come much more rapidly when you traverse the State on lines crossing the Catskill highlands and the Alleghany Plateau (e. g. New York City to Oswego) or across the main Catskill elevation (e. g. Catskill via Tannersville, Phoenicia and Arkville to Oneonta).

Transect from Staten Island to Oswego.

Here, again, you begin with the maritime zone where a few northerly ranging species persist which you will have come rather to associate with Virginia, North Carolina, etc., than with New York, Northern Pennsylvania, Ohio, etc. You traverse again the highland region of maximum frequence of chestnut and of dominant chestnut-oak, of flowering dogwood, etc. From Cornwall to Middletown, cultural vegetation — regions of farming and dairying — will have

[1] I am indebted to Mr. George L. Barrus of the N. Y. State Conservation Commission for data as to the distribution of chestnut in New York.

given native vegetation a secondary rôle. You learn to associate this condition, as everywhere else in New York, with the fine growths of scattering American elms. Still in wood lots and waste lands you note that oak, chestnut, hickory, tulip and their associates persist, and this continues to Mountain Dale, elevation, 1000 feet. Here you enter a northward extending arm of the Appalachian association of rhododendron and mountain laurel, first in forest of chestnut, oak, hickory and tulip, but above Fallsburg (elevation 1,200 feet), the forest becomes dominantly sugar maple, beech, yellow birch, hemlock, and white pine or, on denuded forest lands, red maple, popple birch and fir cherry. The rhododendron continues in this Zone C to some 1,400 feet elevation. You now come well up on the high ridge which farther northeast culminates in the main Catskill Mountain region. The maple, beech, hemlock forest continues dominant on uplands, the northerly type of swamp forest and much alder thicket and willow shrub on wet flats. Finally at the highest point, Young's Gap, elevation 1,800 feet, red spruce and an occasional balsam indicate the Canadian Transition Zone, D, which you will note dominates the Catskill Mountains generally and of course the main body of the Adirondack region. Then from Parksville (1,700 feet) down to the Delaware at Cadosia (1,000 feet) the zonal arrangement is repeated, rhododendron again appearing in Maple, beech, hemlock forest. Then over the divides at Apex, Northfield, Summit, Smyrna and Eaton the typical Appalachian-Transition (Zone C) forest type is dominant, the oak, chestnut, hickory only intensified with each descent into valleys (Rock Rift, Sidney, Oxford to Norwich).[1] Finally, after you have concluded that the maple-beech-hemlock type has become fully dominant, you drop down into the Oneida Lake basin to find pure stands of oak (several species and on shore sands), sycamore, and occasional tupelo gum and hackberry on bottom lands. Then on the sand beds at Phoenix the finest

[1] This recurrence of Zone B elements along valley walls leads to the suggestion that purely edaphic conditions may play a stronger rôle in this case than simply lower elevation.

single specimens of chestnut and the finest bit of chestnut forest which you have seen during this transect — or perhaps any other in New York especially in view of the destruction of this species by chestnut blight. So across the low elevation of the Oneida-Ontario basins to Oswego, oaks, hickories, chestnut and tulip continue, especially on the sand beds. You have therefore a combination of factors; not merely the return to near the low elevation with which you began the transect, but the modifying influence of the great inland lakes and the effect of deep, well-drained sandy soils. It should be noted that even in the basin country from Oneida to Oswego the normal climatic type of maple, beech, birch, hemlock and pine asserts itself on elevated ridges, drumlins, etc.

Transect of the Adirondacks.

The maximum effects of elevation on temperature difference and zonal relations may be seen in traversing the Adirondack region from the low elevation of Lake Champlain to the similarly low St. Lawrence valley westward. This may be done by rail from Plattsburg to Lake Placid, thence via Tupper Lake Junction to Childwold, to Cranberry lake, thence from Wanakena to Carthage and via Philadelphia to Clayton.

The following transect is constructed from rail, stage and foot travel between Clayton and Westport including the highest elevation of the Adirondacks, Mt. Marcy.

Beginning at Clayton on the St. Lawrence, one finds a sprinkling of oak and hickory representing the weak or thinned out extension of this element which extends down the St. Lawrence valley in notably less strength than on the south side of Lake Ontario. Chestnut scarcely extends this far — certainly only in sporadic specimens. The flat plain east to Philadelphia has characteristic lowland woodlots of elm, red maple, ash, etc., or typical swamp forest minus the better commercial stuff — hemlock, pine, white cedar, which have been cut out. Occasional flat sandy soils are covered with aspen, popple-birch, etc. From Philadelphia eastward the delta sands intervene and where was formerly white pine is now heath-shrub and pitch pine. But in general, this valley rim up to 1000 feet elevation or rather more, is a sugar maple, beech, hemlock, pine region. (Zone C.) At Lake Bonaparte and Harrisville, (1400 feet) red spruce on uplands, balsam and tamarack on flats and paper birch on projecting points are indication of the Canadian-Transition (Zone D) which then becomes more intensified on through to the higher Adirondacks. Here it will be noted, sugar maple, beech, yellow birch, hemlock and white pine forest is reinforced by the more boreal red spruce and balsam and paper birch and partly for this reason the zonal distinction,— Canadian-Transition,—is made. But this distinction is strengthened by the character of the forest floor species. Thus, witch hobble, spinulose shield fern (*Dryopteris spinulosa* [Muell.] Kuntze), and American shield fern (*Dryopteris intermedia* [Muhl] Gray) (especially the latter of these ferns), wood sorrel and shining club-moss (*Lycopodium lucidulum* Michx.) constitute the greater per cent — some times practically the whole — of a dense ground cover. Bunch berry, yellow *Clintonia* and twin flower (*Linnaea americana* Forbes) yet more boreal species, are also abundant. The further results of elevation are known to me chiefly by data from Mt. Marcy and adjacent peaks. Between 3000 and 3500 feet one passes out of the Canadian-Transition Zone (D). The sugar-maple, beech, yellow birch, hemlock and white pine thin out, giving place to a (scarcely typical because rather dwarfed) Canadian Zone forest (E), in which red spruce balsam, paper birch and mountain ash (*Sorbus americana* Marsh) are dominant. Above 4500 feet the forest becomes strongly dwarfed and a few hundred feet below the summit it is a dense scrub thicket scarcely man-high. This makes a compact mat-like growth still farther up in the ravines (See Fig. 3) and finally the conifers are mere dwarf, spreading shrubs. With this we come into a distinct zone (F) in which although species from lower elevations persist, the character giving species are arctic plants (see list under Zone F. indicators, page 77) which by some are looked upon as relicts of a glacial flora but which in any event are circumpolar in their distribution (America, Eur.-Asia) and besides occupy high mountain peaks in New York and New England.

Descending from Marcy summit, from Lake Tear of the Clouds down to within perhaps two miles of Upper Ausable Lake, boreal conifer forest remains dominant, but below 3000 feet the sugar maple, yellow birch, beech and hemlock, return and with red spruce and balsam constitute again the characteristic forest. Descending rapidly from the Ausable Club ground in the sheltered north-south valley (Keene Valley) one is impressed after days of Adirondack vegetation, by the presence of oaks, elm, ash, cherry and some other non-Adirondack species. But it remains for the stretch from Elizabethtown to Westport to carry you into a clear-cut arm of Zone C. Within a distance of three miles, walking east from Elizabethtown, you can list nearly all of the indicator plants of this Alleghany Plateau (in New York) type as seen for example at Tully. Finally as you approach within a mile or two of Lake Champlain, oaks, hickories, red cedar and other species indicate, not a characteristic, but a "thinned out" extension of Zone B. It should be stated in this connection however that red oak and white oak range farther north than others just as in the case of shag-bark and pig-nut hickories and so constitute less valuable indicators of Zone B as one finds it, for example, in the Hudson valley and the Highlands.

Effects of Plateau Dissection on Zonal Relations.

The study of certain features of the dissected highlands — deeply cut valleys and the slope and exposure of their adjacent sides — yields instructive data as to the distribution of floristic elements.

In general the dissection of the plateaus by north-south drainage channels leads to a northerly extension of austral species.[1] In the Hudson Valley the oak, chestnut, hickory

[1] I am indebted to Mr. W. D. Funkhouser of Ithaca for confirmation of this statement in the case of certain insect distributions.

forest elements persist more or less strongly to Glens Falls and Whitehall. These forest forming species follow the drainage valleys of the Delaware, Susquehanna and Alleghany systems well into the Alleghany plateau, i. e., into the zone of sugar maple, hemlock, white pine, beech and yellow birch. This northerly extension appears to be especially marked in the region where the long, deep valleys of the Cayuga and Seneca lake basins continue the dissection across the plateau into the Ontario basin.

The case of Keene Valley above mentioned seems properly to be explained on the ground of a north-south cleft along which more southerly species extend into otherwise characteristic Adirondack conditions. Naturally these north-south channels give rise to the so-called "warm pockets" where natural species exist or cultivated ones thrive which could not endure the temperature conditions (early and late frosts probably) of the general region. No doubt numerous such warm pockets are known to farmers and fruit growers although I have not gathered the data concerning them. Kaaterskill clove (see frontispiece) is a cleft opening southward from the Catskills upon the Hudson Valley. Here the oak, chestnut, hickory zone (notably chestnut-oak in force) is thrust up beyond 1500 feet elevation into the sugar maple, yellow birch, beech, white pine, hemlock zone on the border of a yet more boreal expression of it as indicated by red spruce and balsam (at 2000 feet).

On the other hand, these same north-south channels cut in the Alleghany plateau, appear to favor the extension of boreal species southward beyond their general New York range. This phenomenon is associated with the exposure by dissection of high steep north and east cliffs and slopes. Without the support of experimental data or frost records one would say that we are here dealing on a large scale with a difference like that between the sunny side and the shady side of a house standing in the open. Such a case is found on a north facing wall of the Genesee gorge at Letchworth Park where paper birch and red pine are present. The valley of the Canisteo shows this sort of thing even more notably. At Cameron for example, the high steep north-eastward facing valley slope bears an almost pure stand of paper birch. Twin flower (*Linnaea americana* Forbes) was one of the ground cover species here. This is a boreal species very common in typical Adirondack forest.

I suppose we may consistently use the name "cool pockets" for situations created by plateau dissection where imperfect air drainage permits the gathering of chilled air thus favoring unseasonable frosts.

Possibly the occurrence of such a boreal plant as dwarf Canadian primrose (*Primula mistassinica* Michx.) at different stations in the Alleghany Plateau region might be explained in this connection. However, I have not personally seen it there.

Finally, in this connection, the Mohawk Valley shows the effect of plateau dissection through slope exposure on distribution where apparently temperature differences are created. Thus in the more gorge-like part of the valley from Little Falls eastward the south exposures (north side of valley) bear the oak, hickory, chestnut type of growth while the prominent north exposures of the south rim of the valley show a large percentage of paper birch.

Influence of Lakes upon Zonal Relations in New York State.

This subject has been investigated especially with reference to the influence of the Great Lakes upon agriculture through their effect upon the occurrence of frosts. Von Engeln[1] in a contribution on the effects of continental glaciation upon agriculture devotes several paragraphs, (pages 346-350 of bull. listed below) to a discussion of glacial lakes and their effects on local climates and agriculture in which he cites especially the work of Whitson and Baker[2] for

[1] Von Engeln, O. D. Effects of continental Glaciation upon Agriculture. Bull. Amer. Geogr. Soc., 46:1914. pp. 241–264 and 336–355.

[2] Whitson, A. R., and Baker, O. E. The climate of Wisconsin and its Relation to Agriculture, Univ. of Wis. Agr. Expt. Sta. Bull. 233: July, 1912, pp. 25–27, 44, 54, 64.

Wisconsin, Schneider for Michigan and Wilson[1] for New York. The basis for the influence of bodies of water upon local climate is set forth in the following from Von Engeln, p. 347. "Where bodies of water of considerable area exist they exert an important equalizing effect upon the temperature. Water absorbs more heat, holds more heat, is warmed to greater depth, absorbs and radiates heat more slowly than land. Further, 50% of the insolation on water areas is used

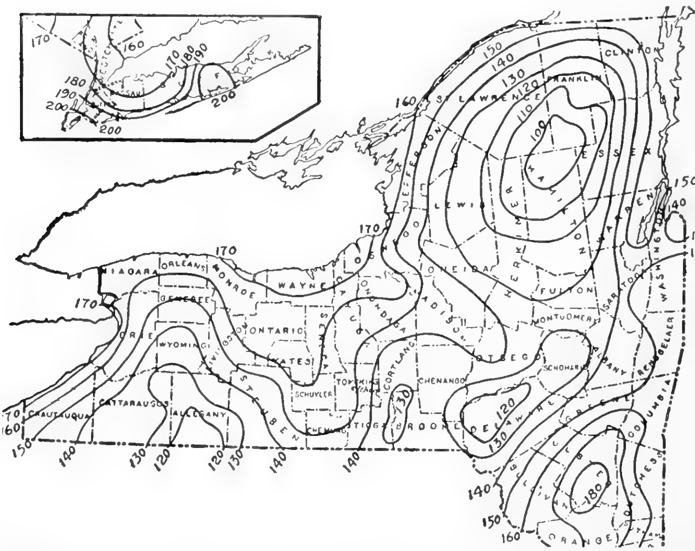

Fig. 2. Number of days between the last frost of spring and the first frost of fall. Reproduced by permission of N. Y. State College of Agriculture, Cornell University, from Experiment Station Bulletin 316, Frosts in New York

in evaporating water. This develops a moist blanket of air above and adjacent to the water surfaces that is less subject to marked temperature fluctuations than dry air. The total effect of these differences is to make summers cooler, winters warmer, to prolong the fall season and retard spring and also to check sudden temperature changes in short time periods. This last is especially important in the northern

[1] Wilson, W. M.: Frosts in New York, Cornell Univ. Agric. Expt. Sta. of the College of Agriculture. Bull. 316, 1912.

belt of prevailing westerly winds with its alternation of cyclones and anti-cyclones in which the glaciated regions are situated."

Again, p. 348, "In New York the areas to the south and east of Lakes Erie and Ontario constitute distinct, wide climatic provinces with longer growing season than more southerly parts of the State and constitute the great apple, grape and nursery growing areas for which the State is famous. In more restricted areas, adjacent to the narrow Finger Lakes of Central New York, the same climatic relations make possible the very successful growing of grapes."

A study of the relief map of New York, p. 52 and of Wilson's frost data maps (bulletin cited, Figs. 138,[1] 139, 140) and his map showing climatic divisions of New York (l. c. fig. 151) will be instructive in this connection. It is to be noted from these:

1. That the influence of Lake Ontario is felt farther inland by reason of the wide extent of the lowlands of the Ontario-Iroquois basin.

2. That in the case of Lake Erie the nearness of the Alleghany plateau to the lake restricts, by the factor of elevation, the zone of moderated climate.

3. That the extension of southerly species of plants would be favored across the plateau region by the moderating influence of the larger finger lakes as well as by the factors of dissection and elevation referred to on page 60.

Does the Native Vegetation Reflect This Moderating Influence of the Lakes?

A closer analysis of floristic data is desired before an elaborate answer can be given, but my own observations in the field reinforced by citations of species from local floras seem to warrant the following:

1. The general occurrence of oak, hickory and chestnut on well-drained soils, the number of species of both

[1] Reproduced here by permission, fig. 2.

oak and hickory and the large growth of chestnut indicate the presence of this zonal condition much as it prevails in the middle Hudson Valley region.

2. The prominence of basswood and American elm in the wet land forest (woodlots) of the Ontario plain (e. g. in Niagara and Orleans counties) with the infrequence or absence of conifers, especially white cedar and tamarack (except in bogs), contrasts with the infrequence of basswood and tendency to dominance of conifers (particularly of white cedar) as noted in the St. Lawrence Valley and indicates an austral rather than boreal relation of the former.

3. Perhaps even more convincing evidence is given of the moderated climatic conditions of the region lying in the lee of the Great Lakes in New York by the presence of species of more pronounced austral affinities such as paw-paw, hop tree, spiny aralia, American crab apple, hackberry, tupelo gum, flowering dogwood and redbud among trees or large shrubs, and lotus, swamp rose-mallow, golden seal, sensitive pea, wild senna and other miscellaneous species.

Apparent Effect of Glacial Filling on Zonal Relations Through the Creation of Bog Habitats.

Throughout the State, generally speaking, one of the effects of glacial filling, i. e., the deposition of glacial debris so as to obstruct drainage, has been to promote bog formation by vegetation. In every such case there comes to be a dominance of so-called boreal species — black spruce, tamarack, various heath shrubs, sedges, orchids, sphagnum moss and so on — and often these bogs have been spoken of as "islands" of boreal life. Such bogs occur also in the region we have just been considering as having an austral trend of the flora by reason of lake influence; for example, the Mendon Ponds, twelve miles southeast of Rochester. We naturally suppose that the lake influence would be effective here, but the character of the plant society remains as fixed as it does at elevated points on drainage divides of the Alleghany plateau

— e. g. Machias — or in the Adirondacks. The question arises as to whether the factor of temperature plays a rôle in the occurrence of boreal species in these bogs or whether it is not a matter of the physical and particularly of the chemical nature of the substratum. In this bulletin I am discussing bogs in connection with vegetation development as determined by the substratum, page 119, but I am disinclined to regard the factor of temperature as of no special moment. Certainly it is a common experience that bog waters are cold. My own experience in using *Sphagnum* in starting seeds to germinate, etc., leads to the conviction that rapid evaporation from wet *Sphagnum* operated to lower the temperature materially. The absorption and giving off of heat by bog water must be retarded not only by the covering of bog vegetation but by the effect of the peaty substratum in checking free movements of the water.

Nevertheless Dachnowski [1] found that in a Cranberry bog the temperature of the peat substratum during the spring and summer is not lower than that of other soils and is more uniform than that of air.

On the other hand, investigations with respect to conditions under which frosts occur in cranberry bogs appear to support the lower temperature claim. Thus Wilson [2] discussing the effect of soil and soil covering on frost says: "The writer found that old cranberry bogs covered with a thick carpet of vines were much more liable to frosts than were bogs recently planted. It was believed that the thick covering of vines prevented a large part of the heat received from the sun during the daytime from reaching the soil and since but little heat was stored up by day, only feeble resistance was offered to the fall of temperature at night."

"In the Cape Cod cranberry marshes it is the practice to spread about half an inch of sand over the surface of the marshes each year, thus covering the dry vines and furnish-

[1] Dachnowski, Alfred, The vegetation of Cranberry Island (Ohio) and its relation to the substratum, temperature and evaporation. Bot. Gaz., 52:1911.

[2] Frosts in New York; *loc. cit.*, p. 516.

ing a reservoir for the storage of heat received by day against the low temperatures at night." Wilson quotes the results of Professor Cox's observations on the temperature of the air over peat and sanded bogs respectively in which it was found that during August and September the night temperature at five inches above the surface averaged higher over sanded bog than over peat bog by about 5 degrees and the greatest daily difference in one instance was 19 degrees.

Zonal Features of the New York Flora.

I am concerned especially at this point that you should keep in mind the special object of the portion of the bulletin dealing with so-called zonal relations, which was to show that in the long course of time and especially since the later Cretaceous and early Tertiary periods of the earth's history, there has been a segregation of species into categories which represent different degrees of climatic differentiation — in short that plants have kept pace with their changing environment so far especially as the temperature factor is concerned. That the species which dominate New York vegetation — and by *dominate* I mean species that constitute the massive element in the climax forest especially, and therefore trees — either as now constituted or through closely related ancestral species, have had this climatic experience so deeply impressed that they reflect a certain fixity of temperature relation so that whether their "zone" moves northward as in the Miocene and in interglacial periods or whether southward as must have happened during glacial encroachments, they have taken up their relatively fixed position on the temperature scale. So the temperature relation, whatever that may mean as determining plant distribution, represents an environmental factor or set of factors which stimulate a very definite response in plant behavior so far as the climatic conditions are concerned in which they carry out their life processes. I bear in mind the adaptability of plants, their possibilities as to acclimatization, the degree to which the favorable soil relation may render them independent of temperature barriers, and still I must look upon them as indicator species taken in the large; for example, sweet gum and persimmon and willow oak suggest a warm temperate zone; balsam and red spruce and paper birch a cool temperate zone or even "boreal conditions." In a relatively small area like New York, selected on a purely arbitrary basis, zonal differences may not be very obvious (except where notable differences of elevation are taken), still it is of very vital concern to the farmer, the fruit grower, the nurseryman, arboriculturist, the landscape architect and even the forester to know as minutely as possible the climatic or zonal relations of his region.

It will be understood therefore that these zonal designations are not offered as a final expression of the floristic relations of the New York area — that is precisely one of the important lines of investigation to be undertaken in connection with or as a result of the botanical survey of the State above referred to — but as an effort to orient ourselves with respect to the present status of plant distribution over the country at large and always with the implication that what we observe must be seen in the light of paleobotanic as well as of geologic history in order to reach the more satisfying interpretation of it.

As previously mentioned, we commonly look upon our flora as possessing two contrasting elements; on the one hand the boreal plants whose greatest development is upon Canadian territory. It is especially the northern coniferous forest region. We regard the higher Catskills and the Adirondacks as being a part of this region. On the other hand, the austral plants whose region of greatest development lies along the Appalachian axis to the south and to the southwestward through Tennessee and Arkansas to Eastern Texas. On this meeting ground, which from this point of view really comprises most of the State, is a forest flora which is neither strongly austral nor strongly boreal but as Merriam [1] calls it, transitional. It may be said fairly to reach its maximum development in the New York type of environment. This is

[1] Merriam, C. H. Life Zones and Crop Zones. Bull. U. S. Biol. Surv., 10:1897.

the element which composes the familiar maple, beech, yellow birch, hemlock, white pine forest.

Also from this boreal-austral contrast point of view we say that the Appalachian axis makes an elevated highway over which boreal species — spruce, balsam, paper birch, etc., pass far into the southern states; that the Atlantic slope of this axis and the coastal plain, possessing a climate much ameliorated by ocean influence, furnish a terrain over which austral species pass far to the north of their general continental range. Thus, sweet gum, willow oak, southern shortleaf pine, persimmon and other species reach the lower New York region (mouth of the Hudson) and some of them extend up the Connecticut coast to Massachusetts, and American holly for example reaches the Maine coast.

Now in the light of developmental history as we have briefly reviewed it and thinking especially of the status of vegetation centering about the Glacial epoch, I should like to consider this whole matter of our flora — and particularly of our forest flora — from a radically different point of view; that is, a post glacial northward migration of the entire flora. We can start out in this project by expressing conviction as to three pertinent matters:

1. That before the glacial invasions, or if you please, before the last glacial invasion, essentially the present aspects of plant life as to floristic content, growth forms and vegetation types were present in eastern North America.

2. During the period of glacial dominance, the vegetation of the northern half of the continent was exterminated. If any species were represented only in this glacial region they either migrated to unglaciated territory or became extinct.

3. After the disappearance of the ice sheet and with the gradual return of milder climate, vegetation reoccupied this glaciated terrain. This vegetation consisted essentially of the elements which had been present before.

The situation was therefore essentially the migration northward of vegetation upon new terrain open to it as the glacier melted and the warmer zones pushed northward. Considering that the region had been covered by vegetation of similar floristic stock in preglacial or interglacial times, it would be as previously expressed a falling back of species into the zonal relations which long environmental experience had impressed upon them. We must look upon the southern Appalachian region especially, but the greater southern deciduous forest region in general, as being the region to supply the floristic stock and therefore the center from which the northward migration proceeded. The present botanical status of the southern Appalachians is most instructive in this connection. A transect of the Appalachian range from the " downfall " of the Piedmont Plateau over the highest summits in North Carolina, southwestern Virginia and Tennessee would include, in addition to species which do not reach so far north as New York, essentially the forest flora both of our deciduous and of our coniferous forests and more or less segregated into zonal relations by elevations as ours are by latitude, elevation, and maritime and lake factors. Taking the flora of this transect as a standard, a transect northward to and across New York shows the gradual dropping out of one species after another — or groups of species — until when we come to the higher Adirondacks essentially only boreal conifers and paper birch remain of the climax forest trees. (See zone E of New York.) Thus, sweet gum, persimmon and a few others finally drop out at the lower Hudson region (so far as New York is concerned) ; the oaks, hickories, chestnut and many other associates extend yet further up the valleys and into the Erie-Ontario basin ; maple, beech, yellow and sweet birch, hemlock, pine and a few others upon the plateau region, dropping out finally at more or less 3500 feet elevation in the Adirondacks where as stated, spruce, balsam (*Abies balsamea*) and paper birch persist. It is interesting to observe that the forest floor species extend in great abundance even to the Alleghany plateau in New York and the more boreal ones into the higher Adirondacks.

On the Atlantic slope with its maritime conditions the various species groups extend correspondingly farther northward, the oak, hickory, chestnut and associates over New England, and the maple, beech, birch, hemlock and pine to make the dominant forest elements of the maritime provinces of Canada. Of course, also, the coastal plain species (sand strand vegetation of Harshberger, sand barren species of New Jersey, Long Island coast, etc.), extend correspondingly far to the north.

With regard, finally, to the alpine flora of the highest peaks of the Adirondacks, it also is held to be a relict flora of this post-glacial migration,[1] but see further, page 79.

Suggested Zones and Their Indicator Species.

A. *Zone of Willow Oak, Sweet Gum, Persimmon, Etc.*

Indicator Species.

Short-leaf pine	=(*Pinus echinata* Mill.).
Willow oak	=(*Quercus phellos* L.).
Oak	=(*Quercus pogodaefolia* (Ell.) Ashe).
Black-jack oak	=(*Quercus marilandica* Muench.).
Laurel magnolia	=(*Magnolia virginiana* L.).
Sweet gum	=(*Liquidambar styraciflua* L.).
Hop tree	=(*Ptelea trifoliata* L.).
Mistletoe	=(*Phoradendron flavescens*(Pursh.) Nuttall).
Virginia spiderwort	=*Tradescantia virginiana* L.).
Day flower	=(*Commelina virginica* L.).

In addition to these and others perhaps equally important, the species of Zone B and many of Zone C.

Distribution and Extent: Staten Island, southern Long Island, especially coastward, and a narrow belt bordering the Sound from Manhattan and the Bronx to and continuing along the Connecticut coast. Growing period (estimated from last frost of spring to first of fall) 190 to 200 days.

[1] Adams, C. C. Post Glacial Origin and Migration of the Life of the Northeastern United States. Jour. Geo., 1:1902, Nos. 8 and 9. See especially p. 309. Also Harshberger, J. W.: Phytogeographic Survey of North America. In Die Vegetation Der Erde XIII:1911. In this connection, p. 189.

B. *Zone of Dominance of Oaks, Hickories, Chestnut, Tulip-Tree, Etc.*

Indicator Species.

Red cedar	=(*Juniperus virginiana* L.).
Black walnut	=(*Juglans nigra* L.).
Butternut	=(*Juglans cinerea* L.).

Hickories.

Bitternut. Swamp-hickory	=(*Hicoria cordiformis* (Wang.) Britton).
Shag-bark. Shell-bark	=(*Hicoria ovata* Mill.).
King-nut. Big shag-bark	=(*Hicoria laciniosa* (Michx. f.) Sarg.).
White-heart hickory. Mocker-nut	=(*Hicoria alba* (L.) Britton.).
Small-fruited hickory	=(*Hicoria microcarpa* (Nutt.) Britton).
Pignut-hickory	=(*Hicoria glabra* (Mill.) Britton).
Sweet birch	=(*Betula lenta* L.).
Chestnut	=(*Castanea dentata* (Marsh) Borkh.).

Oaks.

Red Oak	=(*Quercus rubra* L.).
Swamp or pin oak	=(*Quercus palustris* DuRoi).
Scarlet oak	=(*Quercus coccinea* Wang.).
Gray oak	=(*Quercus borealis* Michx. f.).
Black oak	=(*Quercus velutina* Lam.).
White oak	=(*Quercus alba* L.).
Post oak. Iron oak	=(*Quercus stellata* Wang.).
Mossy-cup. Burr oak	=(*Quercus macrocarpa* Michx.).
Swamp white oak	=(*Quercus bicolor* Willd.).
Rock chestnut oak	=(*Quercus prinus* L.).
Chestnut oak or yellow oak	=(*Quercus Muhlenbergii* Engelm.).
Hackberry	=(*Celtis occidentalis* L.).
Red mulberry	=(*Morus rubra* L.).
Cucumber tree. Mountain magnolia	=(*Magnolia acuminata* L.).
Tulip-Tree. Yellow poplar	=(*Liriodendron tulipifera* L.).
Paw paw	=(*Asimina triloba* (L.) Dunal.).
Sassafras	=(*Sassafras sassafras* (L.) Karst.).
Wild hydrangea	=(*Hydrangea arborescens* L.).
American crab-apple	=(*Malus* (*Pyrus*) *coronaria* (L.) Mill.).
Sycamore	=(*Platanus occidentalis* L.).
Red-bud	=(*Cercis canadensis* L.).
Kentucky coffee-tree	=(*Gymnocladus dioica* (L.) Koch.).
Honey-locust	=(*Gleditsia triacanthos* L.).
Prickly-ash	=(*Xanthoxylum americanum* Mill.).
Flowering dogwood	=(*Cynoxylon* (*Cornus*) *floridum* (L.) Raf.).
Tupelo	=(*Nyssa sylvatica* Marsh.).
Great laurel	=(*Rhododendron maximum* L.).
Mountain laurel	=(*Kalmia latifolia* L.).

Among small, herbaceous species:

White dog-tooth violet	=(*Erythronium albidum* Nutt.).
Lizards tail	=(*Saururus cernuus* L.).
Lotus (American) or Water chinquapin	=(*Nelumbo lutea* (Pers.) Willd.).
Golden-seal	=(*Hydrastis canadensis* L.).
Wild sensitive-plant	=(*Chamaescrista* (*Cassia*) *nictitans* (L.) Moench.).
Partridge-pea	=(*Chamaecrista* (*Cassia*) *fasciculata* (Mx) Greene).
Shooting-star	=(*Dodecathion Meadia* L.).
Virginia-cowslip. Bluebells	=(*Mertensia virginica* (L.) DC.).

In addition to the above, certain other austral groups e. g. *Smilax,* legumes, composites (southwestern species especially in the Erie-Ontario basins), certain grasses, e. g., *Paspalums,* represented rather strongly in this zone disappear, or are sparsely represented in Zone C.

The list could be much enlarged and, of course, more accurately determined.

New York Distribution: Morainic region of Long Island and Staten Island; Hudson Valley region and adjacent highlands (Westchester hills, Highlands of the Hudson, Lower Catskills (especially dissected channels, e.g., Kaaterskill clove, becoming "thinned out" by disappearance of many species (chestnut stops below Lake Champlain, red oak, white oak, shell-bark hickory, red cedar and some others extend up the Champlain valley to the St. Lawrence); the Delaware, Susquehanna and Alleghany drainage valleys; across the Alleghany plateau in Finger Lake valleys; up the Mohawk valley (especially south exposures) and notably strongly developed in the narrow Erie belt and the broader Ontario-Iroquois basin (notable occurrence of chestnut on sandy soils) to the Oneida Lake region; northward "thinning out" (by disappearance of chestnut, tulip tree, certain oaks and hickories and most of the secondary austral woody species) toward the St. Lawrence valley.

Low elevations to more or less 1200 feet southward and in territory under maritime and especially lake influence.

Growing season 160 to 180 days (Lower Hudson region; Erie and Ontario basins). "Thinned out" at low elevations of 150 days growing season. (Apparent exception — see Fig. 2. — in case of Delaware, Susquehanna and Alleghany valleys?)

C. Dominance of Sugar Maple, Beech, Yellow Birch, Hemlock and White Pine Mixed Forest. Alleghany-Transition Forest Zone.

Indicator species.

White pine	=(*Pinus strobus* L.).
Hemlock	=(*Tsuga canadensis* (L.) Carr.).
Hop hornbeam	=(*Ostrya virginiana* (Mill.) Willd.).
Blue beech. Water beech	=(*Carpinus caroliniana* Walt.).
Yellow birch	=(*Betula lutea* Michx. f.).
Beech	=(*Fagus grandifolia* Ehrh.).
Witch hazel	=(*Hamamelis virginiana* L.).
June berry	=(*Amelanchier canadensis* (L.) Medic.).
Wild black cherry	= (*Padus* (*Prunus*) *virginiana* (L.) Mill.).
Sugar maple	=(*Acer saccharum* Marsh.).
Red maple	=(*Acer rubrum* L.) Notably in swamps.
Striped maple	=(*Acer pennsylvanicum* L.). Zone D?
Mountain maple	=(*Acer spicatum* Lam.). Zone D?
Basswood	=(*Tilia americana* L.).
White ash	=(*Fraxinus americana* L.).

Of special note is, one may well say, the maximum occurrence of the forest floor herbaceous growth-forms which comprise especially the popularly favorite spring woodland flora of the eastern half of the continent generally. Their relation to the deep, warm, soil blanket of climax forests seems to render them less susceptible to the limiting factor of winter cold or other expressions of the temperature factor (daily extremes, etc.). Hence one finds such elements extending in force even into the more boreal conditions of the Adirondacks, though becoming notably supplanted at length by more strictly boreal species — see under Zone D. Familiar species in this connection are:

Virginia grape-fern, hay-scented fern, christmas fern, evergreen-wood fern, maiden-hair fern, plantain-leaved sedge, jack-in-the-pulpit, wild leek, yellow adder's tongue, false spikenard, bellworts, solomon's seal, indian cucumber root, large-flowered trillium, ill-scented trillium, showy orchis, wild ginger, carolina spring-beauty, red baneberry, white baneberry, wild columbine, tall anemone, hepatica, tufted buttercup, early meadow-rue, blue cohosh, twin leaf, may apple, bloodroot, dutchman's breeches, squirrel corn, pepper root, two-leaved toothwort, false mitrewort, bishop's cap, barren strawberry, downy yellow violet, striped violet, long-spurred violet, american spikenard, ginseng, ground-nut, anise-root (sweet cicely), indian pipe and beech drops.

Distribution in New York.

Tendency to recurrence upon every favorable edaphic situation throughout the State up to more or less 2000 feet (Catskills) excepting, in general, the Adirondacks, but dominant over the Alleghany plateau region and the Catskills below the spruce-balsam zone.

Frostless period in general 130 to 150 days.

More or less arbitrarily distinguished from the maple, beech, birch, hemlock containing (and often dominated) Adirondacks and Catskills by absence (generally) of red spruce, balsam, white birch etc., on the one hand and presence of certain species of Zone B which are lacking in the Adirondacks.

Similar extensions in mountains of New England, the Maritime Provinces and especially the St. Lawrence region of Quebec and Ontario (but peninsular Ontario is strongly like Zone B) and Michigan and Wisconsin.

D. *Canadian-Transition Zone.*

Dominance of maple, beech, yellow birch, hemlock, white pine as in Zone C, but addition and tendency to dominance in special situations and, especially at greater elevations, of red spruce, balsam, paper birch, mountain ash, etc. Further characterized by absence of oaks (few exceptions), hickories, elms, and, naturally, of tulip-poplar, chestnut, etc. (i. e., dominant species of Zone B). Further, by the decreasing prominence of forest floor herbaceous growth-forms of the Appalachian region generally, and substitution of more northerly ranging species (see below).

Dominant tree species:

Red spruce	=(*Picea rubens* Sargent.).
Black spruce	=(*Picea mariana* (Mill.) B.S.P.).
Balsam fir	=(*Abies balsamea* (L.) Mill.)
Mountain ash	=(*Sorbus americana* Marsh.).

Forest floor species of special note:

The following are not only very generally distributed through the Adirondack and higher Catskill forest but each may occur in exclusive formation over large stretches:

Shield fern	=(*Dryopteris intermedia* (Muhl.) Gray.)
Hobble bush	=(*Viburnum alnifolium* Marsh).
True wood-sorrel	=(*Oxalis Acetocella* L.).
Shining club-moss	=(*Lycopodium lucidulum* Michx.).
Ground hemlock	=(*Taxus canadensis* Marsh.).

Others less abundant are characteristic of this zone although occurring in C.

Red-berried elder	=(*Sambucus racemosa* L.).
Bush honeysuckle	=(*Diervilla Diervilla* (L.) MacM.).
Wild sarsaprilla	=(*Aralia nudicaulis* L.).
Fetid currant	=(*Ribes glandulosum* Grauer). Zone E?
Large-leaved golden-rod	=(*Solidago macrophylla* Pursh.). Zone E?
Mountain aster	=(*Aster acuminatus* Michx.). Zone E?

Finally, species which, while occurring in mixed forest, are especially associated with greater dominance of conifers and the duff soil beneath them rather than the leaf mold soil of maple, beech, birch stands. Cooper[1] cites most of these as characteristic of the Canadian climax forest of Isle Royale and of the Northeastern conifer forest in general. In the Adirondacks and Catskills these species become more con-

[1] Cooper. W. S. The Climax Forest of Isle Royale, Lake Superior and its Development. Bot. Gaz., 55:1913, Nos. 1, 2, 3.

spicuous — largely by reason of the absence of others above cited — wherever the Canadian type of forest is indicated.[1]

Bunch berry	=(*Chamaepericlymenum (Cornus) canadense* (L.) Asch. and Graeb.).
Yellow Clintonia	=(*Clintonia borealis* (Ait.) Raf.).
Twin flower	=(*Linnaea americana* (Forbes).
Two leaved Solomon's seal	=(*Unifolium canadensis* (Desf.) Greene).
Stiff club-moss	=(*Lycopodium annotinum* L.).
Gold thread	=(*Coptis trifolia* (L.) Salisb.).
One-flowered pyrola	=(*Moneses uniflora* (L.) A. Gray.).

Distribution of D in New York.

In the Catskills from about 2000 feet to 3700 feet (above which Canadian Zone forest is indicated by dropping out of maples, beech, hemlock and pine) and in the Adirondacks generally as climax forest up to 3500 feet more or less.

Growing season 100 to 130 days more or less.

E. Canadian Zone. Dominance of Red Spruce, Balsam and Paper Birch.

Indicator species.

Red spruce	=(*Picea rubens* Sargent).
White spruce	=(*Picea canadensis* (Mill.) B.S.P.).
Black spruce	=(*Picea mariana* (Mill.) B.S.P.).
Balsam fir	=(*Abies balsamea* (L.) Mill.).
Paper birch	=(*Betula papyrifera* Marsh).
Dwarf paper birch	=(*Betula cordifolia* Regel).
Mountain ash	=(*Sorbus americana* Marsh).
Fetid currant	=(*Ribes glandulosum* Grauer).
Twin flower	=*Linnaea americana* Forbes.).
Creeping-snow berry	=(*Chiogenes hispidula* (L.) T. & G.).
Bunch berry	=(*Chamaepericlymenum canadense* (L.) Asch. and Graeb.).
Gold thread	=(*Coptis trifolia* (L.) Salisb.).
Yellow Clintonia	=(*Clintonia borealis* (Ait.) Raf.).
Stiff club moss	=(*Lycopodium annotinum* L.).
Large-leaved golden rod	=(*Solidago macrophylla* Pursh.).
Mountain aster	=(*Aster acuminatus* Michx.).

Tendency to increase of boreal (or bog) heath shrubs.

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[1] As a matter of fact pure Canadian forest scarcely exists in the Catskills although it is strongly indicated, e. g., on Hunter and Twin Mountains.

Increase in lichens (incident to mountain exposure?)

Increase in rôle of mosses. See Cooper l. c. page 16.

Distribution of E in New York

Scarcely typical on summits of highest Catskills but indicated by dominance of red spruce and balsam, much somewhat dwarfed or gnarled topped yellow-birch, and sparse paper-birch, and by forest floor species. In the Adirondacks, the zone of spruce, balsam, paper-birch and mountain ash which succeeds maple, beech, birch, hemlock and white pine above 3500 feet more or less, is here referred to the Canadian Zone which in its typical composition as described by Cooper (l. c. page 16) is the Northeastern conifer forest *par excellence.* For general distribution of the Canadian forest type, see Map 3 in Zon's bulletin on balsam fir already referred to.[1]

F. *Arctic Flora of Adirondack Peaks.*

Indicator species.

Fir club-moss	=(*Lycopodium Selago* L.).
Alpine holy-grass	=(*Sevastana* (*Hierochloe*) *alpina* (Sw.) Scrib.).
Mountain spear-grass	=(*Poa laxa* Huenke).
Small-flowered wood-rush	=(*Juncoides* (*Luzula*) *parviflorum* (Ehrh.) Coville).
Scirpus-like sedge	=(*Carex scirpoidea* Michx.).
Highland rush	=(*Juncus trifidus* L.).
Bearberry willow	=(*Salix Uva-Ursi* Pursh.).
Glandular or scrub birch	=(*Betula glandulosa* Michx.).
Black crowberry	=(*Empetrum nigrum* L.).
Diapensia	=(*Diapensia lapponica* L.).
Lapland rose-bay	=(*Rhododendron lapponicum* (L.) Wahl.).
Moss bush	=(*Harrimanella* (*Cassiope*) *hypnoides* (L.) Coville).
Cutler's alpine golden-rod	=(*Solidago Cutleri* Fernald).
Low rattlesnake-root	=(*Nabalus* (*Prenanthes*) *nanus* (Bigel.) DC.).
Boot's rattlesnake-root	=(*Nabalus* (*Prenanthes*) *Boottii* DC.).

[1] Bull. U. S. Dept. Agr., 55:1914. Forest Service Contribution.

Photo by W. L. Bray.

FIG. 3. Dwarf balsam and spruce on the summit of Mt. Marcy. In the photograph the dwarf, shrub-like conifers are matted in a shallow ravine.

Photo by W. L. Bray.

FIG. 4. The heath-mat type of vegetation — chiefly *Rhododendron Lapponicum* in the foreground — on the summit of Mount Marcy. A matrix of fibrous peat interwoven with woody stems and roots of living heath shrubs, dwarf conifers, etc. is formed.

Occurrence in New York: On the summit of Mt. Marcy above 5000 feet; on Mt. McIntyre and to a less marked degree on Whiteface and others of the high peaks.

General Occurrence: On the higher peaks of New England where this arctic element is more strongly represented; in the arctic regions of America (Labrador, Alaska) of Greenland and of Europe and Asia and high mountains of Southeastern Asia; some of them in the Rocky mountains south to Colorado and in Arizona.

It would seem as if, in this case, we are dealing with a plant population that had no relation to the migration from the Appalachian highlands and subsequent establishment of species in the region round about, but Harshberger [1] thinks that these species may be relicts of a glacial flora which lay along the front of the glacial ice and were the first species to migrate northward as the ice receded.[2] Or according to Harshberger if any mountain summits remained above the ice sheet (as the nunataks of the Greenland glaciers) such a flora might have been conserved there throughout the last ice invasion. On the other hand Diels [3] has shown in his study of the *Diapensiaceae* that certain floristic elements have in post-glacial (?) times migrated from the mountain region of Southeastern Asia to arctic regions and many mountain summit of Asia, Europe and North America. *Diapensia lapponica* he regards as in this category. This and other boreal *Diapensiacae* are certainly more closely related to the Asiatic mountain species than to such " disjunct " species as galax (*Galax aphylla* L.) in the mountains of North Carolina or pyxie moss (*Pyxidanthera barbulata* Michx.) of the coastal plain sands from New Jersey southward. These two species and numerous others of this disrelated or disjunct status, must be referred to pre-glacial, perhaps even to the Tertiary period. As to the Alpine flora of Mt. Marcy and other iso-

1 Phytogeographic Survey of North America, pp. 189 and 204.

2 See also Adams, *l. c.*, p. 309.

3 Diels, L. Diapensiaceen Studien. Bot. Jahrb. für Syst. Pflanzengesch. u. Pflanzengeogr. Band 50: Supplement Band (Engler Fest-Band) 1914, pp. 304, 330.

lated peaks it appears to me scarcely necessary to assume that its establishment on these peaks dates back to any such remote period even as the close of the Glacial epoch, since factors at present operative might account for the carrying of such species to any habitat suited to them, at least in the northern continents.[1]

Extra-Continental Relations of the New York Flora.

The case just considered of arctic plants on the Adirondack summits brings to a point the question which has suggested itself all along through the review of pre-glacial and post-glacial development and movements of vegetation, namely; has all this history had any relation to the Eur-Asian continents whose land masses together with that of North America converge about the north polar regions? The matter has been discussed from the time of Gray and Hooker, notably by Engler, Drude and more recently by Fernald, by Chamberlain and Salisbury and by Harshberger.[2]

It is not a question to be gone into minutely in this bulletin, but certainly such a biologic matter has more than a passing interest for the thoughtful man. I would put it on the basis of an analogy with racial movements in human history which are of course of fundamental consequence in the study of human progress. Indeed it is certain that the study of biologic phenomena of the kind embraced in the development and movements of plants and animals generally would greatly enlarge the horizon as respects a larger view of the history of man. It is precisely because of this conviction that I have ventured to put into this bulletin so large an element of what may appear to be speculative biology. Biologists — scientists generally — have gradually

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[1] In this connection, see Engler, A. On the behavior of plants of the north-temperate zone in their transmission to the high mountains of tropical Africa. London. Rep. Brit. Assoc. Adv. Sci. 1904:799–801. Also Engler, A. Polymorphe Pflanzentypen der nördlich gemässigten Zone bis ihrem Uebergang in die Afrikanischen Hochgebirge. Ascherson Festschrift, 1904:552.

[2] See Harshberger, Phytogeographic Survey of North America, pp. 45–92, for specific citations of literature bearing on this.

fallen into the acceptance of such interpretations as a matter of course. We may forget that the layman has not had time or occasion — perhaps not the opportunity — to follow the evidence minutely, and naturally would look skeptically upon doctrine presented thus in general and confident conclusions. What I am saying at this point has of course no more pertinent application to the question of the above caption than it has to the conclusions about the development of plant life in remote geologic periods, or to the doctrine as to the relation of glacial encroachments to the plant life of that epoch, and the post-glacial migrations into the glaciated regions.

As to the immediate question, one naturally thinks of the ocean barrier on the one hand and of the barrier of frigid climate on the other. But even aside from the rather abundant interchange of plants between Europe, Asia and America incident to ocean traffic it does not appear that oceanic and climatic barriers have been wholly effective under present conditions. Certainly the case of *Diapensia* indicates that so far at least as arctic plants are concerned, species of a certain aggressive individuality (whatever qualities that may involve of "*wanderungsfähigkeit*" (possibly the simple matter of vigorous seed of a kind which migrating birds might carry) are able to disperse from their distribution center (as seems to have been notably the case from the mountain lands of south eastern Asia) to the remotest habitat — e. g., the summit of Mt. Marcy — in the circumpolar regions. Engler[1] has repeatedly called attention to these migrations or dispersals over long distances of intervening climatic or oceanic barriers and notably in the case of species distribution as between the high mountains of southern Asia and Europe to the summits of high mountains south of the equator in Africa (the Kilimanjaro district).

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[1] Engler, Adolph. See papers previously cited. Also, Engler, A. Uber die Geographische Verbreitung der Rutaceen im Verhältniss zu ihrer systematischen Gliederung. Abhandl. d. k. preuss. Akad. d. Wiss, 1896, and similarly the Zygophyllaceæ (ebenda, 1896). Bray, W. L. The geographical distribution of the Frankeniaceæ considered in connection with their systematic relationship. Engler's Bot. Jahrb., 24: 1898.

But what impresses one especially is the fact that for temperate and boreal Europe, Asia and North America, the plant life appears so generally to have been derived from a common source. The floristic stock, so to speak, is largely the same. The growth forms (as referred to earlier, p. 23) are largely the same and the vegetation aspects likewise. So frequently, one finds the same species in all three continents (see the notable case of the arctic indicator species of Mt. Marcy, all of which fall in this category, though there are others which have not been found in all three continents) or at least closely related species (as our paper birch which Fernald [1] calls a variety of the European white birch). This agreement among the species of the three continents was naturally emphasized first as to the higher plants — trees, flowering plants, angiosperms and gymnosperms, generally — as to certain pteridophytes also and these more as the group became more generally studied. More recently this identity or close similarity of species has also been noted for the lower groups and more and more as each group (for example of fungi) is closely revised by special students of them, the conviction comes that the relationship is very thorough-going indeed; that not merely species, but especially the composition and aspect of vegetation types (plant societies) points, as one may say, to a common developmental experience. Thus one notes the agreement as between swamp plant societies, bog societies, the vegetation of sand plains in Europe and America (where these cases have been especially studied) and a fundamental similarity as between the diverse members of the high forest or climax forest of the three continents in similar zones, from dominant trees down to forest floor herbs, mosses, liverworts, lichens and fungi. Close comparison studies of these matters would seem to be the next inviting field made possible especially by the rapid progress in monographing the various taxonomic groups.

The era of development to which we must look as offering an explanation of these fundamental agreements between

[1] Fernald, M. L. The relationships of some American and Old-World birches. Amer. Jour. Sci., 14:1902, pp. 167–194.

the three northern continents would seem to lie in the Tertiary period. Speaking broadly, then was a time when the factors which stimulate plant response appear to have reached a degree of intensity, or of effective working together, sufficient to call forth what seems from the remote time of the present a marvelous bursting forth of plant energy, especially in number of new species and diversity of growth forms. Among these factors must be reckoned favorable, diversified climate, the presence of new and favorable terrain and the combination of effective means of reproduction as represented in the, then, new type of plant — the angiosperm — and particularly the floral structures of this group. It is certain that in the Miocene, for example, the climate was mild as far north as present arctic regions and that a heavy forest including many of our familiar genera — even apparently the same species in many cases — extended into the far north. Indeed, with forests on Greenland, Grinnell Land and Northern Alaska and with correspondingly mild climate in Europe and Asia this forest could extend, and evidently did extend, on into Europe and Asia.[1] Then could take place the free intermingling or migration of species between these continents which the present status of vegetation presupposes. Perhaps this close floristic relation is shown even more vividly than the present status shows it by certain species "Miocene relicts" in America but represented from Europe-Asia only by fossil forms (the species having meantime become extinct there). Thus *Taxodium distichum*, at present in swamps of our southern states, was found fossil by Heer from Greenland to the McKenzie River and in Alaska and on the Island of Sachalin north of Japan.[2] Numerous other species including one of *Sequoia* (of which we have living *Sequoia gigantea* (big trees) and *S. sempervirens* (red-wood). In the genera of this category were also *Liriodendron*, *Magnolia*, *Liquidambar*, *Sassafras* and *Nyssa*. That is, all these now are represented by one or more species

[1] Chamberlin and Salisbury, *loc. cit.*, III, page 281.

[2] Harshberger, *loc. cit.*, p. 174. Citations of papers by Heer, Engler, Gray and others will be found here and especially under the full bibliography, pp. 45–92.

Photo by W. L. Bray.

FIG. 5. Young, mainly sprout forest of rock-chestnut oak with ground cover of mountain laurel (*Kalmia latifolia*) on the slope of Bear Mountain in the Hudson Highlands. (*Palisades Interstate Park.*)

Photo by W. L. Bray.

FIG. 6. Drainage trench cut through the cat-tail mat in the Hackensack Meadows, N. J. Tough blocks of brownish peat and black muck bound together by the roots and root stocks of cat-tail, show the efficiency of this type of vegetation in firming the ground.

in the United States. The fossil forms are found in arctic lands of North America and Eur-Asia.

It is of importance to observe that the floras of the eastern and western continents of the northern hemisphere have been growing less similar as one would predict as a result of isolation. This isolation grows out of the forced migration southward by polar cooling, and was of course exaggerated by the glacial period. Indeed, one reason ascribed for the disappearance from Europe of certain species, some of which were near or identical with American species, is the fact that in the southerly migration the Mediterrean Sea offered a barrier which species could not cross and so escape extermination by the glacial ice.

As to the Sources of New York Flora in General.

The impression will have been gained that when the glaciated terrain of New York and of the northeastern part of the continent generally was open to the return of vegetation the source of vegetation forming flora was the Appalachian region lying to the south of the terminal moraine (the southern margin of the ice sheet). It should also be understood, however, that species migration is taking place constantly and toward whatever terrain is open to them, environmentally speaking. Thus we have seen evidence that some species have come in from other continents in post glacial times and, admitting the category of migrations or dispersal by human agency, a very extensive addition has been made to our flora (e. g. 613 species in the vicinity of New York [1]). So more locally have there been migrations into the State from adjacent territory. Thus certain species of the middle western prairie flora appear to reach the Erie-Ontario basin regions. In this connection it is suggestive to recall that according to Hornaday [2] the American bison is known to have entered New York along the valleys leading up from the southwest. Local historians believe also that the buffalo existed in Erie county.

[1] Taylor, Norman, Flora of the Vicinity of New York, p. 651.

[2] Hornaday, W. T. Extermination of the Buffalo, Smithsonian Report 1887.

DEVELOPMENT OF VEGETATION AS INFLUENCED BY THE SUBSTRATUM AND THE RESULTING INFLUENCE UPON THE SUBSTRATUM.[1]

If the preceding account of the climatic relations of our vegetation resulted in giving a view of the movements and adjustments of vegetation in the large, it will seem discouragingly inadequate to account for the aspects of vegetation of any particular locality. No doubt in view of your common observations you will think of the zonal segregration of our flora as a sort of theoretical construction. I can imagine the demonstrator pointing out the general dominance of sweet gum, oaks, hickories, tulip-tree and chestnut (if it had not been exterminated by chestnut blight) in the Bronx, and suddenly coming upon a hemlock grove, or a stony place with sweet fern and bayberry or a shallow pond of *Peltandra.* Also within excursion distance, cat-tail marsh, or a bog with *Sphagnum, Chamaedaphne* and southern white cedar (*Chamaecyparis*) or a hillside with mountain laurel. You get the conviction that vegetation is all jumbled together more or less haphazard. I am frank to say that, all along, as we tried to follow a consistent climatic segregation of species, we met, as in fact we do meet in the field at large, many instances where local conditions of soil or water table operate to nullify the effect of climatic factors. You can't account for the status of our vegetation on either climatic or edaphic (the substratum in general) grounds alone. Nor will observations merely of the operation of these factors suffice. On the basis of general knowledge and observation it may suffice to say that sweet gum and willow oak and persimmon and mistletoe do not

[1] The reader who may desire to go more fully into the literature of this subject of the development and structure of vegetation should consult the works of Clements, Cowles and their associate investigators and numerous others. See for example, Clements, F. E. The development and structure of vegetation. Rep. Bot. Surv. Nebraska, vii:1904; Cowles, H. C. The physiographic ecology of Chicago and vicinity. Bot. Gaz., 31:1901, and The Causes of Vegetative Cycles. Bot. Gaz., 51:1911.

migrate farther up State because the climate becomes too severe once you are out of range of modifying ocean influence. Nevertheless, some horticulturist may take these very species and grow them, say, at Rochester. Practical experience (experimentation really) is showing repeatedly how elastic the temperature boundaries are if only the species has the most favorable conditions for nutrition and growth so far as the soil is concerned. In this connection the northern extension of that large list of forest floor species to which attention was called on page 73 whose perennial parts lie buried over winter in the blanket-like cover of leaf mold under the leaf mulch of the last leaf fall, may be suggestive. Cultivation results appear to show that, in nature, species often are kept at a point notably below their possible efficiency in growth, fecundity and ground gaining ability, i. e. capacity to occupy a wider range, by a combination of factors which, whatever they may be, are not referable to climatic temperatures. Of course, under cultivation, selection begins to play a rôle in eliminating mediocrity.

In this discussion, however, the relation of vegetation to climatic and soil factors has been considered separately because it seemed that the main idea of showing the developmental history of vegetation could best be brought out in that way. So let us take it that we have followed the migration of a flora into a new region and the segregation of floristic elements into certain climatic relations of fixed character, and now we are ready to go into the more local matters of segregation of species and growth forms into associations or societies as determined chiefly by the nature of the substratum in and upon which they grow. Most important of all we wish to show the effects upon the substratum of this work of a vegetation cover and how thereby the different associations are brought into a developmental relation to one another so that the history reads as a sequence of development leading up to a highly organized, permanent or equilibrium stage of vegetation — the climax forest.

Let us review once more the situation that confronted as indeed it still confronts vegetation. You recall that as to New York we are dealing with a glaciated terrain. This glaciation effect is expressed in areas of bare, polished rock on the one hand and basins occupied by lakes on the other; in deposits of coarse boulders — particularly glacial moraines — in some quarters and in delta sand plains in others; in former valleys and streamways blocked by glacial filling; in accumulation of glacial till laid down upon hills and valleys; in sand beds of weathered rock covering the granite base over much of the Adirondacks; in mounds and ridges of till — the drumlins, kames, etc.; in well drained deposits of fairly constant moisture content, or too well drained and therefore periodically deficient in moisture (sand, and gravel beds) or in lowlands habitually flooded or with the water table at or near the surface.

Of course factors of weathering, erosion and deposition are at work on this terrain tending in the long run to level down and even up but, meanwhile, vegetation is at work, and we not only can see at present how it works and what results it produces but by reviewing the brief period of human history we can gain an idea as to how far vegetation had gone in its general development over the State and the total results accomplished in modifying the character of its surface. Thus we recall that New York was found to be a great forest region; that a vast blanket of humus material had been spread over the land, hilltop as well as valley; that upon bare rock, great boulders (See Fig. 22) as well as broad rock surfaces, a matrix of organically rich soil had been built up so that forest trees grew upon it; that kettle holes had been filled with vegetation remains — peat — until, rising above water level, a swamp forest occupied the place of a former lake or pond; that lake basins and blocked streamways have been similarly filled so that forest trees now stand upon peat beds thirty feet or more in depth. It is asserted [1] that even the climax

[1] Harshberger, *loc. cit.*, p. 41.

or high forest stage has been reached in such situations as also it had on areas covered by great boulders or on areas of formerly bare rock. Now forest trees do not grow on bare rock or great boulders, nor do they spring up from the bottom of a lake (quite manifestly!) so that the conclusion is drawn that the effect of vegetation, augmented more or less effectively by weathering, transport of sediment by wind and water and its deposition, is to build up the substratum, beginning at either extreme, *i. e.,* bare rock or lake bottom, to one common condition, a condition of soil structure and energy, of drainage and aeration, of sanitation and vigorously active soil organisms which supports a relatively permanent or climax stage of vegetation. As a corallary to this, one would say that the vegetation history from either extreme to this climax point had been one of vegetation successions. For example, in the lake-bottom case, the successive vegetation stages might include (1) floating plants (microscopic forms, larger algae, duckweeds, etc.); (2) wholly submerged vegetation (pond weeds etc.); (3) floating-leaved plants (water lilies etc.); (4) marsh plants (sedges, bulrushes, cat-tail etc.); (5) marsh meadow (grasses and sedges, many annuals etc.); (6) marsh shrub or swamp shrub (willows, alders etc.); (7) swamp forest (red maple, black ash, elm, etc.); and finally (8) climax forest (maple, beech, birch, hemlock and white pine).

It seems that the sequence of development hinges on the evolution of the substratum as one may say. In the building up of this, whether from lake bottom or from bare rock, its character, viewed as plant habitat, changes constantly *i. e.*, successively, so that each stage of vegetation — each plant association — as it contributes to this up-building and consequent modification destroys, if one may be permitted this manner of expression, its own chance of permanency and its place is invaded by plants of a different soil requirement; and so the succession goes on until the soil condition becomes stable. What these modifications of the soil are that entail a succession of differently constituted plant associations I could not undertake to point out, but, certainly, one factor or condition furnishes a pretty good criterion for measuring the general trend and the successive stages of vegetation. This factor is the quantity and condition of the water of (and in water habitats over) the substratum. On this basis, which is of course a standard and well known basis of classification of vegetation in ecological botany, [1] the glaciated terrain would present various degrees of the moisture supply as it would affect plant growth, from habitually dry or arid habitats (bare rock, loose sand, fallen logs) to water-covered or water-soaked soils (excess of water) on the other extreme. Between these, soils of such structure and drainage conditions as to facilitate the holding of moisture in film form about soil particles as in well-tilled field soils. In spite of the diverse conditions of the substratum and the forbidding aspect of some of it, it would seem as if there were no feature of it from which plants, at least of some sort, were wholly excluded. Dryness, submergence, heat and cold, even wind and water erosion are not absolute barriers in this State. For green plants the one absolute limiting factor would be light and this would apply practically only in limiting the depth to which green plants would invade lake bottoms. We are especially concerned with the development of vegetation from the two extreme conditions of the moisture relation: Namely (1) Upon a substratum under water or with excess of water. (2) Upon a substratum normally deficient in moisture.

The Developmental Sequence of Vegetation upon a Substratum Having Excess of Water.

1. *Floating Vegetation of the Open Water.*

The history begins here with aspects of plant life which are not at all associated with the lake bottom or else merely lie upon it. They are not large plants anchored to the soil by roots. They embrace —

(1) Plankton.— The free-floating, microscopic life of lakes and ponds is to be considered in this connection as

[1] See under "Ecology" in elementary textbooks on botany. Also Warming, (English translation) Ecological Plant Geography.

Photo by W. L. Bray.

Fig. 7. Reproduction of mountain paper birch (*Betula cordifolia* Regel) red spruce and balsam on a burn on Dibble mountain in the Catskills at 3,600 feet elevation.

Photo by W. L. Bray.

Fig. 8. A pure stand of *Eguisetum fluviatile* occupying shallow water adjacent to cat-tail marsh, marsh-meadow and swamp forest at Tully Lake.

having a significance comparable to that of wind-carried dust particles so far as total volume and lake filling effects are concerned. The volume of organic debris (peat) which is formed by the dead bodies of such organisms will be appreciated by anyone who has observed the co-called "blossoming" or "fermenting" of a lake such as Tully and Oneida. At certain periods, especially midsummer in this particular case, the water becomes clouded, light penetration is materially hindered and a thick scum lies on the water in quiet bays or is cast upon the shore gravel, etc. Of course these organisms are by no means all plants. In Tully lake zoöplankton constitutes at times the bulk of floating or suspended organisms. Usually however colonies of a blue green alga (*Merismopedia*) are the most abundant and continue to cloud the water the longest. On one occasion in November I took samples of water to a depth of six inches over a five mile course on Oneida Lake and found spherical colonies of a blue-green alga, *Rivularia,* evenly distributed through the water to an undetermined depth in numbers averaging roughly estimated, six colonies per cubic centimeter of water (no doubt too low an estimate.) I judged that the conditions found over this five-mile course taken at random was prevalent throughout the entire area of this largest of New York lakes. If so, it meant a mass of organic material that should have a notable effect upon the biological and sanitary conditions of the water and upon the accumulation of organic ooze upon the bottom.

Davis[1] writing as to floating algæ as sources of peat says: "They sometimes occur in such numbers especially in northern and mountain lakes as to give a distinct green color to the water and by their death and partial decay to form very considerable deposits of soft structureless peat; they may also constitute an important part of peat formed in lakes and ponds where remains of larger and more com-

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[1] Bastin, E. S., and Davis, C. A. Peat Deposits of Maine. U. S. Geog. Surv. Bull., 376: p. 11.

plex seed plants are also abundant and mask the algal material by their coarser structures."

Mud lake north of Bangor is cited as a specific case. This lake was visited at a time when "its waters were teeming with some species of minute green floating plant organisms too small to be easily distinguished by the naked eye but readily made out with a hand lens and giving the water if seen in the proper light a distinct greenish tint" "In the bottom of this lake and below the turf about its borders was a considerable depth of yellowish, fine grained, structureless peat, which on examination proved to be made up of the remains of similar minute algæ." "In northern Michigan there are several lakes that are nearly filled by the remains of such minute plants. In these lakes are forming beds of soft, light-colored peat, which differs so much from ordinary peat as to be easily distinguished by its fineness of grain and peculiar soft, cheesy consistency."

Instructive data in this connection are found in the work of Birge and Juday [1] upon the plankton of the Finger Lakes of New York. Thus the average number of diatoms per cubic meter of water in the first fifty feet in depth of Cayuga Lake was on August 12, 1910, about six million. In Conesus Lake, on August 25, 1910, the blue-green algæ averaged about one-half million per cubic meter in the first thirty feet of water depth.

(2) *Normally Not Free-Floating Algal Vegetation.*

This purely arbitrary classification of vegetation elements aims to single out a relatively bulky amount of algal growth of fresh water lakes and ponds which, while not anchored to the lake bottom by root-like organs, normally lies upon the lake bottom or is attached or adheres to submerged objects — stems, and leaves of vascular water plants, trunks and branches of trees which have fallen in the water, etc. It may subsequently be broken loose by wave action or be buoyed to the surface by gas caught in the filamentous mass.

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[1] Birge, E. A., and Juday, C. A Limnological Study of The Finger Lakes of New York. Bull. U. S. Bur. Fisheries, vol. 32:1912. Doc. 791, 1914.

A few illustrations will suffice to define the status of this algal growth as related to lake filling.

(a) At a depth of twenty-two feet in Tully Lake I have found heavy masses of the alga popularly called water silk (a species of *Spirogyra*, probably *S. crassa*). This rested lightly upon the ooze of the lake bottom.

(b) At other points in this same lake, the bottom down to at least as great a depth as in (a) is covered by a slimy felt of blue-green alga (*Spirulina*) patches of which become detached by the buoyancy of gas and appear at the surface as the familiar (locally at least) floating "volcanoes" seen in late summer.

(c) In shallow bays protected from strong wave action, filamentous green algae, notably a species of *Mougeotia*, develop so rapidly as to form a dense tangle among the anchored vascular plants. The shallow water becomes literally blocked by this growth. During windy weather masses become detached and carried into deeper water as peculiar cloud-like objects of curiosity or are piled up along the shore.

(d) Gelatinous bead-like colonies of blue-green algæ (*Rivularia*) develop in great masses on the bottom of Oneida Lake, and in late summer are washed upon the beach in quantities sufficient to resemble deposits of smooth pebbles. Algae of this sort and other of the blue-greens develop habitually a thick beady or slimy coating on all submerged objects — notably old or dead stems of lake rush and *Equisetum* — which adds materially to the volume of debris finally laid down upon the lake bottom.

(e) Especially noteworthy are the blue-green algæ which in some New York lakes — notably the so-called green lakes of the Jamesville and Kirkville districts — are associated with the deposition of lime upon submerged branches of trees, etc. and apparently also upon lake margins. These masses of lime become remarkably thick — like a fall of soft wet snow upon twigs — and if the shore ledges are thus built up as seems likely, then the rôle of these organisms in

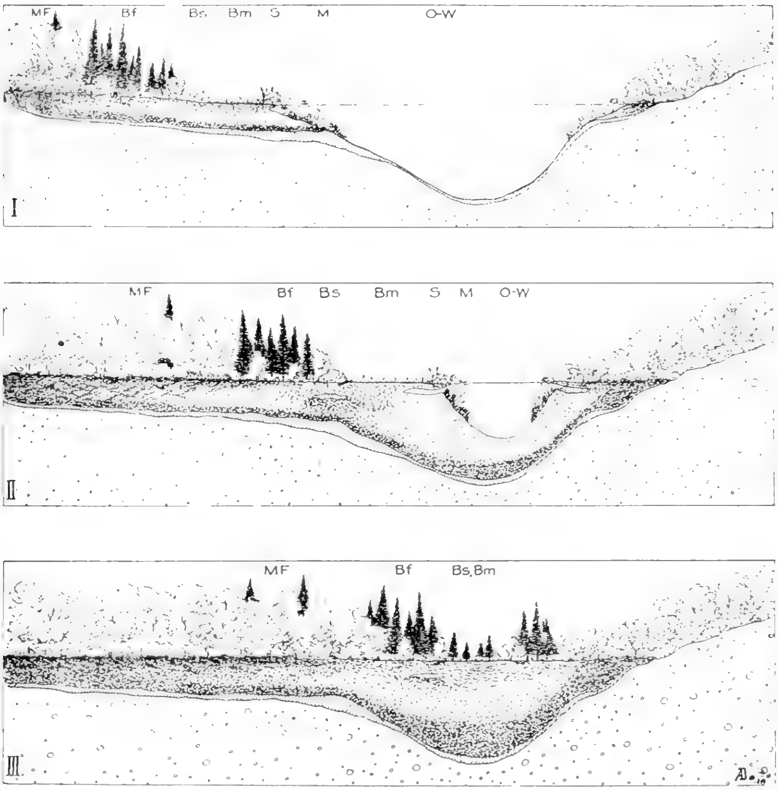

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Fig. 9. Diagram illustrating stages in the origin of peat and marl deposits in lakes. The several plant associations of the Bog series, displacing one another, belong to the following major groups:— (1) O. W.— open water succession; (2) M.— marginal succession; (3) S.— shore succession; (4) B.— bog succession, comprising the bog meadow (B. m), bog shrub (B. s) and bog forest (B. f.); and (5) M. F.— mesophytic forest succession.

rock formation is most significant. Walcott[1] and others ascribe to such organisms the rôle of forming massive limestone deposits.

(3) *Floating Plants of Groups Higher than Algae.*

In our latitude this group comprises especially the duckweed family among angiosperms, *Salviniaceae* of the pteridophytes and certain *Ricciaceae* of the *Hepaticae* or liverwort group. Duckweed should be especially familiar because of its abundance in small ponds or quiet shore waters where it forms a close cover over the water and materially affects the penetration of light below the water surface. The more bulky vegetation such as is formed by the water hyacinth in southern streams will be recalled in this connection.

2. *Submerged Aquatics.*

The developmental sequence of static vegetation, i. e. plants anchored to the substratum by roots (rhizoids in the case of stoneworts), really begins with this stage in which the whole plant is under water of varying depth and with roots (or rhizoids) and often root stocks imbedded in the accumulating, loose, oozy, organic soil of the lake or stream or tide flat bottom. Its dynamic significance lies partly of course in the bulkiness of the vegetation, familiar as heavy banks of pondweed (Potamogetons) or of beds of "ditch grass" (*Elodea canadensis*) of shallow lake waters, but especially in binding the loose bottom sediment into a firmer matrix. The occupation of lake bottom soil is facilitated by the perennial habits of the imbedded parts and the

[1] Walcott, C. D. Pre-Cambrian Algonkian Algal Flora. Smithsonian Miscel. Coll., 64:No. 2, 1914. In this paper, p. 87, notes taken by Dr. C. A. Davis on the calcareous deposits in Green and Round Lakes near Kirkville, Onondaga county are quoted. From these, the following: "In Green Lake, considerable spaces along the shore have deposits of tufa which extend out into the lake from the shore for as much as twenty feet or more in places, forming perpendicular or overhanging sub-aquatic cliffs or terraces." Again, "In two places, logs of white cedar (*Thuja*) were noted which were completed imbedded in the solid faces of the cliff and projecting from them."

See also Dr. John M. Clarke's paper on "Water Biscuit" (notably from Canandaigua Lake). Bull. N. Y. State Mus., No. 39, vol. 8, 1900.

great activity in vegetative propagation which is associated with the capacity of such vegetation to form the heavy banks or beds above referred to. Thus a large proportion of the shallow bottom of Oneida lake — for example the whole area of Big Bay — is occupied by Potamogetons. The most noteworthy case which has come under my observation is that of the invasion of Tully lake and the adjacent Crooked Lake bottoms by *Elodea*. Beginning with an insignificant occurrence, within a period of some six years this plant has come to occupy most of the lake bottom (except in certain shallows) to the depth of twelve and even fifteen feet. The luxuriant growth and branching build up beds eight to ten feet thick which where they reach the surface of the water materially impede the movement of rowboats. In this case Potamogetons are largely excluded from situations formerly occupied by them exclusively.

The amount of lake bottom covered by this type of vegetation is affected by several factors — the physical character of the bottom to begin with — but in general by the depth and transparency of the water. In the case of Big Bay in Oneida Lake a uniformly shallow bottom is wholly occupied by it. In Tully Lakes where there is a series of shallows and deep basins, Potamogetons, formerly the dominant growth, occur in banks occupying the sloping margins of the basins from a few feet to twelve or more feet in depth. In these lakes there are also lake bottom flats similarly covered but now yielding to *Elodea*. In Conesus lake — e. g., off Old Orchard point — where the bottom falls away to considerable depth, Potamogetons and other aquatics form a zone from the depth of eight or ten feet to a maximum of sixteen or eighteen feet. The so-called " island," a submerged flat under twelve or more feet of water is occupied by Potamogetons. This represents perhaps the general status in waters of average clearness. In the Adirondacks however, especially in the smaller and shallower lakes, the dark color of the water due to humus leachings from the adjacent forest soils appears to operate in excluding light — possibly chemically also ?— and thus in limiting this type of vegetation.

I have not extensive data on this point but in general I should say that in the Adirondacks submerged vegetation is generally sparse and especially limited to slight depths. In the larger lakes of this region the rocky shores and especially violent wave action operate to exclude almost wholly, anchored water vegetation.

As to building up the substratum, the yearly addition of the season's growth — for in my observation the heavy banks of pond weed die down to the imbedded parts or approximately so — results in a material addition to the organic sediment of the bottom although it should be noted that plants of this sort of habitat have only a minimum of firm tissues. The dead material is readily disintegrated and more or less thoroughly decomposed, resulting not in coarser or fibrous peat as that is popularly understood but in an oozy mass which gradually becomes compacted into the fine, black mud characteristic of those lake bottoms where the water is kept fresh and clear and well aerated.

Submerged Aquatics and Marl Formation.

Attention was called, p. 96, to the rôle of certain blue green algae in the deposition of calcium carbonate formations. The formation of the numerous and rather extensive marl beds in lake bottoms and in swamp soils built up under water — Cicero Swamp, Montezuma Marsh, Tully Lakes, etc. — is ascribed now largely to water vegetation, in part to the blue-green algae as stated and particularly to *Chara* and in lesser degree to Potamogetons, etc. Discussion as to this matter will be found in Warming's Ecolgy [1] pages 64 and 65 and by Davis.[2]

That material deposits of carbonate of lime are annually made by *Chara* and even Potamogetons is clearly shown in the case of Tully Lake. In one instance notably, heavy beds of Potamogeton were found in September to be so deeply lime incrusted as to be very brittle and fragile and the whole

[1] Warming (English translation), Ecological Plant Geography.

[2] Davis, Chas. A. A contribution to the Natural History of Marl. Jour. Geo., 8:1900, pp. 485–497.

bed was settling to the bottom as if prematurely weighted down by the lime.

But one or more species of *Chara* (stonewort) show particularly well the rôle of rapid additions to the marl substratum. The *Chara* beds in question are in from one to four feet of water. The plants form a close mat looking not unlike a well kept turf. Lime accumulates upon them in such quantity that by midsummer the beds become gray and the whole mat being now brittle and heavily weighted breaks down as did the Potamogetons above mentioned.

3. *Aquatic Vegetation With Floating or Exposed Leaves or Emerged Stems.*

Certain species of submerged plants of group 2 grow habitually in shallow water and, among these, some which as the water level falls or the plant elongates have exposed leaves. Thus in *Potamogeton natans* when floating leaves are developed (and in water only a foot or two in depth the leaves are nearly all floating) they are different in shape and structure from the submerged ones; indeed their greater spread must retard the further development of submerged leaves by shading. The fullest expression of this idea of the floating leaf and with it the harmony between plant form and shallow water habitat is found in the water lily type. Recall in this connection the maximum expression of this in the remarkable *Victoria regia* of the Amazon. It is not the aim here to try to show how this representative type of shallow water vegetation is qualified to replace the submerged types, although the inference as to the broad floating leaves and shutting off of light from the water beneath insinuates itself, but certainly in shallow water whether on mineral bottom or sedimentary deposits or on a substratum built up by aquatic vegetation and mineral debris, a "water lily zone" is expected in our lakes and ponds except of course where the force of wind and waves would prevent. We regard it here as the natural successor to the submerged zone. Other growth forms appear in this shallow water zone also. Arrow arum (*Peltandra virginica* L.) is one. Its large leaves are supported quite above the water surface and apparently to be correlated with the greater weight and stress incident to the lack of buoyant effect and protection of water and to the exposure to atmospheric stresses, is the clump or tussock forming tendency of such a type. These qualities are particularly applicable however to the succeeding type of marsh vegetation. So with certain other growth forms, notably lake rush (*Scirpus validus* Vahl.), pipes (*Equisetum fluviatile* L.), etc., and even cat-tail (*Typha* species) which commonly or frequently appear in shallow waters even to the depth of two or three (in case of lake rush up to five) feet.

In the smaller Adirondack lakes, shallow water vegetation is fairly abundant, but in this case again, the suspended matter and especially the humus leachings operate to reduce the intensity of light by giving the dark color to the water, hence the type is limited to yet more shallow water than in the clear lakes — e. g. Long Lake, Big Shallow and Little Shallow Ponds, Hoel Pond, etc. My impression is that such vegetation is also sparser even in the most favorable substratum conditions and that in the case of water lilies the habit reflects the deficiency of light beneath the water surface. These matters, however, need more extended study in that region.

In general, the total acreage of this shallow water vegetation is small and limited to relatively small areas. In ponds and lakes with steep, sloping margins the zone is necessarily narrow and very often eliminated from much of the lake margin by violent wave action, sandy bottom, etc. Often it occurs upon a submerged delta of sediment brought in by tributary streams and the two agencies of filling — stream sediment and vegetation remains — hasten the stage on to the marsh condition. Sometimes whole ponds, being uniformly shallow, are in the "water lily" stage of vegetation as in Big Shallow and Little Shallow Ponds in Herkimer county. Or an entire arm or bay of the lake will be occupied by shallow water plants as in Long Lake, Tully Lake and so on. Marsh vegetation by reason of the mat and tussock forming aptitudes of some of its growth forms and their tolerance of partial submergence (lake rush sometimes stands in a five-foot depth of water) rapidly encroaches on the shallow water associations. One may often find water lilies, Potamogetons and the like persisting in small open-water patches in a marsh.

4. *Marsh Vegetation.*

A new vegetation type appears when the substratum lies at approximately mean water level so that with seasonal fluctuations it may lie exposed at low water and submerged at high water stages. This is the case especially when the substratum has been built up under water either by vegetation chiefly or by stream sediment and vegetation. Where the normal land contour lies so that the soil is habitually water soaked and periodically submerged, swamp forest has developed in our area, but even here there is reason to think that marsh and marsh-meadow stages preceded it (See below under swamp forest).

In this marsh type the new condition of environment lies essentially in the absence of the protective and buoyant effect of water to sustain weak, soft-tissued spindling shoots or leafstalks of floating leaves. The plant is anchored in the substratum by freely branching roots and generally by an extensive development of rhizomes (root stocks) but the vertically growing parts (long leaves of cat-tail and the tall leaf and flower bearing stem of this; the wand-like stems of lake rush, the expansive leaves of royal and cinnamon fern) rise clear of any water protection or support. This means that such a plant must meet the stress of weather, winds, rain storms, etc., or in high water stages, of violent current or wave action (notably in Montezuma Marshes) and therefore a corresponding degree of firmness is required in stem and leaf which is pretty generally supplemented by a type of growth form such as those of cat-tail, lake rush, and sedges and grasses generally, capable of distributing the stress among a multitude of flexible leaves or wand-like stems. A certain firmness of substratum is required in this case. If

Photo by W. L. Bray.

FIG. 10. Cat-tail marsh stage of vegetation occupying and hastening the filling of a tract of lowland — probably a former bay — on the south shore of Lake Ontario at Charlotte. The sand barrier which cuts it off from the lake is occupied by summer cottages. The foreground shows marsh-meadow.

Photo by W. L. Bray.

FIG. 11. Nearer view of marsh shown in fig. 10. The cottages and shade trees stand on the sand barrier which cuts off the marsh from Lake Ontario.

a stiff clay, or clay and gravel forms this substratum as may happen where the normal contour permitted a high groundwater level, then such firmness is assured, but if — and this is particularly the case we are supposing — the substratum is a built-up bed of soft muck then it is soft and miry, even loose ooze, under shallow water. In this case it is especially necessary for the plant to construct a firm base. Or to put the matter differently, the plant society is limited to growth forms which, in the first place, can tolerate a submerged or water-soaked soil of organic stuff, and in the second place, possess a habit of growth calculated to construct a firm mat or tussock. If you happen to have tried to cut a block of cat-tail mat from the marsh or to cut through a sedge tussock or pull up or dig out a tussock of royal fern, you have gained a fine appreciation of the effectiveness with which marsh plants firm the soil. You have found a firm, tough, fibrous mass made up of innumerable root fibres, rhizomes, and the bases of living and dead shoots. See Fig. 6.

Cat-tail Marshes.

In New York extensive cat-tail marshes are very obviously associated with the early stages of land emergence and upon close examination of the substratum they are just as obviously the agency in consummating this. Striking illustrations of this are furnished by the marshes of the Long Island coast and of the lower Hudson where low flats have been built up above or barred against tidal flooding. The Hackensack Meadows on the New Jersey side are perhaps the most widely known instance. Again, the shores of Lake Ontario — see topographic sheets of Pulaski, Rochester and Ontario Beach quadrangles respectively — offer even clearer if more limited areas of this young land building under cat-tail mats. The cases are those where a small bay — in the case of Irondequoit Bay much larger and less advanced in filling — has been cut off from the lake by a beach-sand barrier leaving a narrow opening for the discharge of flood waters of the stream whose valley, opening upon the lake, determined the extent of the bay so cut off by the barrier.

See Fig. 10. I have not determined by borings the depth of filling by cat-tail vegetation, but the muck in certain places traversed was several feet thick and, in cases, the filling had passed beyond the reed marsh to the meadow marsh and even the swamp shrub stage. See Fig 11.

Montezuma Marsh is of course the great show feature of New York in this connection. Here the young emerging land consists of peat and muck and marl beds built up by hydrophytic vegetation, latterly largely by cat-tail, upon a deep, glacial fill of sand and gravel laid down across the north end of the Cayuga Lake basin. Barge canal excavations and borings showed in a record of nine miles of marsh, four or five feet of muck, thin strips of marl, blue clay, then sand down to one hundred or even two hundred feet.

The efficiency of cat-tail as a growth form for this sort of environment is particularly obvious in these marshes. Its rapid and extended development of rhizomes gives it the capacity to cover ground rapidly and to the exclusion of other forms — in its earlier development — and meantime, to weave as one may say, a firm mat which resists wave action which here is right severe in high water stages because of the high winds which have clear sweep across the marsh. Fig. 12 shows a view of a bit of the marsh taken during an early and unusually dry spring at a low-water stage. The curious ridge and furrow effect appears to be correlated with wave action. Note here that royal fern is associated with cat-tail in forming these ridges — literally rows of small tussocks. Now the bulk of vegetation in such a case is right large, and of course all the aerial parts, together with wind-swept or flood-carried or other debris caught in the mass, become each winter beaten down to form a new, if finally thin, addition to the slowly rising bed of organic remains topped by and knit into some firmness by the perennial root stalks and roots of the living plants. Also, of course, as the whole mass rises, this living mat dies away below and thus adds to the total depth of peaty stuff. You will observe also that in this type of vegetation, in contrast with the delicate "collapsible" structures of aquatics, the plant has a firmer skeleton and this adds more solid fibre to the peat or muck beds. This makes the surface firmer, though in marshes the whole mass is pretty thoroughly decomposed.

At a later page in the bulletin (p. 119) the question is discussed as to what becomes of the dead vegetation and especially what effect it has upon the course of living vegetation. This question applies sharply to the case before us. We shall see later that under certain conditions the course of vegetation is turned at this stage of the substratum level toward bog formation, bog meadow, bog heath and bog forest. In this particular case — certainly in Montezuma swamp — there is no tendency toward bog formation, but to pass through marsh meadow to swamp-shrub or swamp-forest. Frankly, I cannot explain why this is so but I believe the open, exposed situation which permits free sweep of winds and hence shaking up of water and consequent aeration, together with the accumulation of flood and wind-swept mineral stuff, operate on the one hand to permit the activity of the bacteria which decompose the accumulations of dead vegetation and on the other make available certain mineral nutrients — likely to be deficient in the less decomposed peat beds — for the meadow marsh and subsequent shrub and forest plants.

The case of tide-water marsh meadows is not discussed here, partly because I have less first-hand knowledge of them, partly because the vegetation problem is largely identical with that above considered. The case is by no means unimportant since Parsons [1] estimated the total marsh area of the lower Hudson region and the Long Island coast at near 50,000 acres.

5. *The Marsh Meadow Stage of Vegetation.*

In following the successions of vegetation on a substratum built up from beneath the water level, and composed chiefly of the more or less completely decomposed remains of dead

[1] Parsons, A. L., Peat: Its Formation, Uses and Occurrence in New York. 23rd Ann. Rep. State Geologist in 57th Ann. Rep. N. Y. State Mus., 1903: pp. 15–88.

plants, we approach a stage — as can be observed in the Montezuma marshes for example — where the building up has gone so far that the soil lies habitually exposed above the water table, is firmer and by reason of exposure and aeration the organic stuff is more thoroughly decomposed. Such ground becomes, then, virtually a new terrain inviting an invasion of plants of different requirements as to the soil status — especially as respects the moisture relation — than the species of the marsh vegetation (cat-tails, etc.). Certain grasses and sedges constitute the dominant element in this invading vegetation and with them comes to be associated a group of species large enough and of such diversity of form as to give this society a complex make-up not approached in the simple associations preceding.

The occurrence of marsh meadows in New York is common enough, but because of the forage value of the grasses, these meadows have been subject to the factor of human interference in such degree that it becomes a little difficult to make them fit into the scheme of succession. For example, after the removal of swamp forest, a marsh meadow may become established. In a way, this is simply enlarging the pasturage area of the farm. In the Mohawk Valley many pastures are virtually marsh meadows, some of them covered with sedge tussocks, showing the nearness to marsh conditions. Striking examples of marsh meadow on a large scale are shown in the St. Lawrence valley where streams from the Adirondacks emerge upon the gently sloping plain — e. g., Norwood to Ogdensburg. The " Beaver Meadows " of the Adirondacks and the " Vlaies " are really marsh-meadows, although the tendency toward *Sphagnum* (moss) and heath shrub development in these, rather relates them to the category of bog societies. It is instructive to note in this connection that the practice of cutting the grass for hay on these meadows serves to emphasize and prolong the grass-land status. Thus in the report of the State Forestry Com-

Photo by W. L. Bray.

Fig. 12. View of the cat-tail vegetation mat in Montezuma marsh in early spring and during an abnormally low-water stage. The ridged effect is probably due to violent wave action during high winds which have clean sweep across the marshes.

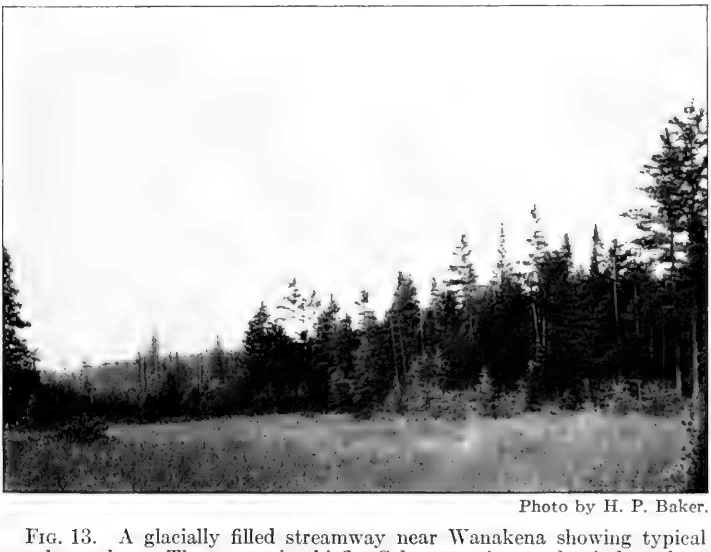

Photo by H. P. Baker.

Fig. 13. A glacially filled streamway near Wanakena showing typical marsh-meadow. The grass is chiefly *Calamagrostis canadensis* but there are also sedges, etc., and a good deal of *Sphagnum*. The conifers are balsam and black spruce.

mission of 1885 it is stated that after cutting beaver meadows or vlaies for three years they become so matted down as to be improved by burning. This means of course a change in the substratum to a firmer meadow floor rather than a tussocky marsh. In their content of "gay wild flowers" mixed with grasses and sedges is indicated their identity with grasslands generally.

Smythe[1] has called attention to these meadows as a natural stage in the building up of the substratum (lake filling). Reference has been made on previous pages to the effect of glacial filling in the Adirondacks where just this frequence of lakes and of sluggish streams invites the occurrence of large areas of hydrophytic vegetation, notably of marsh or marsh meadow, marsh shrub and swamp-forest.

Of course the "beaver meadows" are assumed as the name suggests, to have been formed by beaver dams. So far as this may have been the case, however, the dam must have first entailed the destruction of some forest cover (popple, etc.) so that the meadow is in such cases a reversal of natural succession. In reality it is not likely that any great proportion of such meadows is to be ascribed to the activity of the beaver.

6. *Swamp Shrub Vegetation.*

This type of vegetation will be familiar to you when you recall the large patches of alder thicket and the still more extensive willow flats observed in traversing the State, notably the Mohawk valley above Little Falls, the lake and marsh region west of Syracuse, the Ontario Basin from Syracuse to the St. Lawrence valley, the St. Lawrence val-

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[1] Smythe, C. H., Jr. Lake filling in the Adirondacks. Amer. Geol. XI, 1893. This cites especially Big Rock meadow west of Morehouseville in Hamilton county. Other lakes two to ten miles north and west of Big Rock Lake are spoken of as "entirely surrounded by meadows" and Big Vlaie as "covered by tall grass." This "tall grass" is, according to the present writer's observation, generally blue-joint (*Calamagrostis canadansis* [Michx.] Beauv.).

ley from Odgensburg to Rouse's Point and the railways running through the Adirondacks. Again you will have observed other aspects of the shrub vegetation. For example, the marsh meadow stage about Tully and similar lakes, the marshy divide above Apulia and similar situations will present small shrubs like shrubby cinquefoil (*Dasiphora* [*Potentilla*] *fruticosa* (L.) Rydberg), sweet gale (*Myrica gale* L.), swamp rose (*Rosa carolina* L.), red osier dogwood (*Cornus stolonifera* Michx.) and encroaching willows and alder (usually *Alnus incana* [L.] Moench.). Still another aspect you may have seen, e. g., at Hoel Pond and similar situations in the Adirondacks, where mountain holly (*Nemopanthus mucronata* [L.] Trel.), withe-rod or wild raisin (*Viburnum cassinoides* L.), black choke-berry (*Aronia melanocarpa* [Michx.] Britton), and smaller heath shrubs. In Cicero Swamp, to these will be added high-bush blueberry (*Vaccinium corymbosum* L.). Tussocks of royal fern and cinnamon fern will, in such cases, show a persistence of the marsh vegetation. This would indicate the invasion of marsh directly by shrub, thus eliminating or materially shortening the marsh meadow stage and it should be mentioned here that the vigor with which swamp shrub and swamp forest establish themselves on wet lands has just this tendency to shorten the life of the grass land stage. Perhaps it is pertinent to remark that our climate is so thoroughly a forest climate as contrasted with grassland climate that this tendency to encroachment of woody plants is just what one should expect. Certainly the persistence of the grassland stage appears to be more marked in the middle west, e. g. in southwestern Wisconsin [1] than in New York. Still, although the sequence is so generally disturbed by human interference in New York State, so that marsh meadow and

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[1] Stout, A. B. A biological and statistical study of the vegetation of a typical wild hay meadow. Trans. Wisc. Acad. Sci. Arts and Letters. 17:pt. 1, 1912.

swamp forest develop apparently on marshland, and marsh meadow seems to follow forest naturally, there remain examples sufficiently clear to support the general rule that in normal sequence, grasses, sedges, annuals, etc., invade the marsh and transform it for a longer or shorter period into grassland. This is then invaded by small shrub (shrubby cinquefoil, sweet gale, etc.), large shrub (alder, willows) and swamp forest (red maple, elm, black ash, etc.). In the case of beaver meadows and (or) vlaies, the small shrub stages will generally embrace a number of heath shrubs (sheep laurel, pale laurel, leather leaf, etc.) and while willows and alders may appear, followed by swamp maple, black ash, etc., the trend is toward conifer forest. Thus tamarack, white cedar, balsam and black spruce invade the heath shrub. This condition, further emphasized in cases (as cited above) where mountain holly, black chokeberry, high-bush blueberry, etc., invade *Sphagnum*-containing marsh meadow (bog meadows, therefore?) points to a trend of vegetation which finds its extreme expression in *Sphagnum*-heath-black spruce bogs. See later under Bog Vegetation, page 125.

The case of one of the land locked bays on the shores of Lake Ontario, previously referred to in discussing cat-tail marshes, is instructive in this connection, first because it shows the undisturbed or natural sequence of vegetation and second because it bears upon the question as to whether the zonal segregation earlier discussed is observable in hydrophytic vegetation. The basin in question was largely in the cat-tail marsh stage. At several points this was becoming marsh meadow. At one place the shrub stage was reached and this consisted of buttonbush (*Cephalanthus occidentalis*) which so far as my observation goes is common only in those parts of the State classified in Zones A and B, i. e. in regions especially of climate moderated by lake or maritime influence.

7. *The Swamp Forest Stage.*

Swamp forest comprised a material percentage of the "forest wilderness" which was found occupying this State three hundred years ago. Some of this occupied built-up land which was, to begin with, lake bottom. Stream sediment carried into lakes may have been the chief agency in the building up. Peat or muck deposits of greater or less depth show that vegetation was the agency in many cases. But, of course, a vast amount of land as left by glacial activity lay so low that the ground water level was at or very near the surface — was swamp land in short. There was, of course, no question of a sequence involving aquatic or perhaps even marsh vegetation. On the other hand the forest did not develop as if it were a planted mixed stand. It came on the ground gradually. What stages of vegetation preceded it and how and when the forest developed is speculation of course. This speculation naturally carries us back to the post glacial migration period when the life zones "expanded", i. e., floristic elements followed the retreating glacier as their respective zones moved northward. You will note that the theory is presented — page 166 — that this migration involved several "waves", e. g., tundra vegetation, conifer forests, and finally, deciduous forests. But so far as forest on built up land is concerned at least, the sequence was of the sort we have been following; that is, woody vegetation invaded marsh meadow. Cicero Swamp — a large, filled basin or streamway lying south of Oneida Lake — furnishes a good illustration of the course of succession. In this swamp, which is really in part bog, built-up soil of clear peat and occasional marl beds has been put down to a maximum depth, as so far determined of thirty feet.[1] This great depth of peat has been formed in that part of the

[1] Hopkins, T. C. Geology of the Syracuse Quadrangle. Bull. N. Y. State Mus., 171:1914. On pp. 35 and 36, data obtained by Brainerd and Perry are given.

Photo by W. L. Bray.

FIG. 14. Swamp forest showing tussock-forming cinnamon fern. This site stands adjacent to the giant white pine in fig. 15.

Photo by H. P. Baker.

Fig. 15. Swamp forest at Tully Lake showing the degree to which the substratum is elevated by big trees — in this case a giant white pine. The hatchet blade rests on the water soaked muck. The white cloth above it marks the highest point of the substratum, nearly four feet above the muck. Ground hemlock (*Taxus canadensis*) is the chief ground cover on this elevation. Soil borings here show about one foot of muck and beneath this about twelve feet of marl lying on gravelly clay.

swamp where drainage has become much obstructed. Here the sequence — assuming it to have begun with open water vegetation stages — has been from *Sphagnum* containing grass and sedge marsh, to smaller heath shrub (sheep laurel, pale swamp laurel, leather leaf, creeping snow-berry), and later, to high shrub (high-bush blue berry, mountain holly, choke berry, etc.). The swamp forest stage has been dominated by white cedar, tamarack and black spruce apparently, although red maple is common also.

In the western part of this swamp where a free drainage channel has been maintained, one finds cat-tail marsh, marsh-meadow, willow and alder shrub vegetation and the normal broad leaved swamp species of forest trees. In this section, furthermore, the absence of conifers which dominate the more bog-like area, particularly black spruce and tamarack, is noteworthy.

The question of the presence of white pine and hemlock in the (presumably) later stages of normal swamp forest is not involved with that of the other conifers mentioned here. The fact that very big trees of pine and hemlock do occur in typical swamp forest seems to me noteworthy and to be deserving of special study. Perhaps the rapid differential building up of the substratum as discussed later furnishes the opportunity for invasion by these two conifers.

Now, taking swamp forests of New York generally (except perhaps in the Adirondacks) they do not appear to stand in this simple developmental sequence. Repeatedly you will find this reversed sequence of open lake (with aquatic and shore vegetation), swamp-forest, swamp-shrub, marsh-meadow and pasture or cultivated field. The fact here is, that when settlement and clearing and tilling the land began, development of vegetation had progressed so far that the swamp forest stage occupied nearly all the ground to the lake shore, or the middle of the valley or basin, and in the course of agricultural development, clearing the land began with the better drained areas and patches of swamp forest were left (though lumbered of course) on land too wet to be tilled. Cleared wet lands reverted to marsh-meadow and where willows and alders occur — as especially along the stream channel leading into such swamps — the reversion has again reached the shrub stage and very commonly also the stage of invasion by white cedar, soft maple, etc.

Effect of the Swamp Forest upon the Substratum.

The mere mechanics involved in the erection and support against storm-stress of massive tree trunks with their spread of crown entails a profound effect upon the ground in which they are anchored. As pointed out before, it means the penetration of the soil by the proportionally massive root system. But where the substratum is built upon of organic stuff chiefly and is habitually saturated, owing to the high water table, the root system does not penetrate deeply — develops, rather, superficially and with wide reach and strongly emphasized buttressing effect. This brings about a rapid and unequal elevation of the land. It is in a way the mechanical problem of marsh vegetation over again, only the tussocks and the "woven mat" are on a correspondingly bigger scale. For example, the elevation about a giant white pine as shown in Fig. 15 may be three or four feet above the general swamp level. So in traversing a swamp forest, say, in a wet season, the built-up frame work will be found to lie well above water level and the intervening spaces below it. Later, as the water lowers, these latter will be exposed muck, but subject to invasion by mosses, liverworts, marsh annuals, etc. This rapid and uneven upbuilding of the swamp land is further accelerated by the accumulation of fallen trunks and particularly by the turning up of roots and soil when an old tree is blown over. The size and durability of the woody structure introduce a factor of slow disintegration and decomposition not present in soft herbaceous vegetation.

Thus, partly by the mechanical factors and effects just noted, partly by change of physical conditions as a result of forest crown — shading, intercepted air movements, moister, cooler air — and of aeration and drainage of the unequally built-up substratum, a radically different environment results. To put this significant matter in somewhat technical language, the development of a swamp forest results in or carries with it a rapid and marked differentiation of environment which becomes in effect a stimulus calling forth a more diversified or differentiated condition of the plant community. The tree trunks, the fallen logs, the elevated places about great trees, the depressions, differences of moisture and of illumination, of wind exposure, etc., are marks of the environment. The segregation into dominant and subdominant trees, shrubs, tussock forming ferns, swamp annuals, perennial herbs, vines, etc., including numerous forerunners of climax forests; ground, log, and tree-base covering of mosses, liverworts and lichens, and finally, a large element of forest fungi, particularly of wood inhabitating species, indicate fairly the diversity of growth forms and habitat relations of this diversified type of swamp forest society.

Types of Swamp Forest.

In general, the conifer versus hardwood dominance applies in swamp forest as under zonal relations we found it to apply to the State in general. In the coniferous forest region of the Adirondacks, mixed conifer (balsam, black spruce, white cedar and tamarack) or pure conifer (especially balsam) forests are the rule. In the lower Hudson region these species are largely or wholly wanting, the swamp forest being typically hardwood. In general, climatic factors appear to control this broader aspect of distribution, but it should be noted that it is just in swamps and particularly in bogs where the northern coniferous element presses farthest into the more austral zones A, B and C. The following types are suggested tentatively as being based on perhaps a too general and superficial survey in which secondary forest growth has been too largely represented.

(1) *Dominantly Coniferous Swamp Forest.*

a. Balsam Swamp Forest and Balsam Flat.

The stands of balsam forest on the built-up and glacial-fill soils of the Adirondacks are of course one of the striking features of that well-known region. Zon,[1] pages 4–6, describes these two aspects of essentially swamp forest, giving particularly accurate and full percentage data as to the ground cover which is a key to the floristic relations. His bulletin may profitably be consulted in this and other connections having to do with the floristic relations of the Adirondack region as well as with environmental conditions. Note especially the map showing balsam distribution, page 3.

b. Mixed Conifer Swamp Forest.

As Zon points out, balsam swamp and balsam flat forests contain a certain small percentage of other conifers, especially white cedar, tamarack and black spruce. Perhaps generally each of these species tends to occur in pure stand (e. g. pure white cedar along Marion River) but over any considerable area, either a pretty general mixture or a mosaic of pure stands of each may be presented. This is shown — especially as regards balsam, tamarack and white cedar — in the stretch of built-up land from the inlet of Lake Bona-

[1] Zon, Raphael, Balsam Fir. Bull. U. S. Dept. Agri., No. 55:1914.

Photo by H. P. Baker.

FIG. 16. Devil's Dye-tub at Tully Lake. This is supposed to be an arm of the lake isolated by vegetation filling and now become a typical bog but with remnants of fresh water vegetation — e. g., the cat-tail. Borings made with a Davis peat sampler in the marginal tamarack zone showed over ten feet of peat and beneath this, twelve feet of peat-stained marl. The instrument was not long enough to reach the bottom of the marl bed.

Photo by W. L. Bray.

FIG. 17. Details of a clump of invading heath shrub (leather leaf) seen in fig. 19. The Sphagnum matrix and remnants of the sedge mat are shown.

parte to Harrisville. In my observation black spruce is particularly associated with bog areas. See page 125.

(2) *Mixed Conifer and Hardwood Swamp Forest.*

This may be regarded as intermediate between the boreal conifer types of the Adirondacks and the austral, dominantly hardwood, swamp-forest. The geographical position suggests this conclusion. This general type is particularly developed on lowland of the St. Lawrence valley (from Rouse's Point to Norwood); on the eastward of the Ontario basin toward the Adirondacks up to more or less 1000 feet elevation (see transect page 57); in the Syracuse region and down the Mohawk valley; in drainage divide swamps of the north-south valleys of the Alleghany plateau (e. g. Tully Lakes region).

In this type, aside from the dominance of red maple, black ash, and elm the noteworthy feature in my judgment is the occurrence of white pine (of very large diameter and normal height in the few undisturbed areas) and of hemlock, especially as an element in the reproduction of secondary swamp forest. White cedar, tamarack and balsam may be present, the last however only sparsely and in the territory north and west of the main Adirondack region. Tamarack is strongly represented northward (St. Lawrence valley) but southward becomes more confined to the centers of bog development. White cedar deserves special mention. Its tendency to occur in pure stands is evident in the Syracuse region (Jamesville and Kirkville) increasing northward along the Ontario basin and in the St. Lawrence valley (e. g. Norwood to Ogdensburg) where thickets of young white cedar are a very noteworthy feature.

(3) *Dominantly Hardwood Swamp Forest.*

Two suggestions are put forward as showing how the decrease in swamp-forest conifers is correlated with more austral climatic conditions.

(a) On the level plain of the Ontario Basin in Niagara and Orleans counties, American elm and basswood are more prominent in swamp or at least in near-swamp forest than is red maple. White pine and hemlock are lacking or rarely seen. No white cedar, tamarack or balsam were noted.

(b) In the lower Hudson region elm, ash and red maple appear to be still dominant but conifers are replaced by swamp oak (*Quercus palustris*) and *Q. pogodaefolia* (Ell.) Ashe (*Q. digitata* Sudworth), and no doubt by other species which become common in swamps southward. The occurrence of southern white cedar "swamps" in New Jersey, Virginia, etc., is cited in connection with bog forest under the caption, *The Bog Sequence of Vegetation*, page 129.

The Bog Sequence of Vegetation.

In attempting to present a fairly clear statement as to the course of vegetation leading to swamp forest on built-up organic soils, certain facts have been omitted which throw light on the subject of bog formation. For example, in referring to Cicero swamp (page 113) while mention was made of *Sphagnum*, of certain shrubs (high-bush blueberry, red choke berry, mountain holly) and black spruce, no conclusion was drawn from this combination of species nor was it emphasized that the built-up soil (whose depth has been found in some spots to reach thirty feet) was brown, fibrous peat.[1] It could have been added that tree trunks have been found in this swamp, buried in the peat and in fairly well-preserved condition. This, of course, shows that the accumulation of fallen vegetation is less completely decomposed than the black, fine-grained muck of the marsh and swamp. It is in a more or less disintegrated condition but still evidently plant remains, the larger, firmer pieces — tree trunks — being preserved in natural dimensions. Such cases

[1] The terms muck and peat are used here as generally understood and as distinguished for example in soil circular 65, of the U. S. Dept. Agr. Bureau of Soils. No suggestion is offered for making this distinction on technical grounds.

are generally familiar. You will have read of the "keeping" qualities of bog water. Bodies of large animals are, from time to time, found buried in peat bogs. When the peat of these bogs is scattered on a field it becomes further decomposed, the nitrogen especially becomes available for living plants in the form of nitrates. When bog soils rise above the water table, the peat undergoes at least partial decomposition, the complete stage of which would be the formation of leaf mold. This stage is reached in a moist but well-drained high forest. It is not complete in swamp soils and marshes. Even in Montezuma marshes there appear to be basins or pockets where fibrous peat rather than the blacker, finer grained muck occurs. Decomposition is hindered in some places of the marsh more than in others. The extreme case of retarded decomposition exists where plant (and animal) remains lie indefinitely preserved — the softer parts being disintegrated (macerated) but not chemically broken down in the sense that the elements which entered into the building up of the plant are set free in combinations available for use again.

To have in mind the essentials of what is involved here, recall that the active agents in this reduction or decomposition of dead organisms (animals as well as plants) are certain kinds of bacteria. Whatever would retard or prevent the activity of these bacteria would retard or prevent the decomposition of dead organisms. Oxygen is necessary for these bacteria. A water-soaked soil, being poorly aerated, reduces the oxygen supply, checks the activity of such bacteria and retards decomposition or results in only partial decomposition — e. g. muck. This is the condition prevailing in swamps generally. Still less perfect aeration further impedes bacterial activity and consequently decomposition. This appears to be the condition which prevails where the tendency is toward bog development in small basins (kettle holes); in an arm of a lake cut off from free water movement (Devil's Dye-tub at Tully Lake); in the middle of a swamp; in glacially blocked valleys where basins

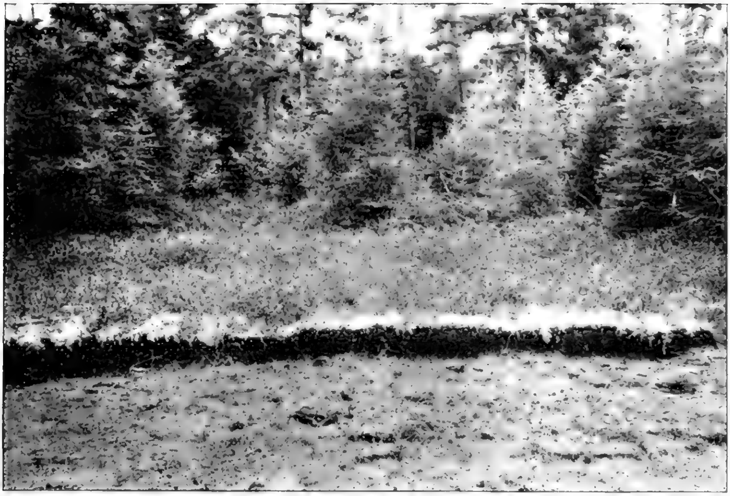

Photo by W. L. Bray.

Fig. 18. Section view of the Sphagnum heath mat in a bog near Saranac Inn Station. Black spruce border. Sphagnum has been removed for packing nursery stock. The heath-shrub is chiefly leather leaf with more or less Labrador tea, bog rosemary, lamb kill, etc.

Photo by W. L. Bray.

Fig. 19. A glacial " Kettle Hole " in the sand bed near Phoenix reclaimed by vegetation. The photograph shows dominant leather-leaf (occupying a sphagnum peat substratum) the large-shrub stage, and beyond, a close stand of invading black spruce.

with impeded drainage occur (Bog River between Long Lake West and Horseshoe and quite generally in the Adirondacks). Beginning with impeded drainage or lack of disturbance of open water by winds, with resulting check to bacterial activity and consequently to decomposition of accumulated vegetation debris, the bog status becomes cumulative apparently by the accumulation of toxic or actively harmful substances in the bog water — toxic at any rate to typical swamp plants — and the failure to release nitrogen and perhaps potassium and phosphorus in a form available for the nutrition of the growing vegetation. Certainly nitrogen in available form is deficient. The deficit of potassium and phosphorus in the bog, whether because these elements are not present in the organic substratum in sufficient quantities, or whether through imperfect decomposition are not made available, is not made up by the slow additions of mineral matter, as by wind-blown soils, for we are dealing with situations where the bringing in of sediment by stream flow is of small moment. Acidity[1] may play a rôle in intensifying bog conditions or, possibly, the "acid reaction" of the bog soil.

It is to be noted that other factors, for example, low temperature, may inhibit bacterial activity and hence favor the accumulation of undecomposed vegetation remains (peat). It has been suggested that this factor would play a rôle in bogs (they are spoken of as "cold bogs") and particularly in the Adirondack region. Certainly on Mount Marcy this seems to be the case as it is notably in the arctic regions generally where peat formation under tundra vegetation occurs. Recent investigations in bogs of regions corresponding to our Zone B[2] do not seem to bear out this suggestion but for the zones D, E and F in the Adirondacks the case may be different.

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[1] Coville, F. V. Experiments in Blueberry Culture, B.P.I. Bull. 193, p. 35.

[2] Dachnowski, Alfred, The vegetation of Cranberry Island (Ohio) and its relation to the substratum, temperature and evaporation. Bot. Gaz., 52:1911.

Having then a situation which tends toward the development of a substratum as above described, a fundamental difference in vegetation types both as to floristic content and as to growth form is entailed. The kettle hole, the arm of the lake, the shallow basin of an impeded stream-way, may to this point have had the sequence of vegetation as described for the hydrophytic successions. The floating vegetation, the submerged aquatics, the partly emerged, floating leaved aquatics may have been — indeed are shown to be — essentially as described above.

I am of the opinion that the later successions may go forward before the bog *closes in,* as one may say. The fact seems to be that while bog conditions eventually eliminate the fresh water (as contrasted with bog water) species, these hold their ground with varying degrees of tolerance becoming gradually a mere remnant of "foreign" flora in the now revolutionized habitat.

1. *The Case of Devil's Dye-Tub at Tully Lake.*

Thus in the above, locally well-known bog, a few plants of cat-tail (*Typha latifolia*), isolated specimens of arrow arum (*Peltandra virginica*) and the small shrub sweet gale, together with a bit of decadent (?) alder thicket still persist in the presence of an otherwise typical bog. The position and surroundings of this bog suggest a history which confirms the opinions here put forward. In the first place, Tully Lakes as a whole exhibit a normal and strikingly complete sequence of the hydrophytic successions, not perfect at any one point, but readily constructed from good illustrations of each stage. The bog in question lies in the center of a swamp forest which furnishes excellent data for statements made about that type of vegetation earlier. The swamp forest bears evidence fully reinforced by actual borings) [1] of having become established

[1] These "borings" were made with a Davis peat sampler along a line extending from the submerged zone of *Potamogeton* and *Elodea* in the above mentioned arm of Tully Lake to the Devil's Dye-tub. At the first test point — the *Potamageton* zone in ten feet of water — the sampler

on a filled arm or bay of Tully Lake proper. Devil's Dye-tub bog is taken to be the last vestige of this former bay, which as the land was built up above the shallower waters became isolated, undrained, unaerated, sour (?) toxic (?) deficient in certain plant nutrients — in short became, if not an extreme type, still a fairly typical bog. Note the attendant circumstances:

(1) A small circular pond some scores of feet in diameter of typically dark bog water without a vestige of larger aquatic vegetation.[1] This is so nearly filled that in dry midsummer the oozy, uncompacted organic substratum lies partly exposed to the air.

(2) A floating *Sphagnum*-sedge zone encroaching upon the open water.

(3) An invasion of heath shrub (leather leaf, bog rosemary and Labrador tea) into the sedge zone with thickening of the *Sphagnum* mat. The substratum still floating at high water stages but generally more firm.

(4) Next outside these a circular zone of tamarack.

(5) The occurrence of such characteristic bog species as snake-mouth (*Pogonia ophioglossoides* [L.] Ker.), pitcher

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showed clear marl at *twenty-two* feet but the solid bottom was not reached. In the water-lily zone near shore and in one foot of water the marl depth was twelve feet to hard bottom. In the swamp forest one hundred feet from the lake shore, one foot of black muck was underlaid by ten feet of marl. This marl deposit (in every respect like that in the lake bottom) shallowed out to less than two feet in depth on the dividing ridge between the lake-arm basin and the dye-tub basin, then on the dye-tub side increased rapidly to four, eight, ten feet in thickness, but as the test stations approached the center of the basin or bog proper, *a deposit of brown fibrous peat from one to ten or more feet in depth lay above the marl.* The final test station lay at the outer margin of the tamarack zone and perhaps one hundred fifty feet from the "dye tub." Here with ten feet of brown peat and thirteen feet of marl with peat fragments, the sampler failed to reach solid bottom. Indeed, it would still sink slowly by its own weight. I have no doubt that further tests will show more than thirty feet of filling in the dye-tub basin and that the adjacent arm of the lake will show as much as fifteen feet of filling — marl — under the present pondweed vegetation.

[1] The occurrence of a slimy layer of blue-green algæ has been noted on the submerged ooze.

plant, sundew, marsh cinquefoil (*Potentilla palustris* [L.] *Scop.*) buckbean (*Menyanthes trifoliata* L.) and hoary willow (*Salix candida* Fluegge). The swamp forest has encroached closely upon the circular bog area and the presence of swamp and marsh plants already named together with others of frequent marsh habitat are features which appear to strengthen the interpretation of vegetation and substratum history at this point.

2. *The Case of a Small Glacial Basin or "Kettle Hole."*

This was a small depression left among the sand deposits of the Iroquois basin. It lies near Phoenix. It was evidently a small pond. At the present time in stages of high water-table, water stands at or close to the top of the *Sphagnum* mat, but the surface of the filled basin is covered by a dense shrub vegetation. The bulk of this is leather leaf (*Chamaedaphne calyculata*) but larger shrubs, withe-rod, black choke-berry and mountain holly occur in small clumps where the ground is a bit higher. With these, also, chain fern. Encroaching upon the shrub mat is a close stand of black spruce (See Fig. 19). A closer examination of the shrub mat shows dense *Sphagnum* growth filling in about and among the heath shrub. Excavating with the hand, one finds the matrix of *Sphagnum* to be very thick. For the first foot or more it is preserved as to structure though only the top few inches is alive. Still further down the *Sphagnum* is disintegrated and becomes a part of the general peat mass. Evidently, however, peat moss has been the chief agent as indeed it is now in filling the basin. The vegetation of the basin stands in no relation, either floristic or associational to the surrounding chestnut, oak, bracken vegetation of the sandy lands.

3. *The Case of Bean Pond.*

This is an Adirondack bog of the extreme type. It lies in a poorly defined valley much filled by glacial till — notably sand — on the land of the Ranger School of The New York State College of Forestry near Wanakena. A low, nar-

Photo by Hugh P. Baker.

FIG. 20. Bean Pond, near Wanakena, an extreme type of Adirondack bog. The lifeless, open-water zone, the dwarf heath-shrub and the surrounding dwarfed black spruce are shown. At the pond margin, borings show over twenty-four feet of brown peat. This becomes shallower toward the margins of the basin, being about eight feet deep under the black spruce one hundred yards to right of pond in the figure.

row sand ridge, doubtless a glacial esker, cuts across the shallow valley. Bean Pond lies immediately below this esker. (See Fig. 20 which was taken from the top of the esker). The " pond " itself appears to be unrelated to the valley drainage at present, but below, a narrow strip of lost drainage land is occupied by balsam swamp and marsh-meadow (both with *Sphagnum*) and a little farther on the stream finds itself in a definite channel. Let us set down serially the circumstances here:

(1) There is the circular, open, almost lifeless zone of black water.

(2) There is no well defined floating *Sphagnum*-sedge zone.

(3) The *Sphagnum*-heath shrub mat runs up to the border of open water forming the shore line which shows almost no evidence of advancing at the present. This mat is compact and while leather-leaf is dominant, there are more species of heath shrub than at the Tully Lake bog. The shrubs are very much dwarfed.

(4) The encroaching zone of bog forest is made up almost exclusively of black spruce. It appears to be in uniformly graded sizes based on age. As a matter of fact, analysis of sample strips running radially from the central pond, showed that the small trees, apparently almost mere seedlings, near the pond are about as old as the tallest ones at the margin of the bog. In short there is noteworthy dwarfing of both spruce and heath shrub, increasing toward the central open water zone.

It really looks as if the logical outcome of bog conditions had been reached in this extreme case; namely, that by reason of toxicity, deficit of plant food, acid reaction or whatever or what all it may be, the progress of vegetation has been brought to a relative standstill. To such a conclusion do the facts seem to point, as to absence of floating sedge zone, firmness of the *Sphagnum*-heath mat and of its border on the open water; the lifeless, open water zone and the progressively intenser dwarfing of spruce and shrub toward this zone. I need scarcely point out that again in this case we have broached a subject for further and more detailed experimental study, particularly since the conclusions here drawn involve a different interpretation of the relation of bogs and bog vegetation to swamps, and swamp vegetation than those usually put forward.[1]

Geographical Distribution of Bogs in New York.

In general, bogs are of frequent occurrence in the glaciated regions but by no means confined to them. Thus cranberry bogs are a pronounced feature in the sand barren region of New Jersey. No part of New York State is without bogs but it may be said that in the Adirondack region the tendency toward bog development is quite general. This may be largely due to the edaphic conditions growing out of the character of glacial filling — blocked streamways and basin formation — and in part to climatic conditions — prevailingly lower temperatures. So far as climatic conditions determine a boreal vegetation in general — progressing in intensity with elevation — they might also be expected to be operative in bog formation. Taking the hydrophytic sequence of vegetation of the Adirondacks generally — sedge marsh, beaver meadow, swamp shrub and swamp forest — there is throughout a greater nearness to bog conditions than to typical swamp. The early presence of *Sphagnum* in the marsh-sedge mat and its continuance on through beaver meadow to forest (balsam forest in very wet soils is dwarfed and commercially worthless according to Zon. The ground cover is 70% mosses, *Sphagnum,* and others, *l. c.,* p. 5) and, again, the appearance of heath shrubs in the beaver meadow or even earlier stage, are other constant differences which point to the great

[1] In this connection see papers by Dachnowski, Davis, Detmers, Livingston, Shaffner, Transeau and others. The literature, especially as relates to bog, moor, heath-moorland, etc., is quite voluminous. The whole subject is pretty fully presented and full literature citations given in Dachnowski's work previously cited. (Peat Deposits of Ohio.) Geol. Surv. of Ohio, fourth series, Bull. 16:1912. Dachnowski, *l. c.,* p. 222, proposed the name "Bog Series" for the successive vegetation stages developing on a peat substratum.

tendency toward bog development in the Adirondacks. In swamp forests elsewhere, the lowest part or middle of the swamp will ordinarily show its zone of tamarack or white cedar though rarely black spruce or balsam. For the rest of the State, small basins in the regions of sand deposits notably in the Ontario-Iroquois basin (Cicero swamp in part, Phoenix bogs, Oswego county bogs, Mendon Ponds in Monroe county) are sites of more or less extreme bog development. So, also, in connection with the more pronounced swamp development of the basin regions previously mentioned, p. 118, and of the poorly established drainage at stream sources or drainage divides in the Alleghany Plateau (Tully Lakes Region, Machias) and small basins in morainic areas (bogs of the Freeville district).

Chamaecyparis Bogs.

Ecologically the bogs with southern white cedar (*Chamaecyparis thyoides* (L.) B.S.P.) appear to be the same as those of the Adirondacks but they are confined to the coastal plain from Massachusetts southward reaching their most noteworthy occurrence in the Pine Barren region of New Jersey and the Dismal Swamp region of Virginia. In New York they figure very little, being limited to the Long Island coast and the lower Hudson region. There may be no sufficient justification for employing the term "bog" rather than "swamp" in this connection. My aim is for the moment to emphasize what appears to be a radical difference in hydrophytic succession where the substratum comes to be of a character to favor the *Sphagnum* -- heath shrub -- conifer sequence rather than what I conceive to be the normal swamp sequence. Harshberger (*l. c.* pages 441) speaks of white cedar swamp formation and says "the cedar swamp has a substratum of red brown peat composed largely of the stems, leaves and roots of *Chamaecyparis* and of buried logs in a remarkable state of preservation." Also, as perhaps bearing on the matter of normal sequence toward climax forest,— "On somewhat higher ground *Quercus aquatica, Q.*

Michauxii, Fagus americana (*F. grandifolia*) invade land formerly occupied by white cedar."

Notable Working Units in Bog Vegetation.

The effectiveness of bog vegetation has been inferred from previous mention of the character and amount of peat laid down by it. The above caption is employed for the purpose of focusing attention upon two unique growth forms as "working units" characteristic of bogs. These are (1) *Sphagnum* and (2) heath shrubs.

(1) *The characteristics and rôle of Sphagnum.*

Botanically, *Sphagnum* is one of the genera of mosses, the only genus of its special group *Spagnales.* There are perhaps 250 species all told of which perhaps 30 to 40 species[1] may occur in New York. Popularly it is simply peat moss which, considered from our present viewpoint, has peculiarities of structure and habits of growth which give it unique qualities as to taking up and holding water. Hence its use by florists and nurserymen. Baled peat moss is a standard article of commerce in this connection. Fig. 18 shows a view of an Adirondack bog from which peat moss is taken for packing young transplants from the State nursery at Lake Clear. This view will also indicate the character of mat which *Sphagnum* builds up. These mosses may in fact be the chief — sometimes practically the sole agents in peat formation. As pointed out in describing a bog near Phoenix, the *Sphagnum* mat may consist of recognizable *Sphagnum* plants to a depth of a foot or so, but below this it is more or less disintegrated. It is often — I believe generally — associated with sedges in forming the zone of floating *Sphagnum*-sedge mat which carries forward the invasion of land vegetation out over the open water zone (recall the case of Devil's Dye-tub). In the *Sphagnum*-heath shrub mat, *Sphagnum* makes an aggressive upward growth among the shrubs, the two together forming small mounds in this part of the bog. Statements as to

[1] The number of species of *Sphagnum* listed from Connecticut is 31.

the aggressiveness of *Sphagnum* in leading a bog invasion to the ultimate extinction and burying of forest may be found e. g., in Warming[1] where its rôle as an agent of invasion and peat forming is more fully described.[2]

(2) *The Characteristics and Rôle of Heath Shrubs.*

The word heath is used in rather the popular sense. Perhaps the expression heath family will be generally understood to apply in the sense in which it is used in Gray's Manual. The heath kinship circle, under the order name *Ericales*[3] embraces the following families: (1) white alder family (2) wintergreen family (3) indian pipe family, (4) heath family (5) huckleberry family (6) diapensia family.

The entire order of *Ericales* is of special interest not only in the more restricted ecological relation but equally in the broader aspects (historical and other) of plant geography. We have noted their occurrence among the arctic species of Mt. Marcy, in bogs of the extreme type, in the filling of glacial "kettle holes", in sand barrens, and on arid mountain ridge habitats (Shawungunk Mts.). Perhaps the chief immediate interest lies in the occupation by certain heath shrubs of these "difficult" or unfavorable soils — substrata — of peat and sand.

The unfavorable qualities of such soils are associated with factors which make the absorption of soil water or soil nutrients or both difficult. They have been thought to constitute "physiologically dry" habitats and to support therefore a xerophytic vegetation. Certain characteristics of heath shrub structure are interpreted in this connection, e. g., the *ericoid* type of leaf. We have already made reference to factors of toxicity, acidity, lack of available nutrients, etc. Certainly so far as peat and sand soils, from

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1 Warming, *l. c.*, p. 201 and following. Again, p. 361.

2 As to the structure and life history of *Sphagnum*, see college text books on morphological botany.

3 Britton, N. L., and Brown, Addison, Illustr. Flora Northern U. S. and Canada. Second edition, 3 vols., 1913.

whatever cause, represent an approach toward conditions which exclude vegetation, the heath shrubs which persist beyond or dominate over most other species must be regarded as having noteworthy tolerance and resistance. As bearing on this problem of soil adaptation, the work of Coville [1] on blueberry, trailing arbutus, etc., is noteworthy. Especially are you recommended to read the bulletin on blueberry culture. Coville found that in the case of blueberry and other heaths, the rootlets instead of possessing the normal absorbing cells called root hairs, are inhabited by a fungus — one of the mycorhizal fungi which appear to exist in a symbiotic relation with the plant whose roots they inhabit. He found further that such fungi exist only in an acid medium and accounted for the presence of blueberry, etc., on peat soils and on sand by reason of the acidity of both these substrata (*l. c.* page 35). It is his view furthermore that the acidity of peat soils is the main factor in inhibiting the activity of nitrifying bacteria and therefore of the non-available condition of the nitrogen. He thinks that the mycorhiza of the heath shrub roots play a rôle in transforming the non-available to available nitrogen which the heath plants then absorb.

THE DEVELOPMENT OF VEGETATION UPON A SUBSTRATUM SUBJECT TO PREVAILING WATER DEFICIT.

This case carries us just to the opposite extreme of the water relation from what we have been considering. Concretely the problem is for vegetation to establish itself upon a substratum of solid rock, boulders, gravel, sand, etc., in a climate like that of New York State where rainfall, humidity, fogs and dew make possible a luxuriant vegetation upon a substratum capable of maintaining a relatively constant water supply. Such constancy of moisture supply is of course impossible upon bare rock and sand if these lie above

[1] Coville, Frederick V. Experiments in blueberry culture. Bull. U. S. Dept. Agr., Bur. Pl. Ind., No. 193:1911.

Photo by W. L. Bray.

FIG. 21. Large boulder at Hoel Pond deeply embedded in the forest debris. The exposed, smooth portion is in process of being covered by vegetation. Crustose lichens, foliose lichens and a rock moss (*Grimmia ovata*) compose this.

Photo by W. L. Bray.

FIG. 22. Encroachment of vegetation upon granitic rock overlooking Hoel Pond. Lichens and rock moss on the vertical face. Early moss-mat above being covered by forest litter, reindeer moss (lichen), American twin flower, and false lily-of-the-valley.

the water level or unwatered by surface seepage. Countless illustrations of this case lie before the eye in any quarter of the State, and not only is the difficult problem apparent but steps in the solving of it may be studied, and this even on a large scale in a region like that of Long Lake West where the disastrous forest fires of 1908 laid bare discouraging acres of rock and sand.

To get the full magnitude of the problem we should once more imagine a terrain in the condition presented upon the retreat of the last glacial invasion, or viewing the ground from the point of view of the present, imagine the heavy vegetation cover of three hundred years ago to be stripped off, together with its body of humus, duff, peat, etc., which it had built up. Now, of course, such a denuded terrain would show a lot of finer till — clay, etc.— capable of retaining a relatively constant and ample supply of moisture. Also as we saw, extensive areas covered with water or lying so low as to be constantly water soaked. But one would especially be impressed by the vast areas of bare and often polished rock, rock ledges, accumulations of angular rock fragments broken loose from their native strata, deposits of rounded water and ice worn boulders — especially the glacial moraines of coarser or finer gravel, and, finally, of sand as laid down in such vast deposits as we find throughout the Adirondacks, on the Ontario-Iroquois basin and at the mouth of the Mohawk, Saranac and other rivers. No doubt some of this terrain — especially rock cliffs and rugged mountain tops — has never been covered with vegetation, but really the areas upon which vegetation had not established itself in strength enough to build up an organic substratum would be almost negligible. This statement is ventured in the face of the desolate landscape of bare rock which one sees in so much of the Adirondack region to-day. Can vegetation reestablish itself on this lost ground and if so, what is the course of development? We may get some light on this question from specific illustrations.

1. *The course of vegetation on bare rock.*

Hoel Pond near Saranac Inn Station offers a good field for a study of this. A tolerably high, rocky promontory fronts southward upon the lake. The surface generally is strewn with coarse fragments of the granite-like rock, some worn smooth and rounded, some — including numbers of huge dimensions — are angular. At one point a few square rods of native rock lie with a southern exposure. This outcrop is not clifflike but rounded off, although fractured enough to present seams or small fissures and the surface is minutely roughened in the characteristic fashion of weathering granite. Some of this rock is entirely bare of plant life in midsummer at least, though doubtless certain blue green algae and perhaps minute lichens cover it in somewhat wet, foggy and cloudy weather. But generally a close examination will reveal minute crusts of lichen attached to the rock as if a part of it. These may be regarded as the beginning of the invasion. Their presence may have promoted the formation of deeper pits in the rock where dust and some organic debris may lie long enough to offer a foothold for the broad disc-shaped lichens (*Umbellicaria* and *Gyrophora*) which now cover most of the rock, being held firmly by root-like holdfasts set in the minute pockets. These relatively large plants make a thin interrupted mat which tends to accumulate dust and the small amount of organic debris. The lichens are extremely tolerant of dessication and are in fact dry and brittle most of the day in midsummer. With dewfall or fog and especially when it rains they expand and become very prominent.

The seams or fissures present an easier point of invasion because of the accumulation of soil and a more constant water supply. These seams are occupied by mosses — *Polytrichum*, and especially by a rock fern (*Cheilanthes Feei*). Larger plants such as blueberry may get a start in these fissures. At the crest of this rock exposure, a thin body of mineral soil and raw humus composed largely of pine needles has been built up and upon this, mats of reindeer lichen are established. See Fig. 22. Further up and on more level ground, a matrix of fine sand covers the bed rock. A thicker layer of duff covers the sand and this supports a shrub vegetation chiefly of heath species and especially blueberry (*Vaccinum angustifolium*), but this way beneath a stand of red pine which has become established at this point. Farther back from the lake, the vegetation history has proceeded so far that the rock strewn area is quite generally hidden beneath a deep cover of duff in drier places (under conifers) and of leaf mold in moister places (under hardwoods). Even large boulders rising above the general level are more or less covered with a soil matrix which supports at least polypody (See Fig. 23) and perhaps small shrubs and even young saplings (e. g. *Betula lutea*). Finally, the main area of the promontory, which, to begin with, was strewn with boulders and big angular rock fragments, is covered in general with a climax forest dominated by sugar maple, yellow birch, beech, hemlock, some paper birch and red spruce and a varied forest floor vegetation.

Returning now to the problem of the bare rock surface: it is quite within probability that with such a steep slope and so full an exposure to sun and storm, the instense drying effect, the wash of rainfall and the sliding snow and ice, vegetation could never establish itself strongly enough to build up a supporting humus cover. But even this seemingly hopeless invasion may be carried through especially with help given by the established vegetation at the crest. But as to the general status of the boulders covering the promontory, for the greater number, the problem is solved by their being covered by the great mass of debris which accumulates over the area on which they lie. There are, however, some so large that they stand out free from the general substratum. A rounded boulder more or less exposed to the sun had only this vegetation: (1). Closely adhering crusts of lichen; (2), patches of dark colored moss (*Grimmia ovata?*) (3);

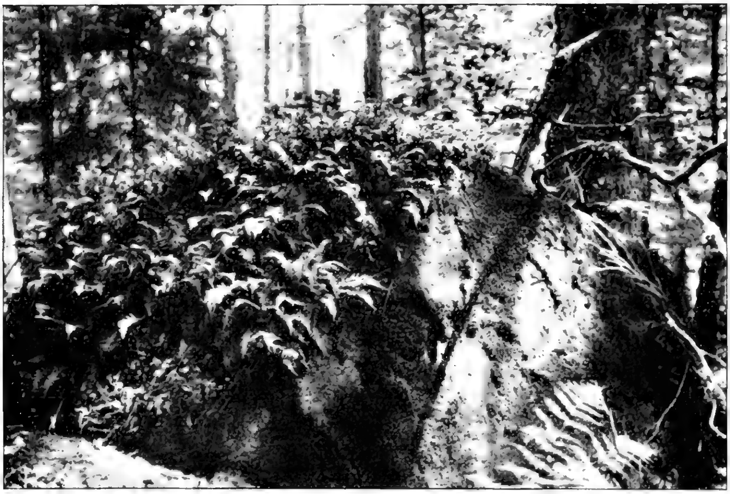

Photo by W. L. Bray.

Fig. 23. Large angular boulder, Heel Pond, with moisture-holding blanket built up by vegetation, and now covered by polypody.

Photo by W. L. Bray.

Fig. 24. A boulder upon which the soil blanket became heavy enough to support approximately climax forest vegetation.

thallus like spreading rosettes of lichen (*Parmelia tiliacea*)[1] (see Fig. 21). Another boulder (angular, with sloping top) had a mat of partly humified duff from one to three inches thick, knit together by the roots and rhizomes of polypody which made a close vegetation cover. Some larger plants (spermatophytes) were gaining a foothold here. Upon yet another and much larger boulder the vegetation history had progressed so far as to build up a soil mat one to six or more inches in depth which retained water so well that it supported not only raspberry canes but fair-sized saplings. The seepage of water from this soil mat kept the sides of the boulder wet for at least a day or two following a soaking rain and an algal growth (probably *Protococcus* and blue-greens) covered the vertical face while mats of moss had formed whereever a slight fissure or ledge gave mechanical support. Of course some of you will have seen fair sized trees growing on top of large boulders in the Adirondacks. See also Fig. 24.

A study of conditions in the Long Lake West district seven years after the disastrous forest fire of 1908, reveals among other items to be mentioned subsequently that bare rock surfaces are gradually but of course slowly in most cases, being covered by mats of moss — especially *Polytrichum* Fig. 43 — which gains its foothold first at fissures and spreads from these. In some cases the rock surface lies so that seepage keeps it moist in which case the spread of moss is relatively rapid. On the other hand, all the gain of a wet season may be lost by drying up of the moss mat in very dry weather. It may be mentioned here that even in the severe fire of 1908, not all the blanket of vegetation debris—duff, peat, leaf mold — was burned off so that the return of vegetation is faster than on surfaces that were burned bare. The accumulations of drier — often dustlike — duff are largely covered by a *Polytrichum* mat which is being invaded by red raspberry

[1] In this connection, see Cooper, W. S., The Climax Forest of Isle Royale, Lake Superior and its Development. Bot. Gaz., 55:1913, p. 118 *et seq.* Also Whitford, H. N., The Genetic Development of the Forests of Northern Michigan. Bot. Gaz., 31:1901, p. 306 *et seq.*

and certain annual plants. More generally, the country burned over is covered by a growth of aspen (*Populus tremuloides*), fire cherry (*Prunus pennsylvanica* and occasional birch (*Betula lutea*) and large toothed poplar (*Populus grandidentata*).

The case of Dibble Mountain in the Catskills is instructive in this matter of the development of vegetation on exposed rock. The fairly flat top of this mountain was lumbered for red spruce some 15 or 20 years ago. Subsequently a fire or fires cleared the summit of practically everything including a rich, deep blanket of organic debris. Stages in succession moving toward forest recovery include minute algae, lichens and especially moss mats of *Polytrichum* beginning especially at moist fissures. Fire weed (*Chamaenerion* (*Epilobium*) *angustifolium* (L.) Scop.), bristly sarsaparilla (*Aralia hispida* Vent.) and other herbs, and sparse grasses and sedges get a foothold in the fissures or older mats of moss. The dominant cover at this time is made up of the usual fire cherry and aspen growth, with a boreal birch (*Betula cordifolia* Regel = *Betula alba* var. *cordifolia* of Fernald) and the encroaching original forest as seedlings and young saplings of red spruce and balsam. The presence of seams and pockets, the latter due to the presence of the fractured summit rock, are factors in this relatively rapid recovery.

The North slope of Dibble mountain which if stripped of forest cover and organic soil blanket would present a steep talus of rock fragments, many of huge dimensions, with finer debris and weathered products filled in among them, shows a climax forest cover of our zone D type with less maple and yellow birch and more balsam, spruce and mountain ash above 3,000 feet but just the reverse proportions at lower elevation. The presence of such a forest with its constant soil moisture conditions stands in great contrast to those slopes which have been denuded and thrown back into a xerophytic condition. This case represents the conditions and outcome of vegetation development for a large amount of territory in the State namely, the rougher hill and mountain

Photo by W. L. Bray.

Fig. 25. A falling tree exposes the substratum of boulders upon which vegetation has laid a deep blanket, part of which is now a living moss mat. This area appears to be an ancient torrent bed. Near Wanakena.

Photo by W. L. Bray.

Fig. 26. View of a sand flat near Sylvan Beach on Oneida Lake. Foreground shows *Polytrichum* mat. Next, compact heath shrub (leather leaf) and beyond, dominantly popple-birch (white birch) with some aspen.

districts where bare fissured rock or a covering of coarse rock fragments and worn boulders formed the terrain upon which vegetation development carried out its course and where, in many instances, it has been thrown back to the initial or early stages again as a result of destructive lumbering and fires — in some cases also by farming methods. It will be recognized that the problem for vegetation was originally and is now simplified by the fissured, fractured and greatly roughened surface and consequent moisture seepage and the filling of fissures and pockets by the finer products of weathering. Naturally an isolated, rounded summit of exposed rock, especially where this is polished smooth, will always remain in the xerophytic or dwarf shrub and dwarfed and gnarled tree stage.

2. *The Development of Vegetation Upon Sand.*

Our interest in this connection centers in sand deposits which are compact and relatively stable. There is relatively little territory in New York where sand lies loose in dune formations subject to rapid shifting by wind action. There are however such cases on the shores of Lake Ontario and on Long Island notably at Montauk Point. In the former case, sand dunes are occupied by chestnut, oak, white pine, bracken fern, etc. The course of development would, however, carry us back to the early stage when the surface of the sand may have been temporarily held in place by algae and moss protonemata, while sand binding grasses and other sand binding plants and, later, shrubs gained a foothold and by the vigor of rhizome and root development bound the sand in place while the rapid vegetative multiplication spread a vegetation mat over the dune. Such in fact is essentially the course on sand beds in the Adirondacks, for example, although bracken fern rather than grasses, and the dwarf blueberry (*Vaccinium angustifolium* Ait.) and Canada blueberry (*Vaccinium canadense* Kalm) are the chief working units of vegetation in this early stage.

The noteworthy areas of sandy soils in New York comprise first, sand deltas composed of flat deposits put down under water as where the Mohawk, the upper Hudson, the Saranac and Black river emptied into bodies of water standing at a much higher level than at present; second, the beach sand laid down during the advances and recessions of the great glacial Lake Iroquois, e. g., sand beds of the regions about Rochester, the present Oneida Lake basin and westward, the basin rim running northward from Oneida Lake to Watertown; third, the vast sand beds of the Adirondacks derived by weathering of the prevailing granitic rocks and laid down upon these, modifying the roughness of rock exposure, forming deep beds upon slopes and valley sides and having been subject to erosion and glacial action — formation of sand eskers, etc. The sand deltas of the Saranac at Plattsburg, of the upper Hudson below Glens Falls and of the Black River below Carthage were evidently formed by sands transported from this great Adirondack source of supply.

A series of typical cases will be instructive as regards the course of vegetation, but this important fact is to be borne in mind; namely, that in all of these cases, with the possible exception of " The Plains," we are dealing with a secondary and not with a primary vegetation condition so far as regards the period of human history in New York. Evidence is conclusive to the effect that the sand areas above cited were originally occupied with heavy forest. The dominant tree of the sand delta areas was white pine. Perhaps also on the sands of the Iroquois-Ontario basin, where in addition, oak, chestnut and tulip-tree formed a prominent element, being in fact more abundant than pine at this time. So also, the Adirondacks sands were, and of course where not lumbered are still forested. In this case, not white pine chiefly but mixed forest and often typical climax forest has developed upon sand beds.

(1) *A Sand Flat of the Oneida Lake Basin.*

In the particular site chosen for illustration, the sandy substratum lies flat, low and poorly subdrained and poorly aerated. In wet seasons the water table is near the surface. The compact wet soil favors the growth of pioneer forms such

Photo by W. L. Bray.

FIG. 27. Soil section of the sand flat shown in fig. 26. The leached out sand layer, the humus-stained layer and the normal sand bed below are shown.

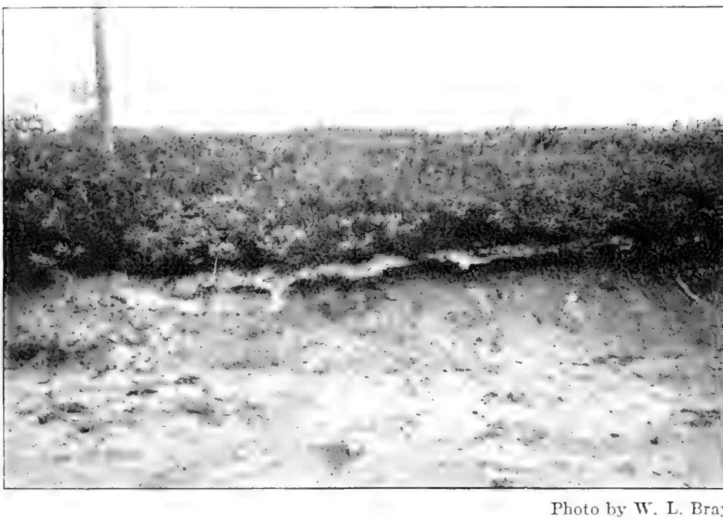

Photo by W. L. Bray.

FIG. 28. The heath shrub (chiefly blueberry) stage of vegetation on Adirondack sand near Lake Clear. The soil section is well shown. The forest and its accumulated duff blanket were wholly destroyed. The land was probably pastured for a period of years.

as blue-green algae and the protonemal phase of mosses. *Polytrichum* readily develops broad, deep mats. See Fig. 26. Herbaceous vegetation is developed sparsely between the mats, but this condition may not be normal (e. g., pasturing may have led to its scarcity). Rapidly, however, a heavy shrub vegetation invades the flat. This, singularly, is composed primarily of leather leaf (*Chamaedaphne calyculata* (L.) Moench.) which makes a vigorous, tall growth. Black chokeberry (*Aronia melanocarpa* (Michx.) Britton) and witherod (*Viburnum cassinoides* L.) occur sparingly. The pioneer forest stage is represented by thickets of white birch (*Betula populifolia* Marsh) and a smaller amount of aspen (*Populus tremuloides* Michx.) and occasional large toothed aspen (*Populus grandidentata* Michx.). On higher lying sands north of Oneida Lake, a barren, heath-like, sand flat showed much *Polytrichum*, small patches of *Sphagnum*, reindeer moss (*Cladonia rangiferina*), bracken fern, hard hack (*Spiraea tomentosa* L.) black chokeberry (*Aronia melanocarpa* (Mx.) Britton), running swamp blackberry (*Rubus hispidus* L.) in great abundance, creeping wintergreen (*Gaultheria procumbens* L.) in thick patches, dwarf blueberry (*Vaccinium angustifolium* Ait.) with occasional very young popple birch and aspen.

Of course the comment thrusts itself forward here as to the presence in this heath-like situation of bog and swamp plants. Part of the year, the ground is water soaked. It is always poorly aerated and evidently strongly acid (not determined by actual test) but during midsummer and fall the soil is subject to drying out as is usually the case with sand. This comment will recur in connection with other illustrations of sand vegetation.

(2). *"The Plains" of the Upper Oswegatchie.*

This is one of the so-called treeless sand plains of the Adirondacks, differing from the general run of sand deposits in the fact of being put down in the flat, compact delta form as in the Carthage and Plattsburg areas. It appears to be a true sand delta and this fact goes far to explain the difference between this and the surrounding Adirondack country, from which both as to topography and vegetation cover it stands out as a unique feature — one of the points to be visited.

Borings show from two to three feet of compact, fine sand evidently offering poor aeration. Below, the deposit is darker, coarser and full of coarser grit. The water table is normally several feet below the surface, but the area has the aspect of wet lowlands, and during a rainy season is in effect like an area of water soaked soils. But, as in other sand areas, it is subject to extremes of drouth.

The vegetation reflects these conditions. It is not known whether "The Plains" were ever forested though quite likely they supported pine forest in an early day. At the present it is virtually a heath barren in process of being invaded by conifers, and strangely enough the dominant invading species is tamarack. Growth studies show that this invasion began some thirty years ago and that the tamarack has made a rapid and symmetrical growth. Black spruce has become established in certain spots and exhibits an interesting and vigorous phase of reproduction by layering. This tamarack invasion is closing in on all sides and has in considerable measure broken up the heath formation. But some scores of acres are open heath. The ground-cover shows patches of grassland, small shrub, large shrub and the invading forest. Two prominent grasses are wet land species, viz. purple wild oat (*Avena Torreyi* Nash), and mountain rice (*Oryzopsis asperifolia* Michx.). Numerous annuals are associated with these and scattered through the heath-shrub, notably composites; for example, Canadian golden rod (*Solidago canadensis* L.), swamp golden rod (*S. uliginosa* Nutt.) and tall flat-top, white aster (*Doellingeria* (*Aster*) *umbellata* (Mill.) Nees). Two species of ladies'-tresses orchid occur among the grasses and composites, thus further emphasizing the marsh-meadow character of the vegetation.

The small shrub vegetation which, on the whole, is dominant, comprises *Vaccinium canadense, angustifolium* and

Photo by W. L. Bray.

Fig. 29. A part of "The Plains" of the upper Oswegatchie near Dobson's Camp. Photographed in October when lichens and *Polytrichum* form almost a complete ground cover in places. Invading tamarack is shown.

Photo by W. L. Bray.

Fig. 30. "The Plains" as in fig. 29, but showing much heath-shrub and the invading tamarack. Heavy lichen cover in foreground.

vacillans, in broken or pure stands, blue honeysuckle (*Lonicera coerulea* L.) in compact clusters scattered over the plain, *Aronia melanocarpa* (Michx.) Britton, and *Spiraea latifolia* (Ait.) Borgh., both very abundant.

The large shrubs comprise *Viburnum cassinoides* L., *Aronia arbutifolia.* (L.) Ell., and choke cherry (called *Prunus Virginiana* in Gray's Manual, seventh edition).

As further emphasizing the hydrophytic aspects of the vegetation, should be noted the abundant occurrence of creeping blackberry, *Rubus hispidus* L. (possibly rightly called *Rubus nigricans* Rydb.). On the other hand, the heath-barren aspect is most strikingly emphasized by the great abundance and sometimes (notably in the late fall) dominance of *Polytrichum* and lichens (*Cladonia rangiferina, alpestris* and *pyxidata*). See Fig. 29.

This association of swamp and bog species with typical members of sand barren vegetation, together with the surprising invasion of vigorous tamarack and some black spruce presents, in a conveniently small area, an inviting subject for more detailed investigation.

(3) *The Plattsburg Sand Barrens.*

This area is evidently a sand delta formed where the Saranac River discharged its load of Adirondack sands into Lake Champlain at a time when the lake level was notably higher than at present. The plain is, in general, flat but still with gentle swells and lower wet lands, the latter having the usual deposits of black organic soil (muck). Some of the land is under cultivation. Practically all the rest is subject to pasturage so that we really have a secondary vegetation trying to establish a plant covering against constant interruption, one item of which is the periodic cutting off of pitch pine. It is stated on good authority that this plain was occupied by white pine forest originally. Mention is made by Pringle in his report of 1885 on the forests of New York [1] of white pine shipments made from this vicinity via. the St. Lawrence River to Europe.

[1] Pringle, C. G. Report upon the Forests of Northern New York.

The full course of vegetation has not been made out, but observation seems to indicate that, as would be expected, a sparse cover of grasses and sand soil annuals is followed by the establishment of a (chiefly heath) shrub association which strongly persists during the open stand stage of pitch pine and is finally thinned out by the closing in of a closer forest cover. See Fig. 33.

The composition of different stages of this sand vegetation is given in the following lists of species taken about the first of September.

(a) *Prairie aspect.*

Sparse grasses and sedges, not determined.	
Bracken	=(*Pteridium aquilinum* (L.) Kuhn).
Ground Pine	=(*Lycopodium tristachyum* Pursh). Rare.
Sand violet	=(*Viola subvestita* Greene).
Pin Weed	=(*Lechea Leggettii* Brit. & Holl.).
Frost weed	=(*Crocanthemum* (*Helianthemum*). *Canadense* (L.) Britton.).
Silvery cinquefoil	=(*Potentilla argentea* L.).
Savory leaved aster	=(*Ionactis linariifolius* (L.) Greene.).
Pale golden rod	=(*Solidago bicolor* L.).

(b) *Heath-shrub.*

Sweet fern	=(*Comptonia peregrina* (L.) Coulter). Pure stands.
Black chokeberry	=(*Aronia melanocarpa* (Mx.). Britton).
Appalachian cherry	=(*Prunus cuneata* Raf.). Common on sand.
New Jersey tea	=(*Ceanothus americanus* L.).
Creeping wintergreen	=(*Gaultheria procumbens* L.).
Bear berry	=(*Uva-Ursa* (*Arctostaphylos*) *Uva-Ursi* (L.) Britton).
Black huckleberry	=(*Gaylussacia baccata* (Wang.) K. Koch). Abundant.
Sheep laurel	= *Kalmia angustifolia* L.).
New Jersey blueberry	=*Vaccinium caesariense* McKenzie). (?).
Dwarf blueberry	= *Vaccinium angustifolium* Ait.). Common.
Blue huckleberry	=*Vaccinium vacillans* Kalm). Pure stands.
Pitch pine	=(*Pinus rigida* Mill.). In open stand.

Photo by W. L. Bray.

FIG. 31. A view of "The Plains" near Dobson's which shows pure heath-shrub, occasional clumps of high-shrub, and the invading tamarack.

Photo by W. L. Bray.

FIG. 32. Heath-shrub and scrub-oak in an open stand of pitch pine on the Hudson-Mohawk sand plain near Schenectady.

White birch and aspen are frequent, but not in the open pine stand.

(c) Pitch pine in pure stands with sparse forest floor species.

(4) *The Hudson-Mohawk Pine Barrens.*

This sand delta region is crossed by the New York Central and the Interurban railways between Albany and Schenectady. The occurrence of sweet fern, white birch, aspen and pitch pine southward from Gansevoort will indicate the occurrence of the Upper Hudson sand delta.

In general, the striking aspect here is the occurrence of pitch pine on the better drained land, sand knolls, ridges, etc., and of the American white birch (popple birch) on the flat or more poorly drained soils, extending here as often noted elsewhere into swampy places. A sand ridge showed an almost pure stand of large toothed aspen (*Populus grandidentata* Michx.) A dry depression adjacent showed a characteristic patch of broom beard-grass (*Schizachyrium scoparium* (Mx.) Nash). Sweet fern, blue huckleberry, New Jersey tea and some other shrubs occur very much as at Plattsburg. Two scrub oaks not found at Plattsburg are part of the shrub vegetation here; viz., dwarf chestnut oak (*Quercus prinoides* Wild.) and bear oak (*Quercus ilicifolia* Wang).

(5) *Sand Beds of the Syracuse, Phoenix and Rochester Districts.*

On the whole, these sands appear to offer better drained and aerated soil than types hitherto considered. Perhaps this fact, together with more intensive cultivation, will account for the general absence of heath-shrub vegetation. Also their "warmth" (growing out of better drainage and aeration) together with the fact that they lie in a region of ameliorated climate (Zone B of low elevation and under lake influence) will no doubt account for the feature which it is desired to emphasize in this connection; namely, the occurrence of heavy growth of chestnut, oaks, hickory and tulip-tree. The finest bit of chestnut forest that I have seen in New York grows upon these sand beds near Phoenix. Fig. 34. It is claimed that in certain districts the farmers realize more income from the sale of chestnuts than from all other farm products.

(6) *The Sand Beds of the Adirondacks.*

The general thought will be, not that the sand deposits of the Adirondacks are a dry or barren terrain, but a great factor in forest production. This is very obviously the case and just on that account it is of moment that we should consider what is involved in the ruthless destruction of such a forest cover and especially its supporting blanket of duff, by lumbering methods which involve not only breaking up the forest stand but burning over subsequently. It means, then, the long story of beginning again the building up a forest soil — a process involving too long a period to be practicable for the private owner. Naturally, more is involved here than the development of vegetation on sand, for there is much bare rock exposure, slopes covered with boulders, soils of clay and other debris than sand, but so far as the sand is concerned the course of forest re-establishment involves a pioneer stage of mosses (*Polytrichum* largely) and of grasses, composites, etc.; of vast patches of bracken fern and in many cases the establishment of heath-shrubs (blueberry patches) or as on other soils, the thickets of red raspberry (*Rubus strigosus* Michx.) Fig. 46, and the customary forest weed stage of aspen (*Populus tremuloides* Michx.) fire cherry (*Prunus pennsylvanica* L. f.) large toothed aspen (*Populus grandidentata* Michx.) and seedlings of the climax forest. In my observation, which for a final judgment is quite insufficient, the percentage of white pine seedlings or those of birch, maple, red spruce, etc., is not large enough to give any lively hope of rapid establishment of a stand capable of developing commercially valuable forest. As in all other cases cited, white pine tends to become dominant, or was the original dominant species on the looser, drier sand beds (I take the instance of heavy pine stands on the high ridges about Big Shallow and Little Shallow ponds in

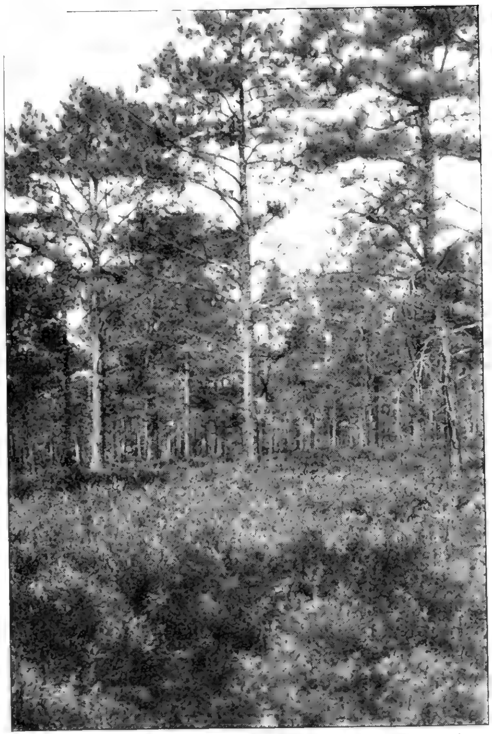

Photo by W. L. Bray.

Fig. 33. Heath-shrub in open stand of pitch pine

Photo by W. L. Bray.

Fig. 34. Pure chestnut forest stand on sands of the

Herkimer county as confirmation of this) but certainly in situations favoring retention of moisture near the soil surface, though still with aeration, a mixed forest of pine, red spruce, hemlock and of yellow birch, red maple, sugar maple and beech, develops on sand beds. Thus, for example, along Cranberry Lake inlet a road cut through mixed climax forest of the above composition exposes beds of deep sand.

The condition of the soil cover as brought about by the forest's activity is the focal point for our present consideration. The qualities of this deserve thorough study. A typical section taken under forest cover (and in a measure also under heath shrub cover) shows:

(a) Undecomposed forest litter varying, of course, with the forest stand.

(b) A layer of greater or less thickness of partially decomposed forest litter, duff, approaching the condition of leaf mold under hardwoods.

(c) A layer of leached out, gray sand three to five inches thick.

(d) A thicker zone of black soil, the humus leachings caught by the sand underlying the leached-out one of gray sand.

(e) The characteristic slightly orange yellow sands of the underlying bed. Figs. 27, 28.

Whatever may be the chemical nature and food supplying power of this modified covering of the sand, there is no gain saying that it brings about a radical change in the moisture relation and as a consequence we have not a xerophytic but a mesophytic condition which last is correlated with climax forest. But it is also certain that a great deal of potential energy has been added to the normally rather barren sand.[1]

Now the sand of the lands denuded of the former white pine stand have no such blanket. Of course, a body of organic

[1] Russell, E. J. Soil conditions and Plant growth; 1915, p. 53.

debris is put down by the heath-shrub and the open pine stand but apparently it is so thoroughly broken up by decomposition organisms that as in soils of arid regions, the accumulation of characteristically black or brown humus material is not noteworthy. In any event such soils are to be regarded only as temporarily barrens. In any scheme for making them productive in the long run it is my opinion that a forest growth would be the most effective, but on the other hand intensive cultivation — truck and small fruit farming — has been shown to be profitable on certain of the sandy soils — e. g., the Syracuse area. Recalling the experience of farmers in the sandy area east of Phoenix, where it is stated that the sale of chestnuts yields a larger return than from all other farming operations, emphasis was earlier put upon the fine quality of trees grown on this soil. Viewing the matter from the farm-yield side, it may be said that the experience simply demonstrates the unfitness of these sands for ordinary farming because of both lack of fertility and of moisture holding capacity.

General Relations of the Sand Barren Vegetation.

Ecologically considered — i. e., as a stage of vegetation or association of plants adapted to certain prevailing xerophytic soil conditions — the pine barrens of Suffolk County, Long Island, appear to be identical with the Mohawk, Plattsburg and Carthage barrens. Indeed the dominant species are the same or equivalent, notably pitch pine, sweet fern, heath-shrubs, etc. A closer floristic comparison would no doubt show first, more species common to all, second, that the floristic differences are correlated with zonal differences. Thus, dwarf chestnut oak (*Quercus prinoides* Willd.) and bear oak (*Quercus ilicifolia* Wang.) which I did not find at Plattsburg are abundant in the Albany barrens and again in the Suffolk County barrens. It is only a step further, then, to suggest that the same ecological relation and a correspondingly differing floristic (zonal) relation exists between all these areas and the pine barrens of New Jersey.

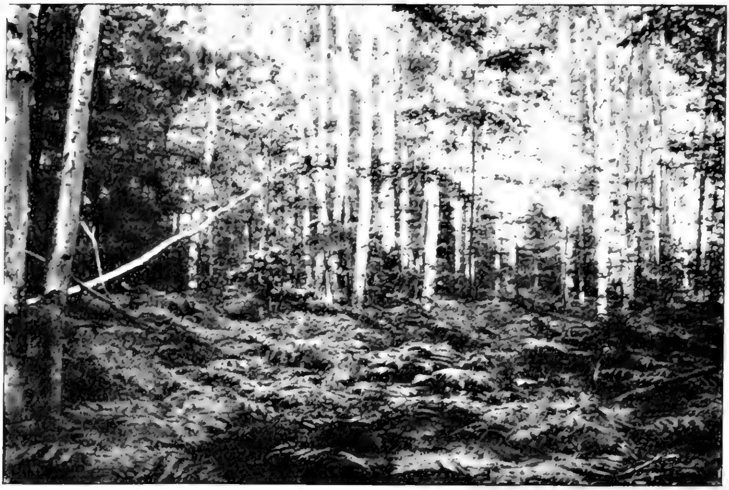

Photo by W. L. Bray.

FIG. 35. Heavy bracken ground cover under and among paper birch on beach sands of Upper Saranac Lake.

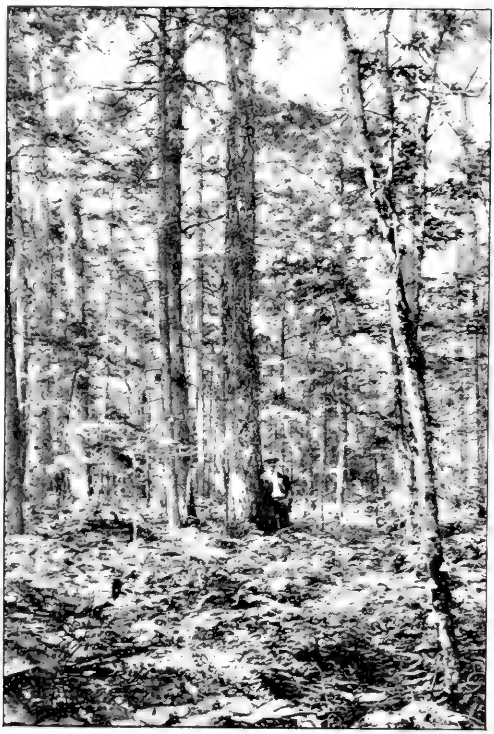

Photo by H. P. Baker

FIG. 36. Climax forest of type in Zone D, Adirondacks. Typical ground, cover here largely witch-hobble and American shield-fern.

Thus we have a further illustration (noted already in case of bog formation) of the tendency of identical edaphic conditions to choose — if an environment may be said to choose — or control the selection of identical ecological vegetation units. Just what the edaphic factors are and how they operate (i. e. whether it is water deficit, lack of available food, acid reaction, or all these that determine the xerophytic aspect of the vegetation) should be determined by further comparative studies. In this connection, the existence of this vegetation type on barren mountain tops and slopes suggests that at any rate it is not a question of deep sand beds. Thus, what appears to be the ecological equivalent of the coastal and delta pine barrens occurs on the summit of the Shawungunk Mountains[1] where pitch pine, dwarf chestnut oak, heath shrub and other elements of the pine barren flora, indicate the pine barrens type of vegetation. The conditions prevailing on the Oneida Lake sand flat where *Polytrichum* and leather leaf are dominant and on "The Plains" where lichens and *Polytrichum* constitute (in October) the chief ground cover, suggest an interesting comparison with the pine barren and heath formations of northern Germany.[2]

The Resemblance Between Heath-Bog and Pine Barrens Vegetation.

In the list of plants which have been given as indicative of, or the controlling elements in bog and sand barren vegetation it has come out that some of the very striking species occur in both situations. Thus, leather leaf (*Chamaedaphne calyculata* which is the main species of the heath shrub cover of the Phoenix bog is also equally abundant on the Oneida Lake sand flat. It is reported also among the sand barren group of

[1] Britton, N. L., Bull. Torr. Bot. Club., XI:125, and XIV:187. Harshberger, J. W. Phytoeogr. Surv. of No. Amer., p. 475.

[2] Graebner, Paul, Allgemeine Pflanzengeographie, 1910, p. 277, says that the vegetation of "nährstoffarmen Sände" may be sparse grasses or dwarf (heath) shrubs, but the "hauptrolle" is played by *Polytrichum piliferum*, *Rhacomitrium* and lichens, especially *Cladonia* species.

species on Shawungunk Mountains. Sheep laurel (*Kalmia angustifolia*) a typical bog plant, occurs on the sand barrens at Plattsburgh and Albany. So with black chokeberry (*Aronia melanocarpa*) swamp golden rod (*Solidago uliginosa*) running swamp blackberry (*Rubus hispidus*) and others.

These facts of distribution seem to point to a similarity of conditions as respects the soil factors in bogs and sand barrens, particularly where the sands lie compact and poorly drained. In this connection I would express the conviction that the tendency toward bog formation is greater in basins which lie in sand regions (e. g. Phoenix bog, Bean pond) than in those lying in regions of clay, silt, fine gravelly clay, etc.

The water deficit which is taken for granted in sand soils seems to have its equivalent in bogs. Schimper [1] called bogs *physiologically dry* habitats, arguing that some factor or factors retarded water absorption by bog plants. The presence of bog toxins may operate in this connection. Although the former assumption of the presence of "free humic acids" seems no longer applicable, it appears difficult to explain the dominance of heath-shrub vegetation in both bogs and sand barrens unless we assume the presence of an acid soil or an acid-reacting substratum in each case. Possibly the case could be explained by the so-called adsorption phenomena displayed by *Sphagnum*, sand soils, kaolin, etc., in which it appears that from a certain neutral solution as for example sodium cloride, the base is taken up, "adsorbed," by the *Sphagnum*, sand, etc., leaving the acid component free to show its reaction — as for example on litmus paper.[2] Recalling the work of Coville (experiments in Blueberry Culture, *l. c.*) in which he demonstrated the presence in heath plants (certain species, and inferentially in all of the *Ericales*) of mycorhizal fungi, and that these fungi can exist only in an acid medium, it appears warranted to use heath-

1 *l. c.*, page 2.

2 Harris, J. E. Some adsorption phenomena in soils and kaolin. Jour. Physical Chem., 18:No. 4, pp. 355–372.

shrubs as indicators of acid conditions (whatever that may mean). The tendency toward dominance of heath-shrubs in both bogs and in sand barrens is certainly noteworthy, but it should be noted that on the whole, species of *Ericaceae* dominate in bogs while *Vacciniaceae* dominate in sand barrens although we found *Chamaedaphne* (leather leaf) very abundant in each and lambkill in both.

General Survey of Xerophytic Succession in New York.

Considering the State as a glacially prepared terrain, the features which would offer habitats with deficiency of water supply — or at least periodic deficiency would be,—

(1) Bare rock surfaces, polished smooth and left uncovered by glacial till or denuded of such in post-glacial time. This includes glacial stream beds (See Fig. 25); rounded, dome-like summits of hills and mountains in the Adirondack region, Catskills, Highlands of the Hudson, etc.; vertical rock ledges of mountain sides and of deeply cut streamways.

(2) Detached rock fragments accumulating on mountain slopes — see Catskills — and smooth rounded boulders deposited by the melting ice — notably in moraines. See Figs. 21 to 24.

In (1) and (2), rock fissures and the space between boulders facilitate the development of vegetation by offering a lodgment for finer mineral and organic sediment in which plants readily gain a foothold. Seepage may cut a figure on mountain sides. Indeed a rocky hillside may thus become the location of a hydrophytic sequence — e. g. *Sphagnum* is common in such situations in the Adirondacks.

(3) Sand deposits; dune sand, delta sand, lake shore sand and glacially distributed sands of the Adirondack gneissic rocks. The development of heath-shrub is notable here.

(4) Exposed hills and slopes either where rock lies with very thin cover of water retaining till (clay, etc.), or till having a large percentage of gravel and sand.

When you consider the plateau ground work of the State with its mountain elevations and extensive dissection by stream action and especially the degree to which glacial action went in laying down boulders, gravel and sand, the conclusion is drawn that, to begin with, the larger portion of the State was of a character to compel a xerophytic sequence of vegetation. Under present conditions — i. e., through the activities of human agency — a great deal of the Adirondacks, Catskills, Hudson Highlands, Alleghany plateau, especially highlands of southern New York, and the sand areas of the Saranac, Mohawk, Hudson and Ontario basins, have been thrust back into the earlier stages of vegetation history. This has been brought about largely through the destruction of the humus blanket or organic cover built up by vegetation. It is certainly interesting to observe that despite the prevalence of xerophytic habitats, the action of vegetation had, by the beginning of the era of cultural interference, brought almost the whole of this territory into a condition of moderately constant water supply and of heavy, large growth vegetation if not of climax forest.

THE DEVELOPMENT OF MESOPHYTIC VEGETATION.[1]

You may have gained the impression by this time that we have gotten the situation in our State drawn out of proportion by dealing with hydrophytic and xerophytic successions of vegetation as if they constituted the predominant features of New York. You will say, and quite properly, that the agricultural and forestal industries of the State constitute its great activities and they are founded on the fact that we

[1] The words hydrophytic, xerophytic and mesophytic are commonly employed in botanical texts to designate the status of a plant or of vegetation with respect to the water supply of the substratum. In this caption we might better say " the development of vegetation upon a stubstratum having constant, moderate supply of moisture, meaning by this a typical field-soil moisture as contrasted with the hydrostatic or drip water of water soaked soils.

Photo by W. L. Bray.

Fig. 37. Ground cover of American shield-fern (*Dryopteris intermedia*) under climax forest of Zone D (Canadian-Transition) near Cranberry Lake.

Photo by W. L. Bray.

Fig. 38. Ground cover of American shield-fern as in fig. 37. Polypody on ledge at right. Cranberry Lake.

have climatic conditions of rainfall, humidity, etc., and soil moisture conditions of a degree to justify expectations of luxuriant crop yield, whether of forage, grain, fruit, vegetables or forests. You might quote my own statements as to the wilderness of forest which originally occupied our State and in itself constituted proof of the essentially favorable conditions for plant growth. Using the special terminology which botanists employ, it was predominantly a mesophytic forest, i. e. it reflected not habitual aridity or recurring aridity, not swamp or periodically submerged lands and constantly water-soaked soils, but a constant water reserve in the soil from which a maximum vegetation cover could draw its daily needs throughout the growing season. In such conditions one could count on this constant, but not hydrostatic, water supply to produce such types of vegetation as a field of corn, cabbage, potatoes, wheat and the like.

Perhaps the space given to the hydrophytic and the mesophytic successions will be justified if it has helped to show how largely vegetation itself has been a factor in producing mesophytic conditions. You know that whether water be in excess or in deficiency in your field soils is very often a matter of keeping up the supply of humus. You may so reduce this in your sandy soils or the gravelly land or on the hill farms that your crops burn up when the rain intervals are a bit strung out. On the other hand, the same lack of humus replacement may result in compact, sour, and if rain intervals are crowded, in water-soaked soils. In other words, the very thing which vegetation tended largely to reduce and which intelligent tillage tends to reduce was this fluctuation between extremes. I suppose there was humus in some of the glacial till carried over from soils of preglacial or inter-glacial periods, but certainly the lack of it as a blanket such as our great forest vegetation had built up when explorers first saw it, would leave much of our glaciated terrain in the situation of the one extreme or the other. Still there was a vast amount of glacial till laid down of a kind and in situations to favor a constant moisture supply. This would be the case where a mixture of clay and sand and fine gravel made up the deposit lying as some of our valley soils do. Our richest farming regions have been developed upon such soils. Naturally the demand for soils of this favorable moisture relation for farming purposes means that not many exist which are not either intensively cultivated or covered with climax forest (the carefully preserved woodlots) and hence few situations are offered where the natural mesophytic sequence is observable from the beginning. If we take the common case of an abandoned field there is always associated therewith a condition of aridity which determines a tendency toward xerophytic succession. Thus the hill farms of southern New York with their cover of moss (*Polytrichum* mats), sparse grasses, daisies, golden rod, field cats-foot (*Antennaria neglecta* Greene) hawk weed, etc.; of sweet fern and sometimes of blueberries; of shrubs of white birch, aspen, fire cherry, sumac, etc.; and finally of seedlings of pine, maple, etc., show a relationship to the xerophytic successions (as I have here defined them) upon sand and burns (as in the Catskills and Adirondacks).

An abandoned stony field in central New York has been under my observation for some twenty years during which period essentially the following progress has been made toward mesophytic (climax) forest; (1) dominance of field weeds; (2) of sparse grasses — timothy, blue grass and pasture weeds, orange hawkweed, ox-eye daisy, golden rod; (3) invasion by red raspberry and blackberry, the latter becoming dominant (a much sought blackberry "patch"); (4) invasion of the blackberry stage by sumac; (5) gradual appearance of fire cherry and species from surrounding swamp and climax forest (white pine, elm, yellow birch, ash, basswood, red maple, hemlock, etc.); (6) shading of ground, elimination of shrubs, etc., first by the most vigorous invader, white pine, and later by broad-leaved trees. In some part of the field the forest crown is forming and thus the "old field" stage is passing. During all this period the forest forming element has been hindered by berry pickers who have habitually broken down seedling trees and particularly have cut white pine seedlings and even young saplings for decoration. But even on this arid land the forest is closing in in spite of hindrance. On an adjacent field, the site of an old dwelling and its surrounding, cleared patch have disappeared under a young forest cover where the young saplings are making their rapid growth-race for survival and many are already starved and falling out. This sort of thing is familiar enough to everyone but it may not have been generally observed that even in the most favored situations a mesophytic forest is not a direct and sudden development. The elaboration or differentiation of the environment by vegetation to the point where the complex forest society occupies the site, involves a period of history rather like the development of a single organism to its mature stage. It is not to be inferred here, however, that a field-weed stage or grass and pasture weed stage, shrub stage, etc., are regarded as necessarily preparing or building up the soil for the later coming trees. The fact in such case is, that the grass cover may delay and doubtless exercise a certain control in the species make-up of the young forest by making the establishment of seedlings difficult. But in such cases as those cited and generally on lands better suited to forest growth than for farming, the earlier stages leading up to the mature forest represent vegetation of a certain xerophytic status, for until the forest crown closes in and the ground becomes shaded and kept moist by the organic debris, the amount of water given off from the foliage is large as compared with the quantity which the roots can absorb from the soil. See also, under *culture status of vegetation* (p. 181).

CLIMAX VEGETATION.

It is hoped that the discussion presented in these pages will lead to the conclusion that there has in the course of time been worked out a certain complex adjustment as between plants and the New York type of environment such that we could say of it that it constitutes the normal or bal-

Photo by W. L. Bray.

FIG. 39. Ground cover exclusively *Oxalis acetosella* in dominantly conifer forest at 3500 feet elevation on the "Marcy Trail" from upper Ausable Lake. This wood sorrel is extremely abundant throughout Zone E in the Catskills and Adirondacks.

Photo by W. L. Bray.

FIG. 40. A characteristic patch of *Lycopodium lucidulum* in Zone D climax forest of which this club moss is an indicator, so called, because of its great abundance and general occurrence throughout the Catskills and Adirondacks.

anced or equilibrium stage of our vegetation. According to this view, vegetation ceases to be the haphazard covering of the land with miscellaneous types of plants; it ceases to be the matter-of-course complement of our human welfare and becomes an orderly sequence of development somewhat in the same sense as the development of a single organism, as a tree for example, from the primitive stage of the fertilized egg to the fully differentiated body of the mature plant. If we should assume this to be an analogy then we should say of vegetation as of the developing tree that the general course of development has grown to be a fixed habit — the result of long environmental experience if you will — and that the daily or seasonal play of environment gets its response in the particular structure or habits of the organism or of vegetation at any given stage of its development. But I do not wish to push any such analogy. I merely wish to show the force of the idea that vegetation development is a march of progress which involves the attainment of a highly advanced and relatively stable condition from primitive or pioneer beginnings. We have viewed this progress both in the large (theoretically) and in detail by the study of actual vegetation stages.

1. *Review of Development in the Large.*

Geological records bear out these conclusions:

(1) That before the Glacial epoch, the vegetation of North America was composed of essentially the same range of floristic elements (many species being identical with those of the present), of the same diversity of growth forms and the same general segregation into zonal relations — especially deciduous forest, conifer forest and arctic vegetation — as at present.

(2) That the last great ice sheet must have obliterated vegetation from the northern half of the continent in eastern North America far enough southward to include practically the whole of New York State.

(3) That species which made up the flora were not all exterminated, for we have many of them still.

It is reasonable to assume therefore that these species — or many of those which covered the region invaded by glacial ice — migrated southward. Personally I like the view that the climatic conditions incident to the prevalence of such a field of ice so far south of the arctics would be equivalent to moving the climatic zones southward and one may imagine the zones of vegetation correspondingly pushed southward [1] Thus we may imagine a zone of tundra vegetation fronting the glacial margin, the boreal conifers next southward or at lower elevations, the Appalachian highland and the zone of deciduous forest still southward or below this, and warmer climate vegetation correspondingly displaced by the southward shift of climatic zones.

I think we must hold to the idea in any event that the floristic stock which now composes the essential body of New York species lay during the glacial epoch, in the Appalachian and adjacent regions to the south of the glaciated territory, and it was chiefly from this source that the returning vegetation came.

The course of their return is speculative. If one could hold to the comfortable theory that we have in all this glacial and post-glacial history an oscillation of zones from north to south and back, the matter would be for a broad view relatively simple. Adams [2] suggests that the northward migration following the retreating glacier would comprise three great waves of life. First, a wave of glacial or arctic vegetation of which we have remnants in New York on Mt. Marcy and two or three other high peaks. Second, a wave compris-

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[1] In this connection Chamberlin and Salisbury (Vol. III, p. 531) say: "Following the last ice-retreat the life of each of these sections moved northward, each biotic zone, arctic, subarctic, cold-temperate and temperate expanding as it went. It was as though the life-zones were elastic bodies which had been compressed to narrow limits about the edge of the advancing ice and then recovered their normal breadth as the ice pressure was withdrawn."

[2] Adams, C. C. Post-glacial origin and migrations of the Life of Northeastern U. S., Jour. Geog. I, 1902, p. 308 and following.

ing the northernmost tree species ("stunted willows, birches and alders") and then the boreal coniferous forest species ("spruce, larch, hemlock and pines"). Third, the wave embracing temperate zone deciduous forests. Harshberger [1] (p. 203), etc., holds that "several waves of plant migration may be recognized" (p. 204); namely, glacial vegetation, tundra, coniferous forests and, for eastern North America, the northward migration of the deciduous forest elements from "the South Eastern center." (p. 209.)

With our attention fixed upon the matter of vegetation development upon the glaciated terrain of New York, we should observe in all this post-glacial migration and adjustment the sequence of vegetation in progressive adaptation to a changing substratum plus a changing climate, being in succession prevailingly tundra, boreal conifer forest, and, finally, on the whole, deciduous or mixed conifer and deciduous forest of normal climax character based, so far as brief human history is concerned, on stable climatic conditions. That is the development of what for New York is the normal vegetation at its highest stage.

2. *Review of Development in Detail.*

This consisted in the construction of a story of development based on what we find happening in our vegetation today supported by obvious records of what it has done in the recent past. We found here that, viewing the water supply as the critical factor of the substratum, neither bare rock nor lake bottom (within the limits of sufficient light penetration) is a complete barrier to vegetation and that, starting from even these extremes, the course of events resulted in the building up of a substratum which, so far as water constancy is concerned, approached the same (mesophytic) condition for each, and that finally the same, or approximately the same, plant society comes to occupy both situations as well as the soils which originally stood at various interme-

[1] Harshberger, J. W. Phytogeographic Survey of North America, 1911.

diate points between the extremes of water deficit and water surfeit.

We have already pointed out (p. 26, that the fixed habitat relation or static character of the typical higher plant entailed the accumulation upon the ground it occupies of dead organic stuff, not merely the yearly fall of leaves, branches, fruits, etc., but the bodies of great trees and of generation after generation of whatever growth forms make up vegetation. Such accumulations constitute on the one hand a great supply of potential energy, but on the other a great menace that by their continued piling up they will make the site unhabitable. It seems to me that perhaps next to the wonderful photosynthetic power of plants, the manner in which this menace has been made a source of energy for further plant production is the most noteworthy. It looks as if the whole course of vegetation development as we have followed it tended toward the stage when this supply of potential energy should be made to yield actual productive energy, and that when this point is reached we have the possibility of producing not only the maximum plant growth upon the land but also the support of the most highly differentiated plant society. In our climate the natural vegetation in which these conditions are realized is the climax forest. In cultivated vegetation the maximum crop yield is realized when, other things equal, the highest energy yield of the soil is maintained. As to what this energy is and how it may be freed, we are learning by experience and research, but certainly a study of the behavior of native vegetation will also teach us.

Characteristics of a Climax Forest Society.

In a climax forest then, we have a number of environmental conditions and plant relations which may be best appreciated by stating them serially:

(1) As to the soil:

(a) It is mechanically affected by the penetration of the great roots of the dominating forest trees.

(b) It is well drained and well aerated.

Photo by W. L. Bray.

FIG. 41. Ground cover of bunchberry and yellow clintonia at Hoel Pond, indicators of boreal forest Zones D and E.

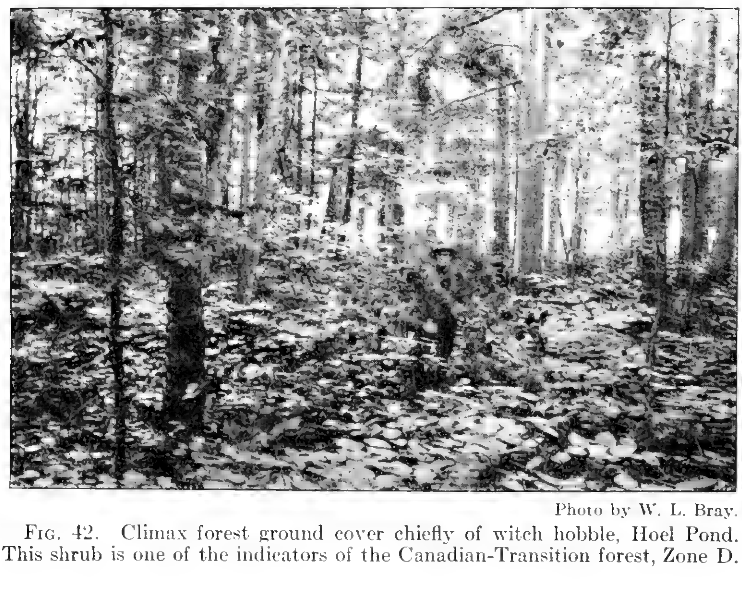

Photo by W. L. Bray.

FIG. 42. Climax forest ground cover chiefly of witch hobble, Hoel Pond. This shrub is one of the indicators of the Canadian-Transition forest, Zone D.

(e) It is densely populated by living organisms — notably fungi and bacteria — whose activity — especially of the bacteria — reduces the potential energy of dead organic stuff to productive energy (soluble nitrogen, etc.) and thus renders a fundamental service to the forest community both as to the food supply and by removing the menace of accumulating dead organisms.

(f) It is, therefore, rich in available soil nutrients.

(g) It is a sanitary soil in respect to being a "healthy" environment for bacteria, forest-soil fungi and for the roots and other imbedded living parts of higher plants.

(2) As to growth forms:

The climax forest is composed of a more highly differentiated association of adaptation forms or growth forms than any other plant society in our area. Without attempting to reduce these to a technical classification[1] we may list as somewhat on a previous page such "working units" as broad-leaved deciduous tree, evergreen needle-leaved tree, shrub types, plants with perennial woody roots and annual stems, forms of various degrees of stem-support requirement (sprawlers, climbers, twiners, etc.); monocotyledonous and dicotyledonous annuals, and perennial or renascent herbs (by bulbs, corms, rootstocks, rhizomes, etc.; here the great bulk of "spring wild flowers"); various ferns perennial by root stocks or elongated rhizomes; club-mosses, notably *Lycopodium lucidulum*. We may regard as growth forms in this connection mosses of erect and creeping habit, leafy and thalloid liverworts, the different types of lichens (crustose, foliose, fruticose) and fungi, at least so far as concerns the fruiting bodies — mushrooms and other fleshy fungi and woody fungi (bracket forming, etc.).

(3) As to growth relations:

The diverse relations which different growth forms occupy in the complex forest society is right impressive. We have to

[1] Taylor, Norman. The growth forms of the flora of New York and Vicinity. Amer. Jour. Bot. 2:23–31, January, 1915. Further references to the literature on growth forms may be found in this citation.

consider primarily the dominating forms, i. e., the trees with direct light exposure whose crown canopy is the chief factor in bringing about the differentiated light relations of the forest environment and in creating special atmospheric conditions (still, moist, cool air, reduced evaporation from the forest floor, disposition of rainfall, etc.) — items not peculiar, of course, to climax forest. A train of consequences follows the shutting off of direct light by the forest crown: in degrees of shade tolerance from the subordinate trees down to the members of the lowest stratum (mosses, liverworts, etc.); in habit, rate and form of growth of stems, size and structure of leaves, time of flowering, leafing, fruit ripening, seed dispersal, etc. The distribution of roots with respect to utilization of soil moisture and soil nutrients by the various associates of the forest may be considered as a noteworthy item under growth relations. Perhaps here, also, may be mentioned the forest floor species — trilliums and other liliaceæ, Jack-in-the-pulpit, wild ginger, pepper root, squirrel corn and the whole list of forest favorites whose perennial parts lie imbedded in the leaf mold or duff blanket and find therein congenial soil for vegetative propagation. The mat forming habits of mosses express features of growth relation of significance for the forest community (e. g. in the taking up and retention of moisture). The rôle of bacteria, forest soil fungi and wood destroying fungi has already been emphasized in connection with the removal of the menace of accumulating dead members or parts of the forest community and the transformation of these into available productive energy. This, of course, expresses most significant growth relations (notably saprophytism). Again, the phenomena of parasitism of fungi in general, but notably such cases as beech drops and broom rapes parasitic on the roots of forest trees. Finally, as perhaps the most unique aspect of growth relations, significant too in its social bearing, should be mentioned the phenomena of symbiosis as between fungi and the roots of forest trees (mycorhiza, mycosymbiosis), which is shown to be of rather general occur-

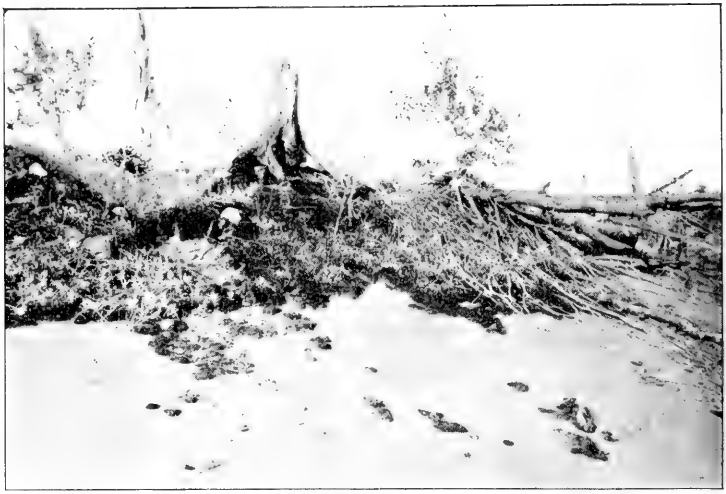

Photo by W. L. Bray.

Fig. 43. Bare polished granitic rock from which the "duff blanket" was burned by the Long Lake West fire of 1908. The moss-mat (*Polytrichum*) stage is making some progress in covering again this difficult type of substratum. The old stumps give some idea of the thickness of duff burned away.

Photo by W. L. Bray.

Fig. 44. View of a detail of the Long Lake West burn and the moss-mat stage of recovery. Some grasses and herbaceous annuals coming in. Also the aspen-fire cherry stage. The space beneath the buttresses of the stump indicates the depth of the duff blanket destroyed.

rence (on beech, birches, pine, hemlock, etc.). In this case the fungus sympiont is supposed to play a rôle in making available for forest trees the non-available nitrogen of the still unreduced organic debris of forest soil (forest duff). The logical outcome of this relation would appear to be reached in such a case as that of the waxy-white Indian pipe, whose whole nutrition economy (lack of chlorophyll, lack of normal branching and absorbing root system) has been reversed, as it would seem, so that one might regard it as parasitic on its fungus inhabitant. You will regard this statement, however, not as having any scientific status but rather as a manner of comment designed to call into relief phenomena which emphasize not merely the complex relations existing in climax forest but the interdependence of members of this association, or as one may say, social organization.

As a final comment on this subject of climax forest, it may be repeated that the stability or equilibrium of this stage of vegetation hinges upon the combination of factors which go toward maintaining a stable condition of the soil against the menace of an indefinite accumulation of dead organisms which brings into focus again one of the main problems worked out in the history of vegetation.

THE STATUS OF NEW YORK VEGETATION UNDER CULTURAL CONDITIONS.

The fact that so much space has been given to the presentation of the geographic relations of the native vegetation of New York should not be taken as ground for concluding that in the eyes of a botanist the native vegetation is at present the matter of greatest consequence to us in an economic sense. The point of view has been that the "genius" of our vegetation, when we come to appreciate it fully, will furnish essential knowledge and suggestions for the adoption of a rational philosophy as to the conservation and further development of the plant producing power of the land as well as for the utilization of those features which contribute to the enjoyment and stimulation of the mind and the health and vigor of the body.

We come now to remark that the greatest thing which we face at the present moment is the accumulated effects of three hundred years of invasion of this terrain by civilized man. By this I do not mean a survey of all that man has accomplished, but the effects upon the vegetation itself and upon the land which it occupied and in some measure still occupies. This is not to be assumed to be a statement which would detract from the pride and complacency with which we are want to view the great things accomplished by man in working out his civilization in this new land. But now that a day of conscientious taking of stock has come, and we are engaged in advocating a future policy in harmony with present scientific knowledge and social conscience, I think we are pretty generally agreed that our resources so far as they were expressed in forest and especially in the plant producing capacity of the land have on the whole been rather badly handled. We are forced to this conclusion when we observe how large a percentage of our land is not at the present producing anything of value or at any rate a reasonable return, and worse, not in a position to become productive land in any adequate sense. One recalls in this connection the depressing landscape of cut over and burned over lands in the Adirondacks and Catskills, the waste, scrub-timbered hill lands of the Alleghany Plateau and the Hudson Highlands, the poor pastures and run down farms of hill lands and swamp lands yielding no good forest and still undrained for crop yield.

The fact is, we are right at the point of appraising our lands and of making a classification and allotment with respect to their permanent productive capacity whether as farm lands or as forest producing lands with the added function of protection of soil cover, water storage and run off and of preserving the natural loveliness of the state and its facilities for recreation. By "we" I mean not only all of us as citizens of New York State but the private land owner also who

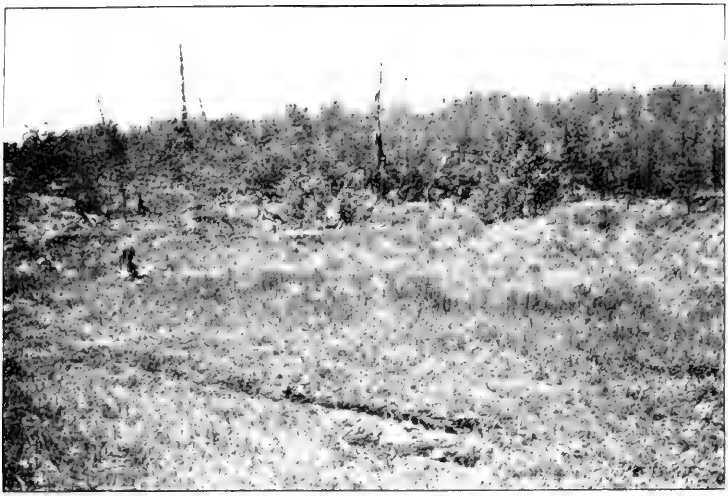

Photo by W. L. Bray.

Fig. 45. The aspen-fire cherry stage of vegetation seven years after the Long Lake West fire. The foreground shows grass sod formed on raw forest duff and sand after clearing and trampling by stock. A dairy farm with clover fields, etc., has been established near this.

Photo by W. L. Bray.

Fig. 46. The red raspberry thicket stage of vegetation following logging and burning of climax forest in the Adirondacks. (Cranberry Lake Inlet.)

in his individual interest cannot remain wholly unimpressed by the force of public opinion and by the more rational sense of obligation and opportunity. But no doubt a good deal of our land has been reduced to so low a state of productive value or ability to regain this, that its restoration to a productive capacity can take place only by combined effort either of all the people of the State or by different communities or associations over the State. There are agencies enough if well organized and effectively put in operation to work quite revolutionary changes in the plant producing power of the land. To be counted among these agencies are: the small land owner who wants to utilize all the available knowledge there is, based on experience and investigation, in the handling of low-priced hill lands to get fair return on his investment — especially of labor — in field crops or pasture or timber and perhaps a well balanced arrangement of all three; the large owner of timberlands who believes that present knowledge and economic conditions warrant him in undertaking to keep his lands permanently at work yielding timber, and the vegetation cover effective in increasing the yield power of his land as well as its protective value for water supply; the societies that have aims of social service such as the preservation of wild flowers, or natural scenery or the reservation of recreation parks, or camping sites for people generally; the clubs which aim to promote outdoor life and the sports of fishing and hunting; and finally, the application of the already effective State policy in these connections, whether through its special Commission or through its technical institutions of instruction and investigation.

In this land allotment or classification with regard to its capacity to produce farm crops, or a forest cover and timber crops, previous experience and financial returns should be a guide, but these items will not always furnish a basis for final judgment as to whether any given tract is better for the one thing or the other. Hill farms may have been abandoned as not yielding a return by methods practiced, while another system of farming might make them pay — particularly as adjuncts to valley farm lands. This is not a plan to restrict the area of farm lands unless these lands can be shown to yield a larger prospective return in the long run in forest growth. In forming such a judgment one needs to be reinforced by a knowledge of soil conditions and of the proggress and results of the development of a forest cover. In fact this whole important matter of policy and its specific application is a field in which the knowledge of the soil specialist, the forester, the botanist and other specialists may be profitably applied and indeed is being applied extensively already.

Taking a broad view of the State, then, as to the status of "man's invasion of the land," the native vegetation is scarcely unmodified over any considerable area, but the vigor of its persistence and tendency to reëstablish itself is visible everywhere, and constitutes a force that must be reckoned with in so far as this vigor tends toward the invasion of valuable farm lands (as for example in the invasion of pasture lands by shrubs, etc., and in the growth of forest weed-trees instead of desirable species on hill lands and in swamps or wet lands). On the other hand, this vigor of asserting itself on the part of our native vegetation constitutes one of the "forces of nature" which may be controlled and utilized for productive purposes. Still more serious is the extent to which the character of the soil itself has been changed by human interference. Of course a lot of it has been put into a condition of permanent agriculture and this constitutes the largest resource of all, being indicated by the agreeable outlook of well kept fields and pastures and quite generally of fairly well tended woodlots and the prosperous look of farm buildings and surroundings. But over a discouraging proportion of the State, the soil has been reduced by the human factor to a condition of unproductive yield expressed in heath shrub, ferns and moss mats, sweet fern, sumac and thorn shrub, aspen and fire cherry and white birch, dwarf juniper, bracken and pasture weeds. Certain cases may be specified more in detail.

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FIG. 47. Depleted pasture land of a hill farm in Chenango County, N. Y. The mats of moss (*Polytrichum*) suggest the beginning of heath-like vegetation of certain sand barrens. The soil no doubt shows acid reaction.

By permission of U. S. Dept. of Agriculture.

FIG. 48. A hill-land pasture invaded by ferns, chiefly hay-scented fern. This is a common aspect following removal of the forest cover and the deterioration of the soil through farming or pasturing.

1. *The Hill Lands of the Alleghany Plateau.*

In this case the value and effectiveness of the forest cover have been reduced to the non-interest paying stage by destructive lumbering and in many cases where hill lands are or were farmed by equally "destructive" farming. By this I mean that the methods pursued were of a kind to depreciate the crop yielding power of the land. In the first place, if it is a question of leaving cut-over lands to return to forest conditions, the sequence of vegetation — grasses and annuals, briars and shrubs, sprout growth and forest tree "weeds" (i. e., undesirable trees)— involves a long stage of development during which no returns may be harvested and therefore the present generation can make only the meager profit of forage pasturing and perhaps of fuel, depending upon how closely the land was lumbered. In the second place, farming operations, of course, broke up and mostly destroyed the blanket of organic soil built up by the preceding forest growth. With the removal of this humus forming and energy giving cover, the structure of the soil was changed until it has become deficient in aeration and drainage and no doubt in healthy soil organisms — nitrifying bacteria notably — and so is in fact or in effect a sour soil. The vegetation stages reflect this, notably in the formation of extensive moss mats (of *Polytrichum* chiefly) fern thickets (sometimes pure stands of hay-scented fern (*Dennstaedttia punctilobula*) and acres of sweet fern (*Comptonia perigrina*) (Figs. 47 and 48). This would suggest a reversion to a xerophytic or heath-like stage (though the particular fern-growth cited would also indicate hillside seepage).

2. *The Highlands of the Hudson, etc.*

On the whole my impression as to the status not only of the "Highlands" proper but of hill-lands along the Hudson generally — Westchester hills, etc.— is that the protective effects of forest cover — the organic soil blanket — have been so far degraded that the vegetation shows an undesirably strong tendency toward xerophytism. The frequence of

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FIG. 49. A hill farm on which a heath-like vegetation — largely sweet fern — is invading the grassland stage. It is in such cases that the soil structure has become degraded.

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FIG. 50. Pasture land in southern New York reverting to forest. The grassland is being invaded by ferns, small shrubs and the advance guard of forest trees.

heath shrubs (e. g. *Vaccinium vacillans*), New Jersey tea (*Ceanothus americana*), braken fern (*Pteridium aquilinum*), etc., in forest stands or woodlands seems to indicate this, as do the barren ridges of red cedar, broom beard-grass and white birch and even the general dominance of rock-chestnut oak and of sprout chestnut growth, e. g., on Interstate Palisades Park lands. It seems pertinent in this connection to remark that the dominance of oak is so frequently associated with edaphic conditions which promote aridity, that our conclusions as to the climatic relations of the oak-chestnut-hickory type must be somewhat modified by this consideration.

3. *Lumbered and Burned-over Lands of the Adirondacks.*

In this great natural forest region which is also our chief recreation ground, the effects of the "era of civilization" are seen in their most unfortunate aspects. The effect of our policy of harvesting the timber crop has been to throw the land back to an arid condition where the constructive work of forest growth has all to be gone over again. Nearly all this unfortunate acreage of cut and burned-over land is simply a forest weed patch so far as desirable timber is concerned. We have already considered briefly the general course of vegetation following lumbering and fire, particularly on sandy soils. But there is worse than the arid sand. Every observant traveler through the Adirondacks has noted — no doubt with poignant regret — the more or less continuous horizon of bare rock. This we have attempted to show, stands as the extreme of aridity. Also we know the slow, if inevitable, process by which vegetation again covers most even of this difficult terrain. A good deal of the organic stuff — forest duff — is left after fire, but in a condition such that it becomes dust dry during drought periods. Thus practically all such lands are in this condition; namely, that the soil water supply too readily falls to a point where the amount which the root system can absorb is too small compared with the amount which the foliage gives

Photo by Glenn, Albany.

Fig. 51. The Mohawk Valley near Rome showing glaciated contour, the development of agriculture upon it and the

off into the air to permit more than a dry land or xerophytic vegetation or at any rate a more tolerant vegetation than the associated species of the climax forest.[1]

I take it that this condition of the moisture relation accounts quite as much for the success of *Polytrichum,* bracken fern, blueberry patches, raspberry thicket and the forest-weed species of aspen, fire cherry and white birch as the factor of soil acidity or the earlier seeding by these species rather than maple, beech, yellow birch, hemlock and white pine.

In all these cases the practice of afforestation by planting will have to take account of this essentially more arid condition of the land than prevails in the natural habitat of some or most of the species which it is sought to plant. The natural sequence of vegetation upon such lands or in any case leading to climax forest may prove to be a most useful suggestion to the forester.

There grows out of all this also the obvious suggestion that a lot of questions have arisen which can be solved only by scientifically conducted investigations.

Conclusion.

It will have become obvious to anyone who has read any considerable portion of this bulletin that it represents the method of the teacher rather than the output of an investigator. The bulletin will in fact have accomplished its purpose if it proves effective in leading the reader to take a certain viewpoint from which to regard the vegetation of his State and particularly if it should stimulate further and more detailed studies of it and, in a measure at least, point out where these fields of investigation lie and what may be expected as the outcome of them.

As to the viewpoint, it is simply to keep in mind the whole forward movement — the dynamics — of the plant life of the

[1] In this connection, see Pearson, G. A. The Rôle of Aspen in the Reforestation of Mountain Burns in Arizona and New Mexico. The Plant World, 17:1914, pp. 249–260.

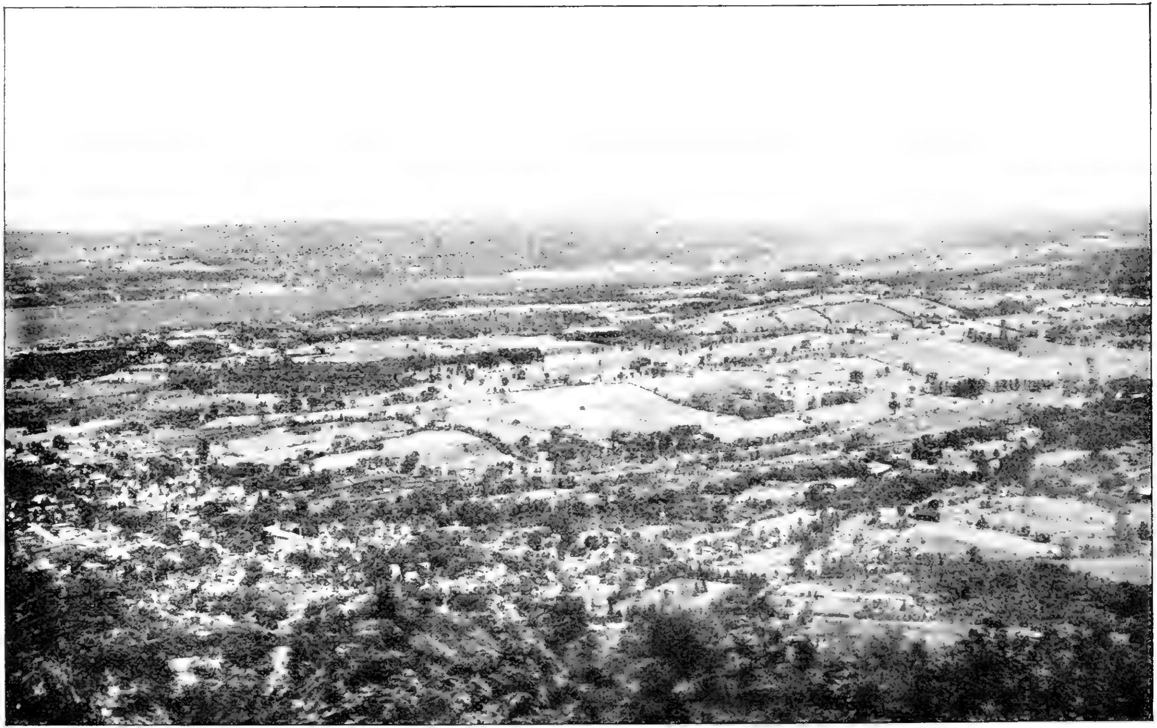


Photo by Glenn, Albany.

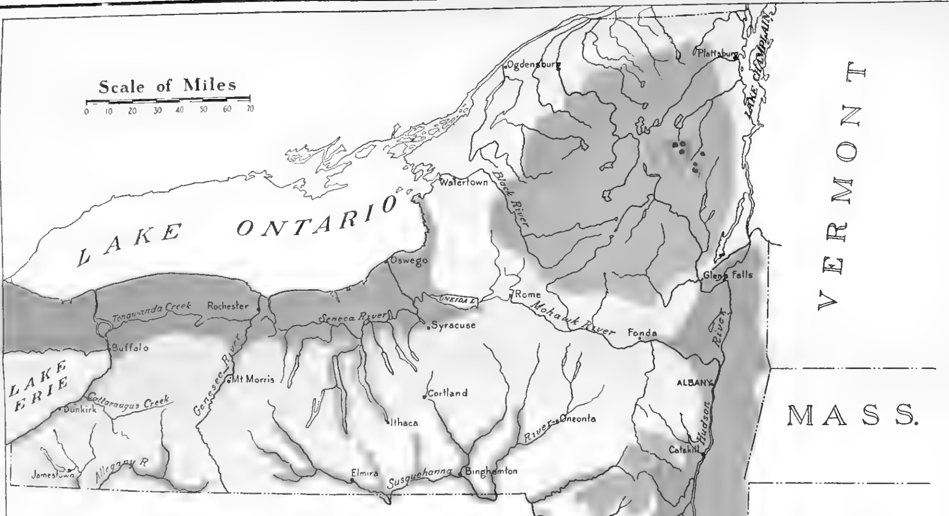
Fig. 52. The Hudson Valley and Highlands from Beacon Mountain showing the land under cultural conditions.

area we are concerned with, seeing in it a more or less definitely organized mass movement of associated living plants, whose momentum and efficiency in occupying and transforming the land are qualities that the vegetation as a whole has come to possess through ages of environmental experience, not the least item of this experience being the contact of plants with each other and the mutual relations growing out of this contact and competition. Thus viewing vegetation, the developmental history which has in a measure been here portrayed becomes a vivid field of action in which one may discern the qualities and aptitudes — the special genius as we have before said — of our native vegetation.

You will recall that this historical review carried us back into geological time when we could discern the dawn of modern aspects of plant life, from which in a later period we could follow the elaboration of the wealth of species, the diversity of adaptation forms and the segregation of floristic zones and vegetation aspects which characterize the earth's vegetation of to-day with its dominant group of angiosperms — perhaps one might venture to say the dominance due to the efficiency of floral structures. We saw the vegetation obliterated from this area by glacial invasions, and especially taking the last glacial retreat as a landmark on the one hand, we were able to judge as to the completeness with which vegetation had covered the glacially prepared terrain, and what effects had been wrought upon the land by the beginning of the present period of human occupancy. We could see in the return of vegetation to the glacially denuded terrain, not only a mass migration in which species at last settle down into their larger zonal or climatic relations, but even more important for us, we could follow, as to-day we can follow, the sequence of events as vegetation invades each aspect of the substratum and through a succession of vegetation types — as aquatic, marsh, marsh-meadow, swamp forest associations — comes at length to a stage of relatively stable equilibrium, i. e., a climax society which in this climate is forest.

Now it is my conviction that this way of viewing vegetation at work will prove to be a dynamic idea no matter whether one aims merely to enlarge the horizon of mental culture by a wider and deeper knowledge of what and how and why things are in the plant world, or whether he is enjoying the beauty or other qualities of field and forest for the good of his mental and physical health, or whether we undertake the solution of biological problems such as the control factors in bog development, or whether we set out to determine a sound policy for dealing with the land as relates to the pursuit of agriculture or the practice of forestry upon it. Certainly also, and particularly, the forester will be the better able to elaborate a policy of silvicultural practice, of forest management and so on if he is able to base his work upon an intimate knowledge of the factors — of geologic as well as present time — that shape the development of his forest.

I am concerned, finally, as a long time teacher of botany, that this method or phase of botanical study — call it dynamic botany or plant geography or whatever — should be recognized *as botany.* A good deal of the sort of thing that has passed as botany has been of a feeble character which tended to rob the subject of the record for virility which is due it. On the other hand, some of the intensive laboratory courses which have been evolved as educational means, have left the student of botany without orientation in the world of out-door plants. We have at length, in any event, to study growing plants in all possible environments and relations in order to interpret yet more of the details which shall enlarge the sum of our knowledge of the story of plant life. Certainly we may with profit pursue some of these studies in the field to which these pages aspire to offer an introduction.



OUTLINE MAP OF THE STATE OF NEW YORK SHOWING THE LOCATION OF

= Zone A; Southern species; sweet gum, willow oak, persimmon, etc.

= Zone B; Chestnut, oaks, hickories, tulip-poplar, etc.

= Zone C; Sugar maple, beech, yellow birch, hemlock, white pine, etc.

= Zone D; Dominant trees of zone C plus red spruce, balsam fir and paper birch.

= Zone E; Canadian zone, red spruce, balsam fir, paper birch, mountain ash, etc.

= Zone F; Arctic-circumpolar plants. Tundra-like vegetation.

Mrs. Britton

Compliments of

Chas C Adams

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AT

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BY

FRANK COLLINS BAKER

Prepared under direction of Chas. C. Adams

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HUGH P. BAKER, Dean

The Relation of Mollusks to Fish in Oneida Lake

BY

FRANK COLLINS BAKER

Prepared under direction of Chas. C. Adams

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BIBLIOGRAPHY

The following is a list of some of the more important previous publications on Fresh Water Mollusks by the author of this bulletin, Frank Collins Baker, late Acting Director of the Chicago Academy of Sciences, and Zoological Investigator during 1915–16 for The New York State College of Forestry. A more complete bibliography will be found in the Monograph of the Lymnæidæ, mentioned below. (1911, b.)

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PREFACE

From the very beginning of its work the New York State College of Forestry has looked upon the development of forestry in New York as an essential phase of the land policy of the State. Three hundred years of agricultural history in New York has brought our people to see agriculture as including not alone the growing of crops from the soil and the production of animals for food and draft purposes but, in many instances, the manufacture of the crude products from the farm, such as in the dairy industry and then finally the marketing of the crops produced on the farm. Such a broad, comprehensive definition of agriculture has been necessary in the formulation of policies for the right handling of the agricultural soils of the State. So, too, in those definite policies for the use of *all* our soils, which unfortunately are not yet satisfactorily formulated, there must be an equally broad application of forestry to the non-agricultural soils.

Forestry means not alone the growing of a crop of trees from the soil for the production of wood, but it includes as well the conservation of water by the forest and the perpetuation of the animal life of the forest where that is beneficial. Therefore, in all of its plans for investigative work in forestry in the State, the College has considered not only the value of the non-agricultural soils for the production of forests but the life of the forests and the forest waters and the use of the forests and the forest waters in the most reasonable and effective way. In considering the question of forestry in this broad, constructive way, the College is not original but is merely using the same vision for the future which has been used during the past century in such European countries as Germany and France, who have made their forests so important a part of their industrial and commercial development.

After the instructional work at the College was under way in the fall of 1912, preliminary studies were carried through with the idea of laying out definite plans for both the educational work of the College and its investigational work. By its Charter the College is obliged to do both educational and research work in forestry. The foresters who came to the College in 1911 and 1912 were so occupied with the organization of teaching work and the general educational work through the State, that the plans laid out for them along investigational lines could not be touched during the first year. Fortunately, upon consultation with the Departments of Botany and Zoology in the College of Liberal Arts of the University, men were found who could give a part of their time to the beginning of investigative work planned by the College. Dr. William L. Bray, in charge of the Department of Botany in the College of Liberal Arts of the University, began in 1912 the studies of the development of the vegetation of the State which have been partially completed and which have resulted in part in the report issued in November, 1915, on "The Development of the Vegetation of New York State." Dr. William M. Smallwood, of the Department of Zoology of the College of Liberal Arts, who has spend many summer seasons in the Adirondacks, became interested at once in the study of the fish of the Adirondacks and his field studies in 1911 and 1912 resulted in the first technical bulletin issued by the College. This is entitled "Preliminary Report on Diseases of Fish in the Adirondacks, a Contribution to the Life History of Clinostomum Marginatum."

The student body of the College developed so rapidly in 1912 and 1913 that it became advisable to establish within the College a Department of Forest Zoology and Entomology, and this Department is now in charge of Dr. M. W. Blackman, Forest Entomologist. In the fall of 1914, Dr. Charles C. Adams came to the College from the University of Illinois, to take charge of the work in forest zoology, which it is desirable to develop in the Department. It then became possible to emphasize in the training of forestry students that the fundamental principles of conserving the fish and game of forest lands as agriculture includes the raising of animals upon agricultural lands. To make instructional work in forest zoology concrete and practical, field studies were begun of both fish and vegetable life in fresh water lakes in nearby forest lands. The College believes that such studies will emphasize especially the influence which animals of all kinds exert upon the forest and therefore upon forest administration in the State.

The College of Forestry was surprised to find there had been little previous investigation of fish life and its relation to vegetation in the forest streams and lakes of the State. Furthermore, the College found that no other institution in the State was devoting its attention to the investigation of this problem or was known to have it in prospect, therefore, it planned to enlarge and carry forward the plans begun in 1912, as outlined above. New York has drawn very heavily for information upon the study of fish made in other states and by the Federal government and it has not so far taken its full share of the burden of investigation along this line. The time has now arrived when the State should take more active part.

Because Oneida Lake is within easy reach by trolley from the College and because it is unique in many ways as a fresh water lake, Dr. Charles C. Adams urged that the systematic investigation of fish problems in the State begin with this lake. Therefore, in the summer of 1915, with the cooperation of Professor T. L. Hankinson of the Eastern Illinois State Normal School of Charleston, Ill., and Mr. Frank C. Baker, formerly Acting Director of the Chicago Academy of Science, he began a comprehensive study which has resulted in part in this report. Messrs. Adams and Hankinson have devoted their attention to the general survey of the fishes of the western half of the lake and during the coming summer season of 1916 will continue this survey. Mr. Baker devoted his attention to a study of the relation of the mollusks to the fish especially in the western half of the lake and the results of this study form the present bulletin.

The studies of the past season have demonstrated very effectively the practical and scientific value of investigations of the fish life of the forest streams and lakes of the State. These studies open up definite lines for future procedure and development. It has long been known for instance that certain fish feed largely upon snails and mussels, but this is a subject which has not been previously investigated carefully in any eastern state Mr. Baker's years of work with the Chicago Academy of Science, his specialization upon the Mollusca which are shown in his papers, "The Ecology of the Skokie Marsh Area, with Special Reference to the Mollusca" (1910), and "The Molluscan Fauna of Tomahawk Lake, Wisconsin" (1911), made him as well fitted to carry on studies resulting in this report as any man in the United States.

Summarizing briefly from our present knowledge of the feeding habits of fresh water fish in New York, we know that 30 out of 158 species, or about 1/5, consume mollusks in varying quantities, the ratios running from 1 to 100 per cent. If we take 25 of the most important food and game fishes that occur in New York State, we find that mollusks provide 31.5 per cent. of their food. Of six of the most important fish eating food and game fish, mollusks form 15 per cent. of the food, indirectly. These figures indicate the importance of mollusks in relation to our food and game fishes and indicates the necessity of preventing conditions adverse to the development of mollusks. In this study, Mr. Baker and those associated with him, have examined 130 specimens belonging to 16 species.

It is expected that Messrs. Adams and Hankison will complete their general studies of the fish life of Oneida Lake this coming season and that a comprehensive report upon their work will appear in the near future. Other and similar studies of the fish and animal life of our forests and their waters will be continued from year to year, thereby carrying out the general plan of investigative work by the College.

HUGH P. BAKER.

CONTENTS

PAGE.

ILLUSTRATIONS

All photographs and other illustrations were made by the author except when otherwise stated.

INTRODUCTION

The chief purpose of the study described in the pages that follow has been to ascertain the character and abundance of the molluscan fauna — the snails and clams — that inhabits Oneida Lake, and its relation to the fish fauna as food. In other places, notably in Illinois, mollusks have been found to constitute an important item in the food supply of such fishes as whitefish, sturgeon, suckers, carp, catfish, sunfish, and other bottom inhabiting fish, and it was thought that similar studies in Oneida Lake would add greatly to our present knowledge concerning the food and food-habits of fish.

The plan of the work carried on during the 1915 field season was to study the west end of the lake rather closely. As time was not available to cover all of the ground, stations were established wherever a locality seemed favorable. By this method all of the principal types of shore life were examined. Collections of all mollusks found at each station were made and now form a part of the study collections of the New York State College of Forestry. Collections of associated animals have also been made and preserved in the collection, as well as the contents of the stomachs of the fishes examined.

Plan of the Investigation. The plan of this report is to show the relation of a group of animals — the Mollusca — to the environment, to the fish fauna, and to all other associated animals. This is brought out in nine related chapters: I, Physiography and Glacial Geology, in which the lake is considered from a physical standpoint; II, Description of the Habitats and their Molluscan Population, in which the different types of habitats are described and their animals and plants listed; III, Biological Valuation of the Lake, in which the Mollusca are considered as a food supply, the food and feeding habits of this group being also considered; IV, Mollusks as Food of Fish, in which the stomach contents of many Oneida Lake, as well as other, fishes are described, and a resume given of our present knowledge concerning the use of this class of animals as food for fishes; V, Mollusks as Parasites of Fish, in which the development of young clams as parasites of fishes is considered; VI, Enemies of Fresh Water Mollusks, in which are noted those animals that feed upon or affect mollusks in any manner; VII, The Classification of Oneida Lake Mollusca, in which the different species of mollusks found in Oneida Lake are considered from a systematic standpoint and their peculiarities of station or distribution commented upon; VIII, Plants and Animals associated with Mollusca, in which the animals found in association with the mollusks, as well as those obtained from the stomachs of fishes, are listed and commented upon; and IX, Summary and Discussion, in which the work is summarized, certain ideals of biological research are discussed, and suggestions are made for further work on the lake. A rather full Bibliography completes the report. For the benefit of those students who may wish to carry on studies such as are outlined in this report, the species of mollusks inhabiting Oneida Lake have been figured. The authority for the names of animals listed in the body of the work will be found in chapters VII and VIII.

Equipment and Methods of Work. September and a part of October were given to studying the biology of the lake. A laboratory was established on the north side of the outlet near Brewerton (Central Square rural delivery), with an adequate equipment for carrying on field studies. The lake studies were made in a gasoline launch and in a large, round-bottom rowboat of light draft. The map of Oneida Lake, Chart No. 4, New York State Canals, U. S. Lake Survey Maps, issued by the War Department, was in constant use for establishing stations and making observations. The use of this map saved a large amount of time that would otherwise have been spent in compiling a rough map and in making soundings. It is a pleasure here to acknowledge the aid afforded by this map and to say that it was found uniformly accurate. (See Fig. 1.) All stations were examined carefully, either by wading or from the rowboat where the water was too deep for wading. A single station received from an hour to a day's time, according to its importance. A representative collection of the biota from each habitat has been preserved in the collection of the New York State College of Forestry. The fishes examined for their stomach contents were largely collected by Doctor C. C. Adams and Professor T. L. Hankinson during parts of August and September. They were mostly from the same localities as the mollusks.

The collecting apparatus consisted of Walker dredges, dip nets, water telescopes, vials and bottles of many sizes, mason jars and tin containers for large specimens. The photographs were all taken with a 5 x 7 camera. A crowfoot dredge (Figs. 49, 50) four feet in length, made in a manner similar to those used on the Mississippi River, was operated successfully for collecting the clams from the deeper parts of the lake. This was also found useful in gathering samples of the bottom flora. To insure accuracy the description of each habitat, and the records of the presence of mollusks on vegetation, were dictated to an assistant in the boat while the collector was wading about or making observations from the boat.

Acknowledgments. These studies have been carried on under the direction of Doctor C. C. Adams, Forest Zoologist of The New York State College of Forestry, and to him and to Doctor Hugh P. Baker, Dean of the College of Forestry, the writer is indebted for the opportunity of carrying on these interesting investigations. The author is especially indebted to Doctor Adams for counsel and suggestion during the progress of the work which have materially added to the usefulness and value of the report. Professor T. L. Hankinson, of the Eastern Illinois Normal School, Charleston, Illinois, has identified the fishes and has critically reviewed the manuscript of the chapter on "Mollusks as Food of

Fish," and to him the thanks of the author are due. Many people have contributed to the success of the work, either by reporting upon critical material or by making suggestions of value during the progress of the investigation. To these, whose names appear in the appended list, the writer desires to express his deep appreciation.

Mrs. Frank C. Baker, Syracuse, N. Y., assistance in collecting material.

Dr. Cornelius Betten, N. Y. State Agricultural College, Cornell University, Ithaca, N. Y., *Trichoptera.*

Dr. M. W. Blackman, N. Y. State College of Forestry, Syracuse Univ.

Dr. Wm. L. Bray, Syracuse University, *Plants.*

Dr. Harry P. Brown, N. Y. State College of Forestry, Syracuse University, *Plants.*

Mr. Frank S. Collins, North Eastharm, Mass., *Algae.*

Dr. E. P. Felt, State Entomologist, Albany, N. Y., *Publications.*

Mr. Wm. J. Gerhard, Field Museum of Natural History, Chicago, Ill., *Coleoptera* and *Hemiptera.*

Mr. John R. Malloch, Illinois State Laboratory of Natural History, Urbana, Ill., *Chironomidæ.*

Dr. C. Dwight Marsh, Bureau of Plant Industry, Washington, D. C., *Copepods.*

Dr. J. Percy Moore, University of Pennsylvania, Phila., Pa., *Leeches.*

Dr. James G. Needham, Cornell University, Ithaca, N. Y., *Odonata.*

Dr. A. E. Ortmann, Carnegie Museum, Pittsburgh, Pa., *Crawfishes.*

Dr. H. A. Pilsbry, Academy of Natural Sciences, Philadelphia, Pa , *Amnicolidæ.*

Dr. Victor Sterki, New Philadelphia, Ohio, *Sphæriidæ.*

U. S. Bureau of Fisheries, Biological Laboratory, Fairport. Iowa (through the director, Dr. Austin Shira), a crowfoot dredge.

Dr. Bryant Walker, Detroit, Michigan, *Ancylidæ, Amnicolidæ*, etc.

Miss Ada L. Weckel, Oak Park, Illinois, *Amphipods.*

This work is an effort to place on record an intensive study of one group of animals — the Mollusca — and to show how this group is economically valuable in carrying on fish cultural operations. It is likewise an attempt to indicate some of the biological interrelations between this group and the animals and plants with which it comes in contact. It is now known that this class of animals can be artificially introduced into bodies of water, in which they are naturally lacking, and the time is not far distant when this procedure will become common practice. It is the earnest wish of the writer that the information set forth in this report may awaken more of an interest in this group of animals and encourage more students to take up their study.

SYRACUSE, *March* 15, 1916.

DEPARTMENT OF FOREST ZOOLOGY.

CHAPTER I. PHYSIOGRAPHY AND GEOLOGY.

1. Description of the Lake. (Fig. 1.)

Oneida Lake lies near the center of New York State in latitude 43° N. and longitude 75° W. Oswego and Oneida counties border the lake on the north and Onondaga and Madison counties on the south. It is 27 miles southeast of Lake Ontario. It is eleven miles north of Syracuse, from which it may be reached in less than an hour by either steam railroad or trolley. Train schedules are frequent during the summer months, and the lake is, therefore, easily accessible from the College of Forestry for purposes of study. The lake is oriented almost directly east and west, which is the longer axis, and is 21 miles in length by 5.5 miles in greatest width. The level of the lake is 369 feet above the sea, or 124 feet above Lake Ontario. The greatest depth recorded is 55 feet, which occurs about 1.5 miles southeast of Cleveland.

The shores are relatively very low, as the lake is in the bed of an ancient lake, lacking the bold character of the country to the south and east, where occur rock-cut valleys, large glacial moraines, and extensive drumlins. This general depression of the country immediately surrounding the lake produces low, swampy shores on many parts of the lake, especially at the east and west ends. The greatest elevation of land is found between Cleveland and North Bay, on the north shore of the lake, where altitudes of 440 to 460 feet occur, rising 71 to 91 feet above water level. On the south

Fig. 2. Cross sections of Oneida Lake. A, Section from Shaw Bay southward on line of 76° 05′ longitude. B, section from Phillips Point south to Norcross Point, cutting through Frenchman Island. C, Section from Constantia south to Maple Bay, on line 76° 00′ longitude, cutting through islands and shoals. D, Section from Bernard Bay south of Shackelton Point. E, east and west section from Brewerton to Shackelton shoals. Horizontal scale 3¼ inches to the mile, A–B; 1⅝ inches to the mile, D. Vertical scale 1/32 inch = 2 feet.

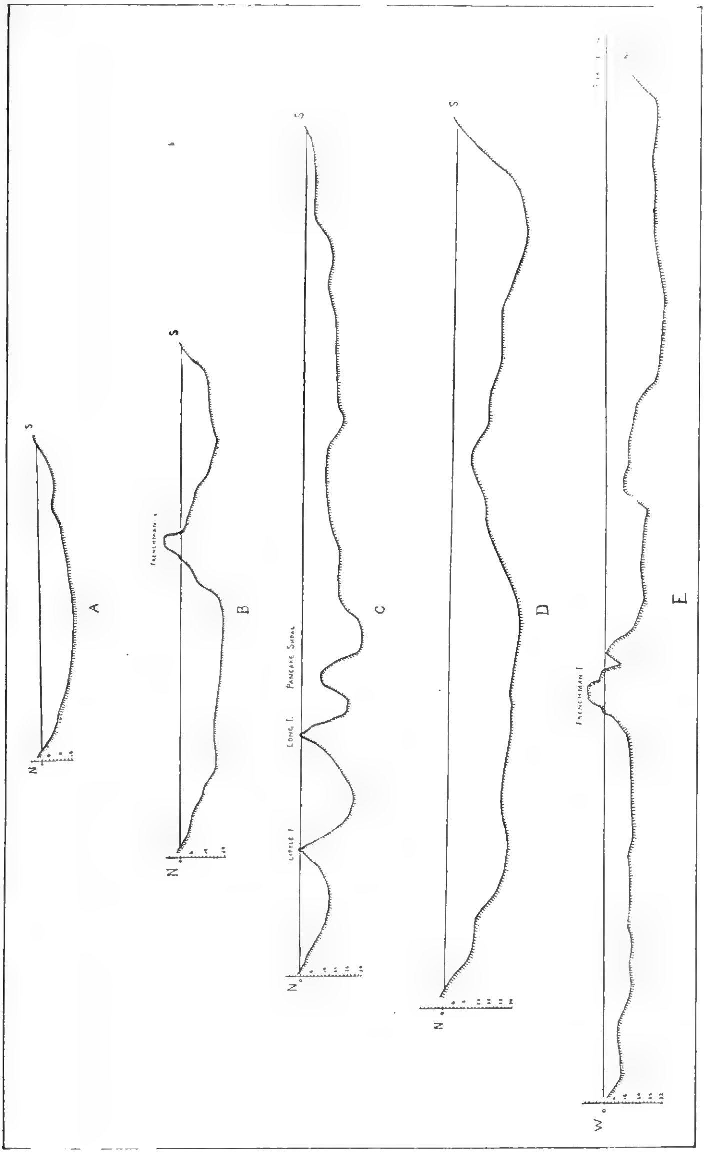

Fig. 2.

shore elevations seldom exceed 400 feet, or 30 feet above lake level.

The construction of the Caughdenhoy dam in the Oneida River, completed in 1909, as a part of the State Barge Canal system, raised the water level several feet, thereby flooding large areas, one especially notable area being on the east side of Big Bay. Large natural swamp areas also occur at Maple Bay, west of Constantia, west of Lower South Bay, and at the east end of the lake. These large swampy tracts cover areas of from four to five square miles. To the south, at a distance of about two miles, lies the large Cicero Swamp, having an area of eight square miles. Several miles west of this swamp area another but smaller swamp occurs.

Oneida Lake is the largest of the inland lakes in the State, having an approximate area of about 80 square miles (51,200 acres) and a shore line of approximately 65 miles. Cross sections of the lake (see figure 2) indicate the basin to be a somewhat saucer-shaped depression, deepening toward the eastern end. The areas bordering the shores are always shallow and usually deepen rather abruptly, forming, in many places, submerged terraces of greater or less width. These terraces are either sandy or bouldery in character, and usually the latter, the rough water washing out the fine particles and removing them to the quieter bays and protected areas near the points. For this reason the points are always stony or bouldery and the bays sandy. A notable fact recognized very early in the investigation was the almost total absence of mud on the shores of the west end of the lake. Muddy areas were observed in several places, notably at the mouths of small creeks, but in the greater part of the area examined there was a hard, sandy or stony bottom.

The wind currents of the lake have cut many points, carrying the eroded material into quieter water, and have in some places formed wave cut terraces, as on Frenchman and Dunham Islands, and along the south shore near Shepard Point. Shallow bars and sand spits have been formed in many places, notably near Long Point and in parts of Lower

South Bay. The fine material washed from the bouldery points, together with the abundant vegetation, is slowly filling up the shallow bays. It seems evident, however, that the presence of such plants as the Water Willow (*Dianthera*) and Bulrush (*Scirpus*), which frequently grow in dense masses on some of these points, prevent excessive erosion in much the same manner that vegetation does on land areas.

As has already been stated, shallow areas border all parts of the shore line. This shallow zone, which is from two to six feet in depth, varies in width from 200 to 1,600 feet, and in one instance (on Frenchman Island) attains a width of nearly 2,000 feet. The approximate area of shallow water, six feet or less in depth, is upwards of 189,462,102 square feet or 4,349 acres (6.80 square miles). This is significant when it is remembered that this shallow water terrace is nearly all covered with vegetation and is the area which supports most of the animal life and affords the breeding grounds for the majority of the fishes in the lake. If we include the bottom area enclosed by the twelve foot contour, below which, according to Pieters (1901), little or no vegetation lives, we find a total approximate area of 363,420,004 square feet or 8,343 acres (13.03 square miles) which affords feeding grounds for fishes and other animals, or about 16 per cent of the total lake area. Forbes (1887, p. 6) calls special attention to the significance of this shallow, vegetation covered area and its relation to the animal life of a lake. These shallow places are especially well marked in Big Bay (867 acres) and Lower South Bay (586 acres), as well as around Frenchman and Dunham Islands (331 acres).

The hydrographic basin of Oneida Lake is relatively large, reaching a distance of 35 miles on the north, 10 miles on the east and 20 miles on the south. Roughly, it embraces an area of approximately 1,612 square miles. Ignoring the many small creeks which drain the areas immediately surrounding the lake, there are four streams of good size which flow into the lake. These are Chittenango Creek on the south side and Oneida Creek, Fish Creek and Wood Creek at the east end. Over thirty other creeks, of which Big Bay Creek and Scriba Creek, the latter near Constantia, are the largest, also add their waters to the volume of the lake.

The outlet drainage is westward and northward by way of Oneida River and the Oswego River into Lake Ontario. The new Barge Canal makes use of Oneida Lake, and about a mile and a half of Oneida River west of Brewerton, at which point excavations begin and the canal turns to the southwest. Oneida Lake lies between locks 22 and 23 of the Barge Canal system.

2. Glacial Geology.

It is not necessary in this report to describe the glacial epoch, its causes or its history. For such information the reader is referred to the papers of Taylor (1913), Chamberlin (1906), and especially Fairchild (1899, 1902, 1903). After many advances and retreats of the ice sheet, during which the glacial drainage fluctuated from west to south and east, a large lake filled the Ontario basin and extended well to the eastward covering the territory of Oneida Lake and draining eastward past Rome into the Mohawk Valley and thence into the Hudson Valley. A long arm of this glacial lake, known to geologists as Lake Iroquois, extended through the Montezuma Marsh region and included the Cayuga Lake Valley. The water at this stage was at a level of 440 feet or 71 feet above the present level of Oneida Lake. The old shore line of the outlet of this glacial lake borders the north side of Oneida Lake, being distant about a mile. The south shore of the outlet lies just south and east of the city of Syracuse.

Oneida Lake apparently occupies a depression in the bed of this outlet. Its bottom does not differ in character from the general physiography of the surrounding territory. There are elevations in the lake resembling morainic hills, the crests of which form the shallows and small islands found in the lake, especially at the central and western ends. The islands, Long, Little, Wantry, etc., and the Shackelton Shoals evidently represent a terminal moraine indicating the point at which the Ontarian ice lobe rested at the Lake Dawson stage. (Fairchild, 1903, plate 41.) Frenchman and Dunham Islands appear to be the tops of submerged drumlins, the long axes being the same as those of the elevations surrounding the lake. (See the map, Fig. 1.)

When Lake Ontario was drained to its present level and its outlet shifted to the St. Lawrence River, Oneida Lake was left as a huge pool. It does not seem possible that this

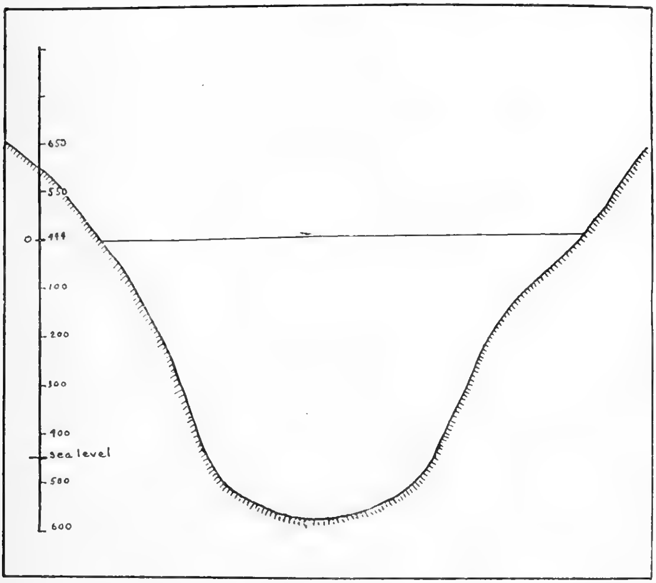

Fig. 3. Cross section of Seneca Lake about a mile south of Long Point. Horizontal scale 2 inches to the mile. Vertical scale ½ inch = 100 feet.

lake can be placed in the same class as those of Cayuga, Seneca, and other of the Finger Lakes, which are rock bound, and were once occupied by preglacial rivers flowing northward, which eroded the valleys during the long ages preceding the advance of the ice. Profiles of the two classes of lakes show this difference strikingly, that of Seneca Lake being sharply V-shaped (Fig. 3), while that of Oneida Lake is saucer shaped. (Fig. 2.) It seems evident, from the data at hand, that Oneida Lake is of glacial origin and is similar in character of formation to Winnebago Lake in Wisconsin. There may have been, in preglacial time, a river or stream

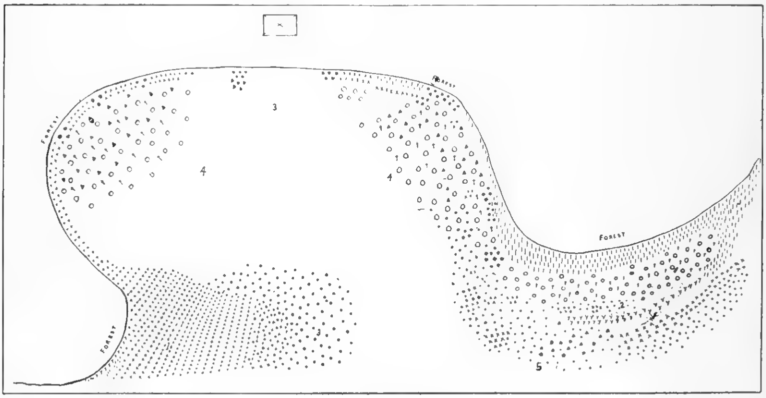

Fig. 4. Diagrammatic map of the vegetation in Nicholson Bay.

.*Scirpus occidentalis.*
▲*Scirpus americanus.*
.*Scirpus smithii.*
†*Potamogeton natans.*
x *Dianthera americana.*
**Pontederia cordata.*
l *Typha angustifolia.*

! *Decodon verticillatus.*
0 *Castalia odorata.*
0 *Nymphæa advena.*
Y. *Carex.*
A. *Sagittaria latifolia.*
1, 2, 3, 4, 5 depths of water.

that flowed through the territory occupied by Oneida Lake, but if such was the case its presence is not indicated by anything in the physiography or hydrology of the region. According to Hopkins (1914, pp. 7, 8) the rock strata beneath and around Oneida Lake consist of Clinton Rochester Shales, a soft rock, and the Lockport Limestone, a more resistant rock. This region had doubtless been reduced to base level before the advent of the ice sheet and the bed of Oneida Lake was possibly a wide, open flood plain of a meandering preglacial river. The successive ice sheets (Illinois and Wisconsin) doubtless modified the original topography, scooping up the soft shale and redepositing it in the form of moraines and drumlins. As the rock (Clinton shale) is but 14 feet below the surface at Brewerton, the outlet for such a hypothetical river must have been in some other direction, perhaps through Big Bay. The west end of the lake is very shallow, indicating a large amount of glacial filling, if a river ever flowed in this direction.

Oneida Lake is physically better adapted for maintaining a large and varied fish fauna than either Cayuga or Seneca Lakes because of its shallowness, especially about its borders, where feeding and breeding grounds are extensive. The Finger Lakes, on the other hand, have little shallow water, excepting at the ends, hence cannot support much vegetation upon which animals depend, in the ultimate analysis, for food.

CHAPTER II. DESCRIPTION OF THE HABITATS AND THEIR MOLLUSCAN POPULATION.

In order that an accurate picture might be formed of the different environments in the lake, field stations or habitats were established in many places, from the outlet at Brewerton to Constantia on the north side of the lake and from Brewerton to Lower South Bay on the south shore. Several islands and the deeper water were also investigated. Detailed studies were made of these stations, in relation to their molluscan inhabitants, as well as to the associated biota, to the depth of water, and to the character of the bottom. Ample material was gathered, and more or less exhaustive field descriptions of the habitats were made. By this means it has been possible to form a very full and comprehensive idea of the number of species and relative abundance of the molluscan life in the lake, its relation to the feeding and breeding grounds of the fish and its adaptability to the needs of the mollusk-eating fish.

A. DETAILED DISCUSSION OF FIELD STATIONS.

For convenience the data will be considered under four heads: 1. North Shore Stations; 2. South Shore Stations; 3. The Islands in the Lake; and 4. The Deeper Water and Open Lake Vegetation.

I. North Shore from Brewerton East to Constantia.

STATION I. NICHOLSON BAY (FIG. 4).

This bay contains two characteristic and diverse habitats.

Habitat 1. West side of bay, Fig. 5 (Field or collection No. 266).

BOTTOM: Hard sand, with few boulders, several very large. WATER: From 12 to 30 inches deep.

VEGETATION: Water Williow (*Dianthera americana*).

Near the shore there is a small association of Narrow-leaved Cat-tails (*Typha angustifolia*) and sedge (*Carex*

Fig. 5. Station I, habitat 1, West side of Nicholson Bay. Heavy growth of Water Willow (*Dianthera americana*).

Fig. 6. Station I, habitat 2, Nicholson Bay. Heavy growth of Cat-tail (*Typha angustifolia*) in background, Bulrush (*Scirpus occidentalis* and *S. smithii*) in the foreground, and the white and yellow pond lilies, with pond-weed, covering the water between. (*Nymphæa advena, Castalia odorata, Potamogeton natans*).

trichocarpa). At the outer or lake border there is an area of Lake Bulrush (*Scirpus occidentalis*) which extends into the deeper water.

ANIMAL LIFE.

Life was abundant in this habitat, the clams burrowing among the stones and the gastropods living on the stones and boulders. Four species of mollusks were noted.

Elliptio complanatus, 1½ inches long.
Lampsilis radiata, rose-colored.
Planorbis campanulatus.
Planorbis antrosus.

Whirligig beetles (*Dineutes hornii*) were abundant on the surface among the Water Willow.

Habitat 2. East side of bay, Fig 6. (Field numbers 259–262, 281.)

Bottom: Sandy or silty. Water: 2 to 5 feet deep.

Vegetation: The plant associations of this habitat are peculiar and interesting, exhibiting an orderly zonal character when closely examined, although apparently badly mixed when first observed. This zonal arrangement may be described as follows:

Zone A. Shore edge, water 10–18 inches deep.

Buttonbush (*Cephalanthus occidentalis*).
Swamp Loosestrife (*Decodon verticillatus*).
Water Willow (*Dianthera americana*) in one sandy spot.
Arrow-head (*Sagittaria latifolia*).
Sedge (*Carex trichocarpa*) near Water Willow.
Cat-tail (*Typha angustifolia*).

Zone B. Water 2 feet deep.

Bur-reed (*Sparganium eurycarpum*).
Bulrush (*Scirpus occidentalis*).
Bulrush (*Scirpus americanus*).
Pickerel-weed (*Pontederia cordata*).

Zone C. Water 3–4 feet deep.

This association is protected from the rough water of the lake by the vegetation of Zone D.

FLOATING LEAVES.

Sweet-scented Water Lily (*Castalia odorata*).
Cow or Yellow Lily (*Nymphaea advena*).
Floating Pond-weed (*Potamogeton natans*).

SUBMERGED PLANTS.

Clasping-leaved Pond-weed (*Potamogeton perfoliatus*).
Water Weed (*Elodea canadensis*).
Hornwort (*Ceratophyllum demersum*).
Water Milfoil (*Myriophyllum spicatum*).
Stonewort (*Chara* species).
Water Celery (*Vallisneria spiralis*).

Zone D. Water 1½–5 feet deep.

Water Willow (*Dianthera americana*).
Pickerel-weed (*Pontederia cordata*).
Arrow-head (*Sagittaria latifolia*).
Lake Bulrush (*Scirpus occidentalis*).
Bulrush (*Scirpus smithii*).
Sedge (*Carex trichocarpa*).

Zone D consisted of a number of small colonies of Water Willow, Pickerel-weed, Arrow-head and Sedge. The Lake Bulrush was generally distributed. Zone C formed a very distinct semicircle sharply dividing Zones B and D. (See Fig. 6.)

ANIMAL LIFE.

Animal life was notably abundant in Zone C, on the upper and lower sides of the pond-lily leaves, and among the submerged vegetation. Eight forms of mollusks were noted, besides insects.

MOLLUSCA.

Acella haldemani, all adult.
Pseudosuccinea columella, half grown and adult.
Pseudosuccinea columella chalybea, half grown and adult.
Planorbis campanulatus, adult.
Planorbis trivolvis, half grown and adult.
Planorbis hirsutus, adult.
Physa ancillaria warreniana, young and adult.
Amnicola lustrica, young.

INSECTA.

Dragon-fly (*Basiæschna janata*) nymph.

Dragon-fly (*Tetragoneuria cynosura*) nymph.

HIRUDINEA.

Leech (*Placobdella picta*).
Leech (*Glossiphonia fusca*).
Leech (*Glossiphonia stagnalis*).
Leech (*Erpobdella punctata*).

On the lakeward side of Zone D, where the Water Willow and Bulrush (*Scirpus occidentalis*) were abundant, many clams were observed in water from two to three feet in depth, on a hard, sandy bottom. All were of one species, *Elliptio complanatus*.

STATION II. FITZGERALD POINT (FIELD NOS. 264–5, 283–4).

This point extends some distance into the lake, having stations I and III on either side. The water is shallow for a

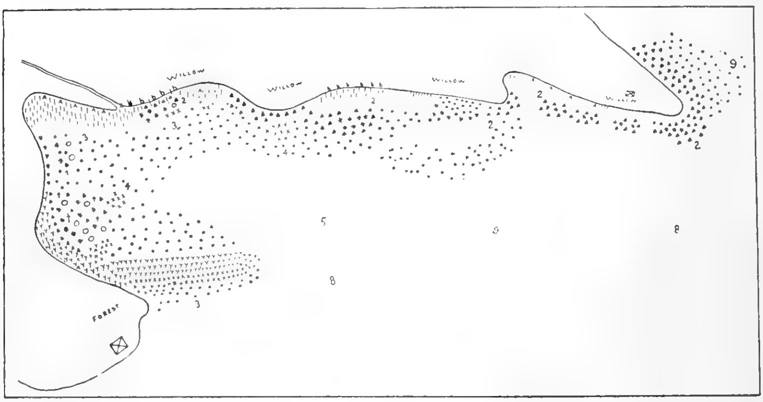

Fig. 7. Diagrammatic map of the vegetation in bay between Fitzgerald and Milton points. 2, 3, 4, 5, 8, 9 depths of water.

.*Scirpus occidentalis.*
▲*Scirpus americanus.*
†*Potamogeton natans.*
0 *Castalia odorata.*
0 *Nymphæa advena.*
A. *Sagittaria latifolia.*
X. *Dianthera americana.*
* *Pontederia cordata.*
1. *Typha angustifolia.*
Y. *Carex.*
! *Decodon verticillatus.*
C. *Sparganium eurycarpum.*
b. *Cephalanthus occidentalis.*

distance of nearly 500 feet, when it drops more or less suddenly to 9 feet in depth.

BOTTOM: Hard sand with many stones and boulders.
WATER: 10 to 30 inches deep.
VEGETATION: Bulrush (*Scirpus occidentalis*).

ANIMAL LIFE.

Clams in sand between stones. Gastropods on stones and on sand. The latter are so abundant as to give a "peppered" aspect to the bottom, and the clams are notably abundant, the posterior or siphon end protruding from the sand between the rocks.

MOLLUSCA.

Lampsilis radiata.
Anodonta implicata.
Anodonta grandis footiana.
Elliptio complanatus.
Sphærium vermontanum.
Galba catascopium.
Goniobasis livescens.

Both *Lampsilis* and *Anodonta* were gravid. Some of the *Galba* had the spermaceti-like color of the same species from Pine Lake, Michigan. The shell of *Lampsilis* was rosy in two-thirds of the specimens.

INSECTA.

Caddis-fly cases (*Helicopsyche borealis*).
Caddis-fly cases (*Leptocella* species).

The larval cases of this insect, which resemble a snail shell so closely that the experienced conchologist, Doctor Isaac Lea, once described it as *Valvata arenifera*, were amazingly abundant, on stones and dead shells. In many cases a stone as large as the hand was covered with 70 or 80 individuals. It is evident that a larger number of species live on or near this point than is indicated by the species found living. From shore debris 16 species of mollusks were identified, as noted below:

*1. *Lampsilis radiata*, abundant.
*2. *Anodonta grandis footiana.*
3. *Anodonta marginata*, 1.
*4. *Anodonta implicata.*
*5. *Elliptio complanatus*, abundant.
*6. *Sphærium vermontanum*, abundant.

7. *Gillia altilis*, 1.
8. *Bythinia tentaculata*, 3.
*9. *Goniobasis livescens*, abundant.
10. *Somatogyrus subglobosus*, 1.
11. *Valvata tricarinata*, 1.
12. *Vivipara contectoides*, 1 young.
*13. *Galba catascopium*, abundant.
14. *Planorbis campanulatus*, 4.
15. *Physa integra*, 10.
16. *Physa ancillaria warreniana*, 9.
*17. *Helicopsyche borealis*, abundant.

Nos. 7, 8, 10, 11, 12, 14, 15 and 16 were evidently washed in from other and different habitats. Those species observed to live on the stony point are marked with an *.

Station III. Bay between Fitzgerald and Milton Points.

As in Station I, this field station is divisible into several distinct habitats characterized by varying depths and diverse vegetation (Fig. 7).

Habitat 1. Sheltered bay at west end of station. Field No. 282.

This habitat is protected from the rough waters of the lake by the heavy fringe of Water Willow, Sedge (*Carex*) and Bulrush (*S. smithii* and *S. americanus*) which forms an effectual barrier (Fig. 8).

Bottom: Sandy silt, varying in hardness. Water: One to four feet in depth.

Vegetation: Zonal and variable, as noted below.

Zone A. Water 1–2 feet deep.

Sedge (*Carex trichocarpa*).
Buttonbush (*Cephalanthus occidentalis*).
Swamp Loosestrife (*Decodon verticillatus*).
Bur-reed (*Sparganium eurycarpum*).
Arrow-head (*Sagittaria latifolia*).
American Bulrush (*Scirpus americanus*).
Bulrush (*Scirpus smithii*).

Zone B. Water 2–4 feet deep.

Pickerel-weed (*Pontederia cordata*).
Lake Bulrush (*Scirpus occidentalis*).

Fig. 8. Station III, habitat 1, sheltered bay north of Fitzgerald Point, protected from rough waters of lake by zone of *Carex*, *Dianthera*, and *Scirpus* (*S. smithii* and *S. americanus*). In the quiet water inside the barrier are found *Pontederia*, *Dianthera*, *Potamogeton natans*, *Castalia* and *Nymphæa*. The shore is bordered by *Typha*, *Carex*, *Cephalanthus*, *Decodon*, and *Sagittaria*.

Fig. 9. Station III, habitat 2. Cat-tail shore, facing lake. The shore is lined with *Typha*, among which also live *Sparganium*, *Sagittaria*, and *Cephalanthus*. In the open water in the foreground are found *Pontederia*, *Scirpus americanus*, and *Nymphæa*.

Sweet-scented Water Lily (*Castalia odorata*).

Cow Lily (*Nymphæa advena*).

Floating Pond-weed (*Potamogeton natans*).

SUBMERGED VEGETATION.

Clasping-leaved Pond-weed (*Potamogeton perfoliatus*).

Water Weed (*Elodea canadensis*).

Hornwort (*Ceratophyllum demersum*).

Water Milfoil (*Myriophyllum spicatum*).

Water Celery (*Vallisneria spiralis*).

ANIMAL LIFE.

MOLLUSCA.

Acella haldemani, on leaves of water lily.

Pseudosuccinea columella, on leaves of water lily.

Physa ancillaria warreniana, on leaves of water lily.

Planorbis campanulatus, on leaves of water lily.

Habitat 2. Cat-tail shore facing lake (Fig 9), Field Nos. 252, 253.

There are three distinct cat-tail associations, each separated by a rounded point free from shore vegetation. One of these is at the mouth of a small creek (Fig. 9). There is little or no protection from the rough waters of the lake. Each association is made up of the following plants, arranged zonally.

Zone A. Shore.

Black Willow (*Salix nigra* var. *falcata*).

Narrow-leaved Cat-tail (*Typha angustifolia*).

Swamp Loosestrife (*Decodon verticillatus*).

Buttonbush (*Cephalanthus occidentalis*).

Zone B.

Bottom: Sandy, rather firm. Water: 12–24 inches deep.

Bur-reed (*Sparganium eurycarpum*).

Narrow-leaved Cat-tail (*Typha angustifolia*).

Arrow-head (*Sagittaria latifolia*).

Zone C.

Bottom: Sandy silt. Water: 2–4 feet deep.

Sweet-scented Water Lily (*Castalia odorata*).
Cow Lily (*Nymphaea advena*).
Pond-weed (*Potamogeton natans*).
Pickerel-weed (*Pontederia cordata*).
American Bulrush (*Scirpus americanus*).

In one habitat, the first west of Milton Point, the bottom was muddy, as was also the case at the mouth of the creek.

ANIMAL LIFE IN ZONE C.

Sphærium vermontanum.
Pisidium variabile.
Pisidium compressum lævigatum.
Pisidium species.
Pisidium species.
Campeloma integrum, young.
Gillia altilis.
Somatogyrus subglobosus.
Amnicola lustrica.
Valvata bicarinata normalis.
Planorbis hirsutus.
Planorbis campanulatus.

Mollusks were here (Zone C) quite abundant. Among the *Campeloma*, one specimen was reversed and one of the shells had a rosy tint like *Campeloma rufum*.

Zone D. (Field Nos. 224, 251.)

Bottom: Sand or gravel with occasional boulders. Water: 2–4 feet deep.

VEGETATION.

Pickerel-weed (*Pontederia cordata*).
American Bulrush (*Scirpus americanus*).
Floating Pond-weed (*Potamogeton natans*).

Zone D occurs conspicuously in the first indentation of the shore west of Milton Point, where Zone C is in about 2 feet of water. The plants occur in patches. Animal life is here abundant, the mollusks living on or between the stones (Fig. 10).

Elliptio complanatus, common.
Sphærium vermontanum, rare.
Pisidium compressum, rare.
Campeloma integrum, rare.
Amnicola lustrica, rare.
Gillia altilis, adult and young, common.
Physa ancillaria warreniana, young, uncommon.
Galba catascopium, adult and young, uncommon.

Habitat 3. Rounded points separating No. 2 habitats. The shores of these locations are bare; in one place the lake had undermined the shore, forming an overhanging bank about one foot above the water. The base of this bank, in a few inches of water, was the optimum habitat of *Campeloma integrum.* Where this bank was absent there was a sandy or gravelly beach. Two conspicuous zones or areas are apparent.

Zone A. (Field No. 250.)

Overhanging or vertical bank; water six inches deep; bottom sandy or stony; no vegetation, but in one place water celery had been washed on shore forming a mat in which mollusks were abundant, eating the plant.

MOLLUSCA.

Campeloma integrum, abundant.
Lymnæa stagnalis lillianæ, eating celery, rare.
Galba catascopium, eating celery, rare.
Planorbis binneyi eating celery, common.
Physa ancillaria warreniana, eating celery, rare.

Zone B. (Field Nos. 223, 263.)

BOTTOM: Hard sand with rocks and boulders. WATER: 12 to 36 inches deep.

VEGETATION.

Lake Bulrush (*Scirpus occidentalis*).
American Bulrush (*Scirpus americanus*).
Pickerel-weed (*Pontederia cordata*).
Water Celery (*Vallisneria spiralis*).

MOLLUSCA.

Physa ancillaria warreniana, on rocks, abundant.
Planorbis campanulatus, on Scirpus and wild celery, common.
Planorbis hirsutus, on Scirpus and wild celery, rare.
Galba catascopium, on rocks, abundant.
Goniobasis livescens, on rocks, abundant.
Elliptio complanatus, between rocks in sand, common.
Lampsilis radiata, in sand, not common.
Anodonta cataracta, in sand, not common.

CRUSTACEA.

Crawfish (*Cambarus propinquus*). Under stones; male of form I.

INSECTA.

Caddis-fly larvæ (*Helicopsyche borealis*). On stones, abundant.

HIRUDINEA.

Leech (*Erpobdella punctata*).
Leech (*Placobdella rugosa*).
Leech (*Glossiphonia complanata*).

On the shelving shore of Zone 1 the dead shells of many clams were observed, showing that these animals are abundant on the sandy bottom of Zone 2. Four species were noted:

Elliptio complanatus.
Lampsilis radiata.
Anodonta grandis footiana.
Anodonta cataracta.

STATION IV. MILTON POINT (FIELD NO. 229). FIG. 11,

Milton Point is a narrow, wedge-shaped piece of land extending well into the lake. It is fully exposed to the winds and waves from the south and east. The land is quite low and is doubtless covered with water during storms and periods of high water. Shallow water extends for a considerable distance into the lake.

BOTTOM: Very bouldery on hard sand. WATER: 1 to 2 feet deep.

VEGETATION.

Bulrush (*Scirpus americanus*).
Water Willow, rare (*Dianthera americana*).

ANIMAL LIFE.

MOLLUSCA.

Elliptio complanatus, between rocks, common.
Lampsilis radiata, between rocks, common.
Goniobasis livescens, on stones, common.
Galba catascopium, on stones, common.
Planorbis antrosus, on stones, rare.
Planorbis campanulatus, on stones, rare.
Physa ancillaria warreniana, on stones, rare.

The last three mollusks (*Planorbis* and *Physa*) are evidently migrants from Station V.

INSECTA.

Whirligig beetles (*Gyrinus ventralis*).
Whirligig beetles (*Dineutes assimilis*).
Caddis-fly larvæ (*Helicopsyche borealis*).

Station V. Ice House Bay (Field No. 230). Fig. 12.

A small, round indentation or bay, well protected from the winds and waves on the south, west and north sides, but widely open on the east side. The water on the south and west shores is shallow, ranging from one to three feet in depth. The bottom is bouldery except in small spots which are of hard sand. The vegetation is fairly uniform, consisting of:

Habitat 1.

American Bulrush (*Scirpus americanus*) in water 10–24 inches deep.
Floating Pond-weed (*Potamogeton natans*) in water 10–24 inches deep.
Lake Bulrush (*Scirpus occidentalis*) in water 36 inches deep.

Habitat 2.

At the west end of the bay there is an extensive area of Cat-tail (*Typha angustifolia*) with occasional plants of:

Arrow-head (*Sagittaria latifolia*).
Pickerel-weed (*Pontederia cordata*).

Habitat 3.

The north side of the bay, on which the ice house of the People's Ice Company stands, is bordered by a heavy zone of:

Salt Reed grass (*Spartina cyanosuroides*).
Water Willow (*Dianthera americana*).
Bulrush (*Scirpus smithii*).
Lake Bulrush (*Scirpus occidentalis*).

The last named plant borders the plant association where the water deepens, forming a channel 4–5 feet deep.

Fig. 10. Station III, habitat 2, zone D. First indentation west of Milton Point. *Scirpus americanus*, *Pontederia*, and *Potamogeton natans* occur in 2 to 4 feet of water. The shore is here lined with *Typha*. Milton Point in the background.

Fig. 11. Station IV. Milton Point, looking east with Frenchman Island and Shaw Point in the distance. Vegetation consisting of *Scirpus americanus* with an occasional *Dianthera*. Bottom very bouldery.

Submerged Plant Association (Habitat 4).

The submerged plants embrace the usual species of such a habitat. They were in 4 feet of water.

Clasping-leaved Pond-weed (*Potamogeton perfoliatus*).
Water Celery (*Vallisneria spiralis*).
Water Weed (*Elodea canadensis*).
Hornwort (*Ceratophyllum demersum*).

ANIMAL LIFE. (FROM HABITAT 1).

MOLLUSCA.

Lymnæa stagnalis lillianæ, near shore.
Galba catascopium, on rocks, on *Scirpus americanus*, and on sandy spots.
Galba emarginata, dead shells, evidently from deeper water.
Goniobasis livescens, on rocks.
Planorbis trivolvis, var., on rocks, on *Scirpus americanus*, and on sandy spots.
Planorbis campanulatus, on rocks, on *Scirpus americanus*, and on sandy spots.
Physa ancillaria warreniana, on *Scirpus americanus*, and on sand near shore. Adult and young.
Elliptio complanatus, in sandy spot, small.
Anodonta cataracta, in sandy spot, large.

INSECTA.

Caddis-fly larvæ (*Helicopsyche borealis*), on rocks.

The mollusks covered the bottom of this bay in great abundance.

STATION VI. HEAD OF BIG BAY (FIELD NOS. 268, 269).

The zonal character of the vegetation at this location was marked. For the distance of several hundred feet, an area of clear water, about 25 feet in width, bordered the shore, the water being about 20 inches in depth. No mollusks were observed in this sandy strip. This area is bordered by a wide zone of plants, in about four feet of water. The plants noted were:

Lake Bulrush (*Scirpus occidentalis*).
Pickerel-weed (*Pontederia cordata*).
Floating Pond-weed (*Potamogeton natans*).
Sweet-scented Water Lily (*Castalia odorata*).
Cow Lily (*Nymphaea advena*).

Where the water becomes shallower, in spots 2–2½ feet deep, the Water Willow grows abundantly. Mollusks were noted here in but one situation. *Physa ancillaria warreniana* was observed on the upper surface of *Castalia odorata.*

A leech, *Placobdella parasitica,* was obtained from turtles caught in a fyke net at mouth of west creek flowing into Big Bay. Collected by Adams and Hankinson, Sept. 9, 1915.

Station VII. Big Bay Creek (Field No. 270).

Big Bay Creek extends for over a mile into the swampy shore bordering the east side of Big Bay. At its mouth the water is five feet in depth and about 20 to 25 feet in width. As the water extends into the country for a long distance, forming a vast swamp, it is impossible to judge of the original size of the creek. The bottom is of fine, sandy silt. The vegetation is zonal in arrangement.

Zone A. Shallow water (12-18 inches). This zone evidently represents the old shore line before the raising of the water table.

Black Willow (*Salix nigra* var. *falcata*).
Swamp Loosestrife (*Decodon verticillatus*).
Broad-leaved Arrow-head (*Sagittaria latifolia*).

Zone B. Water five feet deep.

Cow Lily (*Nymphaea advena*).
Floating Pond-weed (*Potamogeton natans*).
Clasping-leaved Pond-weed (*Potamogeton perfoliatus*).

ANIMAL LIFE.

Animal life was observed on the upper and under surfaces of the Cow Lily. The species all belong to the Mollusca.

Pseudosuccinea columella.
Planorbis campanulatus.
Physa ancillaria warreniana.
Physa gyrina.

Adams and Hankinson collected leeches, of the species *Placobdella parasitica,* from turtles caught in a fyke net set near the mouth of Big Bay Creek, Sept. 4–7, 1915.

Station VIII. Dry Land Point, Big Bay (Field No. 271).

This habitat is a low point of land situated at about the middle of the east shore, extending well into Big Bay. The bottom gradually slopes toward the deeper water of the bay. It is somewhat protected by the lakeward zone of vegetation.

Bottom: Hard, sandy. Water: 18 to 30 inches deep.

Vegetation: None for 30 feet, where a zone of *Scirpus occidentalis* occurs.

ANIMAL LIFE.

Animal life was abundant, principally mollusks, which were on or in the sand.

MOLLUSCA.

Sphærium vermontanum, buried in sand.
Planorbis campanulatus, on sand.
Galba catascopium, on sand.
Campeloma integrum, buried in sand.
Elliptio complanatus, buried in sand, (small specimens).
Bythinia tentaculata, dead; washed in from water plants.

INSECTA.

Caddis-fly cases (*Leptocella* species).

Station IX. Deer Point, Big Bay (Field No. 234).

This habitat is bordered by low, swampy land about a foot above lake level, in most places. The bank has been undermined and overhangs a trifle, forming a perpendicular wall ten to fifteen inches high.

Bottom: Sandy silt, rather soft. Water: 18 to 30 inches deep.

Vegetation: Zonal.

Zone A. Bordering the shore, water 10–15 inches deep.

Narrow-leaved Cat-tail (*Typha angustifolia*).
Bur-reed (*Sparganium eurycarpum*).
Arrow-head (*Sagittaria latifolia*).

Zone B. In water, 15–30 inches deep.

Water Willow (*Dianthera americana*).
Bulrush (*Scirpus smithii*).
American Bulrush (*Scirpus americanus*).
Lake Bulrush (*Scirpus occidentalis*).
Pickerel-weed (*Pontederia cordata*).

Scirpus occidentalis and *Pontederia* occupy the deeper portions of the shore.

All of the animal life was from Zone B on the sandy bottom.

MOLLUSCA.

Sphærium vermontanum, common.
Pisidium compressum lævigatum, common.
Pisidium species, rare.
Campeloma integrum, common.
Amnicola lustrica, common.
Planorbis campanulatus, common.

INSECTA.

Caddis-fly cases (*Molanna* species).
Caddis-fly larvæ (*Leptocerus* species).
Caddis-fly larvæ (*Hydroptila*).
Caddis-fly cases (*Helicopsyche borealis*).
Dragon-fly nymph (*Gomphus sordidus*).

Station X. Poddygut Bay, Big Bay (Field No. 233).

Poddygut Bay is a rounded indentation at the entrance to Big Bay. It is partly enclosed by Willow Point on the north and Poddygut Point on the south. These points are sandy, bouldery, and shallow. The bay is 5 to 7 feet deep and is filled with water plants. It is entirely surrounded by a deep swamp. The vegetation is zonal in arrangement.

Zone A. Bordering the shore, water 1–2½ feet deep.

Buttonbush (*Cephalanthus occidentalis*).
Narrow-leaved Cat-tail (*Typha angustifolia*).
Broad-leaved Arrow-head (*Sagittaria latifolia*).
Pickerel-weed (*Pontederia cordata*).
Sedge (*Carex trichocarpa*).
Swamp Loosestrife (*Decodon verticillatus*).

Zone B. Nymphaea-Potamogeton association.

Bulrush (*Scirpus occidentalis*).
Sweet-scented Water Lily (*Castalia odorata*).
Cow Lily (*Nymphaea advena*).
Floating Pond-weed (*Potamogeton natans*).

Zone C. Submerged vegetation.

Clasping-leaved Pond-weed (*Potamogeton perfoliatus*).
Water Celery (*Vallisneria spiralis*).
Water Weed (*Elodea canadensis*).
Hornwort (*Ceratophyllum demersum*).
Water Milfoil (*Myriophyllum spicatum*).

ANIMAL LIFE (ZONE B).

MOLLUSCA.

Acella haldemani, on leaves and stems of Cow Lily, White Lily and Pond-weed.
Amnicola lustrica, on lily leaves (*Nymphæa*).
Ancylus parallelus, on under surface of Cow Lily and White Lily.

CRUSTACEA (AMPHIPODA).

Hyalella knickerbockeri, on under surface of lily leaves.

Station XI. Poddygut Point, Big Bay (Field No. 228). Fig. 13.

This habitat extends well into the bay. It is shallow for a considerable distance, averaging about eighteen inches, but becomes abruptly deeper, especially on the Poddygut Bay side where a depth of six feet occurs. The bottom is very stony and bouldery on a hard sandy substratum. The habitat is open and fully exposed to the violence of the waves.

ANIMAL LIFE.

MOLLUSCA.

Elliptio complanatus, 2–3 inches long, common.
Margaritana margaritifera, 3 inches long, rare.
Galba emarginata, all dead, rare.

INSECTA.

Caddis-fly larvæ (*Helicopsyche borealis*).

Station XII. Second Bay-like Indentation West of Shaw Point (Field No. 232). Fig. 13.

The shore line of this habitat is usually devoid of vegetation. A ridge of debris, washed in by the waves, usually bor-

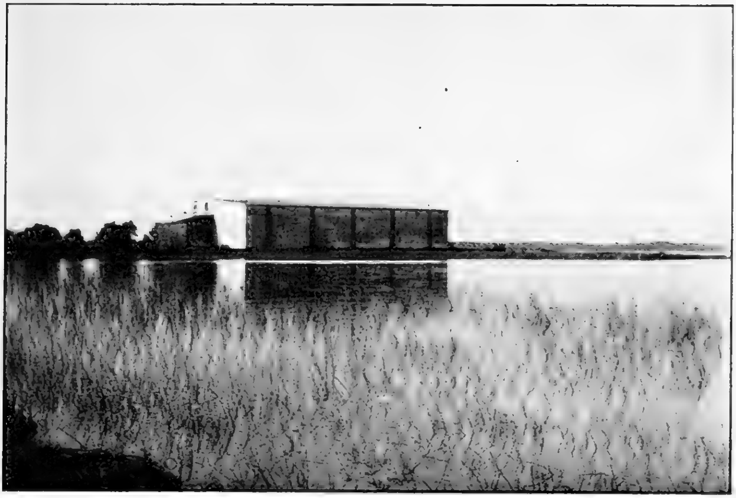

Fig. 12. Station V. Ice House Bay, habitat 1. View looking north from Milton Point. The vegetation consists of *Scirpus americanus* and *S. occidentalis* with a few *Potamogeton natans.* The People's Ice Company's storage plant in the background.

Fig. 13. View northwest from Shaw Point, looking across Poddygut Point to Willow Point, Poddygut Bay being seen on the right. The first point in the distance is Deer Point and the second, the dark line just above, is Dry Land Point. Station XII is in the foreground, the vegetation being principally *Scirpus americanus* and *S. occidentalis,* with a few *Dianthera.*

ders the edge of the shore at the distance inland of a foot. The water is from 10 to 30 inches deep, the bottom is hard sand with some boulders, and the vegetation consists of Bulrush and Water Willow, the latter in a patch on the shoreward edge of the Scirpus association.

American Bulrush (*Scirpus americanus*).
Lake Bulrush (*Scirpus occidentalis*).
Water Willow (*Dianthera americana*).

ANIMAL LIFE.

The shore debris contained the following species, all being dead and representing several habitats.

MOLLUSCA.

Elliptio complanatus.
Anodonta marginata.
Anodonta cataracta.
Anodonta grandis footiana.
Sphærium striatinum.
Planorbis campanulatus.
Planorbis antrosus
Planorbis binneyi
Galba catascopium
Galba emarginata.
Physa ancillaria warreniana.
Bythinia tentaculata.
Somatogyrus subglobosus.

INSECTA.

Caddis-fly larvæ (*Helicopsyche borealis*).
Cadis-fly cases (*Leptocella* species).

Station XIII. First Bay-like Indentation West of Shaw Point (Field Nos. 205, 207, 227). Fig. 14.

This habitat is similar to that of Station XII, except that the land bordering the shore is higher (about 10 feet) and contains several large trees.

Bottom: Hard, sandy, gravelly and bouldery in spots.

Water: 10 to 48 inches deep.

VEGETATION.

Water Willow (*Dianthera americana*).
American Bulrush (*Scirpus americanus*).
Lake Bulrush (*Scirpus occidentalis*).

ANIMAL LIFE.

MOLLUSCA.

Elliptio complanatus, in sand between stones.
Margaritana margaritifera, in sand between stones.
Lampsilis luteola, in sand between stones, 1 female gravid.
Lampsilis radiata, on sand between stones.
Goniobasis livescens, on stones.
Galba catascopium, on stones.
Physa integra, on stones.

The debris along the beach yielded 16 species of mollusks, as noted below. The vast number of shells on shore attest the multitude of molluscan forms living in this part of the lake.

Elliptio complanatus, common.
Margaritana margaritifera, rare.
Lampsilis radiata, common.
Lampsilis borealis, common.
Lampsilis iris, rare.
Sphærium vermontanum, common.
Goniobasis livescens, common.
Somatogyrus subglobosus, common.
Gillia altilis, common.
Campeloma integrum, rare.
Bythinia tentaculata, common.
Physa ancillaria warreniana, common.
Planorbis campanulatus, very common.
Planorbis antrosus, rare.
Planorbis trivolvis, rare.
Galba catascopium, very common.

STATION XIV. SHAW POINT (FIELD NO. 231).

This habitat is a bold point of land extending well into the lake. The shore is rather high (about 6 feet above the lake) and is without vegetation.

BOTTOM: Very bouldery. WATER: 6 to 24 inches deep.

VEGETATION.

Bulrush (*Scirpus americanus*). A green filamentous algæ covers the rocks near the shore and in this *Planorbis binneyi*, *Goniobasis livescens* and *Lymnæa stagnalis lillianæ* were found abundantly, feeding. *Physa* and *Planorbis campanulatus* were found on the *Scirpus*.

ANIMAL LIFE.

MOLLUSCA.

Elliptio complanatus, shells eroded.
Lymnæa stagnalis lillianæ, on rocks near shore feeding on algæ.
Planorbis binneyi, on rocks near shore feeding on algæ.
Planorbis campanulatus, on *Scirpus*.
Planorbis hirsutus, on bottom between rocks.
Goniobasis livescens, on rocks.
Physa ancillaria warreniana, on *Scirpus*.

Station XV. Baker Point (Field No. 78).

On the sandy and bouldery beach at this locality Doctor Adams and Professor Hankinson collected the following species:

Anodonta implicata, common, gravid.
Anodonta grandis footiana, not common.
Elliptio complanatus, common, small (2–3 inches).
Margaritana margaritifera, rare, surface decorticated.

Station XVI. Scriba Creek, Constantia (Field Nos. 202, 203, 206).

Scriba Creek is eighteen miles long and is a large, clear, rapid flowing stream emptying into Oneida Lake at the village of Constantia. Its headwaters rise in the Town of Amboy. At its mouth it is upward of 6 feet in depth, and the bottom is sandy; north of the bridge, and above the junction of Frederick Creek, the bottom is very rocky, the current swift and the water shallow (6 to 15 inches deep). Beneath the rocks and clinging to them occur a number of forms of life, as noted below, which form desirable food for the fish in the stream.

ANIMAL LIFE.

MOLLUSCA.

Ancylus tardus, abundant on rocks.

CRUSTACEA.

Crawfish (*Cambarus bartoni robustus*) male of II form and female, among and under stones.
Crawfish (*Cambarus propinquus*) male of II form and female, among and under stones.

INSECTA.

Water-penny, larva of beetle (*Psephenus lecontei*), on stones.
Caddis-fly cases (*Helicopsyche borealis*), on stones.
Caddis-fly cases (*Neophylax* species), on bottom, among stones.
Stone-fly (*Perla* species), nymph.
Stone-fly (*Acroneuria* species), nymph.

Habitat 1. Small pool formed by caving in of bank, protected from rapid moving water by portion of bank and by stones.(Field No. 204).

BOTTOM: Muddy. WATER: 8–12 inches deep.
VEGETATION: Algæ.

ANIMAL LIFE.

MOLLUSCA.

Planorbis trivolvis, on algæ and dead leaves.
Planorbis hirsutus, on algæ and dead leaves.
Physa gyrina, on algæ and dead leaves.

CRUSTACEA.

Amphipod (*Hyalella knickerbockeri*), among leaves.

INSECTA.

Damsel-fly (*Enallagma* species), nymph.
Water beetle (*Tropisternus glaber*).

Habitat 2. In Scriba Creek and its tributary, Frederick Creek, at and near junction of these two streams (Field No. 75).

BOTTOM: Muddy. WATER: 2–3 feet deep.

Elliptio complanatus was the only mollusk observed and the crawfish *Cambarus bartoni robustus* the only other invertebrate.

STATION XVII. FREDERICK CREEK, CONSTANTIA (FIELD No. 201).

This creek is a tributary of Scriba Creek. Near its head the State Fish Hatchery buildings are situated. The creek varies in its physical relations. in some places forming quiet pools and in others running rapidly over stones. Near the hatchery buildings the bottom is composed of fine, impalpable mud. On and in this mud three species of mollusks were observed.

Elliptio complanatus, common and large.
Strophitus edentulus, one dead shell.
Campeloma decisum, common and rusty in color.

STATION XVIII. LARGE POND ABOVE HATCHERY BUILDINGS (FIELD NO. 200).

This pond was formed by damming Frederick Creek above the hatchery buildings. Its depth was not ascertained but probably does not exceed a few feet. Two species of mollusks were observed on the muddy shores.

Anodonta grandis, common. *Campeloma decisum*, common.

II. South Shore from Brewerton East to Lower South Bay.

STATION XIX. BAY-LIKE INDENTATION ONE-HALF MILE WEST OF SHEPARD POINT (FIELD NOS. 225, 238). FIGS. 15, 16.

In this habitat the shore is devoid of vegetation, except in limited areas where there are clumps of Black Willow *(Salix nigra* var. *falcata)*, Buttonbush *(Cephalanthus occidentalis)*, and Iris *(Iris versicolor)*. The shallow water near the shore in such places, usually contains a fringe of Swamp Loosestrife *(Decodon verticillatus)*. Occasionally a mass of vegetation extends into the lake, forming a point. This consists of Pickerel weed, American Bulrush (*Scirpus americanus*) and Water Willow. *Scirpus smithii* may also be present (see Fig. 15). Away from the shore, where the water is from 2 to 4 feet deep, there is an association of Water Willow, Bulrush *(Scirpus occidentalis)* and Pickerel-weed (see Fig. 16). The bottom is of hard sand with a few boulders. The sandy bottom contained a large number of species of mollusks.

ANIMAL LIFE.

MOLLUSCA.

Elliptio complanatus, abundant.
Margaritana margaritifera, rare.
Sphærium vermontanum, common.
Pisidium variabile, common.
Pisidium compressum lævigatum, common.
Pisidium æquilaterale, rare.
Pisidium henslowanum, common.
Pisidium species, rare.
Valvata tricarinata, common.
Amnicola limosa, rare.
Amnicola lustrica, abundant and variable in form. Adult and young present.

Fig. 14. Station XIII, looking northwest from Shaw Point, across first bay-like indentation west of the point. Note area near shore which is bouldery and free from vegetation. Zone of vegetation consists of *Dianthera* and *Scirpus americanus* and *S. occidentalis*. Trees on distant point are *Salix nigra* var. *falcata*. Several associations of *Scirpus americanus* may be noted near the shore in the upper right-hand side of the picture.

Fig. 15. Shore of bay west of Shepard Point, Station XIX. *Decodon, Salix*, and *Iris* at shore. The point of vegetation in the distance consists of *Dianthera, Pontederia, Scirpus ameri canus* and *Scirpus smithii.*

Goniobasis livescens, rare, mostly young, 5 mill. long, strongly carinated.
Bythinia tentaculata, abundant, both adult and young.
Physa ancillaria warreniana, rare, young.
Planorbis campanulatus, rare.
Planorbis antrosus, common, adult and young.
Planorbis hirsutus, all immature.
Galba catascopium, abundant, adult and young.

INSECTA.

Caddis-fly larvæ (*Helicopsyche borealis*), abundant.
Caddis-fly case (*Leptocella* species).
Caddis-fly case (*Molanna* species).
Caddis-fly case (*Phylocentropus* species).
Dragon-fly nymph (*Æschna* species).

In this habitat, the large number of *Pisidia* present is noteworthy. The abundance of small mollusks and the large number of species of this group (18) shows this habitat to be a good feeding ground for bottom feeding fish, such as pumpkinseed and suckers, as well as turtles.

Station XX. Shepard Point (Field Nos. 248, 275, 277).

The Shepard Point region is not characterized by a sharp projection of land, as is the case with other localities called "Points" but is a fairly uniform, rounded area about a mile or less in length. The banks here are very steep and blufflike, rising some 20 feet above the level of the lake. A sandy, gravelly or bouldery beach lies at the foot of this bluff (Fig. 17).

Bottom: Very bouldery. Water: Gradually deepening from 6 inches to 4 feet.

VEGETATION.

Water Willow (*Dianthera americana*).
Lake Bulrush (*Scirpus occidentalis*).

The Bulrush society borders the lakeward side of the Water Willow society. Animal life was here abundant, as noted below, the clams living in the sand between the rocks and the snails on the rocks or vegetation.

ANIMAL LIFE.

MOLLUSCA.

Elliptio complanatus, small, abundant between rocks.
Anodonta implicata, common.
Lampsilis iris, rare.
Strophitus undulatus, rare.
Goniobasis livescens, abundant on rocks.
Campeloma integrum, rare (1 specimen).
Bythinia tentaculata, rare (1 specimen).
Physa ancillaria warreniana, not common, on rocks.
Planorbis campanulatus, abundant, on rocks.
Planorbis antrosus, rare.
Planorbis binneyi, rare.
Galba catascopium, abundant, on rocks.
Lymnæa stagnalis lillianæ, rare (1 immature specimen).

CRUSTACEA.

Crawfish (*Cambarus propinquus*), female, between rocks, common.

Galba catascopium and *Planorbis campanulatus* were observed on the submerged stem of the Water Willow.

STATION XXI. MUSKRAT BAY.

Habitat 1. Point at west entrance to bay (Field Nos. 243, 244).

This habitat includes the area extending from the rounded point of land which forms the west shore of Muskrat Bay, well into the western side of the bay, as it all belongs to the same character of habitat. The shore is here bare of vegetation and forms in some places an overhanging bank upwards of a foot above the water, and in other places a smooth sloping beach (Fig. 18).

BOTTOM: Bouldery, sandy in the deeper water. WATER: 6 to 36 inches deep.

VEGETATION.

Bulrush (*Scirpus occidentalis*).

ANIMAL LIFE.

The clams live between the rocks in the sandy bottom of the deeper water, where they are more numerous. The snails live abundantly on the rocks and are less common in the deeper water with sandy bottom.

MOLLUSCA.

Elliptio complanatus, abundant.
Anodonta cataracta, common.
Anodonta implicata, common, gravid.
Anodonta grandis footiana, rare.
Lampsilis luteola, rare, gravid.
Lampsilis radiata, abundant.
Sphærium vermontanum, rare.
Goniobasis livescens, abundant, on rocks.
Amnicola lustrica, rare.
Physa ancillaria warreniana, rare.
Planorbis campanulatus, rare, on rocks.
Planorbis hirsutus, rare.
Galba catascopium, common, on rocks.
Galba emarginata, 1 dead specimen.

INSECTA.

Caddis-fly larvæ (*Helicopsyche borealis*).

Habitat 2. Western part of Muskrat Bay (Field No. 239). Fig. 18.

BOTTOM: Sandy silt, near shore, bouldery near center.
WATER: 2–3 feet deep.
VEGETATION: Zonal.

Zone A.—Shore.

Water Willow (*Dianthera americana*).
Broad-leaved Arrow-head (*Sagittaria latifolia*).
Pickerel-weed (*Pontederia cordata*).
Bur-reed (*Sparganium eurycarpum*).
American Bulrush (*Scirpus americanus*).
Lake Bulrush (*Scirpus occidentalis*).

Zone B. Center of Bay.

Lake Bulrush (*Scirpus occidentalis*).

ANIMAL LIFE.

Mollusks were abundant in the sand and among the boulders, especially in Zone B.

MOLLUSCA.

Elliptio complanatus, abundant.
Alasmidonta undulata, rare, only one found.
Anodonta marginata, rare.
Anodonta cataracta, common, gravid.
Anodonta implicata, common, gravid.
Anodonta grandis footiana, common.
Sphærium vermontanum, common.
Campeloma integrum, common, in sand.

INSECTA.

Caddis-fly larvæ (*Helicopsycke borealis*), common on shells of *Elliptio complanatus*.

HIRUDINEA.

Leech (*Placobdella phalera*, probably juv.)

Habitat 3. Southeast side Muskrat Bay (Field Nos. 246, 247).

BOTTOM: Sandy with occasional boulders. WATER: 2 to 3 feet deep.

VEGETATION: Zonal.

Zone A. Shore, water 10–24 inches deep.

Narrow-leaved Cat-tail (*Typha angustifolia*).
Bur-reed (*Sparganium eurycarpum*).
Broad-leaved Arrow-head (*Sagittaria latifolia*).
American Bulrush (*Scirpus americanus*).

Zone B. More open water 2–3 feet deep.

Pickerel-weed (*Pontederia cordata*).
Lake Bulrush (*Scirpus occidentalis*).
Sweet-scented Water Lily (*Castalia odorata*).
Cow Lily (*Nymphæa advena*).
Floating Pond-weed (*Potamogeton natans*).

SUBMERGED VEGETATION.

Water Weed (*Elodea canadensis*).
Hornwort (*Ceratophyllum demersum*).
Water Milfoil (*Myriophyllum spicatum*).
Water Celery (*Vallisneria spiralis*).
Clasping-leaved Pond-weed (*Potamogeton perfoliatus*).
Stonewort (*Chara* species).

ANIMAL LIFE (IN ZONE B).

MOLLUSCA.

Anodonta cataracta, 1 juvenile 9 mill. long.
Sphærium striatinum, infrequent.
Amnicola lustrica, common, adult and young.
Galba catascopium, common, on stray boulders.
Planorbis campanulatus, on under surface of lily leaves.

INSECTA.

Caddis-fly larvæ (*Helicopsyche borealis*).

Station XXII. Fiegel Point (Field No. 241).

Fiegel Point marks the eastern boundary of Muskrat Bay. It is a bare, windswept area, the vegetation being a heavy growth of Water Willow *(Dianthera americana)* in water from 1 to 3 feet in depth. The bottom is gravelly or bouldery. Mollusks were very abundant.

ANIMAL LIFE.

MOLLUSCA.

Anodonta implicata, gravid, common.
Anodonta cataracta, common.
Elliptio complanatus, common.
Sphærium vermontanum, rare.
Goniobasis livescens, common, on rocks.
Galba catascopium, abundant, on rocks.
Physa ancillaria warreniana, rare. young.

INSECTA.

Caddis-fly larvæ (*Helicopsyche borealis*), abundant on rocks.

Station XXIII. Walnut Point (Fig. 19).

This habitat is a long, narrow point extending in a northerly direction for a distance of over a quarter of a mile into the lake. The point itself turns to the northeast almost at a right angle. The water about this point is from 1 to 3 feet in depth and the bottom is very bouldery. The only vegetation is the Water Willow *(Dianthera americana)*.

ANIMAL LIFE.

MOLLUSCA.

Goniobasis livescens, abundant, on rocks.
Galba catascopium, abundant, on rocks.
Elliptio complanatus, common, between rocks.

Adams and Hankinson collected the leech, *Hæmopis marmoratis,* in considerable numbers on Walnut Point and on the shore east of the point, Sept. 3, 1915.

Fig. 16. Station XIX. Shore of bay west of Shepard Point showing bare condition. The bottom is sandy. Plant associations in distance, in the water, consist of *Dianthera, Scirpus occidentalis,* and *Pontederia.*

Fig. 17. Shepard Point from Bartel's pier, Station XX. The vegetation consists of *Dianthera* and *Scirpus occidentalis* which form a heavy growth along the shore and on the point. The man in the boat in the foreground is holding up the crowfoot dredge.

Station XXIV. Bay East of Walnut Point (Field No. 245). Fig. 19.

This habitat is a wide bay, lying between Walnut and Old Man Points. It is well filled with vegetation which is arranged in zones.

Bottom: Sandy, with occasional boulders. Water: 2–3 feet deep.

Vegetation: Zonal.

Zone A. Bordering shore, water 6–18 inches deep.

Narrow-leaved Cat-tail (*Typha angustifolia*).
Bur-reed (*Sparganium eurycarpum*).
Broad-leaved Arrow-head (*Sagittaria latifolia*).

Zone B. The Open Bay, water 2–3 feet deep.

Pickerel-weed (*Pontederia cordata*).
Water Willow (*Dianthera americana*).
Lake Bulrush (*Scirpus occidentalis*).
Sweet-scented Water Lily (*Castalia odorata*).
Cow Lily (*Nymphæa advena*).
Floating Pond-weed (*Potamogeton natans*).

The Water Willow and the Pickerel-weed grow in societies which form considerable patches here and there.

SUBMERGED VEGETATION.

Clasping-leaved Pond-weed (*Potamogeton perfoliatus*).
Water Celery (*Vallisneria spiralis*).
Water Weed (*Elodea canadensis*).
Hornwort (*Ceratophyllum demersum*).
Stonewort (*Chara* species).

ANIMAL LIFE.

MOLLUSCA.

Planorbis campanulatus; common on stems of pickerel-weed two feet below the surface.

Elliptio complanatus, common on sandy bottom.

Station XXV. Old Man Point (Field No. 242). Fig. 19.

A broadly rounded point extending into the lake between Walnut Point and Long Point.

Bottom: Bouldery and gravelly. Water: 1 to 3 feet deep.

VEGETATION.

Water Willow (*Dianthera americana*).

American Bulrush (*Scirpus americanus*).

ANIMAL LIFE.

MOLLUSCA.

Elliptio complanatus, common, between rocks.

Lampsilis radiata, common, between rocks (gravid).

Lampsilis luteola, rare, between rocks (gravid).

Anodonta grandis footiana, not common, between rocks.

Goniobasis livescens, abundant, on rocks.

Galba catascopium, abundant, on rocks.

Lymnæa stagnalis lillianæ, abundant, on rocks, near shore.

Planorbis campanulatus, abundant, on rocks.

Planorbis hirsutus, not common, between rocks.

Physa ancillaria warreniana, abundant, on rocks near shore.

Station XXVI. Long Point (Field No. 240).

Long Point is a narrow piece of land extending into the lake eastward for about three-quarters of a mile. It is about one-eighth of a mile wide and is bordered on both sides by shallow bays filled with vegetation (Fig. 21). The habitat under discussion is at the extreme end of the point, on the north side.

Between Long Point and Frenchman Island several shallows occur (see map, Fig. 1), which are covered with a heavy growth of Water Willow *(Dianthera)* surrounded by two species of Bulrush *(Scirpus americanus* and *S. occidentalis)*. These shoals are from 3 to 5 feet deep and are surrounded by water from 12 to 15 feet deep. They are plainly indicated by the dense association of Water Willow (Fig. 20).

The animal life is the same as that found nearer the shore on Long Point.

BOTTOM: Bouldery on point, sandy in western part of embayment. WATER: 1 to 2 feet deep.

VEGETATION.

Water Willow (*Dianthera americana*).
American Bulrush (*Scirpus americanus*).
Lake Bulrush (*Scirpus occidentalis*).

ANIMAL LIFE.

MOLLUSCA.

Elliptio complanatus, common, between rocks.
Lampsilis radiata, common, between rocks.
Anodonta implicata, rare, between rocks.
Anodonta cataracta, common, between rocks, gravid.
Sphærium vermontanum, not common.
Goniobasis livescens, abundant, on rocks.
Galba catascopium, abundant, on rocks.
Lymnæa stagnalis lillianæ, rare, on rocks along shore.
Planorbis antrosus, rare, on rocks.
Planorbis campanulatus, common, on rocks.
Physa ancillaria warreniana, on *Scirpus*.

INSECTA.

Caddis-fly larvæ (*Helicopsyche borealis*), abundant on rocks.

STATION XXVII. LOWER SOUTH BAY.

Two places were examined at this station.

Habitat 1. Steamboat Wharf. Mollusks on stones and loose timbers in a few inches of water, on protected side (Field No. 278).

Bythinia tentaculata, abundant.
Planorbis trivolvis, abundant.
Physa integra, common.
Anodonta marginata, dead specimen on shore.

Habitat 2. Debris on shore, near Thierre's landing (Field No. 280). The shore in several places was paved with the dead shells of mollusks, clearly attesting the abundance of these animals in the bay. Species marked with an * were very abundant.

**Elliptio complanatus.*
Lampsilis radiata.
Lampsilis borealis.
Sphærium vermontanum.
Goniobasis livescens.
Campeloma integrum.
Somatogyrus subglobosus.
Gillia altilis.
Amnicola lustrica.
Bythinia tentaculata.
Valvata bicarinata normalis.
Physa ancillaria warreniana.
Physa integra.
**Planorbis campanulatus.*
Planorbis antrosus.
**Galba catascopium.*

STATION XXVIII. GRAVES BAY (FIELD NO. 93).

From shallow water, on a bouldery bottom, Dr. Adams collected *Lymnæa stagnalis lillianæ* in great abundance.

STATION XXIX. CHITTENANGO CREEK (FIELD NO. 90).

East of mouth of Chittenango Creek, on sandy beach, from knee deep to shore on firm sand or firm black mud. Clams abundant (collected by Adams and Hankinson).

Elliptio complanatus, badly eroded. *Lampsilis luteola*, gravid.

Adams and Hankinson found leeches, *Hæmopis marmoratis*, feeding in a lamprey scar on a dead catfish, in Maple Bay, Sept. 2, 1915.

III. Islands in the Lake.

In addition to the two large islands in the western part of the lake (Frenchman and Dunham), there are several small islands and shoals, the former being but a foot or so above the surface of the water, and the latter one or two feet beneath the surface. These islands have proven to be among the most interesting of the habitats, life being unusually abundant.

STATION XXX. FRENCHMAN ISLAND, NORTHEAST SIDE.

Frenchman Island is situated about a mile east of Long Point. It is a high body of land rising about eleven feet above the surface of the lake. On the west, north and east sides there are strong wave-cut terraces but the south side is low and lacks this bold character. A shallow zone, or terrace, surrounds the island. This is notably broad on the north, east and south sides, where the water is from 2 to 4 feet deep, but on the west side there is an abrupt drop to 8 feet. A quarter of a mile west of the island the water is 15 feet deep, and east of the island it is 20 feet deep.

Habitat 1. Fig. 22. (Field No. 213.) This habitat is a quiet water, pond-like tract, separated from the open lake by a ridge, in some places subaqueous, upon which the following plants are growing:

Buttonbush (*Cephalanthus occidentalis*).
Water Willow (*Dianthera americana*).
Swamp Loosestrife (*Decodon verticillatus*).

Inside this lakeward barrier the water lies in a long shallow pool, not exceeding 20 inches in depth. The bottom is soft silt in spots, for the depth of a few inches, then hard sand or clay. It is mostly of firm material. The vegetation is very dense and consists of:

Broad-leaved Arrow-head (*Sagittaria latifolia*).
Smith's Bulrush (*Scirpus smithii*).
Water Willow (*Dianthera americana*).
Sedge (*Carex trichocarpa*).
Larger Blue Flag (*Iris versicolor*).

The subaqueous terrace on the northeastern side of the island is characteristic and clearly shows its origin. The material cut from the high part of the island has been carried lakeward forming the wide, submerged terrace. The sequence of events as shown here is noteworthy. Below the high terrace formed by the island there is an area of stones and boulders which represents the first bouldery beach. The sandy area in habitat 1 was the deeper water not subject to violent wave action. Later the water had been lowered and a barrier was formed which arrested the force of the waves. This became covered with bushes and other plants, providing a very effective barrier. The lake again sorted the material on the new beach and the bouldery habitat, No. 2, was the result.

Fig. 18. Station XXI, habitats 1 and 2, Muskrat Bay. Inside the point is a small bay (habitat 2) with sandy shores and bottom, in which *Scirpus americanus*, *S. occidentalis*, *Pontederia*, *Dianthera*, and *Sparganium* are found. *Salix nigra falcata* forms a dense growth a few feet back of the sandy beach.

Fig. 19. Stations XXIV and XXV. View from Old Man Point looking across a small bay, station XXIV. Walnut Point is seen in the distance. The vegetation in the foreground is *Scirpus americanus;* in the middle distance, *Dianthera* and *Scirpus occidentalis;* in the background, near Walnut Point, *Pontederia, Dianthera, Castalia, Nymphæa, Scirpus americanus* and *S. occidentalis.*

ANIMAL LIFE.

MOLLUSCA.

Elliptio complanatus, rare, two specimens found; emigrants from the next station.

Lymnæa stagnalis lillianæ, common, on bottom and plants.

Lymnæa stagnalis lillianæ, eggs on stems of plants.

Galba catascopium, abundant on bottom and plants, a migrant from station XXX.

Planorbis trivolvis, var., abundant, on bottom and plants.

Planorbis campanulatus, not common, on plants.

Physa ancillaria warreniana, not common, on plants and bottom.

Succinea retusa, in pool on Water Willow.

INSECTA.

Back-swimmer (*Notonecta undulata*), common.

Water-strider (*Gerris buenoi*), common.

Small Water Bug (*Belostoma flumineum*), nymph, common.

Water-scavenger Beetle (*Tropisternus glaber*), abundant.

Water-scavenger Beetle (*Philhydrus cinctus*), common.

Preaaceous Diving Beetle (*Laccophilus maculosus*), abundant.

Dragon-fly nymph (*Æschna* species).

Dragon-fly nymph (*Gomphus sordidus*).

Damsel-fly nymph (*Enallagma* species).

Damsel-fly (*Enallagma* species).

Nymph.

It is probable that such species as *Galba catascopium* and *Elliptio complanatus* are emigrants from the next station, as there are one or more wide connections between this pool and the open lake. In times of storm or high water the barrier must be covered with water and is of little avail as a barrier. The *Planorbis trivolvis* is not the large, narrow form typical of swampy ponds, but a wider, smaller form, evidently closely related to *binneyi*.

It is evident from a study of the habitats on Frenchman Island, that a rapid change is going on, and that the environments are in a transition stage from open lake to swamp habitats. Station XXX indicates how this may come about by the formation of a lakeward barrier which more or less effectually bars the rough water of the open lake. This area becomes inhabited by those animals, insects and mollusks, that thrive best in calmer water. When such a habitat becomes entirely closed to the lake, preventing the influx of fresh water, a true swamp takes the place of the lake-shore type and the vegetation and the animal life change accordingly. Such a transformation is in progress over the entire area between Frenchman and Dunham Islands and will eventually result in the formation of a pure marsh or swamp type, separated from the open lake by beach barriers, which will support such vegetation as Buttonbush, Swamp Loosestrife and Black Willow. The presence of cat-tails and pond lilies indicate that this transition is now well under way.

Habitat 2. (Field Nos. 211, 212). Fig. 23. This habitat begins near the barrier mentioned in habitat 1, where the water is six inches in depth and extends lakeward gradually deepening for 500 feet until a depth of 5 feet is reached, at which point the bottom drops suddenly to 12 and then to 20 feet. The shoreward margin is lined with Water Willow which extends lakeward, in patches, for a distance of several hundred feet. The bottom is very bouldery for over a hundred feet from the barrier, where it becomes sandy with an occasional boulder.

ANIMAL LIFE.

MOLLUSCA.

Anodonta marginata, between stones, in sand, common.
Anodonta cataracta, between stones, in sand, common.
Anodonta implicata, between stones, in sand, common.
Lampsilis radiata, between stones, in sand, common.
Lampsilis borealis, between stones, in sand, common.
Lampsilis luteola, between stones, in sand, rare.
Nephronajas ligamentina, rare, but one found.
Elliptio complanatus, between stones, in sand, abundant.
Musculium securis, rare, between stones, near shore.
Musculium rosaceum, rare, between stones, near shore.
Goniobasis livescens, abundant, on stones.
Galba catascopium, abundant, on stones.
Lymnæa stagnalis lillianæ, common, on stones, near shore.
Planorbis trivolvis, var., abundant, usually on stems of plants, near shore.
Planorbis binneyi, common on rocks near shore.
Physa ancillaria warreniana, common, on rocks and plants.

INSECTA.

Caddis-fly larvæ (*Helicopsyche borealis*), on rocks, abundant.
Water-penny, beetle larvæ (*Psephenus lecontei*), on rocks, abundant.

HIRUDINEA.

Leech (*Erpobdella punctata*).

The *Goniobasis* varies greatly in width of shell. On the shore, back of the Water Willow association, numerous piles of empty, clean shells attest the presence of that good clam collector, the muskrat. Seven species were noted. A count of two related species revealed an interesting relative abundance of the two sexes. This is shown below.

Lampsilis radiata, male, 66 per cent; female, 34 per cent.
Lampsilis borealis, male, 20 per cent; female, 80 per cent.

STATION XXXI. FRENCHMAN ISLAND, SOUTH SIDE.

For a distance of a third of a mile southeast of the island a shallow terrace extends, which ranges from 1 to 4 feet in depth. On the edges of this area the water abruptly drops to 6 and 8 feet in depth. The two islands, Frenchman and Dunham, are joined by a submerged ridge which is not deeper than 4 feet, near the latter island.

The vegetation bordering Frenchman Island is abundant and varied and the station is divisible into several habitats. The arrangement of the vegetation is also zonal.

Habitat 1. East of Typha Association. Fig. 24.

Zone A. The Shore. Buttonbush-Loosestrife Association.

Buttonbush (*Cephalanthus occidentalis*).
Swamp Loosestrife (*Decodon verticillatus*).
Sedge (*Carex trichocarpa*).

Zone B. Burreed-Arrowhead-Nymphaea Association.

BOTTOM: Sandy-silt, rather soft. WATER: 12–24 inches deep.

Bur-reed (*Spraganium eurycarpum*).
Broad-leaved Arrowhead (*Sagittaria latifolia*).
American Bulrush (*Scirpus americanus*).
Pickerel-weed (*Pontederia cordata*).
Sweet-scented Water Lily (*Castalia odorata*).
Cow Lily (*Nymphæa advena*).

Zone C. Bulrush-Water Willow Association.

BOTTOM: Hard, sandy with an occasional boulder.
WATER: 2–3 feet deep.

American Bulrush (*Scirpus americanus*).
Smith's Bulrush (*Scirpus smithii*).
Water Willow (*Dianthera americana*).
Pickerel-weed (*Pontederia cordata*).

Zone D. Pure Water Willow Association.

BOTTOM: Hard, sandy. WATER: 2–4 feet deep.

Water Willow (*Dianthera americana*).
Lake Bulrush (*Scirpus occidentalis*).

ANIMAL LIFE.

Zone B. (Field Nos. 214, 215.) Fig. 24.

MOLLUSCA.

Ancylus fuscus, under side of pond lily leaves, common.
Acella haldemani, on *Scirpus smithii* and on under side of pond lily leaves, common.
Lymnæa stagnals lillianæ, egg capsules on lily leaves.
Lymnæa stagnalis lillianæ, abundant on bottom, near shore.
Galba catascopium, rare, on the bottom.
Planorbis trivolvis, common, on the bottom.
Planorbis campanulatus, common, on all vegetation and on the bottom.
Physa ancillaria warreniana, rare, on vegetation.
Bythinia tentaculata, not common, on *Scirpus* and *Dianthera*.
Amnicola limosa, rare, on the bottom.

INSECTA.

Caddis-fly cases (*Helicopsyche borealis*).
Caddis-fly larvæ (*Platycentropus maculipennis*).
Caddis-fly cases (*Leptocella* species).
Dragon-fly nymph (*Gomphus sordidus*).

Lymnæa and *Planorbis* were observed on the bottom and on stems of Water-Lily, Arrow-head, Pickerel-weed, and leaves of water lily. The best *Lymnæa* habitat was a strip about 20 feet wide bordering the shore (Fig. 25), where the bottom was of soft, brown material (detritus, see Chapter III). The water lily societies occurred in holes about two feet deep, which were scattered over this habitat. *Acella* was abundant on lily leaves and especially on *Scirpus smithii*, where they resembled spines, the spires of the shells pointing upward. These animals were observed from six to twelve inches beneath the surface. The pond lily leaves afforded food and attachment for *Planorbis, Acella, Physa,* and *Ancylus.*

Zone C. (Field Nos. 216, 217).

MOLLUSCA.

**Galba catascopium*, not common, on plants.
**Planorbis campanulatus*, abundant, on bottom and plants.
Planorbis antrosus, common, on bottom and plants.
Planorbis hirsutus, rare, on bottom.
Planorbis trivolvis, var., common, on bottom and plants.
Physa ancillaria warreniana, rare, on plants.
**Bythinia tentaculata*, abundant, on bottom and plants.
Amnicola lustrica, common, on bottom.
Valvata bicarinata normalis, rare, on bottom.
Sphærium vermontanum, common, on bottom in sand.
Musculium securis, rare, on bottom in sand.

The two zones, B and C, overlap to some extent, but no *Lymnæa stagnalis lillianæ* were found in Zone C. Those species marked with an * were more abundant in Zone C than in Zone B. In Zone C *Bythinia* was notably abundant on the stems of Water Willow and Smith's Bulrush. *Sphærium, Amnicola* and *Planorbis campanulatus* were abundant on the sandy bottom. This habitat evidently provides an excellent hunting ground for bottom feeding fish, such as pumpkinseed, suckers, and catfish.

In Zone C several thousand specimens were gathered from a depression beside a boulder, in 20 inches of water. This contained both dead and living material, mostly the former. Twenty-three species of mollusks are represented. The large number of individuals contained in this lot strikingly attests the great abundance of this class of animals in Oneida Lake. Those marked with an * are known especially to be eaten by fishes.

MOLLUSCA.

Elliptio complanatus, 8 specimens.
Alasmidonta undulata, 1 specimen 6 mill. long.
**Sphærium vermontanum*, abundant.
**Musculium securis*, abundant.

Fig. 20. Station XXVI. View from Long Point looking eastward toward Frenchman and Dunham Islands. The dark masses of vegetation consist almost wholly of *Dianthera*, which occur in well marked associations. *Scirpus americanus* and *S. occidentalis* fill in the areas between the *Dianthera* associations.

Fig. 21. Station XXVI. View from Long Point looking northwest toward a small point of land (see map, fig. 1). This is a small, sandy embayment, with the same vegetation shown in fig. 20. *Scirpus* is here of heavier growth than shown in the previous figure. The man shows one method of collecting material with the Walker hand dredge.

Pisidium ferrugineum, rare (1 specimen).
**Pisidium variabile*, common.
**Pisidium compressum lævigatum*, abundant.
Pisidium species, rare.
**Amnicola lustrica*, abundant.
Amnicola lustrica, var., rare (1 specimen).
**Amnicola limosa*, common.
**Bythinia tentaculata*, very abundant.
Campeloma integrum, rare.
**Valvata tricarinata*, abundant.
**Galba catascopium*, abundant.
Planorbis trivolvis, not common.
**Planorbis antrosus*, common.
**Planorbis campanulatus*, abundant.
**Planorbis exacuous*, rare.
**Planorbis hirsutus*, rare.
**Planorbis parvus*, common.
**Physa ancillaria warreniana*, common.
Physa integra, uncommon.

INSECTA.

Caddis-fly larvæ (*Helicopsyche borealis*).
Caddis-fly cases (*Molanna* species).
Caddis-fly cases (*Leptocella* species).
Caddis-fly cases (Limnephilid species).

Habitat 2. Typha Association. (Field No. 218). Fig. 25.

This is a pure association of the Narrow-leaved Cat-tail (*Typha angustifolia*). The only other plant present on the surface was the Larger Duckweed (*Spirodela polyrhiza*).

Bottom: Muddy, with accumulation of dead plant debris.
Water: 16–24 inches deep.

ANIMAL LIFE.

MOLLUSCA.

**Planorbis parvus*, common, on dead *Typha* leaves.
**Planorbis exacuous*, common, on dead *Typha* leaves.
**Ancylus fuscus*, abundant on dead *Typha* leaves.
**Planorbis trivolvis*, abundant on dead vegetation.
**Lymnæa stagnalis lillianæ*, egg capsules on dead *Typha* leaves.
**Lymnæa stagnalis lillianæ*, floating in water among debris.
Bythinia tentaculata, 2 young individuals.
Valvata bicarinata normalis, 1 individual.
Anodonta cataracta, I individual, 1½ inches long, on bottom.
Lampsilis radiata, 1 individual, 1 inch long, on bottom.

Those names marked by an * may be considered as normal inhabitants of this habitat. The others have been washed in.

Habitat 3. Nymphæa-Pontederia Association.

This habitat (Field No. 219) lies west of the *Typha* association. The vegetation is unusually thick. Fig. 26.

BOTTOM: Sandy mud. WATER: 12–24 inches deep.

VEGETATION.

Pickerel-weed (*Pontederia cordata*).
Cow Lily (*Nymphæa advena*).
Sweet-scented Water Lily (*Castalia odorata*).

ANIMAL LIFE.

MOLLUSCA.

Lymnæa stagnalis lillianæ, common.
Planorbis trivolvis, abundant.

These mollusks were observed floating on the water, shell downward, or on the leaves of pond-lilies, or on the stems of Pickerel-weed. Near the *Typha* association a mud-bog is forming. In one spot the mass of dead vegetation, mud and living *Typha* have formed a trembling bog, floating on the surface.

Habitat 4. (Field Nos. 209, 220, 221). An area comparatively free from water plants, not far from shore, subject to moderate wave action, although protected by a zone of Water Willow about 100 feet from shore.

BOTTOM: Hard, stony and bouldery, on sand. WATER: 6–15 inches deep.

ANIMAL LIFE.

MOLLUSCA.

Ancylus parallelus, in dead shells of clams, common.
Planorbis hirsutus, 1 specimen, on rock.
Planorbis campanulatus, 4 specimens, 1 distorted, on rocks.
Planorbis binneyi, 3 specimens, young, on rocks.
Planorbis antrosus, 2 specimens, on rocks.
Galba catascopium, common, on rocks, many young.
Physa ancillaria warreniana, common, on rocks.
Bythinia tentaculata, abundant, in dead shells of clams, mostly young.
Amnicola lustrica, abundant, in dead shells of clams, mostly young.
Campeloma integrum, 1 specimen, half grown.

The dead shells of six species of clams were noted, the first four containing *Ancylus, Amnicola,* and *Bythinia.*

Elliptio complanatus.
Lampsilis radiata.
Lampsilis borealis.
Anodonta grandis footiana.
Anodonta marginata.
Anodonta implicata.

INSECTA.

Caddis-fly larvæ (*Helicopsyche borealis*).
Caddis-fly cases (*Leptocella* species).

Station XXXII. South Shore Frenchman Island.

Near the shore, in damp or even wet spots, many land snails, *Polygyra thyroides,* were observed. Twenty feet from the shore they were seen to feed upon the leaves of the nettle (*Urtica,* Field No. 222). Some of the shells of the snails were rose colored.

Station XXXIII. Long Island (Field Nos. 208, 143). Figs. 27, 28.

Long Island is a long, low body of land, a trifle more than a mile south of Constantia. It is situated in the center of a cluster of five large islands and shoals (three islands and two shoals), and lies in a northwest by southeast direction. It is a trifle more than an eighth of a mile long and about 20 feet wide. The water immediately surrounding the island is shallow (1 to 2 feet deep), but drops to 8 and then to 18–24 feet a short distance away. The shallowest spots are at the north and south ends, where they extend eastward and westward for the distance of an eighth of a mile (Fig. 28). Sedges (*Carex trichocarpa*) and other plants are growing upon the narrow islet and slowly adding to its surface. The bottom in the shallow water is bouldery and the vegetation consists of Water Willow (*Dianthera americana*) and Bulrush (*Scirpus occidentalis, S. americanus*). Animal life is exceedingly abundant, covering the boulders and clinging to the water plants. The island is exposed on all sides to the rough waves of the lake, which, however, are modified in spots by the thickness of the colonies of Water Willow, which form a dense barrier 20–25 feet from the shore. (See Fig. 27.)

MOLLUSCA.

Elliptio complanatus, abundant, between rocks.
Margaritana margaritifera, rare, between rocks.
Lampsilis radiata, common, between rocks (gravid).
Lymnæa stagnalis lillianæ, abundant, on rocks, near shore.
Lymnæa stagnalis lillanæ, egg capsules on water plants.
Galba catascopium, common, on rocks and plants.
Planorbis binneyi, common, on rocks, near shore.
Planorbis campanulatus, common, on rocks and plants.
Physa ancillaria warreniana, common, on rocks and plants.

CRUSTACEA.

Crawfish (*Cambarus propinquus*), male, of I form.

INSECTA.

Water-penny, larvæ of beetle (*Psephenus lecontei*), on rocks.
Caddis-fly larvæ (*Helicopsyche borealis*), common, on rocks.

HIRUDINEA.

Leech (*Hæmopis marmoratis*).

IV. The Outlet, Brewerton.

The original character of the outlet, or that part of the lake which narrows into the Oneida River, has been greatly modified by the Barge Canal. In the portion bordering the north shore a channel 12 feet deep has been dredged for the Barge Canal. The material taken from this channel has been dumped in the outlet bordering the south, or Brewerton shore, changing portions of the outlet from comparatively deep, vegetation-filled water (5–10 feet) to a very shallow (1–3 feet) sandy condition.

Station XXXIV. Artificial Islands. (Field No. 235). Fig. 29.

Bottom: Hard, sandy or stony. Water: 1–3 feet deep.

VEGETATION.

Water Willow (*Dianthera americana*).
Broad-leaved Arrow-head (*Sagittaria latifolia*).
Swamp Loosestrife (*Decodon verticillatus*).
Sedge (*Carex trichocarpa*).

ANIMAL LIFE.

MOLLUSCA.

Vivipara contectoides, abundant.
Campeloma integrum, rare.
Goniobasis livescens, rare.
Planorbis campanulatus, rare.

STATION XXXV. CENTER OF OUTLET, MODIFIED BY CANAL (FIELD NO. 237). EAST OF DAVISON'S LANDING.

BOTTOM: Fine sand. WATER: 3–5 feet deep.

The vegetation is divisible into two classes, aerial and submerged (figure 30, page 104).

AERIAL VEGETATION.

This type of vegetation grows in water from 3 to 5 feet in depth, and forms several islands where the plants are massed. These islands exhibit a typical zonal disposition of plants, each type surrounding a central core in a complete circle. One of these islands, situated a few hundred feet northeast of the cemetery at Brewerton may be taken as typical of these island-like plant associations (Fig. 30). In the center the water is but a few inches deep and there is a growth of Sedge (*Carex trichocarpa*); surrounding the *Carex* is a heavy growth of Water Willow (*Dianthera americana*) followed by a ring of Lake Bulrush (*Scirpus occidentalis*). In the center of the south side a bay-like indentation occurs, which is protected from the rough water by the heavy mat of vegetation, and in this spot are a few Cow Lilies (*Nymphæa advena*), Sweet-scented Water Lillies (*Castalia odorata*), Floating Pond-weed (*Potamogeton natans*) and Broad-leaved Arrow-head (*Sagittaria latifolia*).

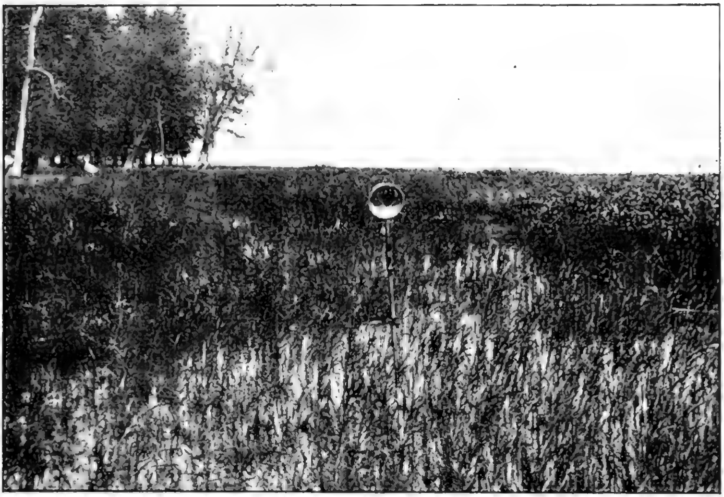

Fig. 22. Station XXX, habitat 1. View looking north on Frenchman Island. Sheltered pond-like body of water, separated from the lake by a ridge of land covered with *Cephalanthus* and *Decodon*. The water is filled with a mass of *Dianthera*, *Sagittaria*, and *Scirpus smithii*. The Walker dredge placed upright indicates the size of the plants.

Fig. 23. Station XXX, habitat 2. View looking north on open shore of Frenchman Island. The shore is lined with a heavy growth of *Dianthera*, back of which, on the left of the picture, may be seen several *Cephalanthus* bushes. The man in the foreground indicates one method of securing material.

SUBMERGED VEGETATION.

Clasping-leaved Pond-weed (*Potamogeton perfoliatus*).
Water Celery (*Vallisneria spiralis*).
Water Weed (*Elodea canadensis*).
Hornwort (*Ceratophyllum demersum*).
Water Milfoil (*Myriophyllum spicatum*).
Stonewort (*Chara* species).

ANIMAL LIFE.

MOLLUSCA.

Elliptio complanatus, in sand, common.
Vivipara contectoides, in sand, common.
Bythinia tentaculata, in vegetation, abundant.
Galba catascopium, in vegetation, not common.
Planorbis campanulatus, in vegetation, common.
Physa ancillaria warreniana, in vegetation, common.

Station XXXVI. Near Davison's Landing (Field No. 285).

Bottom: Sandy silt. Water: 6–18 inches deep.

This habitat borders the shore at Brewerton and is thickly lined with vegetation, including:

Narrow-leaved Cat-tail (*Typha angustifolia*).
Swamp Loosestrife (*Decodon verticillatus*).
Broad-leaved Arrow-head (*Sagittaria latifolia*).
Sedge (*Carex trichocarpa*).

ANIMAL LIFE.

MOLLUSCA.

Galba palustris, not common.

Adams and Hankinson found the large leech, *Hæmopis grandis*, in a boat here, Sept. 4, 1915.

Station XXXVII. Shafer's Boat Landing (Field No. 279).

This habitat is situated between the land and Zett Island. The water is from 2 to 3 feet deep, and the vegetation, all submerged, includes:

Water Celery (*Vallisneria spiralis*).
Water Weed (*Elodea canadensis*).
Hornwort (*Ceratophyllum demersum*).
Water Milfoil (*Myriophyllum spicatum*).
Stonewort (*Chara* species).

ANIMAL LIFE.

MOLLUSCA.

Elliptio complanatus, common.
Lampsilis radiata, common.
Vivipara contectoides, abundant, adult and half grown.
Campeloma integrum, rare.
Amnicola limosa, not common.
Amnicola lustrica, not common.
Galba catascopium, common.
Planorbis campanulatus, rare.
Planorbis hirsutus, rare.
Physa ancillaria warreniana, rare.

V. Oneida River, Below Brewerton.

STATION XXXVIII. (FIELD NO. 267).

This station is about three-quarters of a mile west of the railroad bridge at Brewerton, on the south bank of the river. Near shore the water is from 1–2 feet in depth and the bottom is muddy. The river rapidly deepens to 14 feet. Such plants as the following border the shore:

Narrow-leaved Cat-tail (*Typha angustifolia*).
Broad-leaved Arrow-head (*Sagittaria latifolia*).
Blue Flag. (*Iris versicolor*).

ANIMAL LIFE.

Mollusks were noted in the shallow water bordering the shore, but they did not appear to be very abundant.

Elliptio complanatus, small specimens.
Lampsilis borealis, 1 gravid specimen.
Vivipara contectoides, mostly immature.
Campeloma integrum, approaching *obesum* in form.
Bythinia tentaculata, not common.
Galba catascopium, 1 dead specimen.
Planorbis trivolvis, common.
Planorbis campanulatus, common.
Physa ancillaria warreniana, 1 dead specimen.
Succinea avara, on *Typha*.

VI. Dredgings in the Open Lake.

The dredgings were all made with the crowfoot dredge.

STATION XXXIX. From a point on the north shore of the outlet, 200 feet east of the railroad bridge, southeastward three-eighths of a mile. (Field Nos. 226, 255–256.)

BOTTOM: Sandy silt to mud. WATER: 3 to 10 feet deep.

VEGETATION: All submerged.

Clasping-leaved Pond-weed (*Potamogeton perfoliatus*).
Various-leaved Pond-weed (*Potamogeton heterophyllus*).
Water Celery (*Vallisneria spiralis*).
Water Weed (*Elodea canadensis*).
Hornwort (*Ceratophyllum demersum*).
Water Milfoil, (*Myriophyllum spicatum*).
Stonewort (*Chara* species).

ANIMAL LIFE.

MOLLUSCA.

Bythinia tentaculata, very abundant.
Valvata bicarinata normalis, rare.
Planorbis campanulatus, common.
Planorbis parvus, rare.
Physa ancillaria warreniana, young, abundant.
Ancylus parallelus, not common.

CRUSTACEA.

Amphipod (*Gammarus fasciatus*), abundant.

INSECTA.

Caddis-fly larvæ (*Oecetis resurgens*).
Caddis-fly larvæ (Polycentropid).
Caddis-fly cases (*Leptocella* species).
Damsel-fly nymph (*Enallagma* species).

Bythinia tentaculata is six times as abundant as all the other species combined. A single plant of *Elodea canadensis* contained 25 individuals, young and old, of this species. If this ratio holds good for a large area a square yard of plants would sustain about 1,326 individuals and an acre would contain the enormous number of 8,503,320. From this estimation it may readily be seen that an enormous amount of molluscan life is present in the submerged vegetation of the lake.

In 5 feet of water two species of clams were obtained with the crowfoot dredge (Field No. 257).

Margaritana margaritifera.
Lampsilis borealis.

STATION XL. BIG BAY (FIELD NOS. 272, 273). FIG. 31.

Dredgings were made in lines as follows: One-eighth mile from shore off Milton Point to near end of Big Bay; thence southeastward to off Deer Point; thence back to starting point off Milton Point.

BOTTOM: Sandy or muddy, with occasional boulders. WATER: 8 to 10 feet deep.

VEGETATION.

Water Celery (*Vallisneria spiralis*).
Clasping-leaved Pond-weed, (*Potamogeton perfoliatus*).
Various-leaved Pond-weed (*Potamogeton heterophyllus*).
Water Weed (*Elodea canadensis*).
Hornwort (*Ceratophyllum demersum*).
Water Milfoil, (*Myriophyllum spicatum*).
Stonewort (*Chara* species).

ANIMAL LIFE.

MOLLUSCA.

Planorbis campanulatus, in vegetation.
Physa ancillaria warreniana, in vegetation.

A *Physa*, mostly young, was abundant on the leaves of *Elodea canadensis.*

CRUSTACEA.

Amphipod (*Gammarus fasciatus*), in vegetation.

INSECTA.

Caddis-fly cases (*Leptocella* species).
Caddis-fly larvæ (Polycentropid).
Damsel-fly nymph (*Enallagma signatum*).

HIRUDINEA.

Leech (*Glossiphonia picta*).

STATION XLI. MIDDLE OF LAKE (FIELD NO. 274).

Dredgings were made east and west in the line of the channel, and north and south on a line between Shepard Point and Milton Point.

BOTTOM: Hard sand, with occasional boulder. WATER: 10 to 16 feet deep.

Below a depth of 10 feet no vegetation was observed, but clams were numerous. As many as 8 were brought up at one time on the crowfoot dredge. As observed in all stations studied, *Elliptio complanatus* was the most abundant species. Three species were secured.

Elliptio complanatus. *Lampsilis borealis.*
Lampsilis radiata.

B. ANALYSIS OF ENVIRONMENTS.

A study of the forty-one stations described in the previous pages naturally leads to their division into several more or less distinct types. Each type is found wherever a given combination of environmental factors occur. These forty-one stations may be classified under four major heads, and thirteen minor heads. It is not to be supposed that these habitats are sharply divided. On the contrary, they fade into each other more or less completely, the amount of gradation being governed by the sharpness of the characteristics of the intermediate zones.

1. Lake Types.

I. Boulder-Bottom Type. (Figs. 11, 23.)

Stations II, IV, XI, XIV, XV, XX and XXI are examples of this type of habitat. The shore may be free from vegetation, or it may have associations of Water Willow (*Dianthera americana*) and Bulrush (*Scirpus occidentalis* or *S. americanus*). It receives the full force of the winds and waves from the open lake. The water is from 1 to 3 feet in depth and the bottom is heavily and thickly covered with stones and boulders, many of the latter being of large size. These shallow, rocky areas are almost always at the end of points of land which extend into the lake. Their area varies from 100 to 500 feet in length and from 50 to 200 feet in width. Animal life is abundant, the clams living between the stones and the snails on the stones and on the sand between the stones.

Fig. 24. Station XXXI, habitat 1. View looking southeast from Frenchman Island. Dunham Island in the distance. The shore is lined with *Decodon* and *Cephalanthus*. The plant societies in the water include *Dianthera*, *Carex*, *Sagittaria*, *Pontederia*, *Scirpus smithii* and *S. americanus*, *Castalia*, and *Nymphæa*.

Fig. 25. Station XXXI, habitat 2, Frenchman Island. Habitat 1, A and B zones are shown in the foreground. The *Typha* association is largely developed to the right. Habitat 1, zones C and D, are clearly defined on the left, zone D, almost pure *Dianthera*, being especially clear.

ANIMAL LIFE.

MOLLUSCA.

Elliptio complanatus, common.
Lampsilis luteola, rare.
Lampsilis radiata, common.
Lampsilis iris, rare.
Margaritana margaritifera, rare.
Anodonta cataracta, common.
Anodonta implicata, common.
Anodonta grandis footiana, common.
Strophitus undulatus, rare.
Sphærium vermontanum, not common.
Goniobasis livescens, common.
Amnicola lustrica, not common.
Galba catascopium, common.
Planorbis antrosus, rare.
Planorbis campanulatus, rare.
Planorbis hirsutus, rare.
Physa ancillaria warreniana, rare.
The last four are emigrants from the next type of habitat.

INSECTA.

Caddis-fly larvæ (*Helicopsyche borealis*).
Caddis-fly cases (*Leptocella*).
Whirligig beetles (*Gyrinus ventralis*).
Whirligig beetles (*Dineutes assimilis*).

CRUSTACEA.

Crawfish (*Cambarus propinquus*).

II. Water-Edge Type. (Figs. 14, 16, 27.)

Stations III,[3] V, XIV, XX, XXV, XXVI, XXX,[1] XXXI,[1] XXXI,[4] XXXIII. This includes that part of the shore from the water line to about 8 inches in depth. It may be simply hard sand, or it may be rocky. When uprooted vegetation is carried on shore it affords food for the inhabitants. In some cases the bank is grassy and has been undermined a few inches, forming a vertical bank, a foot or less in height. Usually this habitat is free from vegetation. This type is always more or less protected from the rough water of the lake by a growth of lakeward vegetation of greater or less extent. Mollusks live abundantly on the stones, gravel and sand or under the protection of the overhanging bank.

ANIMAL LIFE.

MOLLUSCA.

Campeloma integrum, common.
Lymnæa stagnalis lillianæ, abundant.
Galba catascopium, not common.
Planorbis campanulatus, common.
Planorbis binneyi, abundant.

Planorbis trivolvis, var., common.
Planorbis hirsutus, rare.
Ancylus parallelus, abundant.
Physa ancillaria warreniana, common.
Bythinia tentaculata, not common.
Amnicola lustrica, not common.

HIRUDINEA.

Leech (*Hæmopis marmoratis*).

CRUSTACEA.

Crawfish (*Cambarus propinquus*).

INSECTA.

Water-penny, beetle larvæ (*Psephenus lecontei*).
Caddis-fly larvæ (*Helicopsyche borealis*).

A type of habitat, which should probably be classified with the water-edge type, occurs in Station XXX, on Frenchman Island (Fig. 22). This is partly protected by a beach ridge, behind which the lagoon-like habitat has been formed. There are one or more small, open channels which connect the lake with the lagoon. The beach ridge is covered with Buttonbush and Swamp Loosestrife, which further protects the quiet pool behind the bar. Quiet water vegetation fills the lagoon, consisting of:

Broad-leaved Arrow-head (*Sagittaria latifolia*).
Smith's Bulrush (*Scirpus smithii*).
Sedge (*Carex trichocarpa*).
Larger Blue Flag (*Iris versicolor*).
Water Willow (*Dianthera americana*).

The last is a remnant of the lake shore vegetation, which persists because of the open channels. It will finally disappear when the lagoon is completely shut off from the lake. (See page 72.)

The animal life noted below occurs more or less abundantly in this lagoon. Minnows and young fish were more or less abundant in this habitat, evidently feeding.

MOLLUSCA.

Elliptio complanatus, rare, emigrant from Type I.
Lymnæa stagnalis lillianæ, common.
Galba catascopium, common, emigrant from Type I.
Planorbis trivolvis, var., abundant.
Planorbis campanulatus, not common.
Physa ancillaria warreniana, not common.
Succinea retusa, not common.

INSECTA.

Back-swimmer (*Notonecta undulata*), common.
Water-strider (*Gerris buenoi*), common.
Small Water Bug (*Belostoma fluminecum*), nymph, common.
Water-scavenger beetle (*Tropisternus glaber*), common.
Water-scavenger beetle (*Philhydrus cinctus*), common.
Predaceous Diving Beetle (*Laccophilus maculosus*), abundant.
Dragon-fly nymph (*Æschna* species).
Dragon-fly nymph (*Gomphus sordidus*).
Damsel-fly nymph (*Enallagma* species).
Damsel-fly nymph (*Enallagma* species).

III. Bulrush-Water Willow Type. (Figs. 5, 12, 19, 20, 21, 28, 29.)

Stations I,[1] I,[4] III,[2 B] V, VIII, XII, XIII, XXI,[2] XXII, XXIII, XXV, XXVI, XXX,[2] XXXIII, are examples of this type of habitat, which is not as exposed to the waves as is the boulder-bottom type. In area it may be as large as 300 by 500 feet. The bottom is more or less covered with stones and boulders, but there are sandy spots here and there. The water varies from 1 to 4 feet in depth. Vegetation is greater in bulk than in type II, consisting of:

American Bulrush (*Scirpus americanus*).
Lake Bulrush (*Scirpus occidentalis*).
Water Willow (*Dianthera americana*).
Pickerel-weed (*Pontederia cordata*).

The principal differences between this habitat and the boulder type are the less exposed situation, the density of the vegetation, the deeper water and the sandier bottom. Such a habitat is particularly favorable for black bass, sunfish, rock bass, and others, because of the hiding and breeding places provided by the thick vegetation, the attachment for eggs by the roots and stems of the plants and the excellent feeding ground by the abundance of animal life, insect, crustacean, and molluscan. The largest number of molluscan species, 39, occur in this type of habitat, including upwards of 15 which are known to be eaten by bottom feeding fish.

ANIMAL LIFE.

MOLLUSCA.

Elliptio complanatus, common.
Margaritana margaritifera, common.
Alasmidonta undulata, rare.
Lampsilis luteola, rare.
Lampsilis radiata, common.
Lampsilis borealis, common.
Nephronajas ligamentina, rare.
Anodonta cataracta, common.
Anodonta implicata, common.
Anodonta marginata, not common.
Anodonta grandis footiana, common.
Sphærium vermontanum, common.
Musculium securis, common.
Musculium rosaceum, rare.
Pisidium ferrugineum, rare.
Pisidium variabile, common.
Pisidium compressum lævigatum, common.
Pisidium æquilaterale, rare.
Pisidium species, rare.
Pisidium species, rare.
Pisidium species, rare.
Goniobasis livescens, common.
Campeloma integrum, not common.
Bythinia tentaculata, common.
Amnicola limosa, common.
Amnicola lustrica, common.
Amnicola lustrica, var., rare.
Valvata tricarinata, not common.
Valvata bicarinata normalis, common.
Physa integra, not common.
Physa ancillaria warreniana, common.
Planorbis campanulatus, common.
Planorbis antrosus, common.
Planorbis trivolvis, var., common.
Planorbis hirsutus, rare.
Planorbis parvus, rare.
Planorbis exacuous, rare.
Galba catascopium, common.
Galba emarginata, rare.

HIRUDINEA.

Leech (*Erpobdella punctata*).
Leech (*Placobdella rugosa*).
Leech (*Placobdella phalera*).
Leech (*Glossiphonia complanata*).
Leech (*Hæmopis marmoratis*).

CRUSTACEA.

Crawfish (*Cambarus propinquus*), common.

INSECTA.

Caddis-fly larvæ (*Helicopsyche borealis*), common.
Caddis-fly cases (*Leptocella* species), common.
Water-penny, beetle larvæ (*Psephenus lecontei*), common.
Whirligig beetle (*Gyrinus ventralis*), common.

IV. Arrowhead-Cattail-Pickerelweed (Figs. 9, 15, 24).

Stations III,[2] IX, XIX, XXI,[3] XXIV and XXXI.[1] In this type of habitat the shore is lined with cat-tails, and beyond these, on the lake side, are such plants as the Arrowhead and Pickerel-weed. The water here is 12 to 36 inches deep and the bottom is firm sand with some gravel and an occasional boulder. The vegetation is arranged zonally, the following species being present:

Black Willow (*Salix nigra* var. *falcata*).
Swamp Loosestrife (*Decodon verticillatus*).
Narrow-leaved Cat-tail (*Typha angustifolia*).
Buttonbush (*Cephalanthus occidentalis*).
Bur-reed (*Sparganium eurycarpum*).
Broad-leaved Arrow-head (*Sagittaria latifolia*).
Pickerel-weed (*Pontederia cordata*).
Lake Bulrush (*Scirpus occidentalis*).
American Bulrush (*Scirpus americanus*).

Toward the lake scattered plants of lilies and pond-weed occur.

Sweet-scented Water Lily (*Castalia odorata*).
Cow Lily (*Nymphæa advena*).
Floating Pond-weed (*Potamogeton natans*).

Animal life is abundant on the bottom or on the stems and leaves of vegetation. This type is a favorable habitat for fish, affording good feeding and probably good breeding grounds. Of the mollusks, upwards of 9 species are used as food by fish.

ANIMAL LIFE.

MOLLUSCA.

Anodonta cataracta, not common.
Elliptio complanatus, common.
Sphærium vermontanum, abundant.
Sphærium striatinum, rare.
Pisidium variabile, abundant.
Pisidium compressum, abundant.
Pisidium compressum lævigatum, abundant.
Pisidium species, rare.
Campeloma integrum, common.
Gillia altilis, common.
Amnicola lustrica, very abundant.
Valvata bicarinata normalis, abundant.
Planorbis campanulatus, common.
Planorbis hirsutus, rare.
Physa ancillaria warreniana, common.
Galba catascopium, not common.

INSECTA.

Dragon-fly nymph (*Gomphus sordidus*).
Dragon-fly nymph (*Æschna* species).
Caddis-fly larvæ (*Helicopsyche borealis*), abundant.
Caddis-fly cases (*Leptocella* species), abundant.
Caddis-fly cases (*Molanna* species), not common.
Caddis-fly larvæ (*Leptocerus* species), rare.
Caddis-fly larvæ (Hydrophilid), rare.
Caddis-fly larvæ (*Phylocentropus* species), rare.

Fig. 26. Station XXXI, habitat 3, Frenchman Island. View looking southeast, Dunham Island in the distance. To the left is habitat 2, the *Typha* association. The middle foreground is habitat 3, which includes a mass of vegitation, *Pontederia*, *Nymphæa*, and *Castalia*. A heavy growth of *Carex trichocarpa* borders the shore, back of which lies the sloping, stony beach which is bare of vegetation. This is shown in the foreground. In the distance, on the right of the picture, may be seen several pure *Dianthera* associations.

Fig. 27. Station XXXIII, north side Long Island, view looking southeast. The shore is lined with *Carex trichocarpa*. The more open water where Professor Hankinson is standing is filled with *Scirpus occidentalis* and *S. americanus* with a few *Dianthera*. The dark patch of vegetation in the background is almost wholly *Dianthera*.

V. Water Lily-Burreed-Bulrush Type. (Fig. 24.)

Station XXXI.[1] This habitat combines characteristics of both the last (IV) and the next (VI) habitats. It is protected from the violence of the waves by the heavy outer zones of Water Willow which serve as an effective barrier against rough water. For this reason the delicate shelled *Acella* is able to live here. The submerged vegetation of the next type is absent and hence some species not found in that association are able to live here. The bottom is sandy silt, rather soft and the water is from 18 to 30 inches deep. The vegetation embraces:

Bur-reed (*Sparganium eurycarpum*).
Broad-leaved Arrow-head (*Sagittaria latifolia*).
American Bulrush (*Scirpus americanus*).
Smith's Bulrush (*Scirpus smithii*).
Pickerel-weed (*Pontederia cordata*).
Sweet-scented Water Lily (*Castalia ordorata*).
Cow Lily (*Nymphæa advena*).

Animal life is abundant on the bottom and particularly on the submerged portions of the vegetation.

ANIMAL LIFE.

MOLLUSCA.

Ancylus fuscus, common.
Acella haldemani, common.
Lymnæa stagnalis lillianæ, common.
Galba catascopium, rare.
Planorbis trivolvis, common.
Planorbis campanulatus, common.
Physa ancillaria warreniana, rare.
Amnicola lustrica, rare.
Bythinia tentaculata, not common.

INSECTA.

Caddis-fly larvæ (*Platycentropus maculipennis*), rare.
Caddis-fly larvæ (Limnephilid), rare.

VI. Water Lily-Chara-Pondweed Type. (Figs. 6, 8.)

Stations I,[2] III,[1] VI, X. This type of habitat is always found in a partly enclosed bay where there is ample protection from the rough waters of the lake. The water is from 2 to 5 feet in depth and the bottom is sandy or silty. The vegetation is abundant, comprising a large number of species as noted below:

Button-bush (*Cephalanthus occidentalis*), common on shore.
Swamp Loosestrife (*Decodon verticillatus*), common on shore.
Water Willow (*Dianthera americana*), rare.
Broad-leaved Arrow-head (*Sagittaria latifolia*), common, near shore.
Narrow-leaved Cat-tail (*Typha angustifolia*), common, near shore.
Bur-reed (*Sparganium eurycarpum*), common, near shore.
Lake Bulrush (*Scirpus occidentalis*), common.
American Bulrush (*Scirpus americanus*), common.
Pickerel-weed (*Pontederia cordata*), common.
Sweet-scented Water Lily (*Castalia odorata*), common.
Cow Lily (*Nymphæa advena*), common.
Floating Pond-weed (*Potamogeton natans*), common.
Various-leaved Pond-weed (*Potamogeton heterophyllus*), common.
Clasping-leaved Pond-weed (*Potamogeton perfoliatus*), common.
Water Celery (*Vallisneria spiralis*), common.
Water Weed (*Elodea canadensis*), common.
Hornwort (*Ceratophyllum demersum*), common.
Water Milfoil (*Myriophyllum spicatum*), common.
Stonewort (*Chara* species), common.

Animal life is abundant on the various water plants.

MOLLUSCA.

Acella haldemani, common.
Pseudosuccinea columella, common.
Pseudosuccinea columella chalybea, common.
Planorbis campanulatus, common.
Planorbis trivolvis, common.
Planorbis hirsutus, rare.
Ancylus parallelus, common.
Physa ancillaria warreniana, common.
Amnicola lustrica, rare.

CRUSTACEA.

Amphipod (*Hyalella knickerbockeri*), common.

INSECTA.

Dragon-fly nymph (*Basiaeschna janata*).
Dragon-fly nymph (*Tetragoneuria cynosura*).

HIRUDINEA.

Leech (*Placobdella picta*).
Leech (*Glossiphonia fusca*).
Leech (*Glossiphonia stagnalis*).
Leech (*Erpobdella punctata*).

VII. Cat-tail Type. (Figs. 6, 9.)

Stations I,[2] III,[2] XXXI.[2] Several habitats occur in which this type of plant prevails. These are always near the shore where the water is from 1 to 3 feet in depth. The bottom here is usually muddy or silty. Vegetation consists of:

Narrow-leaved Cat-tail (*Typha angustifolia*).

Greater Duckweed (*Spirodela polyrhiza*).

Mollusks are more or less abundant, the chief location being on the dead leaves of the cat-tail.

Ancylus fuscus, common.
Planorbis trivolvis, common.
Planorbis parvus, common.
Planorbis exacuous, common.
Lymnæa stagnalis lillianæ, rare.

VIII. Submerged Vegetation Type. (Figs. 29, 30.)

Stations XXXV, XXXVII, XXXIX, XL. In this type of habitat the water is from 4 to 8 feet in depth and the bottom is sandy. It is usually some distance from the shore, either in the outlet or in the lake some distance from land. Big Bay is the largest habitat of this kind, but the outlet produced the greater number of forms of life. The submerged vegetation is very thick, numbering several species and affording food and lodgment for a multitude of mollusks and other forms of life. The clams and a few gastropods live on the bottom, but the majority of gastropods (snails) live on the leaves of the plants. Six species of plants were noted.

Clasping-leaved Pond-weed (*Potamogeton perfoliatus*).
Water Celery (*Vallisneria spiralis*).
Water Weed (*Elodea canadensis*).
Hornwort (*Ceratophyllum demersum*).
Water Milfoil (*Myriophyllum spicatum*).
Stonewort (*Chara* species).

Animal life is usually very abundant in this type of habitat.

MOLLUSCA.

Elliptio complanatus, common.
Lampsilis radiata, common.
Vivipara contectoides, common.
Campeloma integrum, rare.
Valvata bicarinata normalis, common.
Bythinia tentaculata, abundant.
Amnicola lustrica, common.
Galba catascopium, rare.
Planorbis campanulatus, common.
Planorbis hirsutus, rare.
Planorbis parvus, not common.
Physa ancillaria warreniana, common.
Ancylus parallelus, common.

HIRUDINEA.

Leech (*Glossiphonia picta*).

CRUSTACEA.

Amphipod (*Gammarus fasciatus*), abundant.

INSECTA.

Caddis-fly cases (*Leptocella* species), common.

Caddis-fly larvæ (*Oecetis resurgens*), not common.

Caddis-fly larvæ (Polycentropid), rare.

Damsel-fly nymph (*Enallagma* species), common.

Damsel-fly nymph (*Enallagma signatum*), not common.

IX. Deep Water Type. (Fig. 30.)

Station XLI. This type of habitat occurs only in the center of the lake some distance from the shore. The water is from 12 to 16 feet deep and the bottom is sandy with occasional boulders. There is little or no vegetation. The only life observed on the bottom was three species of clams.

MOLLUSCA.

Elliptio complanatus.

Lampsilis radiata.

Lampsilis borealis.

2. Creek Types.

A number of creeks, of greater or less size, empty into the lake. Several very diverse habitats are provided by these streams, varying with the flow of water and the character of the bottom. In some cases the species are different from those found in the lake.

X. Deep Creek Type, Still Water.

Station VII. This habitat is at the mouth of the creek. The area is protected by the swampy banks on all sides, except the mouth. An embayment on the north side of the creek affords quiet water for a heavy growth of water lilies and other aquatics. The raising of the water level has flooded the swamps bordering Big Bay and covered the banks of this habitat with a foot or two of water. The vegetation consists of floating, submerged and aerial species, as noted below:

Black Willow (*Salix nigra* var. *falcata*).

Swamp Loosestrife (*Decodon verticillatus*).

Broad-leaved Arrow-head (*Sagittaria latifolia*).

Cow Lily (*Nymphæa advena*).

Floating Pond-weed (*Potamogeton natans*).

Clasping-leaved Pond-weed (*Potamogeton perfoliatus*).

Animal life is abundant on the leaves and stems of the water plants.

MOLLUSCA.

Pseudosuccinea columella.
Planorbis campanulatus.
Physa ancillaria warreniana.
Physa gyrina.

XI. Shallow Creek Type, Moving Water, Muddy Bottom.

Station XVII. In this type of habitat the water is from one to two or three feet deep, the current is not rapid and the bottom is composed of mud, usually very fine. In places the habitat changes to a rapid stream flowing over a stony bottom, but again resumes the still pool type when a basin is reached. Three species of mollusks were observed, two of them being abundant.

Elliptio complanatus, abundant.
Strophitus edentulus, rare.
Campeloma decisum, abundant.

XII. Shallow Creek Type, Rapid Water, Stony Bottom.

Station XVI.[1] In this type of habitat the bottom is very stony, the water is 6 to 15 inches deep, except in occasional quiet pools, the current is swift and the water is clear and cold. A typical trout stream. Three types of animal life are abundant on the rocks and between and under the rocks.

MOLLUSCA.

Ancylus tardus, common.

CRUSTACEA.

Crawfish (*Cambarus bartoni robustus*), common.

Crawfish (*Cambarus propinquus*), common.

INSECTA.

Water-penny, beetle larvæ (*Psephenus lecontei*), common.

Caddis-fly cases (*Neophylax* species), not common.

Caddis-fly larvæ (*Helicopsyche borealis*), common.

Stone-fly nymph (*Perla* species).

Stone-fly nymph (*Acroneuria* species).

Fig. 28. Southeast end of Long Island. Shallow water extends for nearly a quarter of a mile in this direction. The vegetation consists of *Dianthera* and *Scirpus occidentalis*, with a few *Carex* bordering the shore. The open water near the center of the picture is an excellent habitat for *Lymnæa* and *Planorbis*.

Fig. 29. Station XXXIV. View looking east from artificial island in outlet near Brewerton. In the foreground may be seen a society of *Sagittaria* and *Decodon*. In the middle distance is an almost pure association of *Dianthera*, with a small society of *Carex*. In the background are several associations of *Dianthera* and *Scirpus*, forming habitat XXXV.

XIII. Shallow Creek Type, Quiet Protected Pool.

Station XVI.[1] When a protected spot occurs in the bank of a rapidly flowing stream (as the previous type) a type of habitat is formed quite different from the hurrying waters of the near-by stream. These pools are filled with algæ and animal life is usually abundant.

MOLLUSCA.

Planorbis trivolvis, common.
Planorbis hirsutus, common.
Physa gyrina, common.

CRUSTACEA.

Amphipod (*Hyalella knickerbockeri*), common.

INSECTA.

Water beetle (*Tropisternus glaber*), common.
Damsel-fly nymph (*Enallagma* species), common.

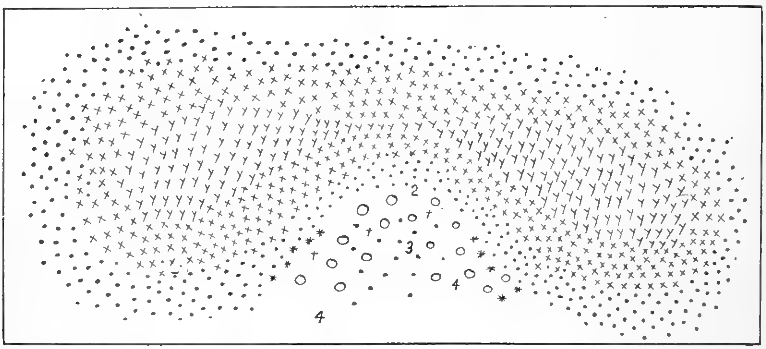

Fig. 30. Diagrammatic map of vegetation island in outlet at Brewerton. 2, 3, 4 depths of water.

Y. *Carex.*
X. *Dianthera americana.*
. *Scirpus occidentalis.*
* *Pontederia cordata.*
0. *Nymphæa advena.*
0. *Castalia odorata.*
† *Potamogeton natans.*

3. River Type.

Stations XXXVI, XXXVIII. In this type of habitat, which is afforded by a narrow strip of water bordering the river bank, the bottom is muddy or sandy, the water is from 1 to 3 feet in depth and there is a quantity of vegetation, such as:

Narrow-leaved Cat-tail (*Typha angustifolia*).

Broad-leaved Arrow-head (*Sagittaria latifolia*).

Blue Flag (*Iris versicolor*).

Mollusks are abundant on the muddy or sandy bottom or on vegetation.

Elliptio complanatus, common.
Lampsilis borealis, common.
Vivipara contectoides, common.
Campeloma integrum, common.
Bythinia tentaculata, common.
Galba catascopium, rare.
Galba palustris, rare.
Planorbis trivolvis, common.
Planorbis campanulatus, common.
Physa ancillaria warreniana, rare.
Succinea avara, rare.

4. Pond Type.

Station XVIII. In this type of habitat the body of water is large, completely protected by rising banks, and the depth ranges from 6 to 8 feet. The bottom usually consists of mud. It is probable that a more extended search would bring to light additional species, only two being noted, both commonly.

Anodonta grandis.
Campeloma decisum.

Fig. 31. Station XL. Big Bay, from Shepard Point.

C. TABLE NO. 1, SHOWING DISPERSAL OF MOLLUSKS AMONG TYPE HABITATS.

LIST OF SPECIES.	1. Lake Types.									2. Creek Types.				3	4
	I. Boulder bottom.	II. Water edge.	III. Bulrush-water willow.	IV. Arrow head-pickerel weed.	V. Water lily-bulrush.	VI. Water lily-Chara.	VII. Cattail.	VIII. Submerged vegetation.	IX. Deep water.	X. Deep, still water.	XI. Shallow, mud, moving water.	XII. Shallow, rocks, rapid water.	XIII. Shallow, protected pool.	River type.	Pond type.
Lampsilis luteola	x		x												
Lampsilis radiata	x		x					x	x						
Lampsilis borealis			x						x					x	
Lampsilis iris	x		x												
Nephronajas ligamentina	x														
Anodonta implicata	x		x												
Anodonta cataracta	x		x	x											
Anodonta marginata			x												
Anodonta grandis footiana	x		x												
Anodonta grandis															x
Alasmidonta undulata			x												
Strophitus edentulus											x				
Strophitus undulatus	x														
Elliptio complanatus	x		x					x	x		x			x	
Margaritana margaritifera			x												
Sphærium striatinum				x											
Sphærium vermontanum	x		x	x											
Musculium securis			x												
Musculium rosaceum			x												
Pisidium ferrugineum			x												
Pisidium compressum				x											
Pisidium compressum lævigatum			x	x											

Pisidium variabile			x	x											
Pisidium æquilaterale			x												
Pisidium henslowanum				x											
Pisidium species			x												
Pisidium species			x												
Pisidium species			x												
Pisidium species				x											
Vivipara contectoides								x						x	
Campeloma integrum		x	x	x				x						x	
Campeloma decisum											x				x
Gillia altilis				x											
Somatogyrus subglobosus				x											
Amnicola lustrica	x	x	x	x	x	x		x							
Amnicola lustrica, var			x												
Amnicola limosa			x		x										
Bythinia tentaculata		x	x		x			x						x	
Goniobasis livescens	x		x												
Valvata tricarinata			x												
Valvata bicarinata normalis			x	x				x							
Ancylus parallelus		x				x		x							
Ancylus tardus												x			
Ancylus fuscus					x	x	x								
Physa ancillaria warreniana	x	x	x	x	x			x		x				x	
Physa integra			x												
Physa gyrina										x			x		
Planorbis campanulatus	x	x	x	x	x	x		x		x				x	
Planorbis antrosus	x		x												
Planorbis binneyi		x													
Planorbis trivolvis, var		x	x												
Planorbis trivolvis					x	x	x						x	x	
Planorbis hirsutus	x	x	x	x		x		x					x		
Planorbis exacuous			x				x								
Planorbis parvus			x				x	x							
Galba catascopium		x	x	x	x			x						x	
Galba emarginata			x												
Galba palustris														x	
Lymnæa stagnalis lillianæ		x			x		x								
Acella haldemani					x	x									
Pseudosuccinea columella						x				x					
Pseudosuccinea columella chalybea						x									
	16	11	39	17	10	9	5	13	3	4	3	1	3	10	2

A study of the table indicates that of the Lake types the Bulrush-Water Willow type of habitat produces the greatest number of species (39) including those mollusks (18 species) known to be of value as food for fish. Other types, as the Boulder type with 16 species and the Arrowhead-Pickerel-weed type with 17 species are noteworthy. Emphasis should be made of the Submerged Vegetation type, in which there are 13 species, because this is probably one of the best locations for mollusk-eating fish, containing as it does such mollusks (9 species) as *Bythinia, Amnicola, Valvata* and *Physa,* all of which are eaten by fish. Of the Creek types, the habitat with rocky bottom and rapid water contains a varied insect and crustacean fauna which is doubtless of value as food to the fish living in this kind of an environment. The single mollusk observed, *Ancylus,* is not yet known to be of food value. In the other types, creek, river and pond, sufficient data is not yet available for comparison.

D. BREEDING GROUNDS FOR FISH.

Available and suitable grounds for breeding purposes are plentiful in Oneida Lake. A large number of fishes breed in shallow water (1 to 3 feet deep), and those building nests, as the Dogfish, Black Bass, Crappie, Sunfish and Bluegill, require a gravelly or debris-covered bottom, with more or less vegetation, as Bulrush, Pond-weed, or Sedge. These conditions are admirably met in Oneida Lake, where there are large areas of shallow water with suitable bottom and vegetation. The area available for this purpose probably exceeds 3,000 acres or 4.7 square miles. Those species seeking marshy or swampy places with much vegetation, as the Carp, Chub-sucker and Common Bullhead, find such habitats along the shores of Big Bay. It is an interesting coincidence that the maximum breeding period of fish, in April and May, is also the period of greatest development of *Entomostraca,* upon which the young fish feed. This is a good example of the interrelation of organisms.

E. COMPARISON WITH OTHER LAKES AND LOCALITIES.

1. Tomahawk Lake, Wisconsin.

The only lake with which the writer is personally acquainted that is comparable to Oneida Lake is Tomahawk Lake, situated on a line between Oneida and Villas Counties, Wisconsin (Baker, 1911a). This lake is over four miles long and two miles wide, and its many bays and coves give it a shore line of over eighty miles. It is surrounded by heavy forests, particularly on the south shore, where there is a virgin forest belonging to the Wisconsin Forest Reservation. The north and south borders have been extensively logged over. A conspicuous subaqueous terrace borders the shore, affording excellent habitats for aquatic plants. The small bays are usually rather shallow, as are also the areas covering the terraces, but in the middle of the lake the depth is reported to be as much as 60 feet.

The molluscan fauna is rich and varied, 47 aquatic species being recorded of which 20 are found in Oneida Lake. Three varieties, not generally known to inhabit the lakes of New York State, are common to both regions. *Planorbis binneyi, Physa ancillaria warreniana,* and *Lymnæa stagnalis lillianæ,* the latter being first described from Tomahawk Lake. The characteristic habitats of Tomahawk Lake are repeated, in a degree, in Oneida Lake.

2. Lake St. Clair, Michigan-Canada.

This lake lies between Lake Huron on the north and Lake Erie on the south (Smith, 1894, pp. 43–44). The lake has an area of 410 square miles, a shore line of 187 miles, and a depth of about 20 feet in the center. There is a great development of shallow water along the shores and hence a large quantity of vegetation, which supports a large and varied fauna.

An extensive molluscan fauna occurs consisting of 45 species. Seventeen species of this number are found in

Oneida Lake. As no *Pisidia* are mentioned in the published list which is quite old, it is quite probable that this total number of species could be increased by at least a dozen species.

3. Traverse Bay Region-Lake Michigan.

Some years ago the Michigan Fish Commission (Walker, 1896, pp. 96–99), conducted dredging in the neighborhood of Charlevoix, Michigan, both in Lake Michigan and in some of the inland lakes, Pine, Bear, etc. Sixty-four species of aquatic mollusks were collected of which 23 are represented in Oneida Lake. A single haul of the dredge over a bed of Chara, near High Island, brought up several hundred specimens of 26 species belonging to 7 genera, as noted below (p. 97):

Lymnæa.	5	species.
Planorbis.	3	"
Physa.	1	"
Amnicola.	3	"
Bythinella.	1	"
Pisidium.	11	"

Several of these genera (*Lymnæa, Planorbis, Valvata, Amnicola, Sphærium* and *Pisidium*) were found living at a depth of 25 meters or about 81 feet. The largest number of species, however, was found where there was an abundance of vegetation as was observed in Oneida Lake.

4. Saginaw Bay Region, Michigan (Lake Huron).

Saginaw Bay (H. B. Baker, 1911, pp. 121–176) has many features in common with Oneida Lake, although it does not belong to the same class of water bodies, being an open bay of a large lake. Here, however, there are rocky, wave beaten shores, sandy exposed shores, protected bays and sandy pools. and the fauna varies in accordance with the habitat. It is noteworthy that the exposed, rocky shores are inhabitated by mollusks with a wide foot, such as *Physa ancillaria magnalacustris, Lymnæa emarginata ontariensis,* and *Goniobasis livescens;* these are paralleled in Oneida Lake by *Lymnæa*

(Galba) catascopium and *Goniobasis livescens*. The sandy, protected areas yielded the greatest number of species, as was the case in Oneida Lake.

There is a larger area of muck bottom in the Saginaw Bay region than has been found as yet in Oneida Lake. The protected pools, sand dune lakes, and swamp localities are paralleled, to a degree, by the protected bays, shoals and swamps of Oneida Lake.

5. Georgian Bay Region, Ontario, Canada (Lake Huron).

Recently an excellent census of the mollusks of Go Home Bay (Robertson, 1915, pp. 95–111), an embayment of Georgian Bay, has been published and is of interest when compared with the Oneida Lake fauna, although the ecological notes are not as full as could be wished. The area is made up of ponds, protected bays and exposed shores similar in character to those of the Oneida Lake region. It is interesting to note that the same mollusks varied according to habitat as they were seen to do in the area under consideration.

6. European Lake Studies.

The European ecologists have given much study to the inland lakes from a habitat standpoint, and examples could be cited of studies carried on by German, French, Swiss, English, Swedish, Danish and other students. Among the best of these studies from a habitat standpoint, though somewhat old, is that by K. E. Sternroos (1898) who studied a Finnish lake, situated 40 kilometers (64.37 miles) north of Helsingfors. The lake is 2.5 kilometers (4.22 miles) long and about 1 kilometer (1.6 miles) broad, and reaches a depth of 53 meters (57.69 feet). This author recognized such habitats as the *Scirpus* region and the *Equisetum* region, and the fauna described for these greatly resembles that found in Oneida Lake. The relation between plant zones and animal life is brought out clearly. The discussion of the *Scirpus* region (p. 83) which is farther divided into sessile, mud, poor swimming and free swimming fauna, is very interesting in connection with the fauna of Oneida Lake. The mud fauna includes 11 species of mollusks, one of which, *Bythinia tentaculata*, is also found abundantly in Oneida Lake. The other species belong to the same genera.

Another European work which is perhaps unique in the form of its illustrations of habitat characteristics, is written jointly by Ant. Fric and V. Vavra (1894) on the fauna of two artificial ponds or pools near Bechovic, Bohemia. The fauna of these lakes, insect, crustacean and molluscan, is notably like that of Oneida Lake, although the Bohemian lakes are small and shallow. From one of these bodies of water 22 species of mollusks were collected. There is much in this paper which is of great interest to the ecologist.

No. 2. Comparative Table of Species.*

	Oneida Lake.	Tomahawk.	St. Clair.	Lake Mich.	Inland lakes, Charlevoix.	Saginaw Bay.	Georgian Bay.
Total number of species.....	62	44	45	39	53	88	41
Species common to this region and to Oneida Lake.......	.....	21	18	15	23	27	21
Unionidæ..................	15	11	20	3	7	17	7
Sphæriidæ.................	4	6	2	3	4	9	5
Pisidia....................	10	4	....	12	9	10	1
Water breathers (*Amnicola*, etc.).....................	12	2	7	9	9	11	8
Air breathers (*Lymnæa*, etc)..	21	21	16	12	24	41	20

The comparison of the Mollusca of the American localities mentioned above is of interest, showing the total molluscan population of each and the number of species of certain groups found in each body of water. With the exception of the Saginaw Bay Region, the Oneida Lake fauna is seen to be the largest in number species.

*In this table varieties are treated as species. The comparison with Lake St. Clair is not quite fair as modern data is not at hand with which to make a corrected list. A larger number of species live there than is here indicated.

F. SUMMARY.

The habitats analyzed may be reduced to three general types. 1, boulder bottom; 2, sandy bottom; and 3, vegetation-covered bottom. The first is usually subject to rough water and has little or no vegetation; the second is more or less protected from rough water and has considerable vegetation; the third is generally adequately protected from rough water and supports a maximum amount of vegetation. In no habitat does the depth of water exceed 10 feet and the average is about 3 feet. The greatest number of molluscan species (39) is found in the second type, the sandy bottom. These three types of habitat are found in all parts of the lake examined. The absence of mud, except in small isolated spots, is of special interest. With one exception, the fresh water molluscan fauna of this lake is greater in number of species than that of any similar body of water in the United States.

CHAPTER III. BIOLOGICAL VALUATION OF THE LAKE; A STUDY IN PRODUCTIVITY.

A. HISTORICAL REVIEW.

The scientific study of the food relations of fresh water animals has occupied man's attention for a comparatively short time, and the realization of the intimate relation between the entire environment and any one group of animals, as the fishes for example, is of quite modern origin. As long ago as 1880, Dr. S. A. Forbes (1880, p. 19), writing on the important question of the food of fishes, said: "Doubtless, of all the features of the environment of an individual, none affect it at the same time so powerfully, so variously and so intimately as the elements of its food. Even climate, season, soil and the inorganic circumstances generally, influence an animal through its food quite as much as by their direct action. It is through the food relation that animals touch each other and the surrounding world at the greatest number of points; here they crowd upon each other the most closely, at this point the struggle for existence becomes sharpest and most deadly; and, finally, it is through the food relation almost entirely that animals are brought in contact with the material interests of man. Both for the student of science and for the economist, therefore, we find this subject of peculiar interest and value."

A. J. Pieters (1901, p. 59), writing on the plants of Lake Erie, makes the following significant statement: "As has been pointed out by both Reighard and Ward, a complete knowledge of the life of a fish can only be obtained by a study of the entire chain of biological relations existing in lakes and streams. In this chain plant life constitutes an important link. Plants stand between animal life and the inorganic substances it is unable to use. All aquatic animal life is ultimately dependent upon plants, which transform carbon, nitrogen and other inorganic substances into organic compounds fitted for animal use. Directly or indirectly, then, plant life is necessary to the support of the fishes in our lakes and streams. The vigorous growth and reproduction of plants furnishes a large food supply for the smaller animals, which in their turn can reproduce more abundantly and provide a greater amount of food for the fish.

"Barring enemies and artificial hindrances to increase, such as overfishing, fish will multiply up to the limit of the food supply, but can never overstep that limit. If the food supply can be increased, an increase in the number of fish will naturally follow."

Other American authors, as well as some foreign writers, have touched more or less extensively on this very important subject. It remained for two Danish ecologists, Dr. C. G. Joh. Petersen and Dr. P. B. Jensen, the former the Director of the Danish Biological Station, to elaborate some of the most important methods of investigating this subject. Petersen has been studying the marine waters of Denmark for the purpose of determining the amount of life on the sea bottom, the relation of this life to the plant life and to the maintenance of the food fishes of these waters, especially the Plaice. These studies were inaugurated in 1883 and have progressed each year, the notably increasing success being attested by the brilliant reports of the Danish Biological Station (see Bibliography). The work of these Danish ecologists does not appear to have received adequate attention from American ecologists and fish culturists.

Petersen realized at an early period that to understand fully the conditions governing the habits of fish, especially as regards their food, a knowledge must not only be obtained of the kind of food eaten, a knowledge secured by means of an examination of the stomach contents of recently feeding fish, but that we must also know the variety and amount of the possible food supply. In other words, a biological survey of the fish habitat is necessary before we are in a position to understand the conditions governing the physiology of the piscene fauna. In short, such studies lead to a broad consideration of the metabolism of the whole lake or body of water under discussion. Petersen observed that the Plaice from the western part of Limfjord practically ceased growing for a period of about eight months, but when transported to the central part of this body of water they increased to four or five times their original weight. This observation led to the conclusion that there was a serious deficiency in the food supply of the first named locality. To obtain this information it was necessary to examine certain areas in different parts of the body of water and to estimate the amount of the available food supply. To carry on this investigation Petersen experimented with various types of dredges until an apparatus was devised, known as the "$0.1m^2$ bottom sampler" which brought up for examination an area of one-tenth of a square meter with its top layers in their natural position, containing the living organisms in their natural relations. This bottom sampler showed that some of the Danish waters were rich in food supply while others were very poor, some of these differences being correlated with the character of the deposit covering the bottom. This will be discussed on a later page.

With this apparatus Petersen collected from the bottom of the Thisted Bredning more than a hundred samples of the bottom, each one-tenth of a meter square, and carefully counted the number of different animals present. These were tabulated and averaged. In addition to the numerical studies, the animal matter was extracted, dried and weighed so that the amount of dry matter per $0.1m^2$ could be found and the amount of actual available food supply in the whole area estimated. The relative density of the bottom fauna was illustrated by means of diagrams showing the population of one-fourth of a square meter of sea bottom. By means of these studies, Petersen was able to calculate that the fish consumed about 3 grams per square meter, and the whelks and starfishes, predaceous animals, about 6 grams dry weight per square meter. The total amount of dry matter on the bottom was estimated to be about 30 grams per square meter. He also estimated that the bottom fauna consumes several times its own weight in the course of a year.

While studying the samples of bottom brought up by the $0.1m^2$ sampler, Petersen observed that the bottom layers were of two kinds, the first, in which life was abundant, being brown or gray in color, the other being black and giving off an offensive odor. This was either very poor in, or devoid of life. Previous investigation had shown that the digestive tract of the lower animals which were not predaceous was filled with a brownish mass almost identical with this top layer covering the bottom of all the waters where it was sufficiently still and deep for the fine particles to be deposited. Petersen concluded that this material, which he called "dust-fine detritus" forms a large part of the food of bottom dwellers, such as clams and snails. This detritus consists of "dead, deposited particles of plants and animals, among which we comparatively seldom find the remains of plankton organisms. Living microorganisms are naturally also found in the stomachs, but usually only in small quantity. We have so long and so often heard of the rôle the plankton is considered to play in the economy of the sea, that we almost forget the other sources of food, which however, at any rate in the smaller waters, certainly have an even greater importance" (Petersen, op. cit. p. 6).

Petersen's colleague, Dr. Jensen, after investigating the source of this dust-fine detritus, concludes that its origin is primarily from the plants in the sea, principally the grass-wrack, *Zostera.* Thus it is evident that the dependence of animals upon plants for nutrition is as vital in the water as on the land. The plankton, either plant or animal, was also found to play but a small and unimportant part in the formation of this detritus deposit. The marine plants die and either fall to the bottom where they grew or are transported to the same location in some other part of the sea bottom. This material breaks down until it forms the dust-fine detritus described.

Jensen's law that "the organic materials do not remain at the place where they were produced but are distributed more or less uniformly over large areas" is quite as applicable to large lake bodies as to marine bodies of water. This author calls attention to the fact that if this law was not in operation, many parts of the bottom would be devoid of both animal and vegetable life.

An examination of the samples brought up by the bottom sampler, and by another instrument called the detritus sampler (made of a cylindrical glass tube), showed that the bottom was composed of two distinct layers; the topmost being 1–2 mill. thick, brown in color and of a fluffy appearance; and the second layer, which extends to the bottom of the sample, being of dark blue color, consisting of sand-mixed clay with organic remains. Bottom samples of this character are free from smell. Chemical examination of this top bottom deposit shows it to be composed largely of pectose, a substance present in *Zostera,* indicating clearly the origin of at least a part of the material. The amount of carbon in the bottom material which is large in the areas near shore, diminishes progressively as the distance from shore increases, again indicating the influence of the plants in the formation of this rich bottom covering. Jensen also examined the water, by centrifuging, and obtained material identical with the top layer of the bottom deposits. The winds are therefore found to bear an active part in the distribution of this fine detritus material.

The black, odoriferous layers found in certain parts of the region under consideration (and which were devoid of animal life) were found to contain a quantity of methane or marsh gas, due to the presence of bacterial life, together with small amounts of oxygen and carbon oxide. Jensen describes the processes going on in this kind of a bottom as fermentative. The large percentage of hydrogen sulphide found in the inner fjords of Denmark and more largely in the Black Sea is due to the rich plant production, which is great enough to form a bottom-soil containing a large amount of organic matter. "In this way the possibility is created for a rich bacteria life, production of hydrogen sulphide and so on, which certainly contribute to a very high degree to deprive the water of oxygen." The sea furnishes the greater part of these fjords or bays with fresh oxygen, thereby preventing the formation of hydrogen sulphide and rendering them fit for animal life. Jensen aptly concludes that "we may therefore, to a certain extent, regard the large oceans as the lungs of the sea, which supply the water-masses of the inner seas with oxygen and remove the superfluous organic matter." In fresh water it is stated that humic acid probably has some influence in preserving the dead plant material.

Petersen has fully demonstrated that this dust-fine detritus forms a large part of the food of the oyster and other mollusks not of a predatory character. Dissection of the oyster showed the stomach to be filled with a substance in no wise different from the brown upper surface layer of the sea bottom. Certain clams (*Abra*) confined in an aquarium were observed to suck up this surface layer with their long siphon. In addition to the detritus of the bottom these animals also consume a small amount of plankton organisms. Those animals which cannot take the detritus directly from the bottom utilize that which is held in suspension in the water which is said by Petersen to be greatly in excess of the pure plankton in quantity. The work of Lohmann, Hensen, Dahl, Brandt, Rauschenplat and others in the light of Petersen's discoveries, corroborate the fact of the extensive use of the dust-fine detritus as food. Curiously enough, reference to this source of food in American works, on both marine and fresh water animals is all but entirely lacking and the writer has noted no reference to Petersen's hypothesis in a recent work on the oyster (Stafford, 1913, p. 9) which states that the food consists of the smallest particles of material, the minute plants and animals called plankton, including diatoms, etc. A careful study of the food of marine and fresh water pelecypods, in the light of Petersen's discovery, is greatly needed as suggested by Adams (1913).

B. APPLICATION OF THE QUANTITATIVE METHOD TO ONEIDA LAKE.

Investigations similar to those carried on by Dr. Petersen, described in the last section, have not been conducted in America, but there is every reason to believe that such studies would be of very great value in helping to solve some of the problems which confront us in the carrying on of fish conservation policies. Some work has been done and much information gathered concerning the kind of food normally eaten by fish and other animals, but studies on the food value of a lake from the standpoint of all the animals living in the lake are unknown to the writer. Given the amount of available food per square or cubic unit, and its increase during a certain period, and given the amount of food consumed per day by the other animals present, it is comparatively easy to estimate from these factors, the number of animals (as fish) which a given lake will support. To obtain these figures, however, it is necessary to make a large number of observations on both the physical characteristics of the lake and the animal and plant communities. In other words we must study the metabolism of the lake as we would study the metabolism of an animal. As a contribution toward this end, the data set forth in this report is presented.

1. Quantitative Studies.

Lack of time during the 1915 field season prevented the carrying out of precise and exhaustive quantitative studies on Oneida Lake. As it was desired to cover as much of the lake as possible in a preliminary examination, an exact count of organisms from a known area was attempted in but a few places. From these, however, some sort of an idea may be obtained of the richness of the molluscan fauna.

Methods of Obtaining Data. On a rocky shore all of the individuals were collected from an area *estimated* to be one foot square. In the sandy habitats, the bottom was scraped from an area approximately 12 x 12 inches with the Walker dredge. In the case of the plant communities, the count was for each leaf of each plant and the number of plants estimated to grow on a square foot of water. In the latter case, this often meant a columnar area one foot square and of a height varying with the depth of the water. These estimates, and the tables, are not to be taken as final, as they are, at most, general estimates.

Quantitative Tables. In the following tables, examples are given of the number of individuals found in one unit area of each characteristic habitat.

Quantitative Table No. 3.

SHORE HABITATS.

Three types of habitats are included: 1, sandy bottom, with a few stones, water 6–8 inches deep, mollusks on stones and in loose valves of Unios; 2, sandy bottom with but few stones, water 6–10 inches deep; 3, very stony or bouldery bottom, water 6 inches deep. It is to be noted that the first mentioned is the most prolific of the shore habitats including 9 species represented by 115 individuals. The poorest is one of the bouldery habitats (3, XXVI) in which there are but 2 species and 18 individuals.

TABLE NO. 3.

HABITAT TYPE.	1	2		3				
STATION NUMBER.	XXXI, 4.	III, 3A.	VIII.	XIV.	XXV.	XXVI.	XXX, 2.	XXXIII.
Ancylus parallelus	1	..	....	....	....	....	....	....
Planorbis hirsutus	1	..	....	....	....	....	....	....
Planorbis companulatus	1	..	2	....	....	....	....	....
Planorbis binneyi	1	16	....	53	....	....	....	1
Galba catascopium	7	1	11	....	....	....	....	....
Physa ancillaria warreniana	2	3	....	....	14	16	15	....
Bythinia tentaculata	52	..	1	....	....	....	....	....
Amnicola lustrica	49	..	....	....	....	....	....	....
Campeloma integrum	1	19	5	....	....	....	....	....
Elliptio complanatus	....	..	7	....	....	....	....	....
Lymnæa stagnalis lillianæ	....	1	....	6	8	2	7	20
Sphærium vermontanum	....	..	20	....	....	....	....	....
Totals	115	40	46	59	22	18	22	21

Quantitative Table No. 4.

BOULDER-PAVED SHORES.

The habitats listed in this table, eleven in number, are all bouldery and are on more or less exposed shores where the waves exert a marked influence. The water is from 1–3 feet in depth. One habitat (XXV) supports 51 individuals of 8 species. The relation of this community to the bottom is expressed in Figure 32. The bivalves (1, 2, 3, 4) are seen to live in the sand between the stones, while the gastropods live for the most part on the stones. *Goniobasis* is almost

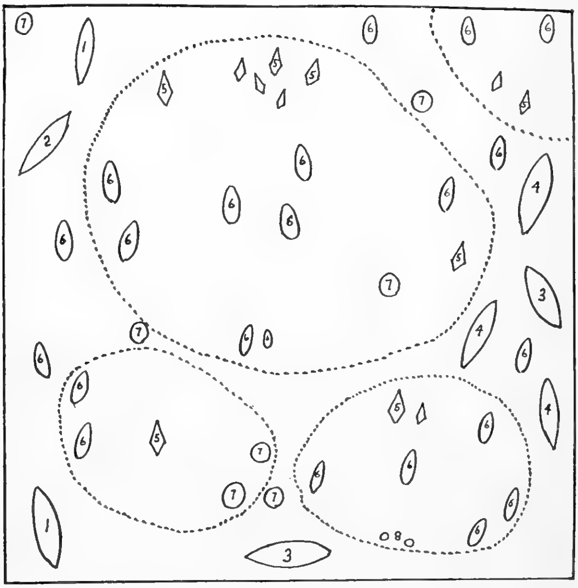

Fig. 32. Diagram illustrating quantity of mollusks in one square foot at station XXV, a boulder habitat, water 16 inches deep, 51 specimens present.

1. *Lampsilis radiata* (2).
2. *Lampsilis luteola* (1).
3. *Anodonta grandis footiana* (2).
4. *Elliptio complanatus* (3).
5. *Goniobasis livescens* (12).
6. *Galba catascopium* (22).
7. *Planorbis campanulatus* (7).
8. *Planorbis hirsutus* (2).

invariably found on the rocks and not on the sand. *Galba* and *Planorbis* live on both sand and rocks. Habitat XXXIII is one of the poorest in number of individuals, although supporting six species (Figure 33). The small number of gastropods is noteworthy. No. XI is the poorest habitat in both species (2) and individuals (7). This is a wave-swept point, too violent for gastropod life, but apparently favorable for bivalve life. Stations XXVI and XXX are especially favorable for gastropods, notably *Galba catascopium*, which is abundant.

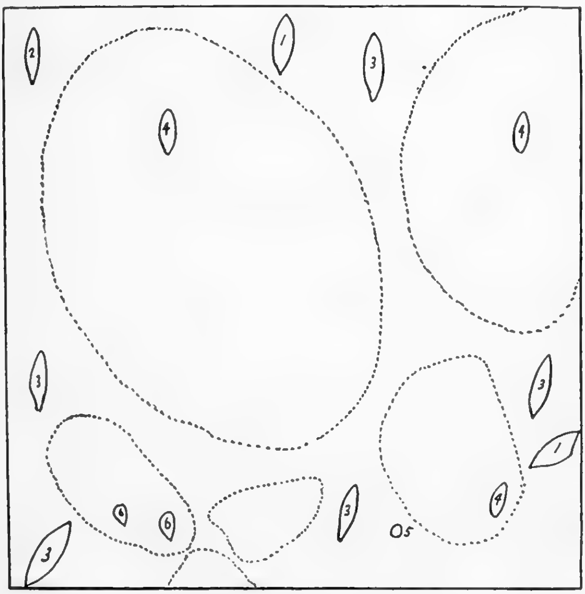

Fig. 33. Diagram illustrating quantity of mollusks in one square foot at station XXXIII, a boulder habitat, water 16 inches deep, 14 specimens present.

1. *Lampsilis radiata* (2).
2. *Margaritana margaritifera* (1).
3. *Elliptio complanatus* (5).
4. *Galba catascopium* (3).
5. *Planorbis campanulatus* (1).
6. *Physa ancillaria warreniana* (2).

TABLE NO. 4.

STATION NUMBER.	II.	IV.	XI.	XIV.	XX.	XXI, 1.	XXII.	XXV.	XXVI.	XXX, 2.	XXXIII.
Lampsilis radiata	3	1	6			4		2	1	1	2
Lampsilis iris					1						
Lampsilis luteola						1		1			
Lampsilis borealis										1	
Anodonta implicata	1					2	4		1		
Anodonta cataracta							1		1	1	
Anodonta grandis footiana	1					1		2			
Margaritana margaritifera			1								1
Elliptio complanatus	5	1		2	5	3	1	3	3	2	5
Sphærium vermontanum						4	1		1		
Musculium securis										6	
Musculium rosaceum										1	
Goniobasis livescens	5	18		15	8	6	3	12	13	3	
Amnicola lustrica						1					
Galba catascopium	7	10			3	5	6	22	24	30	3
Planorbis antrosus									1		
Planorbis campanulatus		1		1	1	1		7	1		1
Planorbis hirsutus				1		2		2			
Physa ancillaria warreniana		1		1		2	2				2
Totals	22	32	7	20	18	32	18	51	46	45	14

Quantitative Table No. 5.

SANDY AND SANDY-ROCKY SHORES.

This table includes a variety of habitats all agreeing, however, in having a large percentage of sand in the bottom composition. Habitat 1 has a soft, silty bottom free from stones. The water is 1 to 3 feet deep, in which such plants as *Scirpus, Dianthera,* and *Pontederia* live. Six species and sixteen individuals occupy this unit area. The four habitats in type 2 have a sandy bottom with a few stones; the water is 2–4 feet deep and the plant forms are *Scirpus* and *Pontederia.* Thirty-seven individuals of 12 species represent the maximum (XXXI, 1, C) and 19 individuals of 5 species the minimum in point of species (V, 1). Station XXI, 2, B, contained the smallest number of individuals per unit area, 10, although the number of species (8) is large (Fig. 34). The majority of the species are bivalves (7). Habitats of the third type in the table have a sandy bottom without stones, the water is from 2–5 feet deep and the dominant vegetation is *Nymphæa, Scirpus,* and *Pontederia.* Of the four stations represented, that of XIX is by far the best from the quantitative standpoint, and its biota is of most value from an economic standpoint. Two samples were obtained from this station which are noteworthy. In one, 98 individuals represented by 17 species were noted; in the other 163 individuals represented by 11 species were observed (Fig. 35). The large number of *Amnicola* and *Bythinia,* as well as of other small species, is to be especially noted, as these are of primary value as fish food, especially bottom feeders, like sunfish, suckers, and catfish. An example of medium density is shown by III, 2, C, (also Fig. 36) where 12 species are represented by 54 individuals. In Station XXXIV but 4 species represented by 10 individuals are noted. In type 4 of the table, the bottom is soft and sandy, there are no stones, the water is from 1–3 feet deep and the dominant plants are *Scirpus, Nymphæa* and *Sagittaria.* Seventeen individuals of 3 species are recorded. This might be considered a fair feeding ground for fish.

TABLE NO. 5.

Habitat.	1	2				3					4
Station Number.	IX, B.	III, 3 B.	V, 1.	XXI, 2 B.	XXXI, 1 C.	III, 2 C.	III, 2 D.	XIX.		XXXIV.	XXX., 1 B.
Elliptio complanatus		5	3	1			1	1			
Margaritana margaritifera								2			
Anodonta cataracta				1							
Anodonta marginata				1							
Anodonta implicata				1							
Anodonta grandis footiana				1							
Alasmidonta undulata				1							
Musculium securis					1						
Sphærium vermontanum	1			3	2	10	4	1	1		
Pisidium variabile						2		5			
Pisidium compressum							1				
Pisidium compressum lævigatum	3					8		12			
Pisidium æquilaterale								1			
Pisidium species	1					3		9			
Pisidium species						4		11			
Campeloma integrum	1			1		2	1			1	
Vivipara contectoides										7	
Somatogyrus subglobosus						3					
Gillia altilis						8	12				
Amnicola limosa					5		1	12	16		1

Amnicola lustrica	9	....	....	....	3	8	....	24	23	....	....
Bythinia tentaculata	....	....	....	....	8	....	....	....	63	....	....
Goniobasis livescens	....	7	2	....	....	....	....	1	5	1	....
Valvata tricarinata	....	....	....	....	....	....	....	1	9	....	....
Valvata bicarinata normalis	....	....	....	....	1	4	....	....	....	....	....
Planorbis campanulatus	1	....	4	....	8	1	....	2	1	1	8
Planorbis trivolvis var.	....	....	....	....	4	....	....	....	....	....	8
Planorbis hirsutus	....	1	....	....	1	1	....	2	5	....	....
Planorbis antrosus	....	....	....	....	2	....	....	2	11	....	....
Galba catascopium	....	5	4	....	1	....	1	9	26	....	....
Physa ancillaria warreniana	....	2	6	....	1	....	3	3	3	....	....
Totals	16	20	19	10	37	54	24	98	163	10	17

Quantitative Table No. 6.

VEGETATION DWELLERS.

The vegetation habitats naturally divide into three well characterized types. 1, includes those species living on lily pads, and five distinct situations of this kind were studied quantitatively. Two species of plants are represented, *Nymphæa* and *Castalia*, the mollusks showing no preference. It is probable that a preference is shown at different times by some species for the upper and lower surfaces of the leaves, but no selection of this kind was noted, mollusks being

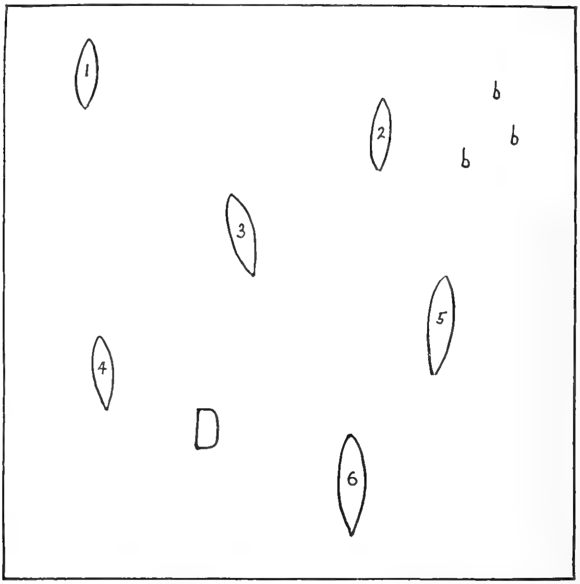

Fig. 34. Diagram illustrating quantity of mollusks in one square foot at station XXI, habitat 2, B, sandy bottom, water 18 inches deep, 10 specimens present.

1. *Elliptio complanatus* (1).
2. *Anodonta cataracta* (1).
3. *Anodonta marginata* (1).
4. *Anodonta implicata* (1).
5. *Anodonta grandis footiana* (1).
6. *Alasmidonta undulata* (1).

b. *Sphærium vermontanum* (3).
D. *Campeloma integrum* (1).

observed on both sides. Station I, 2, C is an example of a maximum lily pad habitat, 10 individuals represented by 3 species being noted (Fig. 37). It was observed that *Acella* usually chose the edge of the leaf for its position, while *Physa* and *Pseudosuccinea* apparently had no choice, using all parts of the surface. In this type of habitat the water is 3–5 feet deep and there is usually a quantity of submerged vegetation present. Each leaf averages about eight inches long and they are close enough together to figure each leaf as occupying a square foot of habitat. The table indicates the variation in number of individuals and species on the lily leaves of other stations.

Type 2 is a pure *Typha* habitat, the surface of the water, and the bottom as well, being covered with dead *Typha* leaves. The water is from one to two feet deep. Open spaces of water support a duck weed society. Clinging to the dead vegetation on the surface 18 individuals representing 5 species were estimated in one square foot of surface area, *Planorbis trivolvis* being the most numerous (see Fig. 38). Type 3 includes those stations in which the water is filled with submerged vegetation, such as *Chara, Potamogeton, Elodea, Ceratophyllum, Vallisneria*, etc. The water is usually from 3 to 7 feet in depth. Numerically, this is the most prolific of all habitats. An area one foot square and reaching to the bottom (in the spot counted, the water was four feet deep) contained 174 individuals, representing 6 species, 147 of which were of one species, *Bythinia tentaculata*. As many of these individuals were young and of small size they are especially valuable as food for the smaller fish that frequent such a habitat. Station XL, in Big Bay, was the poorest, producing but 4 individuals of 2 species.

TABLE NO. 6.

Habitat Types.	1						2	3	
Station Number.	I	2 C.	III, 1 B.	VII, B.	X, B.	XXXI, 1 B.	XXXI, 2.	XXXIX,	XL.
Acella haldemani	3	1	5	....	2	3	....	....	....
Pseudosuccinea columella	....	....	3	1	....	....	....	....	....
Pseudosuccinea columella chalybea	5	....	....	....	....	....	2	....	....
Lymnaea stagnalis lillianæ	....	....	....	....	....	....	....	5	1
Planorbis campanulatus	....	2	....	1	....	....	10	....	....
Planorbis trivolvis	....	....	....	....	....	....	....	....	....
Planorbis hirsutus	....	1	....	....	....	....	2	....	....
Planorbis exacuous	....	....	....	....	....	....	3	2	....
Planorbis parvus	....	....	....	....	....	1	1	....	....
Ancylus fuscus	....	....	....	....	1	....	....	1	....
Ancylus parallelus	....	....	....	....	....	....	....	17	3
Physa ancillaria warreniana	2	1	....	4	....	....	....	....	....
Physa gyrina	....	....	....	1	....	....	....	2	....
Valvata bicarinata normalis	....	....	....	....	....	....	....	147	....
Bythinia tentaculata	....	....	....	....	1	....	....	....	....
Amnicola lustrica	....	....	....	....	....	....	....	....	....
Totals	10	5	8	7	4	4	18	174	4

In many pond-lily habitats, a number of mollusks live attached to the submerged leaves of *Scirpus*, *Dianthera* and the stems of *Nymphæa*, *Castalia*, and floating *Potamogeton*. *Acella* in one habitat (Station XXXI, 1, B) was partial to the submerged leaves of *Scirpus smithii* (Fig. 39, 1). At other stations *Galba catascopium* and *Planorbis campanulatus* were observed on the submerged portions of *Dianthera* (Fig. 39, 2). The latter species (*Planorbis*) often attaches itself to the stems of *Nymphæa*, *Castalia* and *Potamogeton natans*. The leaves of the latter plant also served as a resting place for *Acella* at one station (X, B). No estimates of the number of individuals in these latter habitats have been made.

It will be noted that in many habitats one or more species dominate (these may be called principal species); thus a boulder association may include 30 *Galba* and 3 *Goniobasis*, or 15 *Goniobasis* and no *Galba*. Thus we have communities in which the following genera dominate by the larger number of individuals present.

Lymnæa stagnalis.
Galba, Goniobasis.
Amnicola, Bythinia.
Sphærium, Gillia.

Lampsilis, Elliptio.
Acella, Pseudosuccinea.
Bythinia, Physa.

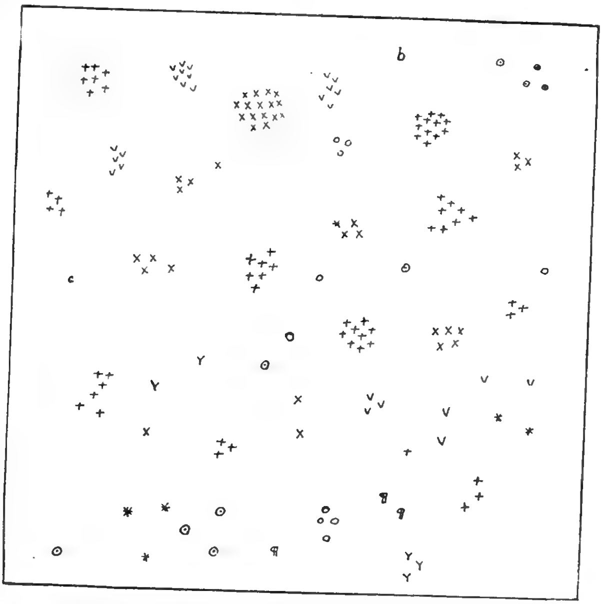

Fig. 35. Diagram illustrating quantity of mollusks in one square foot at station XIX, sandy bottom, water 18 inches deep, 163 specimens present.

b. *Sphærium vermontanum* (1).
X. *Amnicola lustrica* (23).
X. *Amnicola limosa* (16).
† *Bythinia tentaculata*, mostly young (63).
* *Goniobasis livescens*, mostly young (5).
o. *Valvata tricarinata*, ad. & juv. (9).
c. *Planorbis campanulatus* (1).
Y. *Planorbis hirsutus*, ad. & juv. (5).
⊙ *Planorbis antrosus*, ad. & juv. (11).
v. *Galba catascopium*, mostly juv. (26).
¶ *Physa ancillaria warreniana*, ad. & juv. (3).

2. Estimates of Total Valuation.

It would be futile in view of the insufficient and fragmentary character of the data at hand, to attempt to estimate the total amount of molluscan food in Oneida Lake. To do this will require several seasons' work and the accumulation of a vast amount of accurate data. Also, the values should be based on the dry weight of the animal after extraction from the shell. It may not be out of place to consider briefly what some of the estimates indicated in the quantitative tables mean when increased to cover large areas. Thus, a boulder habitat, 300 x 500 feet, such as that of Station XXV, where 51 individuals were counted from an area one foot square, would contain 7,650,000 individuals. Again, a sandy bottom habitat, similar to that of Station XIX, where two counts indicated a population of 98 and 163 individuals respectively, would contain the enormous number of 65,000,000 individuals in an area 1,000 x 500 feet, and areas larger than this occur along the shore, as west of Shepard Point. In the vegetation habitats, a pond lily zone 100 x 30 feet would contain 30,000 individuals, estimating 10 per square foot. In the outlet, where the submerged vegetation gave a count of 174 per square foot, and where there is an area fully 3,500 x 500 feet, if the unit count is a fair average for this entire area, the enormous number of 304,500,000 individuals, mostly *Bythinia,* are present. These estimates might be extended indefinitely but the above examples will suffice to indicate the vast quantity of molluscan food in the waters of the lake. It is to be noted that this rich life is confined exclusively to the shallow area bordering the shores, an area usually not exceeding three-quarters of a mile in width and twelve feet in depth. In deeper water, of 12 to 16 feet, vegetation is scanty or absent, and there is a scattering fauna of bivalves, principally mussels. Only 17 individuals of 3 species were brought up after half a day's dredging with the crowfoot dredge. With proper apparatus and time it will be possible to estimate with a fair degree of accuracy the amount of molluscan, as well as other life, in the waters of this inland lake. The statement made by Petersen, that the bottom conditions and fauna of the habitats examined by him remained practically unchanged for a period of twenty years (op. cit. p. 4) is significant and should be borne in mind when making quantitative studies in Oneida Lake.

It is to be especially noted that where a great abundance of vegetation exists, choking the water, there will be few if any mollusks. Dr. Jean Dawson, after making exhaustive studies upon *Physa* and *Lymnæa*, came to the following conclusions (op. cit. p. 29) concerning this feature:

1. Where the pond weeds have captured quiet waters, there were found no snails alive or dead.
2. Snails live in moderate numbers where there is a luxuriant growth of weeds if there be a considerable depth of water above the plants, or if the water is gently flowing over them.
3. The snails occur in the greater numbers where there is a moderate amount of water plants and organic debris.

It is probable that the abundance of molluscan life in Oneida Lake, where the submerged vegetation forms a heavy mass, is due to the amount of fresh water which is forced into the protected bays by the waves. An adequate oxygen supply seems to be the important factor.

C. MOLLUSCAN FOOD HABITS.

The abundance of molluscan life is dependent upon a favorable environment and a sufficient supply of food. The water must contain a sufficient supply of oxygen, produced by currents of water, bringing in a fresh supply of water or aerating the water present by means of air currents which move the liquid medium. Plants also furnish some oxygen. There must also be a proper substratum or bottom, a requisite depth of water, and the plants or animals necessary for food requirements. Oneida Lake contains all of these conditions in abundance.

Mollusks may be divided into *consumers* or predaceous and *producers* or vegetarians. The former are predatory, feeding upon other animals or their own kind, the latter are mostly vegetable feeders and convert plant material into molluscan tissue. The latter will be first considered. It will be remembered that Petersen observed that the bottom samples were made up of a top layer, brown and fluffy in appearance, which it was suggested formed a large part of the food of mollusks and other animals (see page 117). In Oneida Lake the surface of the bottom deposits, in bays and quiet bodies of water, is precisely this character, and no doubt is used by *Sphærium* and *Pisidium*, both of which lie in this deposit. The *Unionidæ*, however, are probably not able to

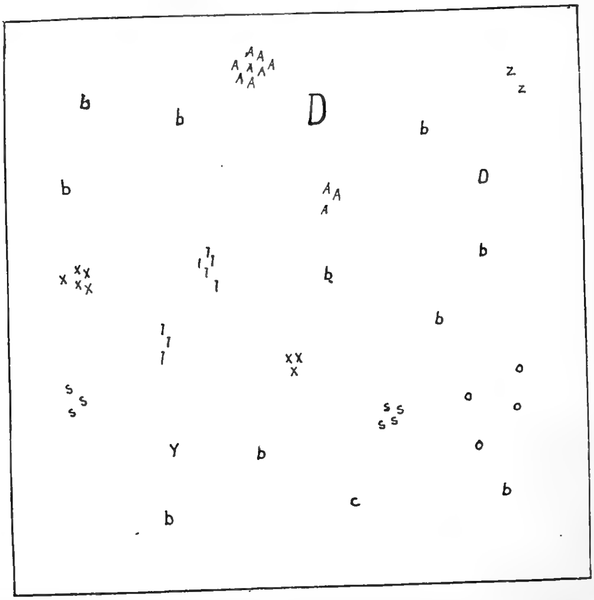

Fig. 36. Diagram illustrating quantity of mollusks in one square foot at station III, habitat 2, c, sandy bottom, water 2 feet deep, 54 specimens present.

b. *Sphærium vermontanum* (10).
z. *Pisidium variabile* (2).
l. *Pisidium compressum lævigatum* (8).
S. *Pisidium* species (3).
S. *Pisidium* species (4).
A. *Gillia altilis* (11).
D. *Campeloma integrum* (2).
X. *Amnicola lustrica* (8).
O. *Valvata bicarinata normalis* (4).
C. *Planorbis campanulatus* (1).
Y. *Planorbis hirsutus* (1).

use this dust-fine detritus on the bottom, but take it directly from the water in which it is held in suspension, or is brought to them by the currents. It has been generally held that the plankton furnishes food for the bivalve fauna, but it has not been demonstrated that the entire food consists of this material. The stomach and digestive tract of the fresh water mussels is often filled with an indistinguishable brown mass exactly like that of the upper bottom layer. Algæ are also used to a large degree.

Fresh water gastropods are normally vegetarians, feeding on algæ and the soft parts of plants, usually the epidermis. An extensive vegetation is, therefore, a prerequisite for an abundant and varied molluscan fauna, and it is notable that where the water is deep and vegetation absent or only sparsely present, molluscan and other invertebrate life is scarce or absent. Plants not only afford a place for support, upon which snails may crawl and find a resting place, but they are actually eaten as the regular food supply, a fact which any one may verify by watching snails upon leaves and stems of plants. In view of this fact the statement of Shelford (1913, p. 58) that "we could probably remove all the larger rooted plants and substitute something else of the same form and texture without greatly affecting the conditions of life in the water; that is, so far as the life habits of the animals are concerned" is misleading. Dissection of snails reveals the tissues of plants in their intestines. Green filamentous and unicellular algæ are largely eaten but do not form all of the diet by any means. Dawson (1911, pp. 68–69) observed *Physa* eating tender green shoots of *Chara* and *Elodea*, also the leaves of grass, maple and elm when partly decayed, the snail eating only the soft tissues leaving the hard skeleton untouched.*

The fresh water pulmonates, *Physa*, *Lymnæa*, *Planorbis*, also feed upon animal matter. Dawson records a *Physa* eating amphipods (*Gammarus*) confined with them in an aquarium, although it is believed that the crustaceans died

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*Op. cit., p. 69. See this author on the use of mucus while feeding.

before being eaten, as *Physa* is not known to eat living animal food. As has been already stated, *Physa* lives on both vegetable and animal food, but does not attack living animals; *Planorbis* lives entirely on plants; while *Lymnæa* eats plants and animals, dead or living, and even commits cannibalism. *Ancylus* is known to eat only plants, mostly decaying material. *Campeloma* is scavengiferous as well as phytophagous, Dr. C. C. Adams having observed species of this genus feeding on a dead fish on the shore of a small stream tributary to the Desplaines River, near Riverside, Illinois.

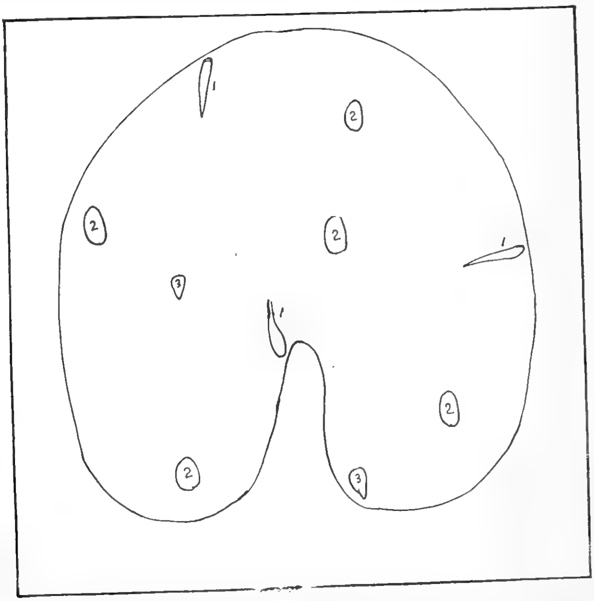

Fig. 37. Diagram illustrating quantity of mollusks in one square foot at station 1, habitat 2, c, vegetation, *Castalia odorata*, 10 specimens present.

1. *Acella haldemani* (3).
2. *Pseudosuccinea columella chalybea* (5).
3. *Physa ancillaria warreniana* (2).

I. Vegetable Feeders.

Vegetable feeders may be divided into the eaters of vegetable plankton, algæ, slime, dust-fine-detritus, and coarse plant-tissues. It has not been possible in the present work to differentiate all of these variations in food habits. During the progress of the field work on the lake, precise records were kept of the species of plants used by the snails for both food and support. In many cases the mollusks were feeding upon the plant upon which they were resting, but it could not always be determined whether the plant tissues, or slime or algæ were being eaten. In the following tables all of the molluscan species are listed which have been observed on each species of plant.

A. Species Living on Macroscopic Plants.

1. Species on submerged stem of Broad-leaved Arrowhead (*Sagittaria latifolia*):

Galba catascopium, common.
Planorbis campanulatus, common.
Planorbis trivolvis, var., not common.
Physa ancillaria warreniana, common.

2. Species on stem of Pickerel-weed (*Pontederia cordata*).

Planorbis campanulatus, common.
Planorbis antrosus, not common.
Planorbis trivolvis, var., not common.
Physa ancillaria warreniana, common.
Galba catascopium, common.
Bythinia tentaculata, common.
Lymnæa stagnalis lillianæ, rare.

3. Species on submerged portion of Water Willow (*Dianthera americana*).

Lymnæa stagnalis lillianæ, not common.
Planorbis campanulatus, common.
Planorbis antrosus, not common.
Planorbis trivolvis, var., not common.
Physa ancillaria warreniana, common.
Galba catascopium, common.
Bythinia tentaculata, common.
Succinea retusa, rare.

4. Species on submerged portion of Bulrushes (*Scirpus*).

Lymnæa stagnalis lillianæ, rare on *S. americanus.*

Planorbis campanulatus, common on *S. americanus* and *S. occidentalis.*

Planorbis antrosus, not common on *S. occidentalis.*

Planorbis trivolvis, var., common on *S. americanus* and *S. occidentalis.*

Physa ancillaria warreniana, common on *S. americanus.*

Galba catascopium, common on *S. americanus* and *S. occidentalis.*

Bythinia tentaculata, not common on *S. americanus* and *S. occidentalis.*

Acella haldemani, common on *S. smithii.*

Acella adheres so closely to the leaf of the Bulrush that it resembles a sharp spine protruding from the plant.

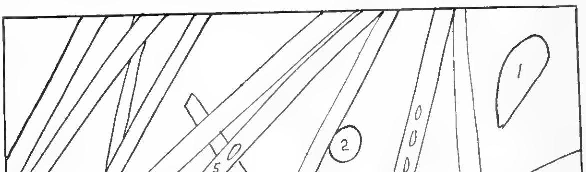

Fig. 38. Diagram illustrating quantity of mollusks in one square foot at station XXXI, habitat 2. A Typha marsh with dead leaves in and on water. 29 specimens present.

1. *Lymnæa stagnalis lillianæ* (2).
2. *Planorbis trivolvis* (10).
3. *Planorbis exacuous* (2).
4. *Planorbis parvus* (3).
5. *Ancylus fuscus* (12).

5. Species on leaves of two Water-lilies (*Castalia odorata* and *Nymphæa advena*).

Acella haldemani, upper and under surface, common.
Pseudosuccinea columella, mostly on upper side, common.
Pseudosuccinea columella chalybea, mostly on upper side, common.
Planorbis campanulatus, on upper and under sides, common.
Planorbis trivolvis, on upper and under sides, common.
Planorbis hirsutus, under side, rare.
Physa ancillaria warreniana, upper and under side, common.
Physa gyrina, a few on *Nymphæa advena*.
Ancylus parallelus, under surface, common.
Lymnæa stagnalis lillianæ, egg capsules common on under surface of leaf.

6. Species on stem of Water-lilies (*Castalia odorata* and *Nymphæa advena*).

Acella haldemani, rare.
Lymnæa stagnalis lillianæ, rare.
Planorbis campanulatus, common.
Planorbis trivolvis, common.
Bythinia tentaculata, common.

7. Species on leaves and stems of Floating Pond-weed (*Potamogeton natans*).

Acella haldemani, common.

8. Species on submerged leaves on *Elodea canadensis*.

Bythinia tentaculata, abundant.
Physa ancillaria warreniana, common, mostly young.
Valvata bicarinata normalis, not common.
Planorbis campanulatus, common.
Planorbis parvus, not common.
Ancylus parallelus, not common.
Amnicola lustrica, rare.

9. Species feeding on green algæ growing on stones.

Lymnæa stagnalis lillianæ, common.
Planorbis binneyi, common.
Planorbis trivolvis, var., common.
Planorbis hirsutus, rare.
Physa ancillaria warreniana, common.
Goniobasis livescens, common.

B. Species Living on and Eating Dead Vegetation.

10. On dead leaves of Narrow-leaved Cat-tail (*Typha angustifolia*).

Ancylus fuscus, common.
Planorbis trivolvis, common.
Planorbis parvus, common.
Planorbis exacuous, common.
Lymnæa stagnalis lillianæ, rare.

11. On dead leaves of Bur-reed (*Sparganium eurycarpum*).

Ancylus parallelus, common.

12. Species on dead Water Celery (*Vallisneria spiralis*).

Planorbis campanulatus, common.
Planorbis hirsutus, rare.
Physa ancillaria warreniana, common.
Galba catascopium, common.

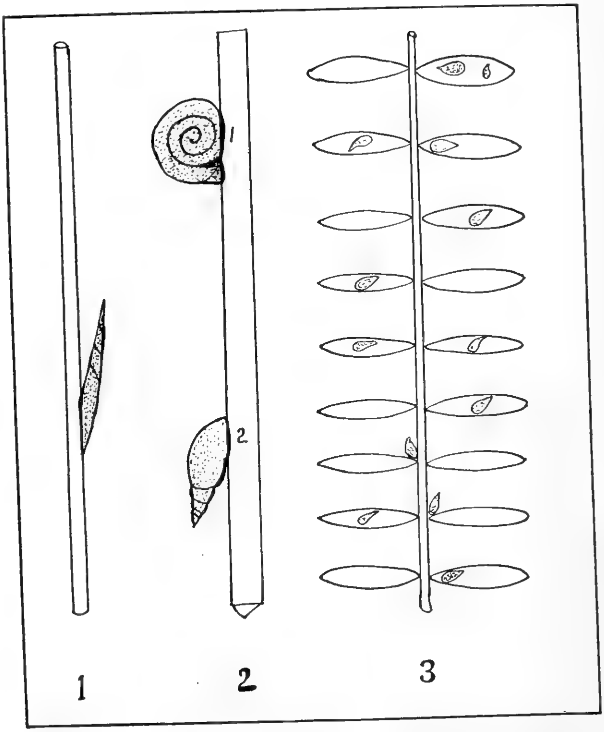

Fig. 39. Diagram illustrating relation of certain mollusks to vegetation.

1. *Acella haldemani* on *Scirpus smithii.*
2. *Planorbis trivolvis*, var. (1) and *Galba catascopium;* (2) on *Scirpus americanus.*
3. *Bythinia tentaculata* on *Elodea canadensis.*

TABLE NO. 7. COMPARISON OF FOOD OR HOST PLANTS.

MOLLUSCAN SPECIES (gastropods). / Food plants.	*Sagittaria latifolia.*	*Pontederia cordata.*	*Typha angustifolia* (dead).	*Dianthera americana.*	*Sparganium eurycarpum* (dead).	*Scirpus americanus occidentalis*	*Scirpus smithii.*	*Vallisneria spiralis* (dead).	*Castalia odorata.*	*Nymphæa advena.*	*Potamogeton natans.*	*Elodea canadensis.*	Green algæ (filamentous).
Amnicola lustrica												x	
Goniobasis livescens													x
Bythinia tentaculata		x		x		x			x	x		x	
Valvata bicarinata normalis												x	
Lymnæa stagnalis lillianæ		x	x	x		x			x	x			x
Galba catascopium	x	x		x		x		x					
Acella haldemani						x	x		x	x	x		
Pseudosuccinea columella									x	x			
Pseudosuccinea columella chalybea									x	x			
Planorbis trivolvis			x						x	x			
Planorbis trivolvis, var	x	x		x		x							x
Planorbis binneyi													x
Planorbis campanulatus	x	x		x		x		x	x	x		x	
Planorbis antrosus		x		x		x							
Planorbis hirsutus			x					x	x	x			x
Planorbis parvus			x									x	
Planorbis exacuous			x										
Physa gyrina										x			
Physa ancillaria warreniana	x	x		x		x	x	x				x	
Ancylus parallelus					x		x	x				x	
Ancylus fuscus			x										
Succinea retusa				x									
Totals	4	7	6	8	1	8	3	5	8	9	1	7	5

The table is instructive, indicating that 22 species have been observed to live upon certain plants. In three instances, 8 species have been observed to use one species of plant for rest or food. Five species have been seen to eat green filamentous algæ and 6 species were observed to eat dead vegetable matter. These observations are too few for generalizations but are suggestive for future work.

II. Species Living on Microscopic Plants, Detritus, Etc.

1. Species living on stones and boulders.

Galba catascopium, very common.
Galba emarginata, rare.
Goniobasis livescens, very common.
Planorbis antrosus, rare.
Planorbis campanulatus, common.
Planorbis binneyi, common.
Physa ancillaria warreniana, common.
Physa integra, common.
Lymnæa stagnalis lillianæ, common.
Ancylus tardus, common.

2. Species living on sandy shore, not burrowing in sand.

Planorbis campanulatus, not common.
Galba catascopium, rare.
Gillia altilis, common.
Somatogyrus subglobosus, common.
Amnicola lustrica, common.
Amnicola limosa, common.

3. Species living on a sandy bottom, burrowing in sand.

Elliptio complanatus, common.
Lampsilis radiata, common.
Anodonta cataracta, common.
Anodonta grandis footiana, not common.
Musculium securis, common.
Musculium rosaceum, rare.
Sphærium vermontanum, common.
Sphærium striatinum, rare.
Pisidium compressum, common.
Pisidium compressum lævigatum, common.
Pisidium variabile, common.
Pisidium æquilaterale, rare.
Pisidium ferrugineum, rare.
Pisidium henslowanum, common.
Campeloma integrum, common.
Campeloma decisum, common.
Vivipara contectoides, common.

4. Species living on gravelly or bouldery shore, burrowing in the sand between the stones.

Elliptio complanatus, very common.
Lampsilis radiata, very common.
Lampsilis luteola, very common.
Lampsilis borealis, very common.
Lampsilis iris, rare.
Anodonta cataracta, very common.
Anodonta implicata, very common.
Anodonta marginata, rare.
Anodonta grandis footiana, rare.
Margaritana margaritifera, not common.
Strophitus undulatus, rare.
Sphærium vermontanum, not common.

5. TABLE NO. 8. EATERS OF MICROSCOPIC FOOD.

SPECIES.	Algæ.	Detritus.	Detritus & Plankton.	Detritus & Plankton.
HABITAT OF MOLLUSKS.	On Stones or Shells.	On Sand.	Burrowing in Sand.	Gravelly Shore, Burrowing.
Vivipara contectoides	....	....	x	....
Campeloma decisum	....	....	x	....
Campeloma integrum	....	....	x	....
Goniobasis livescens	x	....	....	....
Amnicola limosa	....	x	....	....
Amnicola lustrica	....	x	....	....
Gillia altilis	....	x	....	....
Bythinia tentaculata	....	x	....	....
Somatogyrus subglobosus	....	x	....	....
Galba catascopium	x	x	....	....
Planorbis antrosus	x	....	....	....
Planorbis campanulatus	x	x	....	....
Planorbis binneyi	x	....	....	....
Physa ancillaria warreniana	x	....	....	....
Physa integra	x	....	....	....
Lymnæa stagnalis lillianæ	x	....	....	....
Ancylus tardus	x	....	....	....
Sphærium vermontanum	....	....	x	x
Sphærium stratinum	....	....	x	....
Musculium securis	....	....	x	....
Musculium rosaceum	....	....	x	....
Pisidium ferrugineum	....	....	x	....
Pisidium compressum	....	....	x	....
Pisidium compressum lævigatum	....	....	x	....
Pisidium variabile	....	....	x	....
Pisidium æquilaterale	....	....	x	....
Pisidium henslowanum	....	....	x	x
Elliptio complanatus	....	....	x	....
Magraritana margaritifera	....	....	....	x
Strophitus undulatus	....	....	....	x
Lampsilis radiata	....	....	x	x
Lampsilis borealis	....	....	....	x
Lampsilis luteola	....	....	....	x
Lampsilis iris	....	....	....	x
Anodonta cataracta	....	....	x	x
Anodonta implicata	....	....	....	x
Anodonta marginata	....	....	....	x
Anodonta grandis footiana	....	....	x	x
	9	7	17	12

In the table it may be noted that the boulder-inhabiting gastropods are algæ eaters. They have been seen browsing over the slime on the stones. Those species living on the sandy bottom probably eat slime, algæ and the dust-fine detritus of the top layer. Those species that normally burrow in the bottom are doubtless divided in their source of material. The snails and small bivalves must necessarily eat the detritus covering on the bottom while the large bivalves, owing to the position which they assume (the siphons in the water above the bottom), must take their food from the water and this probably consists of dust-fine detritus held in suspension and some plankton. Laboratory experiments, extended field observations and stomach examinations will be necessary to provide a body of facts in support of these inferences.

III. Records of Other Observers on the Vegetable Food of Mollusks.

Records of the use by mollusks of definite species of plants are rare, most statements simply asserting that mollusks feed or rest on plants. A few of these more definite statements appear below.

Hankinson (1908, p. 235) states that in late spring the following snails were collected from algæ, chiefly *Vaucheria*.

Valvata tricarinata Say.
Amnicola limosa Say.
Planorbis parvus Say.
Pisidium sp.

Moore (1915, p. 284) found *Ancylus* on two species of Pond-weed, *Potamogeton americanus* and *P. amplifolius*. The statement is made (p. 285) that "The Mollusca — *Planorbis, Limnea,* and *Physa* — were common on all of the *Potamogetons*."

Walker (1896, p. 97) records an abundance of small mollusks as living in a thick bed of *Chara*, at High Island, near Charlevoix, Mich. A single haul of the dredge brought up several hundred specimens, embracing 26 species belonging to 7 genera as noted below:

Lymnæa	5	species
Planorbis	3	"
Physa	1	"
Valvata	2	"
Amnicola	3	"
Bythinella	1	"
Pisidium	11	"
Total	26	"

Actual records of the stomach contents of fresh water mussels are rare. Two of the best of these papers are by Wilson and Clark (1912). The information on mussel food contained in one of these papers, which describes the mussels of the Kankakee River in Indiana and Illinois, is given below (op. cit., pp. 10, 12). The mussels were collected in the Lake of the Woods, and Pretty Lake, near Plymouth, both localities being in Indiana.

Algae.

Chlorophyceæ

Cosmarium in *Anodonta grandis, Lampsilis luteola.*
Pediastrum in *Anodonta grandis.*

Cyanophyceæ

Clathocystis in *Anodonta grandis, Lampsilis luteola.*
Cœlosphærium in *Anodonta grandis.*

Rotifera.

Anuræa in *Lampsilis luteola.*

Nematoda.

Ascaris in *Anodonta grandis.*

Clark and Wilson (1912, pp. 60, 61) also summarize the food habits of the mussels of the Maumee River as follows: "The stomach contents of mussels taken from the main current of the St. Mary's, St. Joseph, and Maumee rivers were rather noteworthy for their paucity of organic material. Through the large mass of muddy matrix filling the stomach* were usually scattered a few *Scenedesmus,* various diatoms, and an occasional *Pediastrum* or *Cosmarium.* At the riffles small brown cystlike objects, which may have been a species of *Trachelemonas,* were quite common; with the exception of this the mussel contained very little. Among the organisms noted were *Scenedesmus caudatus, Cœlastrum microsporum, Pleurosigma,* several forms of *Navicula, Phacus longicaudus, Pediastrum baryanum, Gomphonema,* a sponge spicule, and an active *Euglena*-like organism.

*This is probably the kind of material described by Petersen as "dust-fine ditritus."—F. C. B.

"The stomach contents of the mussels found in the reservoir of the feeder canal, a shallow, pond-like body of water, bore considerable contrast to that of the river. * * * It was "puddle plankton" rather than that which is characteristic of either lakes or rivers. * * * The main mass consisted of small globular and thick celled green or brownish flagellates, probably *Trachelemonas lagenella.* Among other organisms were species of *Phacus,* several species of *Scenedesmus, Pediastrum pertusum, Gomphonema,* several species of *Navicula,* a little ***Botryococcus brauni, Anu cochlearis, Cosmarium,*** small fragments of a *Conferva*-like alga two or three cells long, fragments of the test of *Ceratium hirundinella,* and the brown objects resembling fungus spores. There were numerous narrow curved objects which were probably loricas of *Trachelemonas.*"

Allen (1914, p. 129) studied the food and feeding habits of eight species of mussels from Winona Lake, Indiana. Those species marked with an * occur in Oneida Lake.

**Lampsilis luteolus* Lam.
Lampsilis subrostratus Say.
Lampsilis alatus Say.
**Lampsilis ligamentinus* Lam.
Lampsilis rectus Lam.
Quadrula rubiginosa Lea.
Unio gibbosus Barnes.
**Anodonta grandis* Say.

"Being by far the most numerous in Winona Lake, *L. luteolus* was used for the greater part of the work." (Allen.)

After considering the methods of digestion and feeding, including the action of cilia and the function of mucus for ingestion, Allen lists (p. 138) the species of plants (by genera) and other material found in the stomach and intestine. No reference is made to Petersen's "dust-fine detritus" but in the statement "but the mussel does not refuse minute dead animals or small fragments of sloughed and decaying animal tissue," this material may be included, as also part of the list of miscellaneous contents listed on page 139. The full list of plants (which is qualitative only) and other material in the alimentary tract is given below:

DIATOMACEÆ.

Amphora.
Arachnoidiscus.
Cocconeis.
Coconema.
Coscinodiscus.
Craspedodiscus.
Cymbella.
Epithemia.
Fragilaria.
Gomphonema.
Melosira.
Navicula.
Pleurosigma.
Surirella.
Synedra.
Triceratium.

DESMIDACEÆ.

Closterium.
Netrium.
Staurastrum.

OTHER ALGÆ.

Anabaena.
Aphanocapsa.
Caelastrum.
Cylindrocapsa.
Eudorina.
Glaeocystis.
Leptothrix.
Lyngbya.
Merismopedia.
Ædogonium.
Oscillatoria.
Pandorina.
Pediastrum.
Protococcus.
Rhaphidium.
Scenedesmus.
Spirogyra.
Tetraspora.
Ulothrix.
Vaucheria.

MISCELLANEOUS CONTENTS.

Inorganic fragments, plant and animal debris, mold, ova and spermatozoa of other animals and of the same individual or species (the sperm living and in motion), and spores and swarm spores.

In a recent work, Robertson (1915, pp. 99–104), indicates the food of a number of mollusks and the information is tabulated below for convenience. *Campeloma decisum* is said by this author to feed on decaying vegetable matter.

TABLE NO. 9.

	Filamentous algæ.	Desmids.	Diatoms.	Green algæ.
Galba emarginata canadensis	....	....	....	x
Galba palustris	x	x	x	....
Pseudosuccinea columella	....	x	x	x
Acella haldemani	....	....	....	x
Planorbis bicarinatus	....	....	....	x
Planorbis trivolvis	x	x	x	....
Planorbis campanulatus	x	x	x	....
Physa heterostropha	....	x	x	x
Physa ancillaria	....	x	x	x
Goniobasis livescens	....	x	x	....

Gleason (1908, pp. 63–64) records the following species as living on the under side of pond-lily leaves, one-third of all leaves having one or two shells on them.

Galba catascopium.
Amnicola limosa.
Physa species.
Valvata tricarinata.
Valvata sincera nylanderi.

In an inland lake (op. cit.), the bottom of which was covered with a thick mass of twigs and coarse vegetation, several species lived and probably fed on the dust-fine detritus, as well as the decaying vegetation. These are:

Planorbis exacuous.
Planorbis antrosus.
Amnicola limosa.
Valvata tricarinata.
Valvata sincera nylanderi.
Pisidium species.

H. B. Baker (1911, p. 164, et. seq.) lists the following relation between mollusks and vegetation:

Planorbis bicarinatus, in algæ, principally *Vaucheria.*
Planorbis trivolvis, on lily pads and among algæ.
Planorbis campanulatus, on lily pads and *Potamogeton.*
Planorbis exacuous, on lily pads under side.
Planorbis hirsutus, on lily pads, under side.
Planorbis deflectus, on lily pads, under side.

Planorbis parvus, on lily pads, under side.
Planorbis crista, on lily pads, under side.
Ancylus parallelus, on lily pads, under side.
Physa heterostropha, on lily pads, and among *Potamogeton*.
Physa gyrina, on lily pads.
Physa integra, among *Vaucheria* and on lily pads, under side.
Goniobasis livescens, on *Potamogeton*, 1 specimen.
Amnicola limosa, on lily pads, *Potamogeton*, in algæ.
Sphærium solidulum, among *Vaucheria*.
Musculium truncatum, among *Sphagnum*.
Musculium securis, among *Sphagnum*.

F. C. Baker (1911, pp. 235–240) records a number of mollusks in relation to vegetation, as noted below:

Ancylus parallelus, on lily-pads, under side.
Planorbis parvus, on lily pads, under side.
Pseudosuccinea calumella, on lily pads.
Galba lanceata, on leaves of *Typha latifolia*.

IV. Species Living on Animal Food, Predaceous in Part.

Only a very small percentage of fresh water mollusks are predaceous. Dr. Jean Dawson has summarized the food habits of the fresh-water pulmonates, and we cannot do better than quote from her valuable paper (1911, p. 84). "*Physa* is almost omnivorous in its food habits, feeding upon a variety of plant and animal forms, fresh or in various stages of decay. *Lymnæa stagnalis, L. palustris* and *L. reflexa* have carnivorous and cannibalistic traits while the genus *Physa* is not known to take living prey. *Planorbis trivolvis* and *P. bicarinata* (*antrosus*) on the other hand have a vegetable diet only. The conditions of the habitats determine largely the food eaten by the snail, the greater variety being found in still water."

Both *Physa* and *Lymnæa* are good scavengers. The writer has observed *Lymnæa stagnalis appressa* and *Galba palustris* on dead bodies of cats, dogs, and fish floating in the water. Several biologists have experimented with species of the family *Lymnæidæ* with interesting results. Thus, Walter (1906, p. 21) remarks that *Galba palustris* " feeds readily on dead flies, tadpoles and its own eggs, as well as on other snails when their shells have been crushed. It was also seen to engulf and retain the fæces of other snails." These snails were seen to rasp off pieces of *Lemna*, both living and dead, and green apples placed in the aquarium were greedily eaten. Colton (1908, pp. 420–425) states that the food of *Lymnæa* consists normally of diatoms, desmids, unicellular and filamentous algæ. This author fed *Pseudosuccinea columella* on *Myriophyllum* and *Elodea*, these water plants being eaten by some and refused by others. The writer (1911, pp. 42–44, 147, 170, 190, 311, 414) has recorded many observations relating to food of the *Lymnæas*, which is here summarized. *Lymnæa stagnalis appressa* was observed to feed upon dead animals and rotten vegetables and it is said to attack small fish (stickleback). *Pseudosuccinea columella* has been seen feeding on decaying water plants and pond scum (*Spirogyra*). The large *Bulimnea megasoma* feeds on pond lily leaves and has been known to devour the animals of land snails and fresh water mussels with great greediness. In Lake Cobalt, Canada, this species lives in water strongly impregnated with arsenic. *Galba palustris* is omnivorous, eating vegetation, rotten fruit or decaying vegetation, dead animals and even attacking living animals (a leech). *Galba emarginata* is said to feed on the confervoid algæ on the rocks in Maine.

In quiet bays and ponds a bottom soil is sometimes formed chiefly by the excrement of the bottom fauna and plant remains. Such a bottom soil is known as gytje among the Danish biologists. This condition has not been observed in Oneida Lake.

Examination of Stomach Contents of Lymnæa.

In order that definite information might be secured concerning the food of the large *Lymnæas*, the crop of a number of examples of *Lymnæa stagnalis lillianæ* were examined. It will be observed that bryozoan statoblasts form 3.75 per cent., *Planorbis* 10 per cent., and algæ and plant fragments 86.25 per cent. Only one individual of the five containing food had eaten animal matter, in this case the mollusk, *Planorbis* *campanulatus* which formed 40 per cent. of the total contents. In this connection it is interesting to note that *Lymnæa stagnalis appressa* has been noted by Prof. W. M. Smallwood, of Syracuse University, to have nearly driven *Planorbis* from the Erie Canal in the eastern part of Syracuse. The data obtained from five specimens of var. *lillianæ* is as follows:

Nos. 1–3, collected on Frenchman Island, in 6 inches of water, clinging to stones near shore, Sept. 10, 1915; No. 4, Long Island, near shore, Sept. 9; No. 5, Shaw Point, in water 6 inches deep, on stones, Sept. 14. All specimens full grown, 35–40 mill. long.

No. 1. In crop and œsophagus.
Algæ and plant fragments.......................100 per cent

No. 2. In crop.
Bryozoa. 5 statoblasts of *Plumatella*............ 5 per cent
Plants. Filamentous algæ and plant tissues..... 95 per cent

No. 3. In crop.
Bryozoa. 10 statoblasts of *Plumatella*........... 10 per cent
Mollusca. 2 *Planorbis campanulatus*, 2 mill. diam. .... } 40 per cent
Fragments of molluscan shell...... }
Plants. Filamentous algæ .... } 50 per cent
Small seed of plant.................. }

No. 4. In crop.
Filamentous algæ and unicellular plants (diatoms) 100 per cent

No. 5. In crop.
Acarina. 1 water-mite; balance of contents digested matter and small pieces of sand, white quartz.

Lymnæa is peculiar in possessing a thick crop resembling the gizzard of a bird, in which are usually found a few fine sand grains, which evidently aid in breaking up or grinding the plant tissues torn off by the jaws and radula. Interesting notes on this organ may be found in the papers by Colton and Baker, cited in this chapter. A series of dissections and stomach examinations would undoubtedly prove of great value in adding to our knowledge of this subject.

D. SUMMARY.

It has been shown that the molluscan fauna of Oneida Lake is of great variety and abundance and provides a valuable food asset for fish. The individuals are abundantly scattered over a wide area in the shallow water, each type of habitat — shore, boulder-paved, sandy and vegetation-filled — having associations of great extent. There is no location in the lake, excepting perhaps the deeper portions, where a poor fauna exists. This abundance of molluscan life is due largely to the shallowness of the lake, which enables a large amount of vegetation to find attachment and favorable environmental conditions.

The majority of mollusks are vegetable feeders, including desmids, diatoms, filamentous algæ, and the tender parts of the higher plants. The larger bivalves in addition to algæ, probably use the dust-fine detritus in the water, as recorded by Petersen for the bivalves of Danish marine waters. Many snails, as *Campeloma,* probably also use this detritus as food. This dust-fine detritus is made from the breaking up of decaying plant material, which floats about in the water, finally falling to the bottom, often at a great distance from its original location. Nearly all species of water plants are used by mollusks for support or food. A number of species prefer dead and decaying vegetation. A few species as *Lymnæa* and *Physa* are omnivorous, eating dead animals, rotting plants and fruit as well as living plants. *Lymnæa* alone is predaceous, living not only on any weaker creature but attacking *Planorbis* and even its own kind. The data set forth in the preceding pages indicates that there is sufficient food material to support an abundance of molluscan life which consequently forms a valuable food supply for mollusk-eating fish.

CHAPTER IV. MOLLUSKS AS FOOD FOR FISH.

Excepting the work of Forbes (1878–1888), whose studies on the food of fresh water fishes were epoch-making, the scarcity of literature relating to this important subject is noteworthy. Volumes have been published on the taxonomy, distribution, commercial importance, and methods of securing the fishes of our inland waters, but in the discussion on fish-culture, little attention has been given to the subject of the food of our native fish. The studies which are recorded in the previous pages have shown the amount and character of one kind of fish food (the Mollusca) now living in Oneida Lake, and its distribution in relation to the aquatic plants and to the general physical environment.

Prof. Forbes recognized the importance of these studies when he said (1888, p. 477): "Among the purely practical results to be anticipated, [from the study of fresh water animals] are a more accurate knowledge of the conditions favorable to the growth and multiplication of the more important species; the ability to judge intelligently on the fitness of any body of water to sustain a greater number or a more profitable assemblage of fishes than those occurring there spontaneously; guidance as to the new elements of food and circumstances which it will be necessary to supply to insure the successful introduction into any lake or stream of a fish not native there; and a clear recognition of the fact that intelligent fish culture must take into account the necessities of the species whose increase is desired, through all ages and all stages of their growth, at every season of the year, and under all varieties of condition likely to arise. We should derive, in short, from these and similar researches, a body of full, precise and significant knowledge to take the place of the guess-work and empiricism upon which we must otherwise depend as the basis of our efforts to maintain the supply of food and the incitement to healthful recreation afforded by the waters of the State."

The fresh-water fishes may be divided into five groups according to the dominance of the kind of food: 1, insect eaters; 2, crustacean eaters; 3, molluscan eaters; 4, fish eaters, and 5, plant and mud eaters. Of these the first and second are the most important, providing food for many young and for a majority of the adult fishes. The ratios of these five varieties of food as used by adult fish may be expressed as follows (the data is principally from Forbes, 1888, b):

1. Insectivorous.	40 per cent	(p. 482)
2. Crustacean.	14 per cent	(p. 486)
3. Molluscan.	6 per cent	(estimated)
4. Fish.	20 per cent	(estimated)
5. Miscellaneous (mud, plants, etc.) . .	20 per cent	(estimated)

Mollusk-Eating Fish.

As has already been stated, the Mollusca form about six per cent. of the total food of our fresh water fishes and upwards of 24 per cent. of mollusk-eating fishes. The proportion of this element of food varies greatly in different species of fish. A few species, as the Sheepshead (*Aplodinotus grunniens*) subsist almost entirely upon mollusks when adult, while others, as the Gizzard Shad (*Dorosoma cepedianum*) eat only an occasional mollusk. Many fish eat no mollusks. The food supply also varies greatly with age, some species, as the Sheepshead noted above, passing through three stages; beginning with the plankton when very young, it changes to an insect eater when a few inches in length, and as it attains adult size it becomes a mollusk eater, the jaws developing a powerful crushing apparatus which is able to crush the heaviest shells of the clams and snails upon which it feeds. The Perch (*Perca flavescens*) is a good example of this food variation passing through three distinct food eating stages, as noted in the table below.

TABLE NO. 10. FOOD OF THE COMMON PERCH SHOWING VARIATION WITH AGE (AFTER FORBES).

1. Infancy.	2. Youth.	3. Adult.
Entomostraca............	Entomostraca at first......	Mollusks.
Larvæ of Diptera..........	Insects....................	Crawfish.
Plankton in general.......	....	Insects.
		Fishes (few).

Many carnivorous species pass through three periods, each marked by the presence of a particular kind of organism, as:

1. Entomostraca.	2. Insects.	3. Fishes.
1. Entomostraca.	2. Insects.	3. Mollusks.

Catfishes live on plankton when young and when adult are omnivorous. Black Bass eat plankton when young and fishes and crawfish when adult. Entomostraca and the larvæ of minute flies form 75 per cent. of the food of the majority of young fishes.

The large clams (*Unionidæ*) form an unimportant element of the available food supply, being used by but few species of fish, notably the catfishes (Forbes, 1888, b, p. 481; Adams, 1892, p. 127); but the gastropods and small clams (*Sphæriidæ*) form a large percentage of the total food chosen by a considerable number of fish families. In a few species the small bivalve *Sphærium* forms a large part of the food, as shown below:

Sucker family	29 per cent.
Dogfishes..................................	19 per cent.
River carp (*Carpiodes*)......................	25 per cent.

It is noteworthy that in a number of families the mouth is especially modified or adapted for feeding upon mollusks, examples being catfishes, suckers, the Sheepshead and the small-mouthed sunfishes.

Data on Stomach Contents of Fishes.

Some years ago Forbes (1888, c, p. 11) wrote significantly concerning the Mollusca as food. "The ponds and streams of the Mississippi Valley are the native home of mollusks of remarkable variety and number, and these form a feature of the fauna of the region not less conspicuous and important than its leading group of fishes. We might, therefore, reasonably expect to find these dominant groups connected by the food relation; and consistently with this expectation, we observe that the sheepshead, the catfishes, the suckers, and the dog-fish find an important part of their food in the molluscan forms abundant in the waters which they themselves most frequent." This statement, so eminently true of the region described by Forbes, is equally pertinent in relation to Oneida Lake, and the data to be presented abundantly indicates that many of its inhabitants are *par excellence* mollusk eaters. It is noteworthy that there is a close relation between the abundance of this life in the lake and its use by fish as food.

METHODS OF OBTAINING DATA.

The majority of the fishes examined had been preserved in formalin. About ten were fresh. Each fish was cut open on the under side from just behind the lower jaw to the anus. The whole digestive system was removed and the contents carefully removed, by cutting open the stomach lengthwise and removing the contents with needles, scalpel and tweezers, care being used not to break or damage the contents. In the case of the intestine, the contents were removed by cutting lengthwise, or by carefully rolling the contents out by way of the anal end. The contents of both stomach and intestine were carefully and minutely examined by means of a Leitz binocular compound miscroscope, powers up to 100 diameters being used. The different classes of food, —molluscan, insect, crustacean, etc.,— were separated, their percentages estimated and the species determined. The stomach contents have been preserved and now form a part of the study collection of the New York State College of Forestry. The percentages are all of total volume. Regarding material, it was found that specimens caught with hook and line, or seined, produced better results than those caught in fyke, trammel, or gill nets. If the fish remained for any time in these nets, as was usually the case, the stomachs were found to be empty and the intestines filled with a mass of, usually, unrecognizable material. The numbers in parentheses are the field numbers of the New York State College of Forestry.

A. ONEIDA LAKE FISH.

Upwards of 110 specimens, representing 16 species have been studied and the contents of their digestive organs noted. For the sake of completeness all available records relating to our American mollusk-eating fresh water fish are included, even though they do not inhabit Oneida Lake or even New York State. It is believed that all important data from American species on this subject is here included, although it is possible that some of the literature may have been overlooked. Unless otherwise stated the references are from the works of Forbes, notably his Summary and Discussion, published in 1888. Species not recorded from Oneida Lake are marked with an *; those not recorded from New York State are marked with a †. The sequence of species is that of Forbes and Richardson (1909).

* *Accipenser brevirostrum* LeSueur, *Short-Nosed Sturgeon.*

According to Bean (1912, p. 190–192) the adult Short-nosed Sturgeon feeds upon mollusks. He says: " Up to the third month of its life the young sturgeon has minute conical teeth in its jaws, and at this age it is believed to subsist on rhizopods, unicellular algæ, infusoria, minute larvæ of insects and worms, crustaceans, etc. Still following the observations of Professor Ryder, we learn that the sturgeon, when it has reached a length of one inch to one and one-half inches, has minute teeth on the floor of the pharynx and feeds on small water fleas, and probably algæ, worms, embryo fishes, insects, and fresh-water copepods. Later in life the fish seeks larger crustaceans, and the adults occasionally contain fragments of mussel shells. The young fish have been caught under the ice in midwinter, and are known to pass most of the year in fresh water." This sturgeon was kept in confinement at the Linlithgo Hatchery Station in 1911 and fed on pond snails and crawfish. They consumed the snails in large quantities (op. cit. p. 192). The species of mollusks which form the food of this sturgeon in the ponds of the Linlithgo Hatchery have been identified as *Vivipara contectoides, Lymnæa* (*Galba*) *catascopium,* and *Planorbis trivolvis* (Bean, 1914, p. 339). No percentages are given and as the Lake Sturgeon is largely a mollusk eater, the Short-nosed Sturgeon is estimated to use at least 25 per cent. of this food.

* *Accipenser rubicundus* LeSueur. *Lake Sturgeon.*

" Sturgeons are bottom feeders, using their hard beaks to stir up the mud in their search for food. Stomachs of sturgeons have been found to contain worms, mollusks, insect larvæ, small fishes, and aquatic plants. In the Great Lakes, Milner found the food to consist almost entirely of fresh-water snails (Gasteropoda). Crayfishes and insect larvæ are also eaten by them and the eggs of fishes have been occasionally found in their stomachs, though not in quantity sufficient to justify the charge of destructive spawn-eating sometimes made" (Forbes and Richardson, pp. 22, 25). Bean (1912, p. 268) says: " The food of this sturgeon is made up chiefly of shellfish, including the genera *Limnæa* (*Lymnæa*), *Melantho* (*Campeloma*), *Physa, Planorbis,* and *Valvata.* Eggs of fishes are also to be found in its stomach."

Amia calva Linnaeus. *Dogfish; Bowfin; Grindle.*

The food (Forbes, 1888, a, p. 463) of this distinctly bottom feeder may be summarized as follows, the data being taken from the examination of 21 specimens, between April and October.

Mollusks	25 per cent.
Crawfish, etc.	40 per cent.
Fishes	30 per cent.
Insects, etc.	2 per cent.

Of the mollusks three genera were recognized but the species are not indicated:

Vivipara, noted in August.
Planorbis, noted in August.
Sphærium, noted in September.

Bean (1903, p. 66) adds *Lymnæa*, *Melantho* (*Campeloma*), *Physa*, and *Valvata*. Marshall and Gilbert (1905, p. 516) examined 13 specimens, 9 of which contained food, 7 contained crawfishes, and 2 minnows. Cestode and other worms were found in every fish.

* *Hiodon tergisus* LeSueur. *Toothed Herring; Mooneye.*

"Feeds on insects and their larvæ, mollusks and small minnows" (Forbes and Richardson, p. 44).

* *Dorosoma cepedianum* (LeSueur). *Gizzard Shad; Hickory Shad.*

The food of this species is mostly vegetable debris contained in the mud of the bottom. Usually about 4 per cent. of animal matter is present, consisting of Coleoptera, Entomostraca, univalve and bivalve (*Sphærium*) mollusks. One specimen contained 25 per cent. of Entomostraca (Forbes, 1888, a, p. 438).

* *Coregonus clupeaformis* (Mitchill). *Common Whitefish.*

Ward (1896, p. 21) found the food of the whitefish to consist of:

Crustacea	63 per cent.
Mollusca	26 per cent.
Insecta	8 per cent.
Small fish	2 per cent.
Miscellaneous	1 per cent.

From the literature it is at once seen that the food taken by the Whitefish varies in different localities. Thus Ward (op. cit., p. 21) finds upwards of twelve species of mollusks in the stomachs of fourteen specimens of fish from Lake Michigan. These are noted below:

Galba catascopium.	*Planorbis parvus.*
Galba species (juvenile).	*Valvata tricarinata.*
Physa species (juvenile).	*Valvata sincera.*
Amnicola limosa.	*Sphærium striatinum.*
Amnicola porata.	*Sphærium* (new species).
Amnicola lustrica.	*Pisidium* (several species).

In three cases out of fourteen, mollusks formed the bulk of the food, being present to the extent of 60, 90 and 95 per cent. One individual contained all but two of the species listed. Of the mollusks it was found that:

Pisidium constituted from 0 to 60 per cent of total food, averaging 16 per cent.

Sphærium constituted from 0 to 55 per cent of total food, averaging 7 per cent.

Valvata constituted from 0 to 10 per cent of total food, averaging 2 per cent.

The balance of the other invertebrate food consisted of *Mysis relicta* (20 per cent.), *Pontoporeia hoyi* (43 per cent.), *Eurycercus lamellatus,* and chironomid and hydrophilid larvæ (about 8 per cent.).

In Walnut Lake, Michigan, Hankinson (1908, p. 201) found the Whitefish to subsist almost exclusively on the larvæ of small flies. During the spring 30 specimens were examined, 19 of which contained insect food, and one a few mollusk shells. The insects consisted principally of midge larvæ and pupæ, with a few larvæ of *Sayomyia, Sialis,* and other insects. In a few examples a small percentage of fish remains was present. In August, nine Whitefish were examined and found to have eaten no midge larvæ, the stomach contents being almost all entomostracans of the genus *Daphnia,* apparently taken from the water above the bottom as they were free from dirt.

In Georgian Bay, Ontario, Robertson (1915, pp. 98–107) reports the following species as having been taken from the stomach of the Whitefish:

Galba emarginata canadensis.	*Valvata tricarinata.*
Galba palustris.	*Valvata sincera.*
Physa ancillaria.	*Musculium securis.*

Bean (1912, p. 273) found three species of mollusks in Whitefish caught in Canandaigua Lake, *Amnicola limosa, Valvata tricarinata*, and *Pisidium abditum*. It is evident that the Common Whitefish is a bottom feeder depending principally upon mollusks and insect larvæ for its food supply. (See Paul Reighard, 1908, p. 651.)

Young Whitefish feed principally on entomostracans. Hankinson (1914, p. 239) dissected eight specimens and found the food to consist chiefly of *Bosmina longirostris, Diaptomus ashlandi*, and *Cyclops viridis* (var. *parcus?*). Fragments of midge larvæ and miscellaneous insects, including winged forms, and filaments of green algæ (*Ulothrix zonata*) were also noted. This is another example which indicates clearly the change of the character of food with the age of the individual. Hankinson's Walnut Lake work also indicates a food change coincident with season.

Leucichthys tullibee (Richardson). *Tullibee; Mongrel Whitefish.*

Examinations of the Tullibee were very unsatisfactory. Five specimens were dissected, the results being as noted below. Nos. 1, 2, caught near Constantia; Nos. 3–5 from Oneida Lake, but purchased in the Syracuse market and caught in November.

No. 1. 290 mill. long; stomach empty.
No. 2. 290 mill. long; stomach empty.
No. 3. 280 mill. long; stomach empty.
No. 4. 290 mill. long; stomach empty.
No. 5. 290 mill. long; stomach containing Entomostraca (Cladocera).

The stomach contents of number 5 were almost entirely of the cladoceran species *Leptodora hyalina,* the individuals being very large. *Leptodora* is a surface species and it is exceedingly interesting to find a whitefish, typically a bottom-feeding group, using this crustacean as food. *Leptodora* is also considered a typically warm weather form and its presence in such large numbers in a fish caught in November is noteworthy. Kofoid (1908, p. 253) records *Leptodora* as occurring usually in small numbers in the Illinois River from June 28 to August 30. In Lake Meredosia, Illinois, it was very abundant in the upper three feet of water at midday in May-June. It was apparently more common in the backwaters than in the channel. Marsh (1903, p. 36) states that *Leptodora* is absent from Lakes Winnebago and Green, Wisconsin, from November to May, its principal occurrence being in the months of July, August and September. (See also page 86 for dates and quantity per square meter.) Birge (1897, p. 350) gives the season as from June 1 to November 30 (see also pp. 353 and 404) in Lake Mendota, Wis. No statement has been seen regarding the food of the Tullibee, but as other members of the group feed largely upon mollusks there is no reason to doubt that the Tullibee appropriates this class of animals as a part of its food, if it is, like the Common Whitefish, a bottom feeder. Additional study is needed on this point.

Both Jordan and Evermann (1911, p. 32) and Bean (1914, p. 342) refer the Whitefish of Oneida Lake to this species, which is known locally as the " Oneida Lake Whitefish." The Common Whitefish is not known to inhabit this body of water.

* *Coregonus quadrilateralis* Richardson. *Round Whitefish; Frostfish.*

Bean (1903, p. 221) records the food of this fish to consist of small shells and crustaceans. Its food is doubtless similar to that of the Common Whitefish.

Anguilla chrysypa Rafinesque. *Fresh Water or American Eel.*

The only reference to this fish as a mollusk eater (noted by the author) is by Kendall and Goldsborough (1908, p. 37). These authors say: "The eel subsists upon almost any kind of animal food. It can and does catch live fish for itself and feeds also upon worms, insect larvæ, small mollusks, and not infrequently upon fish eggs when they are obtainable."

† *Ictiobus cyprinella* (Cuvier & Valenciennes). *Red Mouth Buffalo; Big-Mouth Buffalo.*

Forbes (1888, a, p. 452) examined 17 specimens, collected between April and October, and found the food to consist of

Vegetable food, etc.	33 per cent.
Crustacea (mostly *Entomostraca*)	31 per cent.
Insecta.	33 per cent.
Mollusca (*Sphærium*)	3 per cent.

In one example, *Sphærium* formed 25 per cent. of the total food.

† *Ictiobus urus* (Agassiz). *Mongrel Buffalo; Round Buffalo.*

Forbes (1888, a, p. 452) gives the food of this fish, after an examination of 17 specimens, as

Vegetable matter	12 per cent.
Distillery slops	21 per cent.
Insecta (*Chironomus* and *Hexagenia* larvæ)	42 per cent.
Crustacea (mostly *Entomostraca*)	13 per cent.
Mollusca.	12 per cent.

In the Mollusca, the following genera were represented:

Valvata tricarinata, taken in August.
Sphærium, taken in August and November.
Unionidæ, taken in April.

† *Ictiobus bubalus* (Rafinesque). *Quillback Buffalo; Small-Mouth Buffalo.*

Forbes (1888, a, p. 449–450) gives the food of this fish, after an examination of 17 specimens, as:

Vegetable matter	20 per cent.
Insecta	29 per cent.
Mollusca	30 per cent.
Crustacea	20 per cent.
Miscellaneous	1 per cent.

In the Mollusca, three genera are represented:

Vivipara, taken in October.
Planorbis, taken in October.
Sphærium, taken in August and October.
Sphærium sulcatum, taken in October.

† *Carpiodes velifer* (Rafinesque). *Quillback; Silver Carp.*

Forbes (1888, a, p. 453–454; includes several species of the genus *Carpiodes*) examined 19 specimens in which the food content was made up of

Vegetable food (mostly *Wolffia*)	8 per cent.
Mollusca (*Sphærium*)	25 per cent.
Insecta (principally *Chironomus* larvæ)	33 per cent.
Crustacea (mostly *Entomostraca*)	25 per cent.
Miscellaneous	9 per cent.

The Mollusca were noted in August and October.

* *Minytrema melanops* (Rafinesque). *Spotted Sucker; Striped Sucker.*

Forbes (1888, a, p. 444) examined four specimens which contained nearly all Mollusca, principally *Sphærium;* a few *Entomostraca,* principally *Cyclops* and *Cypris,* and a small ratio of *Chironomus* larvæ. Two molluscan genera have been reported.

Amnicola, taken in October.
Sphærium, taken in September and October.

Bean (1902, p. 283; 1903, p. 108) says "it feeds almost entirely on mollusks, insects, and insect larvæ."

Catostomus commersonii (Lacépède). *Common Sucker; Fine Scaled Sucker.*

Thirteen specimens were examined (12 of which were from Oneida Lake) of which 2 contained Mollusca, 4 Crustacea, 1

Insecta, 5 mud, and 1 was empty. Figuring the food of the three adult specimens, we find the percentages to be:

Mud and plant remains	49 per cent
Mollusca	30 per cent.
Insecta	21 per cent.

The data gathered from the 13 specimens is given below. No. 1 was collected in Scriba Creek below the bridge, dead, injured by lamprey; No. 2, Brewerton, near Davison's Landing, seined in shallow water, October 18, 1915; Nos. 3–5 same locality, October 5; Nos. 6–11, Lower South Bay, seined in shallow water, October 31; No. 12, Constantia; No. 13 purchased in market, caught in Oneida Lake.

ADULT FISH (3 specimens).

No. 1(75)	300 mill. long.	
	Mollusca. *Amnicola lustrica*, many; *Planorbis hirsutus*, 1	50 per cent.
	Mud and plant remains, algæ	50 per cent.
No. 12.	240 mill. long.	
	Insecta. Fragments of Odonate nymphs	5 per cent.
	Mud and plant remains	95 per cent.
No. 13.	390 mill. long.	
	Mollusca. *Valvata tricarinata* 114 (1–3 mill. long); *Amnicola lustrica*, 17 (½–3 mill. long); *Galba catascopium*, 1 (1½ mill. long)	20 per cent.
	Mollusca. *Pisidium henslowanum*, 25 (many fragments); *Sphærium vermontanum*, 1 (young)	20 per cent.
	Insecta. *Hexagenia* larvæ, 4; Chironomid larvæ, 420	50 per cent.
	Caddis-fly (*Helicopsyche borealis*); Caddis-fly, fragments of cases	8 per cent.
	Bryozoa. *Plumatella* statoblast, 1.	2 per cent.
	Mud and vegetable remains, very small amount	.

JUVENILE FISH (10 specimens).

No. 2(314)	85 mill. long.	
	Crustacea. *Cyclops*, a few; *Alona*, abundant	50 per cent.
	Plants. Algæ and plant fragments	50 per cent.

No. 3 (305) 84 mill. long.

Crustacea.	*Hyalella knickerbockeri*, 1	10 per cent.
	Alona, many *Cyclops*, a few	90 per cent.

No. 4 (305) 80 mill. long.

Crustacea.	*Cyclops*	90 per cent.
Plants.	Algæ and plant remains	10 per cent.

No. 5 (305) 78 mill. long.

Crustacea.	*Alona* *Cyclops*	90 per cent.
Plants.	Algæ and plant remains	10 per cent.

No. 6 (5) 98 mill. long. Mud and unicellular plants, small amount.
No. 7 (5) 105 mill. long. Mud and unicellular plants, small amount.
No. 8 (5) 100 mill. long. Mud and unicellular plants, small amount.
No. 9 (5) 95 mill. long. Mud and unicellular plants, small amount.
No. 10 (5) 95 mill. long. Mud and unicellular plants, small amount.
No. 11 (5) 110 mill. long. Stomach empty.

In the juvenile stage the food is Crustacea, largely Entomostraca, the percentages of 4 specimens being:

Mud and plants	17.50 per cent.
Amphipoda	2.50 per cent.
Entomostraca	80.00 per cent.

The change of food habits from crustaceans to mollusks and insects is noteworthy.

Hankinson (1908, pp. 207, 245–251) examined 42 specimens from Walnut Lake, Mich., varying in size from 15 to 19 inches (375–475 mill.) and hence all adult. Seven specimens containing food were caught in April and May and found to have eaten dragon-fly nymphs (36 in one individual), small bivalve mollusks, amphipods, and some marl. Twenty-seven specimens caught in August had eaten only midge larvæ and the small entomostracan *Daphnia*. Hankinson remarks that "it is interesting to compare the food of the specimens taken in August with that of Whitefish caught in the same haul of the net; the Whitefish were feeding upon *Daphnia* only, and apparently away from the bottom, while some of the suckers were feeding on midges at the bottom, and others on the *Daphnia* apparently above it."

J. E. Reighard (1915, p. 223–224) examined 5 young suckers from Douglas Lake, Mich., (43–50 mill. long) in September and found their food to consist almost wholly of a Cladoceran, apparently *Chydorus,* only two or three Copepods being present. The adults examined all had empty stomachs. In this case the food of the young agrees with those from Oneida Lake, both feeding upon Crustacea. Forbes (1888, a, p. 513) did not have sufficient material from which to judge of the food of this species. *Unio* is recorded as being found in June and *Sphærium* in October in the stomach contents. From the data presented above it is evident that the food of the Common Sucker varies with the locality. When the water is shallow and there is a good bottom fauna, this appears to be its natural feeding ground. It is probable that the detritus layer of the bottom also plays an important part in the food economy of this species.

Catostomus nigricans (LeSueur). *Hogsucker; Stone Roller.*

The food of this sucker consists almost entirely of aquatic insect larvæ (92 per cent.) only an insignificant ratio of mollusks being eaten. This sucker, says Forbes (1909, pp. 87–88) "is, in short, a molluscan feeder which has become especially adapted to search for insect larvæ occurring in rapid water under stones." May-flies, principally *Cænis,* form the chief food. Bean (1903, p. 104) says "the food consists of insect larvæ and small shells."

Moxostoma aureolum (LeSueur). *Common Red Horse.*

Forbes (1888, a, p. 443) examined 17 specimens of this species and remarks "the salient features of the food of *Moxostoma macrolepidotum* (= *aureolum*) as exhibited by 12 specimens examined, are the abundance of univalve Mollusca and the bivalve *Sphærium,* the insignificance of the vegetable element, and the absence of Crustacea and the larger and more active insect larvæ. The insect food consisted almost wholly of larvæ of *Chironomus* and other small mud-inhabiting species." The food ratio of this species may be indicated as follows:

Mollusca	62 per cent.
Insecta and Crustacea	33 per cent.
Vegetable matter	5 per cent.

In one specimen, mollusks formed more than half of the stomach contents and embraced the following genera:

Vivipara.	22 per cent. (with *Campeloma*)
Campeloma.	
Somatogyrus.	6 per cent. (with *Amnicola*)
Amnicola.	
Lymnæa.	
Planorbis.	
Physa.	

In five additional specimens, mollusks made up 75 per cent. of the stomach contents, as noted below:

Sphærium.	greater part.
Campeloma.	25 per cent.
Amnicola.	

Ten genera are recorded as food for this fish:

Amnicola.	Recorded in September.
Somatogyrus.	Recorded in September.
Valvata tricarinata	Recorded in September.
Vivipara.	Recorded in September and October.
Campeloma.	Recorded in October.
Lymnæa.	Recorded in May.
Physa.	Recorded in May.
Planorbis.	Recorded in May and June.
Sphærium.	Recorded in June.
Anodonta.	Recorded in May.

Among the insects, dipterous larvæ formed the greater portion. "Two specimens had eaten a small quantity of hydrophilid larvæ, one an *Agrion* larva, and two other larvæ of Ephemeridæ. The Entomostraca recognized belonged to *Alona* and *Cyclops.* The vegetable food consisted of distillery slops, eaten by one of the specimens, with a little *Wolffia, Chara,* filamentous algæ, and some miscellaneous matter." (Forbes, 1888, a, p. 443.)

A specimen of the species, (No. 327) from Oneida Lake, was purchased in the Syracuse market, November 17, 1915.

It was adult, measuring 16 inches (400 mill.) in length. The stomach was empty, but the intestine contained a small quantity of material, in an advanced state of digestion. From this material the following groups were identified:

Insecta.	Chironomid larvæ, 14.
	Hexagenia nymph, 1.
Plants.	Filamentous algæ. Small amount.

More material is necessary to determine the food habits of this species in Oneida Lake. It is interesting to note that DeKay, in his fish report, names the Red-horse of Oneida Lake *Catostoma oneida* and calls it the Oneida Sucker (1842, p. 198). Bean (1902, p. 284) states that the food consists of mollusks and insects.

† *Moxostoma breviceps* (Cope). *Short Headed Red Horse.*

The food of this species, judged from 6 specimens examined by Forbes, appears to be about half Mollusca and half insects, mostly *Chironomus* larvæ and pupæ. Two genera of mollusks were identified, *Vivipara* and *Sphærium,* both taken in June. It is to be noted that in Forbes (1888, a) paper on the food of fresh-water fishes, *macrolipidotum,* page 442, is now *aureolum,* while *aureolum,* page 444, is now *breviceps.*

† *Placopharynx duquesnei* (LeSueur). *Sucker.*

Little is known concerning the food of this sucker, which does not inhabit the waters of New York State. Forbes (under the specific name *carinatus*) records the food of three specimens, two of which were adult. This data appears below (1888, a, p. 442):

No. 1.	Mollusca.	*Valvata tricarinata* / *Amnicola*	60 per cent.
	Insecta.	Hydrophilidæ larvæ / Ephemeridæ larvæ (mostly *Cænis*) / *Chironomus* larvæ	35 per cent.
	Crustacea.	*Allorchestes.* 1 specimen	
	Plants.	*Lemna*	5 per cent.
No. 2.	Mollusca.	*Valvata tricarinata* / *Amnicola* / *Sphærium*	5 per cent.

Insecta.	Hydrophilidæ larvæ	80 per cent.
	Ephemeridæ larvæ (*Cænis*)	10 per cent.
	Chironomus and other Diptera (larvæ)	5 per cent.
Bryozoa.	*Plumatella*	
Plants.	*Wolffia*	

The third example, young 5½ inches long, had eaten chiefly of the bryozoan *Plumatella*, a few Caddis-flies, a small gastropod (Strepomatidæ) and a few *Chironomus* larvæ. The average for three specimens is about:

Mollusca	22 per cent.
Insecta	44 per cent.
Bryozoa	30 per cent.
Plants	3 per cent.
Miscellaneous	1 per cent.

Cyprinus carpio (Linnaeus). *German Carp.*

The percentages of food for this introduced fish stand about as follows:

Vegetable matter	66 per cent.
Animal matter	34 per cent.

Carp are omnivorous feeders, rooting up the mud of the bottom in search of small animals as well as of vegetable food. It also feeds upon water plants at and below the surface. Its animal food consists of insect larvæ, crustaceans, mollusks and other small aquatic animals. The charge that this species seeks the spawn of other fishes for food has not been supported by evidence. The spawn that has been noted in its stomach is quite incidental. Cole (1905, pp. 569–572) dissected thirty-three specimens, twelve of which contained Mollusca in greater or less quantities, as noted below:

1. *Chara, small shells*, insects.
2. Vegetable matter, *shells*, insects.
3. *Chara*, Crustacea, *fragments of shells.*
4. *Chara, broken shells, small bivalves.*
5. *Broken shells, Chara*, amphipods, etc.
6. *Broken shells*, insect larvæ.
7. *Broken shells*, caddis-fly larvæ.
8. Algæ, *broken shells*, larvæ.
9. Caddis-fly larvæ, *broken shells*, algæ.
10. *Shell fragments*, Entomostraca.
11. *Shell fragments*, Entomostraca, insect larvæ.
12. *Shell fragments*, Ostracods, etc.

Exact percentages are not available, but the Mollusca are believed to form more than 15 per cent. of the food of this carp.

Semotilus bullaris (Rafinesque). *Dace; Silver Chub; Fallfish.*

Two specimens of this fish, caught near Constantia, August 31, 1915, were examined. No mollusks were observed, and it is not known to feed upon this class of animals.

No. 1 (76) 245 mill. long. Stomach and intestine empty.

No. 2 (76) 280 mill. long.

Crustacea.	2 *Cambarus bartoni robustus*.....	65 per cent.
Batrachia.	1 small frog, partly digested.....	35 per cent.

A related species *atromaculatus,* is known (Forbes and Richardson, p. 123) to eat algæ and miscellaneous vegetable matter (25 per cent.), small fishes, grasshoppers, ants, caterpillars, beetles and various other terrestrial insects, *Corisa,* dipterous larvæ and other aquatic insects, and crawfishes.

Abramis chrysoleucas (Mitchill). *Golden Shiner; Roach; Bream.*

Food varies in different localities (Forbes, 1883, a, p. 81). In the Pecatonica River, Illinois, the food was entirely molluscan, consisting principally of *Valvata tricarinata* and *Planorbis deflectus,* taken in May. Fishes from the Illinois River at Pekin had eaten largely of mollusks but principally of Entomostraca. As a whole the diet may be expressed as follows:

Vegetation and mud	50 per cent.
Crustacea..	15 per cent.
Mollusks...	14 per cent.
Insects..	6 per cent.
Miscellaneous......................................	15 per cent.

Eighteen specimens from Oneida Lake have been examined, six of which contained food. In this lot mollusks formed but a small percentage of the total food, insects totalling 97 per cent., caddis-fly larvæ predominating. Fresh material is needed to satisfactorily determine the food percentages of this interesting fish. The data obtained from the eighteen specimens is given below.

Nos. 1 to 5, caught in Nicholson Bay, in trammel net, September 8, 1915; Nos. 6 to 8, caught in bay southwest of Shaw Bay, in trammel net, September 7; Nos. 9, 10, Shaw Bay in thick vegetation, September 6; No. 11, caught in little round bay southeast of Shaw Bay in trammel net, September 9; Nos. 12 to 16, Lower South Bay, October 31, 1914, seined; No. 17, Lower South Bay, December 16, 1914; No. 18, Lower South Bay, December 9, 1914.

No. 1 (133).	Fish 162 mill. long.	
	Mollusca. 1 *Physa ancillaria warreniana*, young	5 per cent.
	Insecta, many caddis-fly larval cases (*Leptocella*)	95 per cent.
No. 2 (133).	Stomach empty. Fish 162 mill. long.	
No. 3 (133).	Stomach empty. Fish 140 mill. long.	
No. 4 (133).	Stomach empty. Fish 175 mill. long.	
No. 5 (133).	Insecta only, largely macerated. Fish 150 Mill. long.	
No. 6 (123).	Stomach empty. Fish 190 mill. long.	
No. 7 (123).	Stomach empty. Fish 178 mill. long.	
No. 8 (123).	195 mill. long.	
	Insecta. Caddis-fly larval cases (*Leptocella*)	100 per cent.
No. 9 (122).	Insecta. Largely digested	100 per cent.
No. 10. (122).	Insecta. Grasshoppers (hind tarsi)	60 per cent.
	Caddis-fly larval cases (fragments)	40 per cent.
No. 11 (136).	200 mill. long.	
	Stomach almost empty, small amount of digested matter in the intestines.	
No. 12 (5).	95 mill. long. Stomach empty.	
No. 13 (5).	86 mill. long. Stomach empty.	
No. 14 (5).	83 mill. long. Stomach empty.	
No. 15 (5).	83 mill. long. Stomach empty; intestine with small amount of mud and macerated material.	
No. 16 (5).	78 mill. long.	
	Crustacea. 3 *Bosmina longirostris*.. *Hyalella*, fragments, legs, etc.	1 per cent.
	Insecta. 20 Chironomid larvæ	
	Mud and macerated matter	9 per cent.
No. 17 (10).	155 mill. long.	

The stomach was practically empty as was also the intestine, the latter containing only a piece of molluscan shell and a few unicellular plants.

No. 18 (8). 130 mill. long. Stomach empty.

Hankinson (1908, p. 205, 249) examined specimens in April, May, July and August, and found the food to consist of midge larvæ, filamentous algæ (*Spirogyra*), entomostracans and Protozoa (*Arcella*).

* *Notropis heterodon* (Cope). *Minnow.*

One specimen in eighteen had eaten univalve Mollusca. Entomostraca and insects form the principal food. Molluscan food is not over one per cent. (Forbes, 1883, a, p. 85).

Notropis whipplii (Girard). *Steel Colored Minnow.*

One specimen in 33 had eaten a small *Lymnæa;* less than one per cent. molluscan food (Forbes, 1883, a, p. 87).

* *Ictalurus punctatus* (Rafinesque). *Channel Cat; Fiddler.*

Forbes (1888, b, p. 457) examined 43 specimens of this species, taken during spring, summer and autumn. The range of food may be expressed as follows:

Vegetation (filamentous algæ, *Potamogeton, Lemna*)	25 per cent.
Mollusca.	15 per cent.
Insecta (*Chironomus*, *Hexagenia*, Odonata, Ephemeridæ)..	44 per cent.
Miscellaneous (worms, Bryozoa, fish)	16 per cent.

Among the last item may be mentioned a dead rat, pieces of ham, pieces of dead fish and other animal debris.

Of the mollusks, eight genera were represented, as noted below:

Pleurocera, taken in September.
Campeloma, taken in October.
Lioplex subcarinata, taken in September.
Amnicola, taken in October.
Vivipara, taken in April, September and October.
Planorbis, taken in October.
Unionidæ, taken in September.
Anodonta, taken in August and October.

Large water snails (*Viripara, Campeloma*) and clams form a large part of the diet of this catfish, some specimens examined having eaten little else. Of this food Forbes (1888, b, p. 457) remarks: "Notwithstanding the number of bivalves eaten by this fish, no fragments of a shell was ever found in their stomachs, but the bodies of the mollusks seem to have been separated, while yet living, from the shells, as indicated by their fresh condition and by the fact that the shell muscles were scarcely ever present. Fishermen say that they are often first notified of the presence of catfishes in their seines by seeing the fragments of clams floating on the surface, disgorged by the struggling captives. Still more interesting and curious is the fact that the spiral-shelled mollusks found in the stomachs of these fishes were almost invariably naked, the more or less mutilated bodies having only the opercles attached. The shells are evidently cracked in the jaws of the fish and rejected before the food is swallowed As many as 120 bodies and opercles of water snails (*Campeloma* and *Vivipara*) were by us taken from the stomach of a single Illinois River catfish."

Four young examples of this species were found by Forbes to have fed principally upon insects, including *Chironomus* and *Hexagenia* (eggs and young), with a few crustaceans of *Daphnia* and *Allorchestes dentata*.

Ameiurus natalis (LeSueur). *Yellow Bullhead.*

The molluscan food of this fish is relatively of small amount, forming but 5 per cent. of the total food. Three genera are noted by Forbes (1888, b, p. 459).

Vivipara, taken in October.
Campeloma, taken in October.
Physa, taken in October.

On the whole this fish is a scavenger, eating dead animals and other debris. Forbes examined 12 adult specimens taken from May to November. Vegetation (*Lemna* and *Wolffia*) formed a very small percentage, fishes about 33 per cent., insects (principally *Hexagenia* larvæ) about 30 per cent., and catfishes 17 per cent.

Seven young specimens, 2 to 3½ inches long, had fed chiefly upon Entomostraca (50 per cent.) among which were *Daphnia, Acroperus, Cyclops, Cypris, Simocephalus americanus,* and *Macrothrix laticornis;* 25 per cent. of the food was molluscan (*Physa*); 20 per cent. was insect larvæ (ephemerids and *Chironomus*). A small amount of *Wolffia* and other aquatic vegetation was present.

Three adult specimens of this species were examined from a lot purchased in the Syracuse market, and said to have been caught in Oneida Lake. The contents of the stomachs did not give decisive results owing to their advanced state of digestion. The data is as follows:

No. 1. 310 mill. long. Stomach and intestine were almost empty.
Insecta. 1 Chironomid (?) larval head.
Insect larvæ, legs.

No. 2. 330 mill. long. Stomach empty.

No. 3. 300 mill. long.
Insecta. 2 *Hexagenia* larvæ, 12 and 15 mill. long in stomach.

Insecta. *Hexagenia* larvæ, fragments	In intestine
Mollusca. 1 *Ancylus parallelus*	
Plants. Filamentous algæ	
Mud. (Detritus)	

The Mollusca form about 1 per cent., and is notable for the presence of the fresh water limpet *Ancylus parallelus.*

Ameiurus nebulosus (LeSueur). *Common Bullhead; Speckled Bullhead.*

From studies by Forbes (1888, b. pp. 460–461, 36 specimens) the food of the Common Bullhead (which included also the Black Bullhead (*Ameiurus melas* Raf.) has been ascertained to consist of:

Fishes	20 per cent.
Mollusks	20 per cent.
Insects. (Dipterous larvæ, *Hexagenia*, Odonata, terrestrial insects)	25 per cent.
Crustaceans. (*Allorchestes dentata, Diaptomus,* etc.)	13 per cent.
Miscellaneous, including vegetation	22 per cent.

One-half of the molluscan food consisted of *Sphærium* and one group from the Illinois River (collected in September and October) had eaten little else than *Sphærium.* In another specimen, insects formed 37 per cent and mollusks 63 per cent. of the food. Two specimens had fed only on fish and one specimen had eaten leeches to the extent of 25 per cent. The mollusks eaten by this fish are tabulated below:

Amnicola, taken in May, August and October.
Valvata tricarinata, taken in July.
Vivipara, taken in October.
Campeloma, taken in October.
Physa, taken in August, September.
Physa heterostropha, taken in October.
Sphaerium, taken in May, September, October.
Sphaerium sulcatum, taken in August, September.
Pisidium, taken in September.
Unionidæ, taken in May, October.

Seven specimens of the Common Bullhead from Oneida Lake have been examined. These were taken at the following locations:

No. 1, Shaw Bay, in thick vegetation, lamprey scar on back, September 6, 1915; No. 2, found dead in Oneida River, near Brewerton, September 4; Nos. 3 to 6. Lower South Bay, October 12, 1914, caught in seine in shallow water; No. 7, Brewerton, near Davison's Landing, October 18, 1915, seined in shallow water. Only one of the seven was adult and this one had the stomach empty. The data for these is given below:

No. 1 (122).	215 mill. long. Stomach empty.	
No. 2 (109).	110 mill. long.	
	Mollusca. 2 *Physa ancillaria warreniana*	10 per cent.
	Vegetation and mud, mixed............	90 per cent.
No. 3 (309).	56 mill. long.	
	Crustacea. Entomostraca (*Alona*)......	25 per cent.
	Insecta. Fragments of nymphs (*Odonata*)............................	25 per cent
	Algæ and mud	50 per cent.

No. 4 (309).	50 mill. long.		
	Crustacea.	2 *Cyclops* .... / 200 *Alona* .... / 1 *Hyalella knickerbockeri*	75 per cent.
	Insecta.	2 Chironomid larvæ..........	10 per cent.
	Algæ and mud	....	15 per cent.
No. 5 (309).	43 mill. long.		
	Crustacea.	100 *Alona*	50 per cent.
	Insecta.	Fragments.	20 per cent.
	Algæ.	. . . .	30 per cent.
No. 6 (309).	50 mill long.		
	Crustacea.	1 *Hyalella knickerbockeri* / 2 *Cyclops*. . . . . / 100 *Alona*.	50 per cent.
	Algæ.	. . . .	50 per cent.
No. 7 (314).	55 mill. long. Stomach empty.		

As is usually the case with young fish, the food of these juvenile individuals is seen to consist chiefly of Crustacea. The larger specimen (110 mill., No. 2) had evidently reached the stage when a molluscan diet could be added. Forbes (1888, b, p. 461) records the food of two young individuals (2 to 3½ inches long) as chiefly ephemerid and chironomid larvæ, small crawfish, *Asellus, Corixa tumida, Cyclops, Daphnia,* filaments of *Spongilla, Chydorus, Scapholeberis mucronatus,* a few Diatoms, and traces of filamentous algæ. Hankinson (1908, p. 208, 249) found the food of adults to consist of crawfish, small fish, mollusks, entomostracans, leeches, beetles, and the larvæ of *Hexagenia, Heptagenia,* midges, and dragon-flies; ten stomachs were examined. One specimen contained two dragon-fly larvæ, 32 *Hexagenia* larvæ, 2 midge larvæ, and 1 minute bivalve (possibly *Pisidium*).

Schilbeodes miurus (Jordan). *Brindled Stonecat*

A specimen of this species, caught in seine in shallow water, at Lower South Bay, October 12, 1914, contained only algæ and mud in its stomach and intestine. It was 32 mill. long.

Umbra limi (Kirtland). *Mud Minnow; Mudfish.*

Forbes (1909, p. 204) examined ten specimens and found the food to consist largely of duckweed (*Wolffia*) and unicellular algæ. Insects and crustaceans (mainly Entomostraca) made up more than 25 per cent. of its food. Mollusks were found to the extent of 5 per cent. in some specimens. *Physa* and *Planorbis* (taken in July) were the only genera noted. Hankinson (1908, p. 209) found the food of four specimens to consist of entomastracans, green algæ, water mites, midge larvæ, *Planorbis* shells, and miscellaneous insects. Two of the fishes were caught in April and two in July.

Esox reticulatus (LeSueur). *Chain Pickerel; Green Pike.*

The common Pike or Pickerel of Illinois (*Esox lucius*) feeds almost entirely on fishes when adult; a single specimen, out of 37 examined by Forbes (1888, b, p. 434), had eaten 20 per cent of dragon-files. The fishes eaten were sunfish, black bass, crappie, gizzard shad, Cyprinidæ (chiefly *Notropis hudsonius*) and Buffalo fish (*Ictiobus bubalus* and *I. cyprinella*). A number of the fish eaten are mollusk eaters. No records have been seen of the food of *Esox reticulatus,* and while large individuals probably do feed on fish, small or young specimens 10 to 16 inches long feed almost entirely on crawfish.

The data from five individuals is shown below, all caught in Frederick Creek, above the railway bridge, Constantia, with seine, September 8, 1915. The food of these is summarized below for comparison with those from Green Lake, Jamesville, N. Y. (see p. 201):

Cambarus.	75 per cent.
Rana.	25 per cent.

No. 1 (142). 280 mill long.

Remains of crawfish (*Cambarus bartoni robustus*) in stomach; 2 gastroliths 7.50 mill. in diameter. Intestine filled with jelly-like mass of digested matter.

No. 2 (142). 235 mill. long.
Piece of skin of frog (*Rana*).

No. 3 (142). 247 mill. long.
Remains of two crawfish (probably *Cambarus bartoni robustus*) in stomach; gastroliths, 2 mill. and 6 mill. in diameter.

No. 4 (142). 230 mill. long.
Stomach empty; intestine filled with unidentifiable mass.

No. 5 (142). 240 mill. long.
Stomach and intestine empty. 1 crawfish 30 mill. long in mouth (*Cambarus bartoni robustus*).

Fundulus diaphanus (LeSueur). *Fresh Water Killy.*

Hankinson (1908, p. 209) found the food of this fish to consist of midge larvæ, water-fleas, may-fly larvæ, beetles, and a small amount of filamentous algæ. Forbes (1883, a, p. 71) found the western variety *menona* to feed upon a variety of material, as noted:

Vegetable matter, largely seeds................	20 per cent.
Insecta (*Chironomus*, Hydrophilidæ, Ephemeridæ larvæ, terrestrial insects and spiders)........	40 per cent.
Crustacea (chiefly *Allorchestes dentata*).......	20 per cent.
Mollusca (*Planorbis*)	5 per cent.
Miscellaneous.............................	15 per cent.

Planorbis, taken in June and October and *Pisidium* taken in June were noted.

† *Fundulus dispar* (Agassiz). *Killifish.*

Eighty per cent. of the food (Forbes, 1883, a, p. 73) of this species consists of animal matter, of which 25 per cent. is molluscan. Insects form another 40 per cent. and crustaceans only 4 per cent. Three molluscan genera, *Physa, Planorbis* (taken in July) and *Valvata sincera* (probably should be *lewisii*) were noted.

† *Fundulus notatus* (Rafinesque). *Top Minnow.*

Insects form the chief diet of this fish. Entomostraca and other Crustacea are also present, as well as about 3 per cent.

of mollusks. *Physa* was noted in September and October. As a whole the food of the genus *Fundulus* may be summarized as follows (Forbes, 1883, a, p. 73):

Terrestrial and aquatic insects, etc.............	61 per cent.
Crustacea..................................	4 per cent.
Mollusca..................................	15 per cent.
Vegetable food	20 per cent.

† *Gambusia affinis* (Baird and Girard). *Viviparus Top-Minnow.*

Three genera of mollusks have been taken from the stomach of this top-minnow. (Forbes, 1888, b, pp. 512–513.)

Valvata sincera (probably should be *lewisii?*) taken in September.
Physa, taken in September and October.
Planorbis, taken in September.

Labidesthes sicculus (Cope). *Brook Silversides.*

Forbes (1883, a, p. 65) examined 25 specimens of the Brook Silversides, finding the food to be purely animal, a little over half consisting of insects and a little less than half crustaceans. The larvæ of *Chironomus* were among the important elements, making 30 per cent. of the whole. The crustaceans were all Entomostraca, including Copepods and Cladocera; *Daphnia, Simocephalus, Bosmina, Chydorus, Pleuroxus, Alona,* and *Eurycercus* occurred among the Cladocera, and *Cyclops, Canthocamptus, Diaptomus, Limnocalanus* and *Epischura* among the Copepods. A few terrestrial insects, accidentally washed into the water, formed about 12 per cent. of the food. According to Forbes (1888, a, p. 513) unrecognizable Mollusca have been found in the stomach of this fish. Four specimens from Oneida Lake were examined and the stomach contents noted. They were collected in the west side of Ladd Bay, near Ladd Point, on a sand bottom, covered with Bulrushes, September 3, 1915.

No. 1 (101) 53 mill. long.

Insecta. 23 adult midges, fragments*.... 80 per cent.

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*Midges were noted by counting the number of pairs of eyes, all flies being represented only by fragments.

	Crustacea. 1 amphipod, *Hyalella knickerbockeri*.	20 per cent.
No. 2 (101)	52 mill. long.	
	Insecta. 9 adult midges, fragments.	100 per cent.
No. 3 (101)	51 mill long.	
	Insecta. 17 adult midges, fragments.	89.50 per cent.
	Acarina. 2 water mites.	.50 per cent.
	Crustacea. 74 Entomostraca (*Bosmina longirostris*).	9.00 per cent.
	Bryozoa. 20 statoblasts of *Plumatella*. . . .	1.00 per cent.
No. 4 (101)	55 mill. long.	
	Insecta. 5 adult midges, fragments.	100 per cent.

The average for four specimens is insects, 92.38 per cent.; crustaceans 7.25 per cent.; Acarina and Bryozoa .37 per cent.

Ambloplites rupestris (Rafinesque). *Rock Bass; Red Eye.*

Forbes (1880, a, p. 44) found the food of four adult Rock Bass to consist of small fishes, 15 per cent.; Neuroptera, Odonata, etc., 40 per cent., and crawfishes 30 per cent. Three young fishes had fed on Entomostraca and a few insect larvæ. Hankinson (1908, p. 210) found the Rock Bass in Walnut Lake, Mich., to feed largely on crawfish. Nineteen specimens gave the following results: Crawfish in 10; dragon-fly larvæ in 6; midge larvæ in 2; small fish in 1; May-fly larvæ in 1. Reighard (1915, p. 231) examined 17 specimens, finding a small fish in one, a crawfish in a second and *Cambarus virilis* and dragon-fly larvæ in another. Marshall and Gilbert (1905, p. 518) examined 16 specimens, 13 of which contained food; in 2 insect larvæ were found, and in 12 crawfish were found. Of the Oneida Lake specimens, 3 out of 5 had eaten crawfishes. It seems evident that this is the favorite food as 30 out of 39 specimens had eaten this animal. In the spring the food consists mostly of the larvæ of insects, crustaceans, and worms. In summer and fall the food appears to consist principally of crawfish.

The data for the Oneida Lake records is given below. Nos. 1–2, collected on Grass Island bar in trap nets, Sept. 9, 1915, water 12–16 feet deep, stony bottom; No. 3, Lower South Bay, October 12, 1914, seined in shallow water; No. 4, Oneida Lake, purchased from fisherman; No. 5, from near Constantia.

Nos. 1 and 2 (144).	190 mill. long.	
	Crustacea. Crawfish (*Cambarus*) fragments.	75 per cent.
	Hyalella (*knickerbockeri?*) legs..	25 per cent.
No. 3 (309)	113 mill. long.	
	Crustacea. *Hyalella* (*knickerbockeri?*), legs, etc.	75 per cent.
	Bryozoa. 12 *Plumatella* statoblasts	5 per cent.
	Plants. Algæ and plant cells	20 per cent.
No. 4.	215 mill. long.	
	Stomach, Crustacea. *Cambarus* fragments.	
	Intestine, macerated matter.	
No. 5.	155 mill. long.	
	Insecta. Odonata nymphs, legs and fragments	15 per cent.
	Macerated matter	85 per cent.

* *Lepomis pallidus* (Mitchill). *Bluegill; Blue Sunfish.*

Forbes (1880, a, p. 49) examined 24 adult Bluegills and found them to differ widely in their food. He therefore divided then into three groups:

1. From clear, inland, northern lakes, taken in May and June.
2. From Calumet River and from Lake George, Ind.
3. From Illinois River, taken in May, July, Aug., Oct., and Nov.

GROUP 1.	5 SPECIMENS.	
	Insecta. Caddis-fly, dragon-fly, *Agrion*	62 per cent.
	Crustacea. *Allorchestes dentata*	27 per cent.
	Miscellaneous	1 per cent.
GROUP 2.	4 SPECIMENS.	
	Crustacea. *Allorchestes* and *Asellus*	52 per cent.
	Insecta. (Terrestrial and aquatic, Phryganeidæ abundant)	23 per cent.
	Plants	25 per cent.
	Mollusca. *Vivipara* (trace).	
GROUP 3.	15 SPECIMENS.	
	Mollusca	16 per cent.
	Insecta (terrestrial)	15 per cent.
	Insecta (aquatic)	32 per cent.
	Vegetation. *Ceratophyllum*, *Nais*, algæ	31 per cent.
	Crustacea. (Crawfishes, *Asellus*, and *Allorchestes*)	6 per cent.

Five genera of mollusks are listed.

Amnicola, taken in October.
Vivipara, taken in July and November.
Physa, taken in November.
Planorbis, taken in November.
Sphærium, taken in October.

The food of the young consists of Entomostraca (57 per cent.) and *Chironomus* larvæ (37 per cent.). A few water-spiders and amphipods make up the balance. As the fish increases in size, less Entomostraca are eaten and more insects, specimens two and three inches long having the ratios, *Chironomus* larvæ (30 per cent.), *Corixa* (25 per cent.), Neuroptera (14 per cent.), Crustacea (about 30 per cent.).

Hankinson (1908, p. 212) found the Bluegills of Walnut Lake to feed upon caddis-fly larvæ, crawfish, midge larvæ and pupæ, *Heptagenia*, *Hexagenia*, and *Sialis* larvæ until the middle of May, after which crawfish, grasshoppers, crickets, beetles, and other land insects, together with entomostracans, were the chief articles of diet. No mollusks are recorded. Reighard (1915, p. 233) found a very large percentage of vegetation in three specimens, including *Elodea* and *Chara*. Bryozoan statoblasts, heads, wings and legs of insects, apparently adult Diptera, were also present. Marshall and Gilbert (1905, p. 518) examined 30 specimens, 20 of which contained food; 9 contained plant tissue, 13 plankton, 9 insect larvae, 2 *Gammarus*, 1 leeches, and 1 snails, mostly *Physa ancillaria*.

* *Lepomis megalotis* (Rafinesque). *Long Eared Sunfish.*

The food of this sunfish is said by Forbes (1880, a, p. 53) to be as follows, based on the examination of three specimens: *Chironomus* larvæ (60 per cent.), mollusks (16 per cent.), *Allorchestes*, *Asellus*, *Corixa*, gyrinid larvæ, and a few chrysomelid larvæ. One specimen (taken in June) contained the remains of an *Anodonta*. Hankinson (1908, p. 212) records, from three specimens, May-fly larvæ, dragonfly larvæ, caddis-fly larvæ, and leeches.

† *Eupomotis heros* (Baird and Girard). *Sunfish.*

Three genera of mollusks have been observed in the stomach contents of this sunfish (Forbes, 1888, b, pp. 512-513).

Amnicola, taken in September.
Planorbis, taken in September.
Unionidæ, taken in September.

Eupomotis gibbosus (Linnaeus). *Pumpkinseed.*

Mollusks form about 50 per cent. of the food of this sunfish in Illinois. Forbes (1880, a, p. 54) gives the percentages of food at different ages as follows:

INFANCY. 37-50 mill. long. 9 specimens examined.

Chironomus larvæ	51 per cent.
Entomostraca	26 per cent.
Insects eggs; daphnids	12 per cent.
Ephemerid larvæ	5 per cent.
Miscellaneous	6 per cent.
Mollusks	trace.

YOUTH. 50-75 mill. long. 5 specimens examined.

Chironomus larvæ	44 per cent.
Entomostraca	18 per cent.
Allorchestes	14 per cent.
Neuroptera	11 per cent.
Young Unios	2 per cent.
Miscellaneous	11 per cent.

In two specimens nearly three inches long the molluscan content rose to nearly 50 per cent., the total amount standing as follows:

Mollusca (Chiefly *Physa*)	50 per cent.
Chironomus	few.
Allorchestes	equal quantities.
Ephemerid larvæ	equal quantities.

Entomostraca seem to disappear from the food when the sunfish reaches this length.

ADULT. 9 specimens examined.

Mollusca	46 per cent.
Crustacea	22 per cent.
Insects	20 per cent.
Vegetation	12 per cent.

The species of mollusks noted in the food are as follows:

Amnicola, taken in May, July and August.
Valvata tricarinata, taken in May.
Planorbis, taken in May.
Physa (young).
Anodonta (young).

Hankinson (1908, p. 213, 245–250) records the food of 22 individuals (adults). Of these, 8 had eaten midge larvæ, 5, caddis-fly larvæ, 1, an amphipod, 7, *Heptagenia* larvæ, 9, *Hexagenia* larvæ, 5, leeches, 3, dragon-fly larvæ, 3, May-fly larvæ, and, 4, crawfishes. From this data the sunfish in Walnut Lake prefer insect larvæ, principally *Hexagenia* and *Heptagenia*. Hankinson says " while May-fly larvæ of the genera *Hexagenia* and *Heptagenia* seemed to be the favorite food, crawfish, amphipod crustaceans, snails, leeches, midge larvæ, caddice-worms, and other insects were all found in the contents."

J. E. Reighard (1915, p. 233–234) examined 13 specimens from Douglas Lake, Mich., 9 of which contained food. In 6, mollusks or their fragments were found, 4 of these containing nothing else, while a fifth contained 3 small snails, fragments, and a quantity of orange colored fruits of *Chara;* 4 had eaten insect larvæ and 1 an ostracod. Reighard says " snails appear to be the most important element of the food and next to these, insect larvæ, but exact percentages are not available." Two species of mollusks were identified from the stomach contents, *Amnicola limosa,* adult, and *Planorbis bicarinatus portagensis* (= *P. antrosus portagensis*). Marshall and Gilbert (1905, p. 519) examined 5 specimens, from Lake Mendota, Wis., and found the food to consist of insect larvæ, snails, and small bivalves.

Seventeen specimens were examined from Oneida Lake, 13 of which contained food. The food ratios based on the data in the following pages, are:

	Adult.	Youth.	Infancy.
Mollusca	66.25	67.50	—
Crustacea	5	16.50	90.00
Insecta	6.25	.75	—
Bryozoa	——	.25	5.00
Plants	1.25	15.00	5.00
Macerated material	21.25	—	—

FOOD OF ONEIDA LAKE SUNFISH.

Nos. 1–7, collected on Grass Island bar in trap nets, September 9, 1915, water 12–16 feet deep, stony bottom; Nos. 8–14, Lower South Bay, October 12, 1914, seined in shallow water; No. 15 Oneida Lake, purchased from fisherman; Nos. 16, 17, from near Constantia.

GROUP 1. ADULT.

No. 1 (144). 140 mill. long.
Mollusca. *Planorbis campanulatus*, 1 perfect shell, young, balance fragments. . . . . 75 per cent.
Miscellaneous. Digested matter, unrecognizable. . . . . 25 per cent.

No. 2 (144). 140 mill. long. Stomach empty.

No. 3 (144). 140 mill. long.
Mollusca. *Planorbis*, fragments of shells. . 100 per cent.

No. 4 (144). 140 mill. long.
Mollusca. 1 *Planorbis campanulatus*, 5 mill.
1 *Galba catascopium*, 6 mill.
1 *Amnicola limosa*, 3 mill.
1 *Planorbis antrosus*, 5 mill.
Shell fragments abundant. . . . . 100 per cent.

No. 5 (144). 140 mill. long. Stomach empty.

No. 6 (144). 140 mill. long.
Mollusca. Shell fragments, probably *Planorbis*. . . . . 60 per cent.
Crustacea. Amphipod legs, etc. . . . . 40 per cent.

No. 7 (144). 140 mill. long.
Mollusca. 4 *Planorbis antrosus.*
3 *Galba catascopium.*
Many fragments of shells, majority being of *Planorbis*. . . . 100 per cent.

No. 8 (309). 140 mill. long.
Stomach contents.
Mollusca. 3 *Bythinia tentaculata*. . .
3 *Planorbis antrosus*. . . .
Many fragments of shells } 95 per cent.
Insects. 1 *Helicopsyche borealis* . . . . 5 per cent.
Intestine contents.
Mollusca. 6 *Bythinia tentaculata*, 4 mill.
45 *Amnicola lustrica*, 3 mill.
5 *Valvata tricarinata*, 4 mill.

1 *Valvata bicarinata normalis*, 4 mill.
3 *Planorbis exacuous*, 2 mill.
2 *Planorbis antrosus*, 5–6 mill.
1 *Pisidium* species, 1½ mill.
1 *Sphærium vermontanum*, 4 mill.
Many fragments of shells.

Crustacea. 2 Amphipods, *Hyalella knickerbockeri*.

Insecta. Caddis-fly, *Helicopsyche borealis*.
Many fragments.

Plants. Wild celery, *Vallisneria spiralis*, 1 piece 25 mill. long, 1 piece 6 mill. long.

Total intestine contents:

Mollusca	60.00 per cent.
Crustacea	.05 per cent.
Insecta	34.00 per cent.
Plants	5.05 per cent.
Total	100.00 per cent.

No. 15. 170 mill. long.

Stomach empty, food in intestine.

Insecta.	1 beetle.	
	3 Odonata nymphs (fragments)	30 per cent.
Plants.	1 piece of leaf	10 per cent.
Indistinguishable matter		60 per cent.

No. 16. 150 mill. long.

Stomach empty, intestine filled with macerated material.

No. 17. 155 mill. long.

Insecta.	Odonata nymphs, legs and fragments	15 per cent.
	Digested material	85 per cent.

GROUP 2. YOUNG.

No. 13 (309). 93 mill. long.

Mollusca.	16 *Amnicola lustrica*	50 per cent.
	4 *Planorbis* species Mass of shell fragments	50 per cent.

No. 14 (309). 110 mill. long.

Mollusca.	Fragments of shells	5 per cent.
Crustacea.	*Hyalella knickerbockeri*, legs, etc.	45 per cent.
Plants.	Algæ	50 per cent.

No. 9 (309). 80 mill. long.

Mollusca. 30 *Amnicola lustrica*, ½–2 mill. long.
1 *Physa ancillaria warreniana*, 2 mill. long.
14 *Planorbis*, c. f., *campanulatus*.

Plants. Algæ.

Intestine packed with mollusks including a large amount of broken shells, this group making up over 95 per cent. of the total mass.

No. 10 (309). 80 mill. long. Stomach empty.

No. 11 (309). 80 mill. long.

Mollusca.	11 *Amnicola lustrica*... 4 *Planorbis antrosus*.. 1 *Planorbis parvus*.... Mass of broken shells.	70.00 per cent.
Insecta.	2 caddis-fly cases (*Leptocella*)...............	3.00 per cent.
Crustacea.	Amphipod fragments... 1 Copepod...........	21.50 per cent.
Bryozoa.	3 *Plumatella* statoblasts..	.50 per cent.
Plants.	Algæ..................	5.00 per cent.

GROUP 3. INFANCY.

No. 12 (309). 44 mill. long.

Crustacea.	100 *Alona*............ 8 *Cyclops*..........	90 per cent.
Bryozoa.	6 *Plumatella* statoblasts...	5 per cent.
Plants.	Algæ..................	5 per cent.

To summarize, the Pumpkinseed of Illinois waters, Douglas Lake, Mich., Mendota Lake, Wisconsin, and Oneida Lake, New York, are largely mollusk eaters. Those of Walnut Lake, Mich, are insect eaters. There may be some, as yet unknown, factors which cause this variation in the food of a typical mollusk-eating fish. It cannot be lack of mollusks in this lake because eight or more available species are known to live in the lake (Hankinson, 1908, p. 235). As bottom inhabitating insect larvæ are present and eaten there must be some selection by the fish.

Micropterus dolomieu (Lacépède). *Small-mouthed Black Bass* and

Micropterus salmoides (Lacépède). *Large-mouthed Black Bass.*

In the Manual of Fish Culture of the U. S. Bureau of Fisheries, 1900, page 153, the food of the adult black basses is said to consist of: " Crayfish, minnows, frogs, tadpoles, worms, and mussels." No specific reference to the use of mollusks as food by these game fishes has been noted elsewhere, although as bottom feeders, to a degree, one would expect them to use this class of animals for food. Forbes and Richardson (1909, p. 265) remark that little is known concerning the food of the Small-mouthed Black Bass. Forbes noted, in three specimens examined, the remains of fish and crawfish. In the Large-mouth he noted fishes and crawfishes. The food of the Large-mouthed Black Bass is better known. Forbes (1880, a, p. 43) examined 31 specimens, which gave the following data:

INFANCY.	Less than 25 mill. long. 5 specimens examined.	
	Crustacea. Amphipoda.	7 per cent
	Entomostraca.	93 per cent.
YOUTH.	25-50 mill. long. 6 specimens examined.	
	Crustacea. Entomostraca.	25 per cent.
	Insecta. Diptera, larvæ	2 per cent.
	Hemiptera.	44 per cent.
	Pisces. Fishes.	29 per cent.
YOUTH.	50-75 mill. long. 2 specimens examined.	
	Insecta. Undetermined larvæ	50 per cent.
	Hemiptera (*Corixa*)	50 per cent.
YOUTH.	75-100 mill. long. 4 specimens examined.	
	Crustacea. Entomostraca, trace.	
	Insecta. Hemiptera.	57 per cent.
	Ephemerida.	43 per cent.
ADULT.	14 specimens examined.	
	Crustacea. Decapoda (*Cambarus*)	7 per cent.
	Insecta. Hemiptera, Odonata.	trace
	Pisces. *Perca*, *Percina*, *Dorysoma*, Cyprinidæ, Siluridæ, etc.	86 per cent.
	Plants. Algæ.	trace
	Miscellaneous.	7 per cent.

More detailed information is needed from other localities regarding the food of the adult Black Bass.

Perca flavescens (Mitchill). *Yellow Perch; American Perch.*

The food of the Perch varies with age and with location. Forbes (1909, p. 277) examined 18 specimen from the rivers and found these had eaten 6 per cent. fish, 20 per cent. thin-shelled mollusks, 25 per cent. insect larvæ and about 49 per cent. Crustacea. A dozen specimens from Lake Michigan had eaten nothing but fishes and crawfishes, the former greatly predominating. The Perch is said to eat the spawn of other fishes. Forbes (1880, a, pp. 28–31) examined 49 individuals of all ages, finding the food to vary for the different ages, as noted below:

INFANCY.	Less than 25 mill. long. 2 specimens examined.			
	Entomostraca. About equal quantity of *Cyclops* and *Daphnia*.			
	Insecta. A few minute *Chironomus* larvæ.			
YOUTH.	27-50 mill. long. 9 specimens examined.			
	Crustacea.	Cladocera, *Daphnia.* *Simocephalus.* *Bosmina.* *Chydorus.* *Pleuroxus.*		
		Copepoda. *Cyclops.* *Diaptomus.*		
		Amphipoda. *Allorchestes.*		66 per cent.
	Insecta.	*Chironomus* larvæ. *Corixa.* Ephemeridæ.		34 per cent.
YOUTH.	63 mill. long. 4 specimens examined, from Peoria, Ill., in November.			
	Insecta.	Hemiptera, *Corixa*		12 per cent.
		Neuroptera, *Palingenia* larvæ		83 per cent.
		Odonata, Agrionidæ nymphs		5 per cent.
YOUTH.	88-100 mill. long. 4 specimens examined.			
	Insecta.	Chiefly nymphs of May-flies		45 per cent.
	Crustacea.	Chiefly Amphipoda and Cladocera.		55 per cent.
ADULT.	18 specimens examined from Illinois streams.			
	Crustacea.	*Cambarus.* . . . . . *Palæmonetes.* . . .	10 per cent.	48 per cent.
		Allorchestes.	15 per cent.	
		Asellus. . . . . *Mancasellus.*	23 per cent.	
	Insecta.	Ephemeridæ. . . . . Odonata. Phryganeidæ.		24 per cent

	Mollusca.	*Unio* .... *Sphærium* (Cyclas) .... *Succinea* .... *Physa heterostropha* .... *Valvata tricarinata*	19 per cent.
	Pisces.	*Pœcilichthys* (eaten by one fish).....	9 per cent.
ADULT.	12 specimens examined from Lake Michigan.		
	Crustacea.	*Cambarus virilis*	14 per cent.
	Pisces.	Cyprinidæ	86 per cent.

Hankinson (1908, p. 215) examined 32 stomachs. The contents of 15 are listed in his tables (pp. 245–251). Three of these were in the "youth" stage (34–38 mill. long) and had eaten only copepods and other entomostracans. Of the balance, ranging from 4 to 6 inches (100–150 mill.) in length, 8 had eaten midge larvæ or pupæ, 1, *Hexagenia* larvæ, 1, May-fly larvæ, 2, *Daphnia* (one contained only *Daphnia*), 1, copepods, and 1, crawfish and the remains of a small fish. Of the entire 32 stomachs, Hankinson says 13 had eaten midges in several stages of development, and 11 had eaten crawfish. These two groups, therefore, form the most important food of the Perch in Walnut Lake. The distinction in food between the young and adult fishes is not here as marked as noted by Forbes for Illinois perch. J. E. Reighard (1915, p. 236–7) examined and tabled the food of 24 fish from Douglas Lake, Mich., 19 of which contained identifiable material. "Of these, 11 contained insects only, one contained insects together with a crayfish, three contained crayfish only, and four contained fish only. The relative importance of the three kinds of food is perhaps indicated by the frequency of the occurrence of each, which is the ratio: Insects 3, fish 1, crayfish 1." Marshall and Gilbert, (1905, p. 520–521) found the Perch of Lakes Mendota, Monona, and Wingra, Wisconsin, to feed on a variety of material. Fifty-six specimens were examined of which 39 contained insect larvæ, 14 gammarids, 6 snails (mostly *Physa ancillaria*), 9, crawfish, 2, plant remains, 16, plankton, 2, minnows, and 3, fish spawn. In this locality insect larvæ appear to be the most important food element, in this respect resembling the Walnut Lake fish. Smallwood (1914,

p. 22) found quantities of *Amnicola limosa* in the stomach of Perch from ponds in the Adirondack mountains.

The lot from Oneida Lake, containing 16 specimens, is far from satisfactory because the majority are in the youthful stage. The data obtained from these specimens is presented below. No. 1, collected in trap net on Grass Island bar, in 18 feet of water, September 9, 1915; No. 2, obtained in market at Syracuse; Nos. 3–16, Lower South Bay, October 12, 1914, seined in shallow water.

YOUTH. 45–75 mill. long.

No. 10 (309).	66 mill. long. Stomach empty.	
	Platyhelminthes. 2 tapeworms in intestine.	45 per cent.
	Macerated matter	55 per cent.
No. 11 (309).	71 mill. long.	
	Crustacea. 100 *Bosmina longirostris*	50 per cent.
	Macerated matter	50 per cent.
No. 12 (309).	68 mill. long. Stomach empty.	
	Macerated matter in intestine.	
No. 13 (309).	75 mill. long.	
	Insects. Dragon-fly nymphs, fragments	60 per cent.
	Macerated matter in intestine	40 per cent.
No. 14 (309).	75 mill. long.	
	Crustacea. *Daphnia hyalina*; *Alona*; *Epischura lacustris*, 1 male, 1 female	45 per cent.
	Insecta. Chironomid larvae (a few)	5 per cent.
	Macerated matter	50 per cent.
No. 15 (309).	70 mill. long.	
	Crustacea. *Daphnia hyalina*, many	20 per cent.
	Platyhelminthes. 12 Planarians	50 per cent.
	Macerated matter	30 per cent.
No. 16 (309).	45 mill. long. Stomach empty.	

YOUTH. 75–100 mill. long.

No. 3 (309).	98 mill. long.	
	Insecta. 5 damsel-fly nymphs	85 per cent.
	Crustacea. Entomostraca, *Hyalella*	5 per cent.
	Macerated matter	10 per cent.
No. 4 (309).	100 mill. long.	
	Insecta. Damsel-fly nymphs, fragments.	100 per cent.

No. 5 (309). 98 mill. long.

Insecta. 13 chironomid larvæ......... 100 per cent.

PRE-ADULT, 100–125 mill. long.

No. 6 (309). 113 mill. long.

Crustacea. *Cambarus,* claw 7 mill. long. 20 per cent.
Finely macerated matter.............. 80 per cent.

No. 7 (309). 115 mill. long.

Crustacea. *Cambarus,* fragments...... 25 per cent.
Macerated matter .... 75 per cent.

No. 8 (309). 125 mill. long.

Insecta. Dragon-fly nymph, fragment.. 75 per cent.
Macerated matter .... 25 per cent.

ADULT. 125–200 mill. long.

No. 9 (309). 200 mill. long. Stomach empty. Intestine filled with jelly-like matter.

No. 2. Length unknown, but fish adult (only stomach contents available).

Mollusca. 1 *Musculium securis* ...... 10 per cent.
Crustacea. 1 *Cambarus*. .... 40 per cent.
Pisces. 1 small fish .... 50 per cent.

No. 1 (145). 200 mill. long.

Stomach and intestine empty.

As noted by Forbes (1880, a, p. 29) in his study of Illinois fishes, the food of the Perch of Oneida Lake changes in character as the fish increases in age. Insects and Entomostraca form the food of fish under 100 mill. in length. This may be expressed by the following ratios:

Insecta.	43.13 per cent.
Crustacea, Entomostraca	15.62 per cent.
Platyhelminthes.	11.88 per cent.
Macerated matter	39.37 per cent.

A class of sizes, 100–125 mill., is here designated as pre adult, in which crawfish first appear, and before fish or mollusks are user as food. These afford ratios of:

Crustacea, crawfish	15.00 per cent.
Insecta.	25.00 per cent.
Macerated matter	60.00 per cent.

Of adults there is no data upon which to express an opinion. One stomach contained crawfish, fish, and mollusk material and it is probable that the food is similar to that described by Forbes for Illinois. Fish for stomach examinations should be freshly caught. Those caught in fyke nets, gill nets, or trammel nets are usually unsatisfactory because digestion has usually progressed so far as to render the material unrecognizable. If taken with such nets they should be examined frequently. The average of molluscan food for all localities here considered is about 8 per cent.

Percina caprodes zebra (Agassiz). *Manitou Darter; Log Perch.*

Forbes (1880, a, p. 23, 27) records the food of the Log Perch of Illinois as follows (11 specimens examined):

Mollusca.	*Ancylus rivularis*		1 per cent.
Insecta.	*Chironomus* and other fly larvæ	43	
	Hemiptera (*Corixa*)	5	
	Neuroptera	17	
		——	65 per cent.
Crustacea.	Amphipoda (*Allorchesters*)	3	
	Cladocera (*Daphnia*, etc.)	24	
	Ostracoda (*Cyprididæ*)	1	
	Copepoda (*Cyclops*)	5	
		——	33 per cent.
Plants.	Algæ		1 per cent.

Six individuals, caught in Lower South Bay, October 12, 1914 (with seine in shallow water near pier) were examined and the stomach contents noted. The contents averaged as follows:

Mollusca.	*Planorbis, Amnicola*	1.00 per cent.
Insecta.	Chironomid larvæ and Odonata nymphs	6.00 per cent.
Crustacea.	Amphipoda, Copepoda, Cladocera	36.40 per cent.
	Decapoda	30.00 per cent.
Plants.	Filamentous algæ, etc	18.00 per cent.
Macerated matter		8.60 per cent.

DATA FOR FOOD HABITS OF MANITOU DARTER.

No. 1 (309). 48 mill. long.

Insecta.	1 *Ephemera* nymph	5 per cent.
	1 *Enallagma* nymph	
	2 *Cænis* nymph	

	Crustacea.	Amphipoda (*Gammarus*). 15 Cladocera (*Alona*). 10 Copepoda, *Cyclops strenuus* 1 *Cyclops viridis?* *Canthocamptus staphylinus.* *Canthocamptus northumbricus.*	60 per cent.
	Macerated matter		35 per cent.
No. 2 (309).	83 mill. long.		
	Crustacea.	*Cambarus*, fragments (part of claw)	25 per cent.
		1 *Gammarus fasciatus* 1 *Hyallela knickerbockeri*	25 per cent.
	Mollusca.	1 *Planorbis hirsutus* 3 *Amnicola lustrica*	5 per cent.
	Insecta.	Fragments (probably Odonata)	5 per cent.
	Plants.	Filamentous algæ	40 per cent.
No. 3 (309).	80 mill. long.		
	Stomach and intestine empty.		
No. 4 (309).	82 mill. long.		
	Crustacea.	*Hyalella knickerbockeri*, fragments	50 per cent.
		1 *Cambarus* (6 mill. long)	25 per cent.
	Insecta	1 *Ephemerella* nymph 1 Chironomid larvæ 1 Beetle larva	25 per cent.
No 5 (309).	75 mill. long.		
	Crustacea.	7 *Cambarus* (6 mill. long), with fragments	100 per cent.
No. 6 (309).	75 mill. long.		
	Crustacea.	1 *Hyalella knickerbockeri*	46 per cent.
		1 *Cyclops strenuus*	1 per cent
	Plants.	Filamentous algæ and plant tissue	50 per cent.
	Miscellaneous material		3 per cent.

Boleosoma nigrum olmstedi (Storer). *Tessellated Darter.*

Forbes (1880, a, p. 27) has tabulated the food of 12 individuals belonging to this genus, 9 *nigrum*, 2 *olmstedi* and 1 *camurum*. The diet of these species may be tabulated as follows:

Insecta.	Diptera, mostly *Chironomus* larvæ	73 per cent.
	Ephemerida, Ephemeridæ nymphs	8 per cent.
	Trichoptera, Phryganeidæ larvæ	15 per cent.
Crustacea.	Copepoda, *Cyclops*	4 per cent.

Hankinson (1908, p. 215) examined a few specimens from Walnut Lake, Mich., caught in April and found them to be feeding exclusively on midge larvæ or on filamentous algæ. A specimen caught on May 21 had been feeding on midge larvæ and entomostracans, but several specimens caught on the 22nd of May contained only midge larvæ. J. E. Reighard (1915, p. 239) records the Douglas Lake, Mich., darter as feeding in midsummer chiefly on midge larvæ and Entomostraca.

Three Tessellated Darters from Oneida Lake were examined and their food found to consist of the following ratios:

YOUNG. (36 mill. long).

Crustacea.	Entomostraca.	50 per cent.
Plants.	Algæ.	50 per cent.

ADULT. (60–85 mill. long).

Crustacea.	Amphipoda, etc.	50 per cent.
Insecta.	Diptera.	49 per cent.
Mollusca.	Gastropoda.	1 per cent.

The data from which the above table was made is given below: (Collected in outlet at Brewerton, near Davison's Landing, October 5 and 18, 1915, seined in shallow water.)

No. 1. 85 mill. long.

Crustacea.	1 *Gammarus fasciatus*	15 per cent.
	2 *Hyalella knickerbockeri*	10 per cent.
	15 *Asellus aquaticus*	75 per cent.

No. 2. 36 mill. long.

Crustacea.	*Cyclops strenuus*	50 per cent.
Plants.	Algæ.	50 per cent.

No. 3. 60 mill. long.

Mollusca.	1 *Amnicola lustrica*	2 per cent.
Insecta.	Chironomid larvæ	98 per cent.

The number of specimens examined is far too limited to permit of conclusions. The use of a large percentage of crustaceans together with the presence of Mollusca is the most notable feature. Regarding the use of the latter group of animals as food, it is interesting to read the observations of Jordan (1899, p. 29) who describes the food habits of

Boleosoma in an aquarium as follows: "Crouching catlike before a snail-shell, he will snap off the horns which the unlucky owner pushes timidly out. But he is often less dainty, and seizing the animal by the head, he dashes the shell against the glass or a stone until he pulls the body out or breaks the shell." The Oneida Lake specimens are, apparently, the first to definitely show a mollusk eating tendency of this darter. Much additional data is needed before our knowledge of the food of this species is adequate for generalization.

* *Roccus chrysops* (Rafinesque). *White Bass.*

Forbes (1880, a, p. 37) examined 11 specimens, 8 of which gave the food ratios shown below:

Insecta (May-flies)	69 per cent.
Crustacea (Copepods)	8 per cent.
Pisces (sunfish, etc.)	20 per cent.
Miscellaneous	3 per cent.

Bean (1903, p. 523) records minnows, crawfish and other fresh-water crustaceans, and also minute mollusks.

Aplodinotus grunniens (Rafinesque). *White Perch; Sheepshead; Fresh Water Drum.*

The Sheepshead feeds largely on mollusks, its pavement-like teeth being especially adapted for crushing the shells of clams and large snails. This class of animals furnish the entire food of the adult. Five genera of mollusks have been noted (Forbes, 1888, b, pp. 512–513).

Campeloma decisum, taken in October.
Planorbis, taken in June.
Sphærium, taken in June and October.
Unio, taken in June.
Anodonta, taken in June.

The food varies greatly with the age of the individual. Forbes (1880, a, pp. 64–65) examined 29 specimens of all ages and from his data the following tables are constructed:

INFANCY.	6 specimens examined.		
	29 mill. long.		
	Insecta.	*Chironomus* larvæ	75 per cent.
		Palingenia larvæ	25 per cent.
	50 mill. long.		
	Insecta.	*Chironomus* larvæ	15 per cent.
		Palingenia larvæ	80 per cent.
		Ephemerids.	5 per cent.
	Crustacea.	*Cyclops.*	
YOUTH.	50–100 mill. long, 4 specimens examined.		
	Insecta.	*Chironomus* larvæ	5 per cent.
		Ephemerid nymphs	47.5 per cent.
		Coleoptera, Gyrinidæ larvæ	47.5 per cent.
		Hydrophilidæ larvæ	
PRE ADULT.	Medium sized, 16 individuals examined.		
	Insecta.	*Palingenia*, etc.	76 per cent.
		Odonata nymphs	8 per cent.
	Mollusca.	*Planorbis.*	16 per cent.
		Unios, young	
		Anodonta.	
	Crustacea.	*Asellus.*	
	Pisces.	Sucker.	
ADULT.	3 specimens examined.		
	Mollusca.	*Campeloma decisum*	46 per cent.
		Sphærium, Anodonta, fragments of Gastropoda.	54 per cent.

Bean (1903, p. 592) says " this species is usually found on the bottom where it feeds chiefly on crustaceans and mollusks and sometimes small fishes. It is especially fond or crawfish and small shells such as *Cyclas* [*Sphærium, Musculium* or *Pisidium*] and *Paludina* [*Campeloma*]. Mr. Turpe mentions water plants as forming part of its food and states that it will take a hook baited with worms or small minnows."

The food qualities of this fish are somewhat in doubt. Forbes and Richardson (1909, p. 324) say, " It becomes tough and strong with age, but is at its best when weighing from three-quarters of a pound to three pounds. The market catch of sheepshead from the Illinois River in 1899 was 459,580 pounds." Bean (1903, p. 592) says of its food qualities: " Some writers claim that its flesh is tough and course with a disagreeable odor, specially in the Great Lakes. Individuals from the Ohio River and from more southern streams are fairly good food fish, while in Texas Mr. Turpe considers it one of the most excellent of the fresh-water fishes, comparing favorably with black bass."

There is reason to believe that this species would thrive in Oneida Lake. The molluscan genera *Campeloma* and *Anodonta,* principally used as food by the adult, are abundant in the lake and are not eaten, as far as known, by any other fish. The young, however, would enter into competition with other young fishes for the chironomid and ephemerid larvæ so largely eaten. The habitat conditions indicate favorable environments for these insect larvæ and the introduction of this fish would probably not disturb to any extent the balance of the organisms.

Lota maculosa (LeSueur). *Burbot; Ling; Lawyer.*

Forbes (1888, a, p. 434) gives the food of the Ling as follows, the opinion being based on the data furnished by 10 adult examples:

Pisces, mostly *Perca*	83 per cent.
Crustacea, *Cambarus*	17 per cent.

One specimen collected in spring had eaten only of crawfishes, *Cambarus propinquus.* A specimen from Oneida Lake, purchased in the Syracuse market, had eaten entirely of crawfishes (*Cambarus*). The data for this specimen (420 mill. long) is as follows:

Stomach.

Crustacea.	Cambarus, 4, 30 mill., 4, 20 mill. long	100 per cent.
	7 *Cambarus propinquus.*	
	1 *Cambarus bartoni robustus.*	

Intestine.

Parasitic worms.

2 tapeworms, 85 mill. long	23 per cent.
105 Worms, 3 mill. long	2 per cent.
11 worms, 3 mill. long Macerated matter, including fragments of crawfish.	75 per cent.

B. EXAMINATION OF FISH FROM GREEN AND CRANBERRY LAKES.

Fishes from two localities other than Oneida Lake have been available for study, Green Lake, east of Jamesville, on the Clark Reservation, and Cranberry Lake, Barber Point, Wanakena, in the Adirondacks.

1. Green Lake, East of Jamesville, N. Y.

Green Lake is interesting because of its geological history. It lies in a plunge basin formed at the time of the retreat of the great continental glacier, when an ice drainage stream plunged over the rocky walls, forming a river comparable to that of the present Niagara. The geological features of this region are well described and figured by Fairchild (1899, p. 60; 1909, p. 31). The lake is situated southeast of Syracuse near Jamesville, covers an area at low water (summer) of 3.3 acres and has a maximum depth of 62 feet. W. J. Endersbee and R. D. Adolph of the State College of Forestry have studied the hydrography and the fish fauna. The following mollusks were noted during a short visit early in July, 1915:

Planorbis campanulatus.
Planorbis antrosus.
Galba obrussa exigua.
Physa heterostropha.
Physa gyrina.
Valvata tricarinata confusa.

In a small pool at the subterranean outlet, which is a small stream, two species were noted, *Physa gyrina,* abundant, and *Physa heterostropha,* one specimen. On the hills surrounding the lake seven land snails were collected.

Polygyra albolaris.
Polygyra thyroides.
Polygyra tridentata.
Polygyra sayana.
Pyramidula alternata.
Omphalina fuliginosa.
Omphalina inornata.

These species represent but a small fraction of the total number that undoubtedly inhabit this region. The hills about Syracuse seem especially favorable for the development of a large and varied land-snail fauna.

Two species of fish were examined, Chain Pickerel and Pumpkinseed, seven of the former and five of the latter. The data from these is indicated below:

Esox reticulatus (LeSueur). *Chain Pickerel; Grass Pike.*

Nos. 1 to 4, 150 feet from shore, May 15, 1915; Nos. 5 to 7, southeast side of lake in 20 feet of water, May 4, 1915. The seven fish may be divided into two groups, 1 young 117 to 119 mill. long (about five inches) and 2 pre-adult 265 to 270 mill. long (nearly 11 inches). We find the ratios of these two groups to be as follows:

GROUP 1. Young, 117–119 mill. long. All insects.

Chironomid, larvæ and pupæ	55.50 per cent.
Damsel-fly nymphs	19.00 per cent.
May-fly nymphs	9.75 per cent.
Macerated matter	15.75 per cent.

GROUP 2. Pre-adult, 265–270 mill. long.

Chironomid larvæ	20 per cent.
Damsel-fly nymphs	36.66 per cent.
Cambarus	33.34 per cent.
Fish	10.00 per cent.

The change from insect to fish and crawfish is noteworthy. Comparing the pre-adult with fishes of the same size from Oneida Lake, we note that while the latter fed on crawfish to the extent of 75 per cent., those from Green Lake had used this class but 33.34 per cent. The large percentage of insect larvæ (56.66 per cent.) used by the pre-adult of Green Lake is especially noteworthy. The data from the Green Lake fish is as follows:

GROUP 1.

No. 4 (54). 119 mill long.

Insecta.	8 chironomid larvæ	30 per cent.
	4 damsel-fly nymphs (*Enallagma*)	25 per cent.
	3 May-fly nymphs (*Callibætis*)	20 per cent.
	Macerated matter	25 per cent.

No. 5 (52). 119 mill. long.

Stomach.

Insecta.	4 damsel-fly nymphs (*Enallagma*)	40 per cent.
	15 chironomid larvæ	60 per cent.
	4 chironomid pupæ	
	2 *Corethra* larvæ	

Intestine packed with Odonata and chironomid fragments.

No. 6 (52). 117 mill. long.

Insecta.	1 adult midge	50 per cent.
	41 chironomid larvæ	
	6 chironomid pupæ	
	1 damsel-fly nymph (*Enallagma*)	12 per cent.
	7 May-fly nymphs (*Callibætis*).	
	3 *Cænis* nymphs	
	Macerated material	38 per cent.

No. 7 (52). 117 mill. long.

Stomach.

Insecta.	59 chironomid larvæ.............	82 per cent.
	10 chironomid pupæ	
	2 damsel-fly nymphs (*Enallagma*)	9 per cent.
	2 May-fly nymphs (*Callibætis*)..	9 per cent.

Intestine with fragments of chironomid larvæ.

GROUP 2.

No. 1 (54). 270 mill. long.

Stomach with fragments of *Cambarus*.
Intestine. Crustacea, *Cambarus*, fragments with macerated matter....... 100 per cent.
One round worm (nematode) was present in the intestine.

No. 2 (54). 265 mill. long.

Insecta.	4 damsel-fly larvæ (*Enallagma*)..	60 per cent.
	2 chironomid larvæ	40 per cent.

No. 3 (54). 270 mill. long. Stomach.

Insecta.	257 chironomid pupæ (large)....	69 per cent.
	8 chironomid pupæ (small)....	1 per cent.
Pisces.	Part of backbone of small fish....	30 per cent.

Eupomotis gibbosus (Linn). *Pumpkinseed; Sunfish.*

Nos. 1 to 4, found along shore of lake, May 8, 1915; No. 5, 150 feet from shore in 20 feet of water, May 4, 1915.

No. 1 (53). 70 mill. long. Stomach.

Insecta.	14 chironomid larvæ	35 per cent.
	2 chironomid pupæ	
	4 *Chironomus* pupæ	65 per cent.

No. 2 (53). 61 mill. long.

Stomach and intestine empty.

No. 3 (53). 68 mill. long. Stomach.

Insecta.	44 chironomid larvæ	100 per cent.
	10 chironomid pupæ	

No. 4 (53). 67 mill. long.

Stomach empty. Intestine filled with fragments of chironomid larvæ and May-fly nymphs.

No. 5 (52). 150 mill. long. Stomach.

Insecta.	150 chironomid larvæ	} 100 per cent.	
	9 chironomid pupæ		

Intestine with fragments of chironomid larvæ.

2. Cranberry Lake, Barber Point, Wanakena, N. Y.

Three species of fish were examined from this lake, Pumpkinseed, Horned Dace, and Miller's Thumb. They were collected by Dr. C. C. Adams at the Sophomore Summer Camp of the State College of Forestry situated on Sucker Brook.

Eupomotis gibbosus (Linn). *Pumpkinseed; Sunfish.*

From Sucker Brook near its mouth, August 26, 1915.

No. 1 (62). 100 mill. long.

Crustacea.	*Asellus*, fragments	50 per cent.
Plants.	Algæ and plant cells	50 per cent.

No. 2 (62). 90 mill. long.

Crustacea.	2 *Cyclops*	1 per cent.
Insecta.	10 chironomid larvæ	15 per cent.
	Adult midges, legs and wings	50 per cent.
Plants.	Algæ, etc.	34 per cent.

No. 3 (62). 95 mill. long.

Insecta.	25 chironomid larvæ	40 per cent.
	Midge wings and legs (?)	40 per cent.
Plants.	Algæ, etc.	20 per cent.

No. 4 (62). 95 mill. long.

Insecta.	50 chironomid larvæ	60 per cent.
	Midge legs, eyes and wings (?)	30 per cent.
Plants.	Algæ, etc.	10 per cent.

Comparing these stomachs with those of fishes from Oneida Lake and Cranberry Lake, we find the ratios to be:

	Oneida Lake	Green Lake	Cranberry Lake
	Fish 80–110 mill. long	Fish 61–150 mill. long	Fish 90–100 mill. long
Mollusca	67.50	...	.....
Crustacea	16.50	...	12.75
Insecta	.75	100	58.75
Bryozoa	.25	...	.....
Plants	15.00	...	28.50

The large percentage of mollusks in the Oneida Lake sunfish is noteworthy, as is also the large quantity of insects in those from Green Lake. The lack of mollusks in the two smaller lakes is possibly due to the absence of this class of animals on their feeding grounds.

Cottus ictalops (Rafinesque). *Common Sculpin; Miller's Thumb.*

From Sucker Brook near its mouth, August 20, 1915.

No. 1 (23). 100 mill. long.
Food all digested.

No. 2 (23). 90 mill. long.
Nematoda. 1 round worm, 90 mill. long in stomach.

The above information is very unsatisfactory. Gill (1908, p. 108) says of the food of this group of fishes: "The species are noted for voracity, and they are indiscriminate feeders. They are most active in search of food during the hours of darkness, as has been remarked by Fatio. Insects, worms, gammaroids and other small crustaceans, or the fry or even the small fishes of no inconsiderable size have been noted by Smitt and others as subjects of capture. They are even cannibalistic and do 'not object to eating smaller brothers and sisters'."

Bean and Weed (1909, p. 458) examined 14 specimens of the Alaskan Fresh-water Sculpin (*Cottus dispar*) and found them to have eaten 39 salmon and 46 salmon eggs. One of these had eaten 7 salmon, 2 to 3 inches long. The presence of nematode worms was noted in 13 sculpins, in the intestine, body cavity or other parts of the body. As many as 53 worms were found in one sculpin (a female) and as few as one, also in a female.

Semotilus atromaculatus (Mitchill). *Horned Dace; Creek Chub.*

From Sucker Brook near its mouth, August 23, 1915.

No. 1 (38). 135 mill. long.

Insecta. Fragments, mostly legs..........	10 per cent.
Macerated material	90 per cent.

No. 2 (38). 138 mill. long.

Crustacea. *Cambarus* fragments, principally legs.	40 per cent.
Mud and slime	40 per cent.
Macerated material	20 per cent.

Forbes (1909, p. 123) examined 22 specimens. 25 per cent. of the food consisted of algæ and miscellaneous vegetable debris: "Four of these specimens had eaten little else than filamentous algæ, and three had captured small fishes. Grasshoppers, caterpillars, ants, chrysomelid and scarabaeid beetles and various other terrestrial insects, together with *Corisa*, dipterous larvæ, and other aquatic forms, were the insects represented, and three of our 22 specimens had eaten only crawfishes." The food of this species is not recorded by Hankinson.

C. REFERENCES IN LITERATURE TO FOOD OF NEW YORK FISHES.

Several investigators working on aquatic problems in New York State, mention the presence of mollusks in the stomach contents of fish. These are noted below:

Lepomis megalotis (Rafinesque). *Long-Eared Sunfish.*

Needham (1901, p. 402) examined one specimen of this sunfish collected at Saranac Inn, Adirondacks, the molluscan content being upwards of 65 per cent. The data appears below. The higher percentage of mollusks is noteworthy, Forbes (1880, a, p. 53) finding but 16 per cent. in Illinois fishes.

34 *Physa heterostropha* and *Lymnæa* (*Galba*) *desidiosa*, the largest being 1.5 mill. long.
12 Larvæ of gnats (chironomids).
1 Larvæ of *Chauliodes*, in fragments.

Eupomotis gibbosus (Linnaeus). *Pumpkinseed.*

Needham (1908, a, p. 176) examined 25 sunfish, taken in a weed patch near the hatchery wharf at Old Forge pond, Adirondacks, July 10, 1915. Dividing these into three lots, Needham found the food to vary with age in the manner that has already been described. It is evident that these sunfishes had not quite reached the mollusk-eating stage.

GROUP 1.	*Infancy.* 18–25 mill. long. 8 specimens examined.	
	Insecta.	Midge larvæ. Abundant in 1.
	Crustacea.	Copepoda, abundant in 7.
		Cladocera, 3 specimens in 3 fish, fragments in 2 fish.
		Ostracoda, 1 specimen.
	Acarina.	Water mites, 2 specimens in 2 fish.
GROUP 2.	*Youth.* 50 mill. long. 9 specimens examined.	
	Insecta.	Midge larvæ and pupæ, 24 in 8 fish.
		Caddis-fly larvæ, 1 in 1 fish.
		May-fly nymphs, 6 in 5 fish.
	Crustacea.	Copepoda, abundant in all fish.
		Cladocera, 3 and fragments in 5 fish.
		Ostracoda, 1 in 1 fish.
	Acarina.	Water mites, 5 in 4 fish.
	Mollusca.	Snails (*Lymnæa*), 4 in 4 fish.
GROUP 3.	*Young.* 75 mill. long. 8 specimens examined.	
	Insecta.	Water strider, 1 in 1 fish.
		Beetles, 3 in 2 fish.
		Caddis-fly larvæ, 4 in 2 fish.
		Midge larvæ, 12 in 6 fish.
		May-fly nymphs, 16 in 2 fish.
		Dragon-fly nymph, 1 in 1 fish.
	Crustacea.	Copepoda, fragments in 1 fish.
		Cladocera, abundant in 1 fish.
	Mollusca.	Snails, 20 in 1 fish.
	Plants.	Algæ, fragments in 2 fish.

Ameiurus nebulosus (LeSueur). *Common Bullhead.*

Needham (1908, a, p. 173) also examined 25 specimens of the Common Bullhead, caught July 10, 1905. All were adults, the smallest being about 8 inches in length. None were mollusk eaters. The results of these examinations is shown below:

Pisces.	Sunfish, 17 eaten by 14 bullheads.
	Horned Dace, 7 eaten by 4 bullheads.
	Unidentifiable fish, 3 eaten by 3 bullheads.
Insecta.	Æschnidæ nymphs, 6 eaten by 6 bullheads.
	Libellulidæ nymphs, 2 eaten by 2 bullheads.
	May-fly nymphs, 1 eaten by 1 bullhead.
Crustacea.	Crawfish, fragments eaten by 3 bullheads.
Plants.	Algæ, eaten by 4 bullheads.
Silt.	In stomach of 4 bullheads.

Percentages are not available, but it is evident that fishes, which had been eaten by all but one of the bullheads, formed the chief article of diet of this lot. Small sunfishes 2 to 3 inches in length form the greater bulk of the food. Needham calls attention to the fact that these bullheads were not bottom feeders, the food from such a habitat consisting only of a few legs of crawfish, the libellulid nymphs, only two of which were eaten, and the algæ and silt which was probably purely accidental. It will be noted that Forbes examined 36 specimens from several localities, finding the fish food to amount to 20 per cent. Needham says (1908, a, p. 175), speaking of the food habits shown by his examinations: "This certainly does not indicate the scavenger habits that have been very often ascribed to bullheads." It is probable that the food habits very in the different localities. Those from Illinois and Michigan are largely bottom feeders, as shown by the stomach contents. The majority of the Oneida Lake specimens were young. One specimen about five inches long had fed from the bottom.

Chrosomus erythrogaster (Rafinesque). *Red-Bellied Dace.*

Though not a mollusk eater it seems important to call attention to the food of this species, which has been carefully worked out by Needham (1908, a, p. 183). Forbes (1909, p. 113) gives the food as consisting mainly of mud containing algæ, with an occasional trace of Entomostraca. This was based on the examination of three specimens. Needham (1908, a, p. 183) examined 92 specimens, caught in April, May and June. The results are thus summarized, and clearly indicate the value of studies made in one place at different seasons. In the quotation, the writer has arranged dates of capture (see Needham, 1908, p. 187).

April 25. The table shows at a glance that practically all the food of lot 1 consisted of silt and algæ. The explanation for this is that other food, such as midges and worms, was scarce so early in the year. Spring rains had not yet brought down the earthworms.

May 1. About half of the food of lot 2 was silt and algæ, while the other half was pupæ and adult midges

May 12. Only three out of 16 fishes of lot 3 contained midges, while all but four contained earthworms and half of them contained a large amount of silt.

May 21. Lot 4 shows a large number of adult midges of the genus *Chironomus* and many earthworms. And one of them contained a single large mass of *Chironomus* eggs, the only instance in which these were found.

June 1. Lot 5 shows one adult *Chironomus* and earthworms

June 6. And silt predominates in lot 6.

"Out of 92 stomachs examined, 38 (41 per cent.) contained midges in one stage or another, 27 (20 per cent.) contained earthworms, 6 contained beetles, all adult beetles of non-aquatic habits, 3 contained entomostracans, 2 contained ants, and only 1 contained a May-fly nymph. This clearly shows that *Chironomus* was by far the most important food."

Perca flavescens (Mitchill). *Yellow Perch.*

Smallwood (1914, p. 23) found *Amnicola limosa* abundant in the perch of East Pine Pond, Adirondacks.

Salmo fario (Linn). *Brown Trout.* Introduced.

Bean (1912, p. 334) states that this trout feeds "on insects and their larvæ, worms, mollusks and small fishes and, like its relative the Rainbow Trout, it is very fond of the eggs of fishes."

Salmo trutta levenensis (Walker). *Loch Leven Trout.* Introduced.

Said by Bean (1912, p. 338) to feed upon "fresh-water mollusks (snails, etc.) crustaceans, worms and small fish."

Salvelinus fontinalis (Mitchill). *Brook Trout.*

Needham examined the stomachs of 25 Brook Trout (1901, p. 396; 1903, p. 205) from Bone Pond, Saranac Inn, finding the stomach contents to be as follows:

Insecta.	*Chironomus* larvæ	2462
	Chironomus pupæ	444
	Corethra larvæ	64
	Corethra pupæ	92
	Trichopter larvæ	10
	Trichopter pupæ	4
	Trichopter cases	77
	Æschna constricta	2
	Callibætis nymph	7
	Miscellaneous material	9
Crustacea.	Daphnidæ	250
Acarina.	*Atax crassipes*	8
Mollusca.	Fresh water mussel	1

The value of the chironomids forming 82 per cent. of the food of this trout, is at once manifest. The mollusk, as well as some of the miscellaneous material, was doubtless picked up accidentally with the *Chironomus* larvæ.

Bean (1912, p. 203) speaking of fish food, says "the best of all the foods for trout are insects, their larvæ, small shells, crawfish, etc., which are found in good trout streams. Certain waters contain small crustaceans, including the so-called fresh-water shrimp, and many smaller forms which are excellent for trout. Important trout foods are snails, dragon-flies, May-flies and caddice flies. * * * The snails, of which the *Planorbis* is now most abundant in some lakes, are excellent food for trout. Mr. L. M. Deming, of Edmeston, N. Y., sent to the Commission, on May 25, 1911, a snail which forms an important part of the food of brook trout in a pond belonging to him. He writes that he caught trout from 9½ to 11 inches long on May 25. Their stomachs all contained bugs, insect larvæ and from 5 to 16 snails. * * * One of the trout examined by him on May 25 had eaten 16 snails, 1 June bug, 2 insect larvæ — each about 1 inch long, with a hard shell (probably a caddice fly larva), 1 hard shell and a lot of small flies and bugs." The molluscan food ratio of this fish must have been as high as 10 per cent. The snail was identified as belonging to the genus *Planorbis*. In the N. Y. Conservation Report for 1912 (p. 269) the statement is also made, in speaking of the Brook Trout, that "a large part of its food consists of insects and their larvæ, worms, mollusks, and crustaceans." In the table the molluscan food is placed at one per cent., as not enough data is at hand to provide a more definite ratio.

Juday (1907, pp. 164–171) examined 394 trout stomachs representing six species, from Twin Lakes, Colorado. The percentage of molluscan food was .22. In two species the molluscan content was 1 per cent., or more, viz.: Landlocked Salmon (*Salmo sebago*) of which one specimen contained 1 per cent., and the Rainbow Trout (*Salmo irideus shasta*) in which one specimen contained 40 per cent. of molluscan food. The variation in the character of the food, both in the age of the fish and in the different localities, is well indicated.

D. THE PLANKTON.

Reference has been made on previous pages to the plankton and its use especially by young fishes. The plankton is the floating population of the water and consists of algæ, diatoms (plants), protozoans, rotifers, Entomostraca, *Chironomus* and a few other insect larvæ, and other small animals. Among the plankton are such mollusks as *Ancylus, Amnicola,* and the small Planorbes (*Planorbis parvus*) which become loosened from plants and float in the water (Kofoid, 1908, p. 287). They may often be found gliding on the under side of the surface film of the water.

Among the bivalves or pelecypods, the young or glochidia have been observed in the plankton and are perhaps sometimes eaten, though more often they find lodgement in the gills or on the fins where they carry on a stage of their development. The glochidia of three species were observed in the plankton of the Illinois River by Kofoid (pp. 287–288) as noted below:

Anodonta carpulenta. Observed in October–April and November–March.

Lampsilis anodontoides. Observed in September–December and June–July.

Arcidens confragosus? Observed in December. Identification doubtful.

It is unusual, it would seem, for any amount of glochidia to form a part of the plankton, because when discharged from the adult gill-marsupia they quickly fall to the bottom, to await the passing of some bottom inhabiting fish. Their occurrence in the plankton is probably quite accidental. The plankton of Oneida Lake has not been examined. During September, 1915, the alga *Rivularia* was so abundant as to cloud the water and form a dense surface layer making observations quite out of the question even with a water telescope, the plankton extending to the bottom in shallow water. The wind shifted it from shore to shore and studies had to be conducted on the shore from which the wind was blowing.

E. SUMMARY.

In the foregoing pages 54 species of fish have been reviewed as to their food habits; 46 are more or less mollusk-eaters. In Table No. 11 all of our fresh-water mollusk-eating fishes are listed together with all of the mollusks eaten. At the foot of the table the percentages together with the number of molluscan species eaten by one species of fish are given. The variation in percentages is noteworthy, being from one per cent (Brook Trout) to 100 per cent. (Sheepshead). In 11 species (noted in column by a ?) the percentages of molluscan food eaten is not given, and these might affect the total average a trifle. These are estimated at one per cent. *The average for the 35 ratios is 23.97 per cent.* Among these may be noted Sheepshead, 100 per cent., Lake Sturgeon and Spotted Sucker, upwards of 90 per cent., Common Red-Horse, 62 per cent., Pumpkinseed, 51 per cent., Short-headed Red-Horse, 50 per cent., Common Sucker, 30 per cent., Whitefish, 26 per cent., Common Bullhead, 20 per cent., and Golden Shiner, 19 per cent. In five species the molluscan ratio falls to one per cent. It is to be noted that the majority of the species listed in Table No. 11 are bottom feeders, which accounts in a measure, for the large ratio of mollusks in their food. As has been stated elsewhere in this report, many of the species of fish have especially modified mouths provided with crushing apparatus of greater or less complexity which indicates a molluscan diet.

The number of molluscan species eaten by a species of fish is noteworthy; thus, the Pumpkinseed is known to eat 18 species, Whitefish 17, Yellow Perch 8, Common Red-Horse 10, Common Bullhead 11, and Channel-cat 8 species. *Upwards of 40 species of mollusks are now known to be used as food by fishes,* and this number will doubtless be largely increased with further investigation. In the light of our present knowledge the relative importance in descending order, of the different molluscan genera as food for mollusk-eating fish stands as follows: *Pisidium, Sphærium, Amnicola, Valvata, Physa, Planorbis, Galba, Bythinia,* and *Musculium.* There is need for greater accuracy in the determination of the molluscan contents in the food of fishes, many authors being content with simply reporting Mollusca, Gastropoda, snails, bivalves, or simply the genus, as *Planorbis, Valvata, Amnicola, Virpara,* etc. As the fishes discriminate as to species among these genera, it is of importance to know precisely what species or even race is represented.

Food and Game Fishes Feeding Upon Mollusks.

In Table No. 12 are listed (after Forbes and Richardson, 1909, p. CXIX) in the order of their importance, economically, the food and game fishes of New York, 25 in number, that feed upon mollusks. This list includes a majority of this class of fish and illustrates graphically the importance of the mollusks (shellfish) as a source of food supply. Among the fishes of the first class the molluscan food is 19 per cent. and of the second class it is 28 per cent. In some cases, as in the Round Whitefish and the White Bass, the percentage has not been stated, although known to be large. In the third class the total percentage is over 50 per cent. and in the fourth class is upwards of 29 per cent. The average per cent. for the 25 species is 31.50, or about one-third of the food.

Mo	Bluegill.	Long-eared Sunfish.	Heros Sunfish.	Pumpkinseed.	Yellow Perch.	Manitou Darter.	Tessellated Darter.	White Bass.	Sheepshead.	Tullibee.	Large-mouth Black Bass.	Small-mouth Black Bass.	Brown Trout.	Loch Leven Trout.
Vivipara.....	x	...	...	...	...	...	...	...	...	...	...	...	...	...
Vivipara conte	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Campeloma..	...	...	...	...	...	...	...	...	x	...	...	...	...	...
Campeloma de	...	...	...	...	...	...	...	...	x	...	...	...	...	...
Lioplax subcar	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Somatogyrus..	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Amnicola....	x	...	x	x	...	...	...	...	...	...	...	...	...	...
Amnicola lustr	...	...	...	x	...	x	x	...	...	...	...	...	...	...
Amnicola limo	...	...	...	x	x	...	...	...	...	...	...	...	...	...
Amnicola pora	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Bythinia tenta	...	...	...	x	...	...	...	...	...	...	...	...	...	...
Valvata......	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Valvata tricari	...	...	...	x	x	...	...	...	...	...	...	...	...	...
Valvata bicari	...	...	...	x	...	...	...	...	...	...	...	...	...	...
Valvata sincer	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Valvata c. f. *le*	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Pleurocera...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Planorbis....	x	...	x	x	...	...	...	...	x	...	...	...	...	...
Planorbis cam	...	...	...	x	...	...	...	...	...	...	...	...	...	...
Planorbis antr	...	...	...	x	...	...	...	...	...	...	...	...	...	...
Planorbis antr	...	...	...	x	...	...	...	...	...	...	...	...	...	...
Planorbis part	...	...	...	x	...	...	...	...	...	...	...	...	...	...
Planorbis hirs	...	...	...	...	...	x	...	...	...	...	...	...	...	...
Planorbis defle	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Planorbis exac	...	...	...	x	...	...	...	...	...	...	...	...	...	...
Planorbis trivc	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Physa.......	x	...	...	x	...	...	...	...	...	...	...	...	...	...
Physa ancillar	x	...	...	...	x	...	...	...	...	...	...	...	...	...
Physa ancillar	...	...	...	x	...	...	...	...	...	...	...	...	...	...
Physa heterost	...	...	...	...	x	...	...	...	...	...	...	...	...	...
Ancylus parali	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Ancylus rivula	...	...	...	...	...	x	...	...	...	...	...	...	...	...
Lymnæa.....	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Galba catascop	...	...	...	x	...	...	...	...	...	...	...	...	...	...
Galba desidios	...	x	...	...	...	...	...	...	...	...	...	...	...	...
Galba palustri	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Galba emargin	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Pisidium....	...	...	...	x	...	...	...	...	...	...	...	...	...	...
Pisidium hens	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Pisidium abdi	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Musculium se	...	...	...	...	x	...	...	...	...	...	...	...	...	...
Sphærium...	x	...	...	...	x	...	...	...	x	...	...	...	...	...
Sphærium stri	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Sphærium sul	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Sphærium ver	...	...	...	x	...	...	...	...	...	...	...	...	...	...
Anodonta....	...	x	...	x	...	...	...	...	x	...	...	...	...	...
Unionidæ....	...	...	x	...	x	...	...	...	x	...	x	x	...	...
Pelecypoda...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Gastropoda...	...	...	...	...	...	...	...	...	...	...	...	...	...	x
Mollusca.....	...	...	...	...	...	...	...	x	...	...	...	...	x	...
Succinea.....	...	...	...	...	x	...	...	...	...	...	...	...	...	...
Percenta	16	16	?	51	8	1	1	?	100	?	?	?	?	?
Number	6	2	3	18	8	3	1	1	6	?	1	1	1	1

TABLE NO. 11. SPECIES OF MOLLUSKS EATEN BY FISHES.

Mollusks. / Fishes	Short-nosed Sturgeon.	Lake Sturgeon.	Dogfish.	Mooneye	Gizzard Shad.	Whitefish	Round Whitefish	Eel	Big-mouth Buffalo.	Round Buffalo	Small-mouth Buffalo.	Quill-back	Spotted Sucker	Common Sucker	Hog Sucker	Common Red Horse.	Short-headed Red Horse	Placopharynx	German Carp	Golden Shiner	Minnow.	Steel-colored Minnow.	Channel-cat
Vivipara			x								x					x	x						x
Vivipara contectoides	x																						x
Campeloma		x	x													x							
Campeloma decisum																							x
Lioplax subcarinata																x							
Somatogyrus													x			x		x					x
Amnicola																							
Amnicola lustrica						x								x									
Amnicola limosa						x																	
Amnicola porata						x																	
Bythinia tentaculata																							
Valvata		x																x		x			
Valvata tricarinata						x				x				x		x							
Valvata tricarinata normalis																							
Valvata sincera						x																	
Valvata f. lewisii																							x
Planorbula																							x
Planorbis		x	x								x					x							
Planorbis campanulatus																							
Planorbis antrosus																							
Planorbis antrosus portagensis																							
Planorbis parvus						x																	
Planorbis hirsutus														x						x			
Planorbis deflectus																							
Planorbis exacuous																							
Planorbis trivolvis	x																						
Physa		x	x			x										x							
Physa ancillaria						x														x			
Physa ancillaria warreniana																							
Physa heterostropha																							
Ancylus parallelus																							
Ancylus rivularis																						x	
Limnæa		x	x			x																	
Galba catascopium	x					x																	
Galba desidiosa																							
Galba palustris						x																	
Galba emarginata canadensis						x																	
Pisidium						x																	
Pisidium henslowanum														x									
Pisidium abditum?						x																	
Musculium securis						x																	
Sphærium			x		x	x			x	x	x	x	x	x		x	x	x					
Sphærium striatinum						x																	
Sphærium sulcatum											x												
Sphærium vermontanum														x									x
Anodonta																x							x
Unionidæ										x						x							
Pelecypoda																							
Gastropoda		x			x																x		
Mollusca				x			x	x							x				x				
Succinea																							
Percentage of molluscan food.	25	90	25	?	1	26	26	?	3	12	30	25	90	30	1	62	50	29	15	14	1	5	15
Number of species used......	3	6	6	1	2	17	1	1	1	3	4	1	2	6	1	10	2	3	1	3	1	1	8

Mollusks. / Fishes	Yellow Bullhead	Common Bullhead.	Brook Trout.	Mud Minnow	Fresh-water Killy	Killifish.	Top Minnow	Viviparous Minnow.	Brook Silversides	Bluegill	Long-eared Sunfish	Heros Sunfish.	Pumpkinseed.	Yellow Perch	Manitou Darter.	Tessellated Darter	White Bass.	Sheepshead.	Tullibee.	Large-mouth Black Bass.	Small-mouth Black Bass	Brown Trout.	Loch Leven Trout
Vivipara	x	x								x													
Vivipara contectoides	x	x																x					
Campeloma																		x					
Campeloma decisum																							
Lioplax subcarinata																							
Somatogyrus		x								x		x	x										
Amnicola													x		x	x							
Amnicola lustrica													x	x									
Amnicola limosa																							
Amnicola porata													x										
Bythinia tentaculata																							
Valvata		x											x	x									
Valvata tricarinata													x										
Valvata tricarinata normalis																							
Valvata sincera						x		x															
Valvata f. lewisii																							
Planorbula			x	x	x	x		x		x		x	x					x					
Planorbis													x										
Planorbis campanulatus													x										
Planorbis antrosus													x										
Planorbis antrosus portagensis													x										
Planorbis parvus															x								
Planorbis hirsutus																							
Planorbis deflectus													x										
Planorbis exacuous																							
Planorbis trivolvis	x	x		x		x	x	x		x			x										
Physa										x				x									
Physa ancillaria													x										
Physa ancillaria warreniana		x												x									
Physa heterostropha		x																					
Ancylus parallelus															x								
Ancylus rivularis																							
Limnæa													x										
Galba catascopium											x												
Galba desidiosa																							
Galba palustris																							
Galba emarginata canadensis		x			x								x										
Pisidium																							
Pisidium henslowanum																							
Pisidium abditum?														x									
Musculium securis		x								x				x				x					
Sphærium																							
Sphærium striatinum		x																					
Sphærium sulcatum													x										
Sphærium vermontanum											x		x					x					
Anodonta		x										x		x				x		x	x		
Unionidæ			x																				
Pelecypoda																							x
Gastropoda									x								x					x	
Mollusca														x									
Succinea																							
Percentage of molluscan food.	5	20	1	5	5	20	15	?	?	15	16	?	51	8	1	1	?	100	?	?	?	?	?
Number of species used......	3	11	2	2	2	3	1	3	1	6	2	3	18	8	3	1	1	6	?	1	1	1	1

TABLE NO. 12 NEW YORK FOOD AND GAME FISHES THAT FEED ON MOLLUSKS.

First Class.		Second Class.		Third Class.		Fourth Class.	
Fish.	%	Fish.	%	Fish.	%	Fish.	%
Whitefish...	26	Round Whitefish.	26	Lake Sturgeon....	90	Dogfish.........	25
Channel-cat.	15	Red-mouth Buffalo...........	3	Common Red-horse	62	Toothed Herring	1
Blue gill....	16	Round Buffalo...	12	Short-headed Red-horse...........	50	Gizzard-shad...	1
		Small-mouth Buffalo...........	30	Yellow Bullhead...	5	Spotted Sucker..	90
		European Carp...	15	Common Bullhead.	20	Common Sucker.	30
		Long-eared Sunfish...........	16	Black Bullhead....	20		
		Pumpkinseed.....	51	Sheepshead.......	100		
		Yellow Perch.....	8				
		White Bass......	?				
		White Perch.....	90				
Average....	19	Average.........	28	Average..........	50	Average........	29

Food and Game Fish That Feed Upon Mollusk-Eating Fish.

Some of our most valued food and game fishes feed upon other fishes which of themselves may be of little or no importance as food, but which become of great importance when they are considered as food for these fishes. The mollusks eaten by these animals thus become of food value, second only to the larger fish. The more important of these relations are shown in the subjoined table, No. 13.

The six fish listed in the first column are among the most valued of the game fishes. The mollusks form about 15 per cent. of the food of the fishes eaten by these game fish. In addition to fishes, these and other food and game fish feed upon dragon-fly nymphs, frogs and other batrachians which are to a greater or less degree feeders upon snails. These animals are discussed in this relation in the chapter on the Enemies of Mollusks.

TABLE NO. 13. FISH-EATING FOOD AND GAME FISHES.

Food and Game Fish.	Fish eaten.	Per cent. of molluscan food.
Pickerel, *Esox lucius.*	Buffalo, *Ictiobus bubalus.*	30
	Carp, *Cyprinus carpio.*	15
	Gizzard-shad, *Dorosoma.*	1
	Suckers, Catostomidæ.	23
	Carp-minnows, Cyprinidæ.	2 to 15
	Mooneye, *Hiodon.*	Varying.
*Large-mouth Black Bass. *Micropterus salmoides.*	Common Perch, *Perca flavescens.*	8
	Gizzard-shad, *Dorosoma.*	1
	Catfishes, Siluridæ.	15
	Log-perch, *Percina caprodes.*	1
*Small-mouth Black Bass. *Micropterus dolomieu.*	Carp-minnows, Cyprinidæ.	2 to 15
Sand-pike, *Stizostedion canadense griseum.*	White Perch, *Aplodinotus grunniens.*	100
	Gizzard-shad, *Dorosoma.*	1
	Catfishes, Siluridæ.	15
Wall-eyed Pike, *Stizostedion vitreum.*	Carp-minnows, Cyprinidæ.	2 to 15
	Gizzard-shad, *Dorosoma.*	1
Great-lake Trout. *Cristivomer namycush.*	Whitefish, *Coregonus.*	26

* These fish are known to eat a small ratio of mussels.

ONEIDA LAKE MOLLUSK-EATING FISH.

Of the fourteen species of fishes from Oneida Lake which have been examined as to their food, eight are mollusk-eaters, the ratios running from 1 to 66 per cent. The Pumpkinseed shows the largest ratio eaten, even in the juvenile stage. The relations of the mollusks to the fishes are shown in Table No. 14. This table is quite inconclusive because only a small percentage of Oneida Lake fish (14) have been examined and more specimens of those examined should be studied as to their food habits. In the previous tables (12 and 13) it has been shown that the mollusks form 31.50 per cent. or about one-third of the food of 25 food and game fishes of New York and, indirectly, 15 per cent., or about one-sixth of the food of six important fish-eating food and game fish. Of the 158 species of fish inhabiting the fresh waters of New York State 30, or about one-fifth, are eaters of mollusks.

It is of interest to compare the detailed studies made upon New York fish with those made by Forbes (1876–1887) on the fish of Illinois waters. The latter examined 1,221 specimens of 87 species, of which 914 were adult and 307 were young. Of the 87 species, 39 were mollusk-eaters, more or less, or nearly one-half. Needham has examined 168 specimens of 5 species of New York fish, mostly from the Adirondack region. In the present paper 130 specimens of 16 species are reported upon. Careful studies have been made, therefore, on 298 specimens, of 19 species, of New York fish.

TABLE NO. 14. ONEIDA LAKE MOLLUSK-EATING FISH.

MOLLUSKS. / FISH.	Common Sucker.	Golden Shiner.	Common Bullhead.	Pumpkinseed.	Yellow Perch.	Manitou Darter.	Tessellated Darter.	Yellow Bullhead.
Amnicola lustrica	x	...	...	x	...	x	x	...
Amnicola limosa	...	...	...	x	...	...	...	...
Bythinia tentaculata	...	...	...	x	...	...	...	...
Valvata tricarinata	x	...	...	x	...	...	...	...
Valvata bicarinata normalis	...	...	...	x	...	...	...	...
Planorbis campanulatus	...	...	...	x	...	...	...	...
Planorbis antrosus	...	...	...	x	...	...	...	...
Planorbis hirsutus	x	...	...	...	...	x	...	...
Planorbis parvus	...	...	...	x	...	...	...	...
Planorbis exacuous	...	...	...	x	...	...	...	...
Physa ancillaria warreniana	...	x	x	...	...	...	...	...
Ancylus parallelus	...	...	...	...	...	...	...	x
Galba catascopium	x	...	...	x	...	...	...	...
Pisidium	...	...	...	x	...	...	...	...
Pisidium henslowanum	x	...	...	...	...	...	...	...
Musculium securis	...	...	...	...	x	...	...	...
Sphærium vermontanum	x	...	...	x	...	...	...	...
Species used by fish	6	1	1	12	1	2	1	1
Ratio of molluscan food	30	1	10	66	10	1	1	1

Not enough field work has been done or stomach examinations made to furnish the quantity of data necessary to summarize the relation of the mollusks to the fish fauna of Oneida Lake. We should expect that there was an intimate relationship between the conditions favorable for molluscan life and the food of the fish, and from a knowledge of the biology of the lake one should be able to predict, within reasonable limits, the food of a certain kind of fish in a given habitat. This correlation between the mollusk, the fish, and the environment is interesting, and a knowledge of it is important from the standpoint of fish culture. An attempt is made in Table No. 15 to show the correlation expressed by four species of Oneida Lake fishes and the Mollusca found on their feeding grounds.

TABLE NO. 15. INTERRELATION OF FISHES AND MOLLUSKS.

LOCATION.	Habitat.	Mollusks.	Fish.	Mollusks eaten by fish.	Per cent mollusks eaten.
Lower South Bay.	Sandy, shallow water.	*Somatogyrus subglobosus.* *Gillia altilis.* *Amnicola lustrica.* *Valvata bicarinata normalis.* *Physa ancillaria warreniana.* *Planorbis campanulatus.* *Planorbis antrosus.* *Galba catascopium.* *Bythinia tentaculata.* *Sphærium vermontanum.*	Pumpkinseed, seined in shallow water.	*Amnicola lustrica.* *Valvata tricarinata.* *Valvata bicarinata normalis.* *Planorbis antrosus,* *Planorbis exacuous.* *Bythinia tentaculata.* *Pisidium* species. *Spærium vermontanum.*	95
Nicholson Bay.	Pond lily habitat, with submerged vegetation.	*Physa ancillaria warreniana.* *Planorbis campanulatus.* *Planorbis hirsutus.* *Planorbis trivolvis.* ***Acella haldemani.*** *Lymnæa columella chalybea.*	Golden shiner, caught in trammel net.	*Physa ancillaria warreniana.*	5
Lower South Bay.	Sandy, shallow.	See above.	Manitou darter, seined in shallow water.	*Planorbis hirsutus.* *Amnicola lustrica.*	1
Brewerton, near Davison's Landing.	Sandy, shallow.	*Vivipara contectoides.* *Campeloma integrum.* *Amnicola lustrica.* *Galba catascopium.* *Planorbis campanulatus.* *Planorbis hirsutus.* *Physa ancillaria warreniana.*	Tessellated darter, seined in shallow water.	*Amnicola lustrica.*	1

Supplementary Note.

Since the paper was completed, Prof. M. W. Blackman has called my attention to a paper on the food of fish by A. S. Pearse (1915. On the Food of the Small Shore Fishes in the Waters near Madison, Wisconsin. Bull. Wis. Nat. Hist. Society, XIII, No. 1, pp. 7–22). Upwards of 403 specimens were examined representing 17 species, of which seven were young of larger species (black bass, rock bass, etc.) and the others included young and adult of small fishes (minnows, brook silversides, etc.). Three species were observed to feed upon Mollusca. One fish, the stickleback, is apparently here first recorded as using mollusks for food, increasing the number of mollusk-eating fishes, discussed in this present paper, to 47. The ratios of molluscan food for the three species is indicated below.

Umbra limi (Kirtland), *Mud Minnow*. Pearse (p. 19) examined 60 specimens ranging in size from 30.4 to 105 mill., and found Mollusca (*Planorbis* and *Sphærium*) to make up .9 per cent. of the total food. In ten specimens from one habitat these genera made up 2.5 per cent.

Fundulus diaphanus menona Jordan and Copeland (*Top Minnow*). Pearse (p. 16) examined 49 specimens ranging in size from 28.2 to 37 mill., and found Mollusca (*Planorbis*) to comprise .1 per cent. of the food.

Eucalia inconstans (Kirtland), *Brook Stickleback*. Pearse (p. 19) examined 50 specimens ranging in size from 28.4 to 58.7 mill., the Mollusca forming 6.4 per cent. of the food, the genera present being *Physa*, *Planorbis* and *Sphærium*. Forbes (1883, a, p. 68) gives the animal food of five specimens as about equally divided between insects and crustaceans.

CHAPTER V. MOLLUSKS AS PARASITES OF FISH.

The intimate relation between the Naiades or fresh-water clams and fishes has but recently been given adequate scientific study. Ortmann, Lefevre, Curtis, Isely, Howard, Surber and others have placed the study of this interrelation upon a sound basis. The work accomplished at the United States Biological Laboratory at Fairport, Iowa, has greatly increased our knowledge on the subject of the development of the fresh water clams and the studies carried on there have to a degree solved the problem of the rehabilitation of the depleted clam beds, so necessary as raw material for the making of pearl buttons, one of the principal industries of many cities and towns on the Mississippi River. The results obtained at Fairport illustrate forcibly the value of attacking these economic problems by scientific methods.

The young of clams, known as *glochidia,* have long been recognized as parasites on the external parts of fishes, but their true relation to the fish, and to the mollusk, was not known for many years, and it is but recently that they have been studied in an analytical manner. To understand their true significance one must follow the development or metamorphosis of a clam from the time the eggs are fertilized until the young clams are ready to begin an independent existence.

Metamorphosis of Fresh-water Mussels.

The metamorphosis or development of the fresh-water mussles or clams is quite as wonderful and as interesting as that of the butterfly or beetle and also quite as complicated. In the female clam one or both pairs of gills are modified to form marsupia or brood pouches into which the eggs are carried soon after being fertlized by the sperm which is taken in with the water through the inhalent or upper siphon. After a period of development the eggs become purse-shaped and the gills are swollen and distended by the mass of embryos present (Lefevre and Curtis, 1910, plates VI, VII, VIII). After the lapse of time, the length varying in different groups of clams, the young glochidia are discharged into the water and fall to the bottom where they lie with their two shell valves widely open. Unless the proper host, which is nearly always a fish, comes along, they die. The next stage is passed as a parasite on some part — gills, fin or tail — of a fish. On their host they become encysted by an outgrowth of the skin of the fish which entirely covers the mussel embryo. After the lapse of a certain time (varying from 9 to 74 days in different species) the embryo, having completed its transformation, breaks the cyst and falls to the bottom a perfect young mussel though still very small. There are therefore four distinct stages in the growth of a mussel: 1, fertilized egg; 2, glochidium in marsupium of clam; 3, parasitic stage encysted in fish or a Salamander; 4, post-glochidian development with fully formed shell. Subsequent growth is principally in size. (Lefevre and Curtis, 1910, b; Howard, 1914.)

A single species, *Strophitus edentulus,* is known to develop without parasitism (Lefevre, 1911, p. 863; 1912, p. 171), glochidial development taking place in a cord in the gill which forms a sort of placenta or nutritive body. Both *Strophitus edentulus* and *S. undulatus* live in Oneida Lake or its tributary creeks.

Unless the young mussel falls in a favorable locality on the bottom of the lake or stream, it will not long survive. Young mussels less than 20–25 millimeters in size are seldom observed. Those described by Isely (1911) were found attached to rocks and pebbles by a byssus or thread. They were from 2.9 to 22.5 millimeters in length. The collections from Oneida Lake contained a few young mussels from like situations, as noted below:

Anodonta cataracta, 9 mill. long. Sandy and bouldery bottom, 2 feet water (station XXI, 3, B. field No. 247).

Alasmidonta undulata, 6 mill. long. Debris on sandy bottom, 20 in. water (station XXXI, 1, C. field No. 217).

The almost universal habitat for mussels, a sandy, stony or bouldery shore, is good evidence that these places are the best adapted to the needs of the young mussels, and here they have remained and formed the mussel beds, where the environment provided the optimum conditions for successful growth, a stony or sandy bottom subject to wave action for the aeration of the water. As Isely so aptly remarks (1911, p. 79) " This kind of environment gives a constant supply of oxygen and sufficient food; is free from shifting sand and silt accumulation. Those mussels that drop from the fish in these favorable situations develop in large numbers, while the less fortunate, that drop in shifting sand and silt, die early."

Two major types of glochidia occur, one with a simple rounded shell, the other with a toothed or hooked shell. A third type, with modified hooks, called the axe-head type, is known but is confined to a few species. (See Lefevre and Curtis, 1912, plate VIII.) The importance of these types is recognized when we learn that the hooked type attach themselves to the fins and external parts of fishes while the hookless type become encysted upon the gill filaments. Of the Oneida Lake clams the following genera represent the two types.

Hooked.	Hookless.
Anodonta.	*Lampsilis.*
Strophitus.	*Elliptio.*

It has been quite conclusively demonstrated (Lefevre and Curtis, 1912, p. 153) that the fixation of the hookless type of glochidium upon the delicate gill membrane is induced chemically by the fluid excluded from the gill, which is irritated by the shells of the glochidia taken in through the mouth or gill cavity.

It has also been ascertained that there is a long and short period of gravidity or reproduction. Of these breeding stages in the long period the eggs are fertilized from the middle of July to the middle of August, and the glochidia are carried in the marsupium until the following spring or early summer. In the short period the entire breeding season is confined to about four months, extending from the end of April to the middle of August, and the glochidia are discharged as soon as they are fully developed. The clams of Oneida Lake represent both long and short periods (Winter and Summer breeders) as noted below. The * indicates that the species was observed to be gravid in September.

Long breeding period.	Short breeding period.
Alasmidonta undulata.	*Elliptio complanatus.*
**Anodonta cataracta.*	*Margaritana margaritifera.*
**Anodonta implicata.*	
Anodonta grandis footiana.	
Anodonta marginata.	
**Lampsilis luteola.*	
**Lampsilis radiata.*	
**Lampsilis borealis.*	
Lampsilis iris.	
Strophitus edentulus.	
Strophitus undulatus.	

Fishes acting as Hosts for Mussel Glochidia.

Among the fishes inhabiting the inland lakes and streams there are but a small number which are known to be especially susceptible to glochidial infection. Some of these of special interest in connection with Oneida Lake, are listed below. (Howard, 1914, p. 34.) Those marked with an * are Oneida Lake fish.

Crappie	(*Pomoxis annularis*).
*Green sunfish	(*Apomotis cyanellus*).
Bluegill	(*Lepomis pallidus*).
*Strawberry bass	(*Pomoxis sparoides*).
Red-spotted sunfish	(*Lepomis humilis*).
*White bass	(*Roccus chrysops*).
*Catfish	(*Ameiurus natalis*).
*Yellow perch	(*Perca flavescens*).
*Large-mouth black bass	(*Micropterus salmoides*).
*Rock bass	(*Ambloplites rupestris*).
Yellow catfish	(*Leptops olivaris*).
Spotted catfish	(*Ictalurus punctatus*).
Sauger: Sand-pike	(*Stizostedion canadense*).
Skipjack	(*Pomolobus chrysocharis*).
Sheepshead	(*Aplodinotus grunniens*).

Hankinson (1908, p. 235) observed glochidia of *Anodonta grandis footiana* on Johnny Darters (*Boleosoma nigrum*) in April and May in Walnut Lake, Michigan. *Anodonta cataracta* has been found on the anal and caudal fins of the Pumpkinseed (*Eupomotis gibbosus*) caught in a pond near Westville, N. J., February 25, 1905 (Conner, 1905, p. 142).

No glochidia were observed on the fish examined from Oneida Lake. The presence of a large naiad fauna indicates beyond doubt that large numbers of fishes are infected in the manner mentioned. Young Naiades (*post glochidian*) are rarely eaten by fishes. Forbes (1880, b, p. 481) noted them only in three sunfishes, a brook silversides, and a perch. The effect of glochidial infection on the general health of the fish has not been stated, as far as known to the writer.

CHAPTER VI. ENEMIES OF FRESH-WATER MOLLUSKS.

Since the Mollusca are an important element in the food of fish it is of importance to know how they can be protected and increased in number. The first step is to know their enemies. A large number of animals prey upon mollusks, using them as food. These animals come into competition with the mollusk-eating fishes, causing a heavy drain on this source of supply. This is compensated for, in a measure, by the fact that many fishes live on certain of these animals (dragon-fly nymphs, batrachians, etc.), thereby receiving the benefit of the mollusks, though secondarily. The mollusks are also preyed upon by certain parasites which may, in a measure, affect the life of these animals. Some of these parasites may occupy the mollusk as a secondary host, completing their life cycle in fishes, birds, or other animals.

While collecting the data embodied in this section, the fact has stood out clearly that carefully prepared information on this subject is sadly lacking. In the case of the molluscan food of the Reptilia and Amphibia, the records of this class of animals from stomach contents are far from being as accurate and precise as could be wished. In most cases the record is only "clams" or "snails." It would seem of enough importance to have this important class of animals more carefully identified. We are aware, of course, that such attention to detail consumes much time, but the value of the information warrants it.

1. Predatory Insect Enemies.

Needham and Hart (1901, pp. 17, 47) record the presence of mollusks in the digestive system of the nymphs of dragon-flies (Odonata). These are as follows:

Epicordulia, lives in the deeper waters, as the bottom of small lakes, where it finds principally a molluscan diet, including *Amnicola* and *Physa.*

Anax junius Drury. Thirteen specimens of this species had eaten the percentages of food shown below:

Mollusca (*Amnicola*)	15 per cent.
Algæ	11 per cent.
Crustacea (amphipods, nearly all *Allorchestes dentata*)	11 per cent.
Insects	56 per cent.

The nymphs were observed to attack crawfish three-quarters of an inch long.

The vegetation-inhabiting species have a varied diet, which includes back swimmers (*Notonecta*), water-boatmen (*Corsia*), small crustaceans, such as *Asellus* and *Allorchestes*, thin-shelled mollusks, like *Physa*, coleopterous and dipterous larvæ, and the younger and weaker members of their own order. *Anax junius* has been known to eat young carp (Riley and Howard, 1888, p. 58) and *Cordulegaster maculatus* young trout (Needham, 1901, p. 474).

Nymphs of dragon-flies are largely eaten by some of the best game and food fishes. Forbes (1888, b, p. 485) found four species to feed on this diet, as indicated below:

Grass pickerel (*Esox vermicularis*)	25 per cent.
Crappie (*Pomoxis annularis*)	10–13 per cent.
Pirate perch (*Aphredoderus sayanus*)	10–13 per cent.
Common perch (*Perca flavescens*)	10–13 per cent.

Needham (1901, p. 474) also records horse-fly larvæ (Tabanidæ) as feeding on snails. The giant water bugs (Belostomidæ) feed upon young snails when young (Dimmock, 1886, p. 71) and the Lesser Water Bug, *Zaitha flumineum* (Serverin, 1911, p. 103) occasionally uses mollusks as food; Weed (1889, p. 12) says, "Univalve snails also occasionally contribute to the diet of this insatiable creature, as one was observed feeding upon a small snail with a spiral shell."

Dawson (1911, p. 14, after Tryon, 1882) says, "The species of *Perthostoma* (*Belostoma*), an American aquatic hemipterous insect, eat large quantities of *Lymnæa*, *Physa*, and *Planorbis*, which they hold with the fore legs by folding between the thighs and tibiæ; even the larvæ of this insect, shortly after escaping from the egg, will seize and devour one of these mollusks with as much ease as if schooled in the process a long time."

Cooke (1895, p. 59) cites a case of a *Dytiscus* in an aquarium which killed and devoured seven *Lymnæa stagnalis* in the course of an afternoon. These beetles also ate *Lymnæa peregra,* but seemed to prefer *stagnalis,* for when equal quantities of both species were placed in the aquarium, they chose the later species first (Baker, 1911, p. 44). It is probable that many of the large aquatic beetles, as well as their larvæ, prey upon fresh-water snails.

2. Crawfishes as Enemies of Mollusks.

Crawfishes are described by most authors as omnivorous in their food habits, eating both plant and animal material as well as carrion. Forbes in his food table (1914, plate 1) indicates that they feed upon the Mollusca but no specific records of their use in the native state have been seen. Ortmann (1906, p. 495) states that "any vegetable or animal matter, either fresh, or decaying, serves as food for crawfishes, and although some species may prefer certain classes of food on acount of taste or necessity, they all take readily to any kind, as is seen by the fact that in captivity they eat everything that is offered to them without discrimination. If nothing is given, they eat one another." In captivity crawfishes are fed a variety of food material. Andrews (1906, p. 297) states that " In the spring they generally take food eagerly; eggs, meat, worms, potato, bread, crayfish flesh, mollusks, Chara and other aquatic water plants and algæ, in fact most kinds of soft organic matter will often be consumed." Chidester (1908, p. 712) states that " Raw and cooked meat of all kinds, worms, dead fish, pieces of clam, moulting crawfish, and dead crawfish were eaten by the crawfish in confinement." It is probable that this group of Crustacea eats largely of mollusks, clams and snails. Studies of stomach contents would be of great value in solving this problem.

3. Leeches as Enemies of Mollusks.

Mollusks form a large part of the diet of leeches and these in turn are eaten by many fish. Moore (1901, 1912) records upward of eight species as subsisting to a greater or less degree upon fresh-water mollusks. These species are listed below with the page reference to their description in the work cited.

Glossiphonia complanata (Linn). Johnston.

Feeds chiefly on small snails and annelids. Pages 493 (1901), 83 (1912).

Glossiphonia stagnalis (Linnaeus). Johnston.

Favorite food small annelids and gastropods (1901, p. 498). Eats small annelids, insect larvæ, snails, *Pisidium* and its allies, and dead bodies. Food of sunfish, perch, and other carnivorous fishes. Also eaten by snipe and sandpipers (1912, p. 79).

Glossiphonia nepheloidea (Graf).

Will eat snails and worms but prefers to suck blood (1912, p. 77).

Glossiphonia fusca Castle.

Attaches itself to shells of the larger species of *Lymnæa* (1912, p. 81).

Hæmopis marmoratis (Say).

Feeds on gastropods and lamellibranchs (1901, p. 527).

Hæmopis grandis (Verrill).

Feeds on snails (1912, p. 120).

Placobdella montifera Moore.

Enters shells of living mussels, though it is not known definitely that it feeds on their soft tissues (1912, p. 89; 1901, p. 504).

Nephelopsis obscura Verrill.

Feeds on snails (1912, p. 125).

4. Predaceous Mollusks.

Lymnæa stagnalis lillianæ Baker. *Lillian's Pond-snail.*

In the previous pages reference has been made to the use of *Planorbis campanulatus* by this snail as food. No other records have been observed, excepting that of Cooke (1895, p. 34) who remarks that *Lymnæa stagnalis* feeds on *Dytiscus* larvæ, snails and minnows. Other Lymnæas possibly eat mollusks to some extent.

5. Amphibian Enemies of Mollusks.

Aquatic amphibians, frogs, newts and salamanders, feed to a greater or less degree upon mollusks. Some of the records are very satisfactory as regards detail, but others are very general.

Rana catesbiana Shaw. *Bullfrog.*

Needham (1901, p. 401) records the food of one adult bullfrog to be 7 full grown snails, *Physa heterostropha,* 7 insects, I small bullfrog tadpole, 1 entomostracan. Expressed in percentages, the molluscan content amounts to about 40 per cent. Hay (1892, p. 479) gives the food as crawfish, insects, worms, small fish, snails, mice, and its own species.

Two specimens, collected on the shore of Oneida Lake, October 9, 1914, were dissected, but no mollusks were found in their stomachs. The data for these appears below (field No. 4):

No. 1. Stomach filled with small seeds of plants.

No. 2. Stomach contents.

Reptilia.	Portion of a snake..................	75 per cent.
Plants.	Fragments of leaves and stems......	25 per cent.

Rana pipiens Shreber. *Leopard Frog.*

Drake (1914, page 263) gives the molluscan food of this common frog as 3 per cent. The stomachs of 209 frogs were examined and Mollusca were found in 10 per cent. of the stomachs examined. Insects made up about 60 per cent of the total food. The mollusks identified were *Zonites* *arboreus* (a land snail), *Goniobasis informis, Galba humilis modicella, Physa heterostropha* (all water snails), and some unidentifiable gastropods.

Rana palustris Le Conte. *Pickerel Frog.*

Ruthven (1912, p. 53) states that the food of this species consists of insects, small crustaceans and snails.

Necturus maculosus Rafinesque. *Mud Puppy, Water Dog.*

Hay (1892, p. 419) records the food of this animal as insects, worms, crustaceans, and mollusks. Surface (1913, p. 81) also reports the mollusks as affording a food supply.

Amblystoma opacum (Gravenhorst). *Marbled Salamander.*

Eats mollusks when two months old (Hay, 1892, p. 438).

Amblystoma punctatum (Linnaeus). *Spotted Salamander.*

Surface (1913, p. 89) records slugs and snails among the food of this species.

Cryptobranchus allegheniensis (Daudin). *Hellbender.*

Feeds on mussels, earthworms, crawfish, insects, fishes, etc. (Surface, 1913, p. 85). Smith (1907, p. 12) found nine out of twelve specimens had eaten crawfishes, only three having eaten fishes.

Diemictylus viridescens Rafinesque. *Green Newt.*

Needham (1908, p. 162) says of this species, "very common in lily beds feeding exclusively on a small bivalve mollusk that was common upon the pond bottom." Ruthven (1912, p. 37) records water insects, small mollusks, worms, and tadpoles as the food of this newt. Hay (1892, p. 455) gives the food as insects, tadpoles, worms, and mollusks. Gage (1891, p. 1093) gives the food as minute Crustacea, larvæ, insects, snails and aquatic worms.

6. Reptilian Enemies of Mollusks.

These records are confined to the turtles, these reptiles appearing to be the only members of the class feeding upon fresh-water mollusks.

Platypeltis muticus (LeSueur). *Soft-shelled Turtle.*

Hay (1892, p. 552) suggests the food to probably consist of insects, fishes, water-snails, and similar small animals.

Chelydra sepentina (Linnaeus). *Snapping Turtle.*

Surface (1908, p. 129) examined 19 individuals of the Snapping Turtle, finding mollusks in the stomachs of seven. The mollusks are said to be snails (*Helix*), pond snails, and slugs. It would be of value to know just what species were represented. The above statement is repeated by Ruthven (1912, p. 135). Surface (1908, p. 184) mentions *Physa* and *Melantho* (*Campeloma*) as occurring in the food.

Kinosternon odoratum (Daudin). *Musk Turtle.*

Surface records two out of four as eating snails (1908, p. 138). They are also said to be scavengers and to eat dead mollusks among other things.

Chrysemys picta (Schneider). *Painted Turtle; Terrapin.*

Surface (1908, p. 150) records the molluscan food of this turtle as bivalves, pond snails, slugs, and land snails. *Planorbis* is mentioned as being one of the genera eaten. Twenty-three specimens of turtles had fed on mollusks. Surface also mentions *Physa* and *Melantho* (*Campeloma*) as occurring in the food of this turtle (op. cit. p. 184). The Western Painted Turtle (*Chrysemys cinerea*) is said by Ruthven (1912, p. 143) to feed on dead clams.

Fifteen specimens of *picta* from Oneida Lake were studied, the data of which appears below. The material included both old and young. Nos. 1 to 9 were from Oneida Lake, caught in August, 1915; Nos. 10 to 15 were caught in a fyke net set at the mouth of Big Bay Creek, September 4 to 7, 1915.

GROUP 1. INFANCY, body 25 mill. long.

No. 7. Stomach (108).

Hirudinea.	Leech, 4 mill. long	20 per cent.
Insecta.	3 larvæ. 3 adult flies	80 per cent.

Intestine with fragments of insects.

GROUP 2. YOUTH.

No. 1. Body 40 mill. long (108).

Intestine contained mass of partly digested material including a few legs of insect larvæ.

No. 2. Body 60 mill. long (108).

Stomach.

Crustacea.	100 *Hyalella knickerbockeri*	60 per cent.
Insecta.	2 damsel-fly nymphs (*Enallagma*) 2 *Aanx junius*, nymphs 2 chironomid larvæ 1 caddis-fly larva, fragment	20 per cent.
Nematoda.	4 round worms	10 per cent.
Plants.	Small pieces of plant leaves	10 per cent.

Intestine, middle portion.

Insecta.	Wing cases of beetles	5 per cent.
	Legs and fragments of insects	55 per cent.
Plants.	Piece of leaf of tree, 8 x 5 mill	40 per cent.

Intestine, near anal end.

Fragments of insects, including legs and pieces of thorax.

No. 5. Body 41 mill. long (108).

Stomach and intestine empty.

No. 6. Body 41 mill. long (108).

Crustacea.	200 *Hyalella knickerbockeri*	45 per cent.
Mollusca.	3 *Ancylus parallelus*	5 per cent.
Insecta.	9 beetles (*Hydrovatus pustulatus*). 10 beetle larvæ (*Cnemidotus*) 6 *Plea striola*	45 per cent.
	1 wing of midge (fly) 6 fly larvæ 1 head of small wasp 2 *Callibaetis* nymphs 1 *Corisa*	5 per cent.

No. 8. Body 65 mill. long (108).

Stomach empty.

Intestine with 4 round worms (Nematoda).

No. 3. Body 45 mill. long (108).

Stomach.

Crustacea.	100 *Hyalella knickerbockeri*	95 per cent.
Insecta.	2 chironomid larvæ	1 per cent.
	1 chironomid pupæ	
Plants.	Miscellaneous material	4 per cent.

Intestine with mass of digested matter in which were many legs and fragments of insects, probably Odonata.

No. 4. Body 63 mill. long (108).

Stomach.

Crustacea.	80 *Hyalella knickerbockeri*	50 per cent.
Mollusca.	2 *Ancylus parallelus*	5 per cent.
Insecta.	2 Odonata nymphs	5 per cent.
	5 chironomid larvæ	5 per cent.
	Insect legs and fragments	30 per cent.
Plants.	Algæ and plant fragments	5 per cent.

Intestine with fragments of insects, mostly legs.

No. 9. Body 40 mill. long (108).

Crustacea.	100 *Hyalella knickerbockeri*	75 per cent.
Mollusca.	*Ancylus parallelus*	1 per cent.
Insecta.	17 specimens.	24 per cent.
	1 wing case of beetle.	
	1 wing of dragon-fly.	
	1 mutilated Hymenoptera.	
	10 small beetles (*Hydrovatus pustulatus*).	
	1 beetle larva (*Cnemidotus*).	
	2 chironomid larvæ.	
	1 chironomid pupæ.	
	1 nymph skin of Hemiptera (*Plea striola*).	

GROUP 3. ADULTS.

No. 10. Body 132 mill. long (114).

Stomach and intestine empty.

No. 11. Body 120 mill. long (114).

Stomach empty.

Intestine, at anal end, packed with legs, wings and fragments of Odonata.

No. 12. Body 133 mill. long (114).

Stomach. 2 round worms.

Intestine, anal end.

Insecta.	Odonata wings and legs	99 per cent.
Mollusca.	1 *Physa ancillaria warreniana*, 3 mill. long	1 per cent.

No. 13. Body 150 mill. long (114).

Stomach and intestine empty.

No. 14. Body 154 mill. long (114).
Stomach empty. Intestine with digested material, including some legs of insects.

No. 15. Body 112 mill. long (114).
Stomach empty.
Intestine, anal end.

Insecta.	Legs and body segments of Odonata nymphs	98 per cent.
Mollusca.	Fragments of shells	2 per cent.

The three ages described above may be summarized as follows:

GROUP 1. Infancy, 25 mill. long. 1 specimen examined.

Hirudinea	20 per cent.
Insecta	80 per cent.

GROUP 2. Youth, 40–63 mill. long. 8 specimens examined.

Crustacea	65 per cent.
Insecta	27 per cent.
Nematoda	2 per cent.
Mollusca	2 per cent.
Plants	4 per cent.

GROUP 3. Adult, 112–154 mill. long. 6 specimens examined.

Insecta	99 per cent.
Mollusca	1 per cent.

The change from crustacean to insect food in groups 2 and 3 is noteworthy. Group 1 is not conclusive as only one specimen was examined.

Clemmys guttata (Schneider). *Speckled Tortoise.*

Surface (1908, p. 166) records snails and slugs among the food. These were found in three out of twenty-seven specimens examined.

Graptemys geographica (LeSueur). *Map Turtle.*

Hay says of this turtle (1892, p. 576), "Prof. Henry Garman states that an examination of the contents of the alimentary canal showed that the food consisted exclusively of mollusks, the young eating the thinner shelled species, the adults the larger and thicker shelled kinds. At Lake Maximkuckee three persons caught about 30 specimens of this species in a few hours. Without probably an exception they were found near the shores, where there were great numbers of the water-breathing univalves. After a number had been kept for a few days in a tub there were found in it large numbers of the opercles of such mollusks; and in the intestines of one were the remains of a crayfish, some fish scales and what appeared to be the cases of some kind of caddis-worm. Its broad masticatory surfaces are well fitted for crushing the shells of mollusks." The snails were possibly *Campeloma* or *Vivipara*.

7. Predatory Bird Enemies of Mullusks.

As would naturally be expected, birds enter into competition with fish for the acquisition of food. This competition is mainly confined to those birds that frequent the water and are classed as water birds. To such belong the Black Duck, Baldpate, Green-winged Teal, Shoveler, Lesser Scaup Duck among the ducks, and plover, snipe, etc., among the shore birds. Specific references to mollusks used as food of water birds are very rare, the usual statement being " eats snails." A few specific illustrations are given below.

The Biological Survey, United States Department of Agriculture, has conducted food studies for many years. Mr. W. L. McAtee informs me that upwards of 5,000 stomach examinations have been made of ducks, showing a considerable percentage of mollusks. This information will eventually be published.

Marilla affinis (Eyt.). *Lesser Scaup Duck.*

A specimen of this bird had eaten the claw of a blue crab and 75 snails, mostly *Gillia altilis* with a few *Goniobasis virginica* and *Planorbis albus* (Judd, 1902, p. 81).

Anser albifrons Gambell. *White-fronted Goose.*

Audubon (Forbush, 1912, p. 176) states that in Kentucky this goose feeds on beech nuts, acorns, young blades of grass and snails.

Colymbus auritus Linnaeus. *Horned Grebe.*

The food of this grebe is stated to be as follows (McAtee, 1912, p. 19):

Beetles, chiefly aquatic	23.3 per cent.
Other insects (including aquatic bugs, caddis-fly and chironomid larvæ, dragon fly nymphs, etc.)	12.0 per cent.
Fishes	27.0 per cent.
Crawfish	20.7 per cent.
Other crustacea	13.8 per cent.

Other matter is eaten, including snails and spiders, and a small quantity of vegetable food.

Bartramia longicauda (Bechst). *Upland Plover;* and *Oxyechus vociferus* (Linn). *Killdeer.*

Both of these birds include snails in their diet (McAtee and Beal, p. 16).

Agelaius phoeniceus phoeniceus (Linn). *Red-winged Blackbird.*

This species has been observed to eat *Planorbis* (Allen, 1914, p. 115). This is not surprising as the nests are built over the water in marshes where *Planorbis* and other easily obtained snails live.

Reference is made in Eaton's "Birds of New York" to the presence of mollusks in the stomach of certain water birds, but as the references are not specific they are not quoted here. The crow, grackles, and other land birds eat snails to a greater or less degree but there are no specific records of the use of fresh-water snails. The crow eats dead animal matter thrown upon the shore by wind or waves, and this may include dead mussels or other mollusks, but there is no evidence that it catches or eats living mussels as the same species is recorded to eat sea snails on the coast of Maine (Bendire, 1895, p. 408).

8. Mammals as Enemies of Mollusks.

Among the mammals three species are known to feed more or less on mollusks — all mussels. These are the Muskrat, the Mink, and the Otter.

Ondatra zibethicus (Linn.). *Muskrat.*

The muskrat has long been known as an enemy of the clam or mussel bed, the large piles of empty shells so common on the shores of our lakes, ponds, and rivers being eloquent witnesses of this animal's insatiate appetite for the luscious bivalve. The importance of this class of food is variously estimated. Some of the estimates given by a few authors are given below:

Seton (1909, I, p. 554) states that vegetable food is taken by preference, but that it also eats clams, fish, insects, and even young birds. Lantz (1910, p. 16) says "In the winter the chief food of muskrats consists of the roots of aquatic plants — pond lilies, arum, sedges and the like — but in some localities the animals feed on mussels and also on carp and other sluggish fish that bury themselves in mud."

Merriam (1886, p. 275) states that "They are extremely fond of the fresh-water mussels (*Unio* and *Anodon*) and large quantities of empty shells may often be found near their homes." To just what extent mussels are eaten as compared with other food is not stated; nor it is known, so far as known to the writer, at what season the molluscan diet is used to the greatest extent. The method of opening the shells has long been a mooted question. Adams (1908, p. 408) found the muskrat plentiful at Isle Royale. After stating the fact that little is known on this subject he quotes from Kennicott (1857, p. 106) who says "Collecting them (mussels) from the bottom, it carries them in its teeth to a log or stone, where, sitting upon it haunches, and grasping them in the fore-paws, it opens the shells with the incisors as skillfully as it could be done with an oyster-knife. I have observed that those species with thin shells are more sought for, and have often found large specimens of *Unio* [*Quadrula*] *plicatus* unopened among the piles of empty shells, the muskrat apparently considering them not worth the trouble of gnawing apart the valves at the back, in which manner the heavy shells are sometimes opened." (Lantz, 1910, p. 17) states that "One frequently comes upon heaps of mussel shells, chiefly *Lampsilis* and other Unionidæ, on the margins of ponds and streams. The thin-shelled species frequently have the valves broken, but the heavier kinds are often without injury or tooth marks. The inference is that the unbroken mussels have been left to die and open of themselves, after which the muskrat secures the meat." This last sentence may be nearer the truth than is generally supposed. Rhoads (1903, p. 105) refers to the the same method when he states that "They have a habit of gathering mussels from the mud and piling them upon logs and rocks to die. The shell thus opens and the contents are devoured by some animal, presumably the rats, though I have never seen them do it. No doubt, minks, coons, foxes, etc., participate in this feast." There is need for more direct observation on this matter.

In a muskrat pile on Frenchman Island the following species were observed and counted.

Anodonta cataracta, 3.
Anodonta implicata, 5.
Anodonta marginata, 3.
Lampsilis luteola, 1.
Lampsilis radiata, 21.
Lampsilis borealis, 11.
Elliptio complanatus, 8.

Putorius vison (Schreber). *Mink.*

The Mink is an infrequent feeder upon mussels although normally feeting upon vertebrates. Seton (1909, II, p. 884) states it will eat snakes and clams when nothing better turns up, and also preys upon crawfish and carrion. Merriam (1886, p. 64) states the food to consist of muskrats, rats, mice, birds and their eggs, fish, frogs, turtles' eggs, crawfish, and fresh-water mussels. Coues (1877, p. 177) states that "It is probably our only species which feed habitually upon reptiles, fish, mollusks, and crustaceans — more particularly upon frogs, fresh-water bivalves, crawfish, and the like." No direct evidence of the use of mollusks as food has been seen by the writer.

Lutra canadensis (Schreber). *Otter.*

The Otter, a typical fish-eater, is said to rarely eat crawfish, frogs and shellfish (Seton, 1909, II, p. 835). Rhoads

(1903, p. 158) states that "The crayfish, eel, shrimp, fresh-water mussels and probably such tender-shelled bivalves as are found in the bays frequented by them are also eaten." To what extent shellfish are eaten is not known.

9. Parasites Affecting Mollusks.

Fishes suffer to a marked degree from the attacks of parasitic worms and Protozoa. These include tapeworms, flukes, and other worms which infest the stomach, liver, intestine, eyes, and other parts of the body. A great many worms infest fresh-water mollusks. In a few cases the mollusk is an intermediate host of some worm that completes its development in other animals. Only those parasites will here be considered that have been reported as living in the species of fresh-water mollusks inhabiting the State of New York (cf. Leidy, 1858–1904). The list is sufficiently full to emphasize the importance of the subject. The parasites here mentioned have been accumulated rather incidentally and are listed as follows by authors:

Anoplophyra vermicularis Leidy. *Infusorian.*

This infusorian infests the rectum and intestine of *Campeloma decisum,* often in great numbers (Leidy, 1877, b, p. 260).

Tetracotyle tipica Diesing.

Encysted in liver and genital gland of *Galba catascopium* and *Physa heterostropha* (Leidy, 1904, p. 237).

Monostoma (*Glenocercaria*) *lucania* Leidy. *Fluke.*

Infest intestine, liver and muscular tegument of *Planorbis parvus.* As many as 50 sporocysts distended with cercariæ have been taken from a single *Planorbis* (Leidy, 1877, a, p. 200).

Distoma (*Gymnocephala*) *ascoidea* Leidy. *Fluke.*

Infest liver and intestine of *Planorbis parvus* (Leidy, 1877, a, p. 201).

Rhopalocerca tardigrada Diesing. *Fluke.*

From mantle of *Anodonta fluviatilis* (*cataracta*) and *Anodonta lacustris* (=*marginata*) (Leidy, 1877, a, p. 202; 1858, p. 110).

Heterostomum echinatum Diesing. *Fluke.*

From oviduct of *Campeloma decisum* (Leidy, 1877, a, p. 202).

Cotylaspis insignis Leidy. *Fluke.*

From branchial cavity of *Anodonta fluviatilis* (*cataracta*) and *lacustris* (*marginata*) (Leidy, 1858, p. 110).

Aspidogaster conchicolor von Baer. *Fluke.*

From pericardial cavity of *Lampsilis radiata, Lampsilis cariosa, Lampsilis nasuta, Lampsilis purpurea, Anodonta marginata* and in oviduct of *Campeloma decisum* (Leidy, 1851, b, p. 224; 1877, b, p. 260).

Fasciola hepaticum Linnæus. *Sheep Liver-Fluke.*

This fluke lives as a sporocyst in the respiratory cavity of a small pond snail (*Galba truncatula*) common in Europe. The young escape from the snail and migrate to grassy meadows where they are eaten by sheep and later infest the liver of this animal. In this country, in the western states, the little snail *Galba humilis modicella* is suspected of being the intermediary host of this fluke (Ward, 1895, pp. 246–252).

The Unionidæ or fresh-water mussels are subject to infestation by a large number of parasites including trematodes, oligochætes, infusorians, and the mites, *Atax*. Kelly (1899) found that in 44 species examined, all but 5 were infested. The parasites observed are listed below:

Aspidogaster conchicolor von Baer. This fluke was found in 37 species, including *Strophitus edentulus, Anodonta grandis, Lampsilis luteola* and *L. ligamentina* which are Oneida Lake species. The pericardial and nephridial cavities were the regions infested (p. 404).

Cotylaspis insignis Leidy. This fluke infested 24 species including *Strophitus edentulus, Anodonta grandis, Lampsilis luteola* and *L. ligamentina* which inhabit Oneida Lake. Found in the region of the gills (p. 405).

Distomidæ. A free distomid was observed in 14 species of mussels, including *Strophitus edentulus, Anodonta grandis,* and *Lampsilis luteola* which occur in Oneida Lake. It was observed in the mantle and is frequently the cause of rusty stains on the nacre of the shell (p. 405). This parasite has been observed in *Anodonta grandis* and *Strophitus edentulus* from Chautauqua Lake, N. Y. (p. 406).

Distomidæ. Three speices of distomids were observed in the encysted stage in 5 species of mussels (in the pericardium [3 sp.] the mantle [1 sp.] and the ovary [1 sp.]) only one of which *Lampsilis ligamentina* occurs in Oneida Lake (p. 406).

Bucephalus polymorphus von Baer. Cercaria of this worm were observed in 15 species of mussels, of which *Strophitus edentulus, Lampsilis luteola* and *L. ligamentina* occur in Oneida Lake. The parasites infest the viscera, often in such numbers as to obliterate the sexual glands (p. 407).

Certain members of the Acarina or water mites also infest many species of mussels as ectoparasites. Kelly (p. 407) records the following species. None of these mussels occur in Oneida Lake:

Atax abnormipes Wolcott, infests 4 species of mussels.

Atax arcuata Wolcott, infests 2 species of mussels.

Atax fossulatus Koenike, infests 3 species of mussels.

Atax indistinctus Wolcott, infests 3 species of mussels.

Atax serratus Wolcott, infests 1 species of mussel.

Atax stricta Wolcott, infests 11 species of mussels.

Atax ypsilophorus Bonz, infests 4 species of mussels.

Atax, species not indicated, was observed in 35 species of mussels, including *Strophitus edentulus, Anodonta grandis, Lampsilis luteola,* and *L. ligamentina* which occur in Oneida Lake (p. 409).

Conchophthirus hirtus Ehrbg, and *C. anodontæ* Ehrbg, ciliate infusorians were observed in 30 species of mussels, including the four species mentioned in the last paragraph which occur in Oneida Lake (p. 407, 409).

Chætogaster limnæi von Baer, an oligochæte, was observed in the kidneys and on various parts of the surface of 5 species of mussels, none of which occur in Oneida Lake (p. 407, 409).

Wilson and Clark (1912, p. 11, 12, et seq.) examined many mussels from the Kankakee River basin, Indiana and Illinois, a number of which were infested with parasites, including *Atax, Cotylaspis insignis, Aspidogaster conchicolor,* and several distomids. Of the species of mussels infested, *Anodonta grandis* and *Lampsilis luteola* occur in Oneida Lake.

In an earlier publication these authors (1912, pp. 61–72) discuss the parasites of the mussels inhabiting the Maumee River. The parasites listed which infest species of mussels that occur in Oneida Lake are indicated below:

Cotylaspis insignis Leidy, in *Anodonta grandis, Lampsilis luteola* and *L. ligamentina* (p. 61).

Aspidogaster conchicolor von Baer, in *Anodonta grandis* and *Lampsilis ligamentina* (p. 61).

Marginal-cyst Distomid, in *Lampsilis ligamentina* (p. 62).

Distomid of Osborn, in *Anodonta grandis* (p. 64).

Distomid of Kelly, in *Lampsilis ligamentina* (p. 68).

Bucephalus polymorphus von Baer, in *Lampsilis luteola.* It is of importance to note that the mature form of *Bucephalus* is *Gasterostomum fimbriatum* von Siebold, which is a parasite of the pike (*Esox*) and perch (*Perca*), and an intermediate host in some species of minnow (p. 70).

Atax ypsilophorus Bonz, in *Anodonta grandis* (p. 70).

Atax, species not mentioned, in *Anodonta grandis, Lampsilis luteola,* and *L. ligamentina* (p. 71).

Conchophthirus. This protozoan was universally present (p. 71).

Haldeman (1840) in a supplement of three pages describes three cercariæ:

Cercarina hyalocauda Hald., host, *Physa heterostropha* Say.

Cercarina bilineata Hald., host, *Galba catascopium* Say.

Diplodiscus temporatus Stafford, host, *Goniobasis virginica* Say.

Clinostomum marginatum Rudolphi. *Fluke.*

This fluke is known to affect the Common Perch (*Perca flavescens*). It is thought by Smallwood (1914, p. 22) that the larval stage may be passed in a mollusk, possibly *Amnicola limosa.*

Gordius aquaticus Linnæus. *Hair Worm.*

Early larval stages of this round worm have been observed in the foot of snails, as well as in the mesenteries of a European frog (*Rana temporaria*), in aquatic insect larvæ (*Tanypus, Corethra, Chironomus*), in the parenchyma of leeches, and in the mucus membrane of the intestine of fishes (cf. Cort, 1915, b, p. 199).

In a recent paper by Cort (1915, a) many larval trematodes (flukes) are described from fresh water mollusks. These are listed below with the name of the host.

Cercaria urbanensis Cort.	Host *Physa gyrina.* In liver.
" *inhabilis* Cort.	" *Planorbis trivolvis.* In liver.
" *diastropha* Cort.	" *Planorbis trivolvis.* In liver.
" *megalura* Cort.	" *Pleurocera elevatum.* In liver.
" *trivolvis* Cort.	" *Planorbis trivolvis.* In liver and body cavity.
" *rubra* Cort.	" *Campeloma decisum.** In liver and body cavity.
" *reflexæ* Cort.	" *Lymnæa reflexa.* In liver and body cavity.
" *trigonura* Cort.	" *Campeloma decisum.** In tissues of body above and at bases of gills.
" *douthitti* Cort.	" *Lymnæa reflexa.* In liver.
" *isocotylea* Cort.	" *Planorbis trivolvis.* In liver.
" *polyadena* Cort.	" *Lymnæa reflexa.* In liver.
" *hemilophura* Cort.	" *Physa gyrina.* In body.
" *leptacantha* Cort.	" *Campeloma decisum.** In tissue above gills.
" *brevicaeca* Cort.	" *Physa anatina.* In liver.

This is a most excellent paper and should be read by every conchologist. Fourteen species of cercariæ are noted infesting six species of snails. Other species of snails are doubtless affected in the same manner and it is probable that few species are exampt. The part of the snail affected was usu-

*We wish to call attention to the practice of many biologists of using molluscan material which has not been critically examined by competent conchologists. The study o' the Mollusca has now become so complicated, and the old species broken up into so many new species and forms, and so many old species have been critically examined and assigned to new groups, that it is unsafe to use material that has not been passed upon by some experienced conchologist. The species recorded as *Campeloma subsolidum*, from Hartford, Conn. (Cort, 1915, pages 37, 40, 44, 46, 59) is *Campeloma decisum*. *Subsolidum* is a Mississippi Valley species not found in the Atlantic drainage. The writer is quite familiar with the region about Hartford having made collections in the vicinity and the only species of *Campeloma* there is *decisum*.

ally the liver and the percentage of infestation ranged from 1.50 to 18.

In Europe several species of trematode worms find their intermediate host in mollusks, and the two species cited below are added to show that these worms are parasitic in several kinds of animals during their life history (Baker, 1911, b, p. 41, cited from Cooke, 1895, pp. 61, 62). Many of the American species probably have similar life histories.

Distoma endolabrum Duj. *Fluke.*

This worm first enters as host *Lymnæa stagnalis* or *Lymnæa ovata;* then *Lymnæa stagnalis* or one of the fresh-water shrimps; and attains sexual maturity in the common frog.

Distoma ascidia von Baer. *Fluke.*

This worm passes first through *Lymnæa stagnalis* or *Planorbis corneus;* secondly, through certain flies and gnats, or other insects (*Chironomus, Perla, Ephemera*); and finally matures in certain species of bats.

10. Algæ Living in and upon the Shells of Mollusks.

The shells of mollusks are affected more or less seriously by boring plants (algæ) which perforate the shell, destroying the protective horny epidermis and permitting the carbon dioxide in the water to dissolve the carbonate of lime of which the shell is composed. Several species of algæ have been observed on and in the naiad shells of Connecticut. The same effects were observed in the *Unio* shells of Oneida Lake, and probably the same species of algæ occur. Those described by Collins (1897, pp. 95–97) from Twin Lakes, Salisbury, Litchfield County, Connecticut, are as follows:

Plectonema terebrans Born and Flah.

" Abundant all through the shells, and when the latter were decalcified, formed a dense mat, which made it rather difficult to distinguish the other algæ, that grew in company with it" (p. 95). Also common in marine shells on the shores of Long Island.

Hyella fontana Hüber and Jadin.

"Scattered through the shells, sometimes in rather dense, chroococoidal masses, sometimes in loosely branching filaments. Like the *Plectonema*, it penetrates the interior of the shells" (P. 95).

Gomontia holdenii Collins.

"In old shells of Unio. The plant occurs only in small quantity, and is almost always covered with a dense mass of *Plectonema*, so that it is very difficult to examine" (p. 96).

Syctonema myochrous Ag. *Dichothrix hosfordii* (Wolle) Bonet. *Microcoleus lacustris* (Rab.) Farlow.

Algæ growing on the outside of the shells (p. 96).

Tolypothrix setchellii Collins.

An alga growing on the outside of the shells (pp. 96–97). It is not stated on what species of *Unio* these algæ were found but it probably included *Elliptio complanatus*, this being the common clam of Connecticut. In Oneida Lake many of the bivalves and snails are similarly affected, including *Campeloma*, *Lymnæa*, *Elliptio*, and *Margaritana*. Material has been submitted to Mr. Collins who will report later on the algæ found on and in the Oneida Lake shells.

11. Table of Animals Feeding Upon Mollusks

In the Table No. 16 it will be noted that the mollusks are used as food by seven groups of animals: Insects, 6 or more species; crawfishes, 1 or more species; leeches, 8 species; snails, 2 species; frogs, 3 species; and salamanders, 5 species; turtles, 7 species; birds, 6 species, and mammals, 3 species, a total of upwards of 41 species. It is highly probable that this number will be very greatly increased when more careful and detailed studies are made of the food habits of other species, especially among aquatic invertebrates. Nineteen species of mollusks have been definitely identified from the stomach contents of these species. A study of the table will indicate how meagre our information on this subject is at present, and what a fertile field lies before the investigator.

12. Summary.

It has been shown in this chapter that many groups of fresh-water animals, including insects, crawfishes, leeches, snails, frogs, salamanders, turtles, birds, and mammals feed upon mollusks and enter into competition with the mollusk-eating fish for the available food supply. Boring algæ also attack the mussels and larger snails, causing them to excrete an additional amount of shelly matter to repair these damages. To what extent this agency causes the death of mollusks is not known. Associates are also present in mollusks, either as commensals or as true parasites. In many cases the mollusk serves as an intermediary host for a worm which completes its cycle of development in a fish, bird or other animal.

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TABLE NO. 16. ANIMALS PREYING UPON MOLLUSKS.

Mollusks.	Insecta						Crustacea	Hirudinea.								Mollusca		Amphibia.								Reptilia							Aves						Mammalia		
Predatory Species.	Dytiscus	Epicordulia	Anax junius	Tabanidae	Belostoma	Belostoma fluminium	Cambarus	Glossiphonia complanata.	Glossiphonia stagnalis	Glossiphonia heteroclita	Glossiphonia fusca.	Hæmopis marmoratis.	Hæmopis grandis.	Placobdella montifera.	Nephelopsis obscura.	Lymnæa stagnalis.	Lymnæa lillianæ.	Rana catesbiana.	Rana pipiens	Rana palustris.	Necturus maculosus.	Amblystoma opacum.	Amblystoma punctatum	Chryptobranchus allegheniensis	Diemictylus viridescens.	Platypeltis muticus.	Chelydra serpentina.	Kinosternon odoratum.	Chrysemys picta	Chrysemys cinerea	Clemmys guttata	Graptemys geographica.	Marila affinis	Colymbus auritus	Anser albifrons	Bartramia longicauda	Oxyechus vociferus.	Agelaius phoeniceus.	Ondatra zibethicus.	Putorius vison.	Lutra canadensis
[illegible]		x	x																																						
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Goniobasis virginica																																	x								
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Campeloma																											x		x			?									
Vivipara																																?									
Physa		x			x																						x		x												
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Planorbis campanulatus																	x																								
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Pond snails																													x												
Snails				x	x	x		x		x	x		x		x	x		x		x			x			x	x	x	x		x	x		x	x	x	x				
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Anodonta marginata																																							x		
Anodonta cataracta																																							x		
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Anodonta [illegible] footiana																																							x		
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Bivalves																													x												
Mollusks							x														x	x		x																	
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	2	2	1	1	4	1	1	1	[illegible]	1	1	2	1	?	1	1	1	2	4	1	1	1	2	2	1	1	5	1	8	1	2	3	3	1	1	1	1	1	8	1	2

CHAPTER VII. CLASSIFICATION OF THE ONEIDA LAKE MOLLUSCA.

In this chapter the species and varieties of fresh-water mollusks found in Oneida Lake in 1915 are discussed from the standpoint of their toxonomy — their orderly sequence and division into orders, families, and genera. The mollusks of New York have formed subjects for the pens of many of the early naturalists of the country, including Thomas Say, Isaac Lea, S. S. Haldeman, and John Jay. Later, such men as W. G. Binney, G. W. Tryon, Jr., and Dr. James Lewis carried on the study of mollusks of New York State and other parts of the United States. Of papers relating directly to the Mollusca of New York State there are a large number, among which may be mentioned those of DeKay (1843), Lewis (1856, 1874), Walton (1892), Baker (1898), and Letson (1905). The only complete monograph is that of DeKay, published in 1843. The paper on Monroe County Mollusca by John Walton is well illustrated, although there are no descriptions of the shells. Simpson's Monograph of the Naiades describes all of the mussels of the world, including those inhabiting New York State. The papers of Binney describe and figure many of the fresh-water snails of the State. Two works by the present writer describe and figure many species of shells living in New York State (Baker, 1898–1902, 1911). The paper by Robertson (1915, pl. X–XII) illustrates in a most beautiful manner (excepting that some figures are too greatly enlarged and the scale is not indicated on the plate) many of the common species living in Oneida Lake. A list of the more important of these papers on New York Mollusca will be found in the bibliography, under the name of the above authors. Little has been done to increase our knowledge concerning the distribution and critical affinities of the molluscan fauna of the State since the time of Dr. J. Lewis of Mohawk, who was one of the most discriminating of the students of his time. The only local list (a very good one) of the region under consideration is by Rev. W. M. Beauchamp, of Syracuse, N. Y., who catalogued the Land and Fresh-water Shells of Onondaga County in 1886.

Sixty-two species and varieties, 25 genera and 11 families are represented in the collection of fresh-water mollusks from Oneida Lake. No new species were observed, but six species are reported from the State for the first time — *Lampsilis borealis, Pisidium henslowanum, Valvata bicarinata normalis, Physa ancillaria warreniana, Planorbis binneyi,* and *Lymnæa stagnalis lillianæ.* The peculiar Lymnæid, *Acella haldemani* is reported for the first time from this part of the State, as are also *Sphærium vermontanum, Musculium rosaceum, Pisidium compressum lævigatum, P. æquilaterale, Vivipara contectoides,* and *Ancylus fuscus.* Four species of *Pisidum* still remain to be determined.

Compared with the total number of fresh-water mollusks found in the State, and in several State localities, the fauna of Oneida Lake presents a good showing. This comparison is shown in Table No. 17. Varieties are here treated as species and other lists have been reduced to the modern nomenclature.

TABLE NO. 17.

	Oneida Lake, Baker.	State, Letson.	Onondaga, Beauchamp.	Monroe, Walton.
Elliptio	1	1	1	1
Margaritana	1	1	1	....
Anodonta	5	10	6	5
Alasmidonta	1	5	2	3
Strophitus	2	3	3	2
Nephronajas	1	1	....	....
Lampsilis	4	10	9	5
Sphærium	2	8	6	1
Musculium	2	5	4	1
Pisidium	10	21	6	1
Viripara	1	1	....	....
Campeloma	2	3	3	3
Gillia	1	1	1	1
Somatogyrus	1	2	1	....
Bythinia	1	1	1	1
Amnicola	3	8	9	5
Goniobasis	1	5	5	5
Valvata	2	3	2	3
Physa	3	6	4	2
Ancylus	3	6	3	3
Planorbis	8	10	9	5
Lymnæa	1	2	1	1
Pseudosuccinea	2	2	1	1
Acella	1	1	1	....
Galba	3	31	9	6
Not found in Oneida Lake	....	50	15	16
	62	197	103	71

The preceding list shows that there are in the west end of Oneida Lake nearly one third of the fresh-water species of the State, six-sevenths of the total species in Monroe County, and about two-thirds as many as in Onondaga County. Several species in Monroe and in Onondaga counties are found in the Erie Canal which would not live in Oneida Lake. It is believed that the list from Oneida Lake can be increased to 75 or 80 species with further collecting, because there are many species which should live in the lake and its

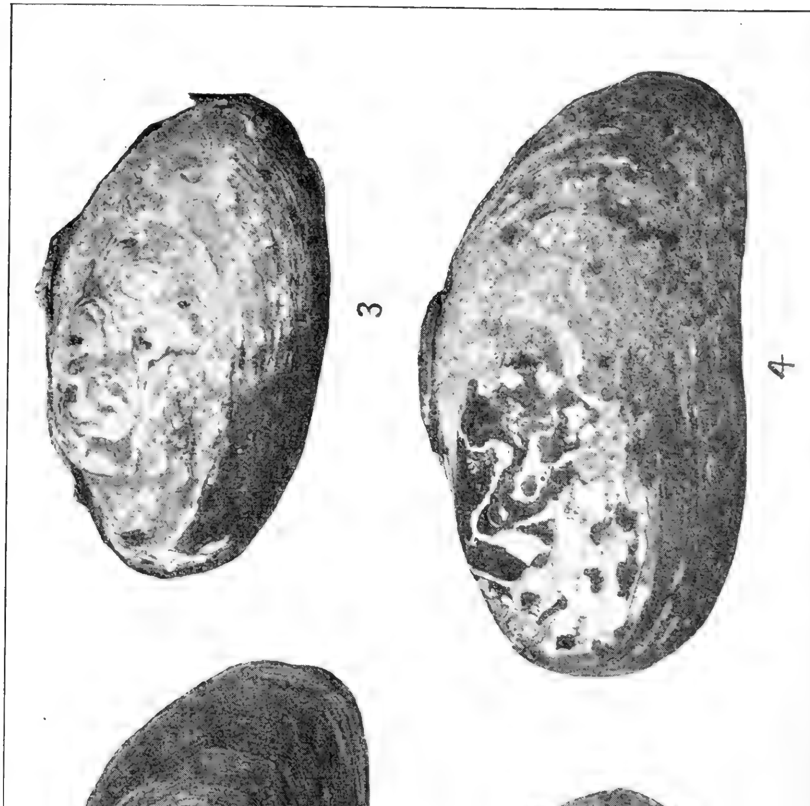

Fig. 40.

tributary waters which were not collected in 1915. It is as here listed, however, a fair-sized fauna, surpassed but little, by any other similar body of water in America. As no other large lake in the State has been studied in a similar manner it is not possible to make direct comparisons.

1. Annotated List of Species.

In the following annotated list, reference should be made to the large Table No. 18 showing the distribution of each species throughout the 41 stations of the lake. Comparison is made with several localities in other parts of the country, as to ecological relations. As these are quoted throughout the list, the page only is given after each reference. These are from Wisconsin, Michigan, and Ontario and are found in the bibliography under the names of F. C. Baker, Tomahawk Lake, 1911; Walker and Gleason, Isle Royale, 1908; H. B. Baker, Saginaw Bay, 1911; and Robertson, Georgian Bay, 1915. These several localities are compared on the large table at the end of this chapter. The plants known to be used as food or for support are given for each species. These four lists are chosen because the nomenclature of each is modern and the comparison is uniform. The nomenclature used is the latest by competent malacologists.

Under each species will be found the names of the plants in Oneida Lake which were observed to furnish either food or support. The different fish species using each molluscan species for food are also given. It is believed that this information will be found useful to fish culturists. For the benefit of those who may wish to identify the different species of mollusks living in the lake, nearly all (57) species and varieties are figured on the plates. The local distribution in Oneida Lake is shown in the table at the end of this chapter.

Fig. 40. 1, *Elliptio complanatus;* 2, *Nephronajas ligamentina;* 3, *Alasmidonta undulata;* 4, *Margaritana margaritifera.*

PHYLUM MOLLUSCA.

Class Pelecypoda.

ORDER PRIONODESMACEA.

Family Margaritanidæ.

Genus Margaritana Schumacher.

1. *Margaritana margaritifera* (Linnæus).* Fig. 40, No. 4.

This widely distributed mussel is not common in Oneida Lake, being found only at five stations, always in an exposed habitat, usually at the end of a rocky point. The specimens collected are not large, none exceeding 65 mill. in length. The distribution of this mussel is the most extensive of any mollusk, including Europe, Northern Asia, Japan, Western America to below the 40th degree of latitude, East of the Rocky Mountains in the upper Missouri River, and in Saskatchewan, and in eastern North America, in Eastern Canada, New England, New York and Pennsylvania. Dr. Walker (1910) has recently described the unique distribution in America of this almost cosmopolitan mollusk.

Family Unionidæ.

Genus Elliptio Rafinesque.

2. *Elliptio complanatus* ("Solander," Dillwyn). Fig. 40, No. 1.

This is the most abundant mussel in the lake, being found at 32 out of 41 stations. It lives on a sandy bottom in both exposed and sheltered locations. It has not been found in bays where there is a thick mass of submerged vegetation. This species is found in Georgian Bay, but does not occur in the other localities mentioned in comparison. It is eaten by the muskrat.

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*The classification of the Naiadacea is that of Ortmann (1912) which is a modification of Simpson's Synopsis (1900, 1914).

Genus Anodonta Lamarck.

3. *Anodonta marginata* Say. Fig. 41, No. 4.

Found at four stations, but common only at one. It occurs both on exposed points and in sheltered bays. It is listed by Beauchamp under the names *fragilis* and *lacustris,* which are synonyms of *marginata.* Found in Tomahawk Lake, Traverse Bay, Isle Royale, and Saginaw Bay. In Tomahawk Lake it is found on an exposed sandy shore, in situations similar to those in Oneida Lake. In Saginaw Bay it lives in both a sandy and a mucky bottom in more or less protected situations. It is eaten by the muskrat.

4. *Anodonta cataracta* Say. Fig. 41, No. 1.

Occurs at ten stations, almost always on an exposed shore or point, on a sandy bottom, or in sand between boulders on the points. It is the most abundant of the Anodontas. Listed as *Anodonta fluviatilis* and *A. williamsii* by Beauchamp. *Cataracta* is a fall breeder (long period), gravid females being observed in September and October, as recorded by Ortmann (1913, p. 293). This species is confined to the lower St. Lawrence drainage. It is eaten by the muskrat.

5. *Anodonta implicata* Say. Fig. 41, No. 2.

A common species, occurring at eight stations, always on an exposed point or shore, in a sandy bottom, usually between boulders. Recorded from Tomahawk Lake on an exposed shore. Not recorded by Beauchamp. Gravid females were observed in Oneida Lake in September and October, the soft parts not differing materially from those of *cataracta.* In Oneida Lake it is one of the most abundant of the paper-shell mussels. It is believed to be the shell figured by DeKay (1843, pl. 17, fig. 233) as *Anodon excurvata.* Eaten by the muskrat.

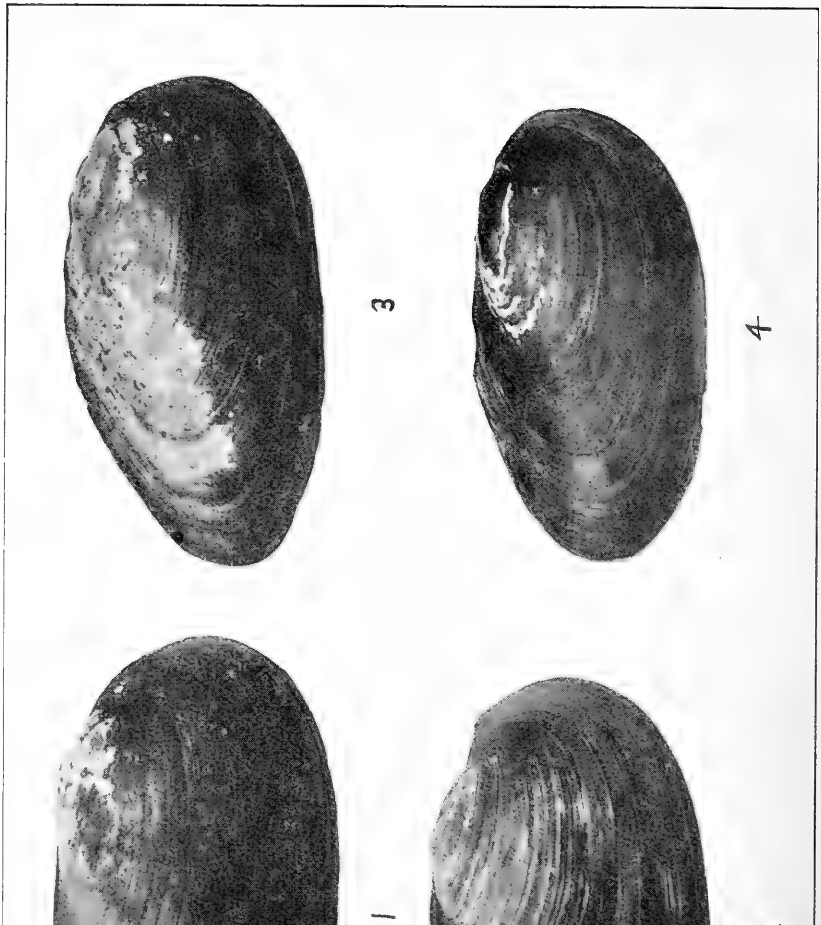

Fig. 41.

6. *Anodonta grandis* Say. Fig. 42, No. 4.

Found only in the artificial pond above Oneida hatchery at Constantia. The specimens were small but typical. Found in Saginaw Bay and Georgian Bay, in pond-like bodies. Listed by Beauchamp under the names *salmonia* and *lewisii*.

7. *Anodonta grandis footiana* Lea. Fig. 41, No. 3.

Collected at seven stations, always on an exposed shore, living, in company with either or both of the two species 4, 5, in sand between boulders. Widely distributed and recorded from Lake Michigan, Saginaw Bay, Georgian Bay, Tomahawk Lake and Isle Royale. In the latter region it is said to live "on a sandy or gravelly bottom in smaller coves sheltered from the waves." It is characteristic of an unprotected shore. The difference between typical *grandis* (Fig. 42, No. 4) and the variety *footiana* (Fig. 41, No. 3) is a striking example of the effect of a change of environment from a still muddy habitat to a rough and sandy habitat. None were observed gravid. It is listed as rare by Beauchamp.

Genus Alasmidonta Say.

8. *Alasmidonta undulata* (Say). Fig. 40, No. 3.

But one specimen of this species was obtained, from a sandy bay, partly exposed to the waves. The shell was badly eroded, possibly by boring algæ. This is a species of the Lower St. Lawrence drainage. It is listed as rare by Beauchamp.

Genus Strophitus Rafinesque.

9. *Strophitus edentulus* (Say). Fig. 42, No. 3.

But one specimen of this species was collected in Frederick Creek near the Oneida hatchery at Constantia. This

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Fig. 41. 1, *Anodonta cataracta;* 2, *Anodonta implicata;* 3, *Anodonta grandis footiana;* 4, *Anodonta marginata.*

was an empty shell. The species is widely distributed, occurring in Traverse Bay, Saginaw Bay, and Tomahawk Lake, in the latter place in a rapidly flowing creek on a sandy bottom. It is listed by Beauchamp.

10. *Strophitus undulatus* (Say). Fig. 42, No. 1.

This species was collected on a bouldery exposed point. It is apparently rare. Some authors consider this species and the last (*edentulus*) as representing variations of the same species (Ortmann, 1912, p. 299) and this may be true. However, ecologically, the two forms found in Oneida Lake are different in color, shape and habitat, the latter being rayed while the former is black and rayless and is more inflated. *Undulatus* is confined to the St. Lawrence and Atlantic drainage systems. It is listed by Beauchamp.

Genus Lampsilis Rafinesque.

11. *Lampsilis luteola* (Lam). Fig. 43, Nos. 1, 2.

This mussel inhabits six stations, all exposed points or shores. It is abundant at one station, common at one, and rare at the other four. Several gravid females were noted, which agreed in all details with Ortmann's description (1912, p. 348). This mussel is widely distributed, being found in Traverse Bay, Saginaw Bay, Georgian Bay, Isle Royale, and Tomahawk Lake. They live either on exposed shores or in protected bays. Listed by Beauchamp under the names *luteola* and *siliquoides,* the latter a synonym. It is eaten by the muskrat.

12. *Lampsilis radiata* (Gmelin). Fig. 42, No. 5; Fig. 43, Nos. 3, 4.

Collected from thirteen stations, all exposed, on a sandy or bouldery bottom, the mussel living between the stones. Next to *Elliptio complanatus* the most abundant mussel in the lake. It is common in the streams flowing into the Atlantic Ocean and the St. Lawrence River and is also said to inhabit Manitoba (Simpson, 1914, p. 65). *Radiata* often approaches *luteola* in size, shape, and markings so closely as to render absolute indentification almost impossible. Typically *luteola* has a smooth almost shining surface, with a few distinct, separated rays, while *radiata* has a rough, dull surface with many rays which are crowded together and more or less wavy. Gravid females of *radiata* were abundant in September. The soft parts did not differ from those of *luteola*. Specimens occur with a pink nacre, as in the variety *rosaceus* of *Lampsilis luteola*. The figures by Robertson (1911, pl. XII, figs. 26, 30) resemble this species more than *luteola*. *Radiata* is a favorite food of the muskrat.

13. *Lampsilis borealis* (Gray). Fig. 44, Nos. 1–4.

This mussel was collected at four stations, all similar to those of *radiata*. It is widely distributed, being reported from the Lake of the Woods east to the St. Lawrence drainage. It was originally described from near Duck Island, Ottawa River, Ontario, Canada. It has not always been distinguished from *radiata*, which it most nearly resembles, and is not reported from any definite locality in New York (Letson, 1905, p. 82). It differs from *radiata* in being rounder and more inflated. As remarked by Simpson (1914, p. 64) it combines many of the characters of both *luteola* and *radiata*. The figures on the plates bring out these differences. Gravid females were observed in Oneida Lake in September. The soft parts do not differ from those of *radiata* or *luteola*. Eaten by muskrats.

14. *Lampsilis iris* (Lea). Fig. 42, No. 2.

This mussel occurred rarely at station XX, a bouldery, exposed point. None were gravid. It ranges from Illinois and Wisconsin east to New York. It is recorded from Saginaw Bay, as rare. Listed by Beauchamp under the names of *iris* and *novi-eboraci*, the latter a synonym.

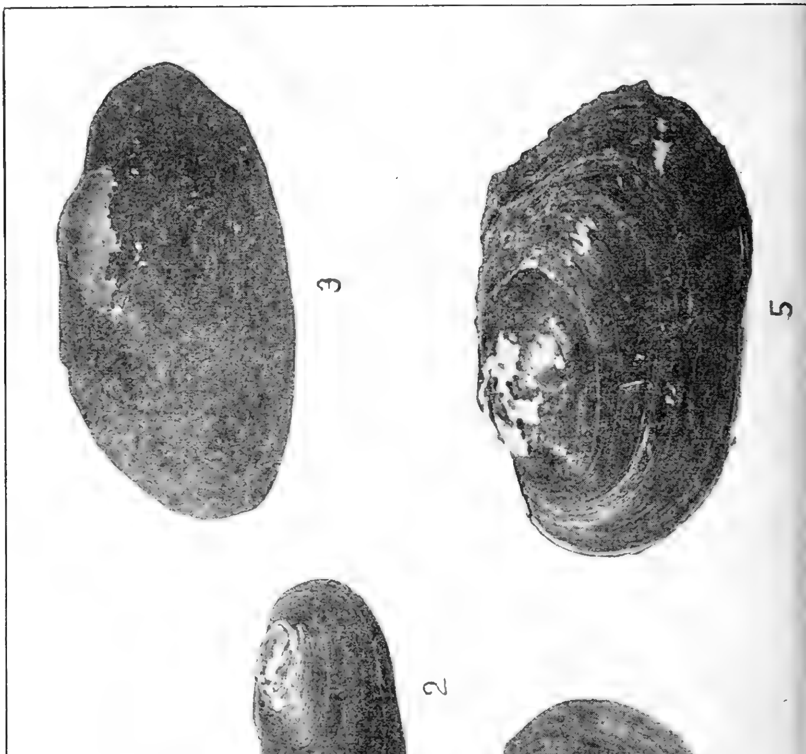

Fig. 42.

Genus NEPHRONAJAS Crosse and Fischer.

15. *Nephronajas ligamentina* (Lamarck). Fig. 40, No. 2.

A single specimen, apparently referable to this species was found at station XXX, habitat 2 (Frenchman Island). It was so peculiar that it was referred to Dr. Bryant Walker who agreed with the writer in considering it *ligamentina*. The specimen is 40 mill. long and is deep grass-green with rays of yellowish green. The species probably lives in deeper water than was investigated at this locality. *Ligamentina* is a species typical of the Mississippi valley which has migrated as far east as western New York. It is recorded in the Tomahawk Lake region from the Wisconsin River and Gilmore Creek. It is not a species of lakes but rather of rivers, and further records from Oneida Lake will be looked for with interest. It is listed from Cross Lake by Beauchamp.

Mussels are eaten by some fishes, although the different species have not been recorded. Under the names of Unionidæ and Pelecypoda, these mollusks have been recorded as eaten by: Round Buffalo, Common Red Horse, Channel-cat, Common Bullhead, Brook Trout, Heros Sunfish, Yellow Perch, Sheepshead, Large-mouthed Black Bass, and Small-mouthed Black Bass.

Anodonta is eaten by: Common Red Horse, Channel-cat, Long-eared Sunfish, Pumpkinseed, and Sheepshead.

ORDER TELEODESMACEA.

FAMILY SPHÆRIIDÆ.

Genus SPHÆRIUM Scopoli.

16. *Sphærium striatinum* (Lamarck). Fig. 45, No. 31.

This small bivalve occurred, uncommonly, at only two stations, where the bottom was sandy and the habitat was

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Fig. 42. 1, *Strophitus undulatus;* 2, *Lampsilis iris,* female; 3, *Strophitus edentulus;* 4, *Anodonta grandis;* 5, *Lampsilis radiata,* male.

more or less partly protected. This is a widely distributed species, listed from Tomahawk Lake, Traverse Bay, Lake Michigan, and Georgian Bay. It is listed by Beauchamp. Used by the Common Whitefish (*Coregonus clupeaformis*).

17. *Sphærium vermontanum* (Prime). Fig. 45, Nos. 32, 33.

An abundant species occurring at twelve stations. It lives in sand in both exposed points and in protected bays. Dr. V. Sterki refers this mussel to *vermontanum* with some doubt as the specimens collected are undersized or immature. *Vermontanum* appears to be comparatively unknown among collectors, being absent from nearly all local lists. It somewhat resembles *solidulum* and was so identified by the writer many years ago (Baker 1898, p. 113; 1902, p. 394). It is listed by Letson (1905, p. 72) but not by Beauchamp, by whom it was probably identified as *solidulum*, which is listed. It is used as food by the Common Sucker and Pumpkinseed.

Genus Musculium Link.

18. *Musculium securis* (Prime). Fig. 45, No. 29.

Observed at two stations, but common at but one on a sandy bottom, partly protected from wave action. This is a common mullusk throughout the United States east of the Rocky Mountains. It is recorded from Tomahawk Lake, Saginaw Bay, Georgian Bay, and Isle Royale. In all of these localities it lives in protected bays, in pools or swamps. It does not live normally on exposed shores. Listed by Beauchamp. It is eaten by the Common Whitefish and the Yellow Perch.

19. *Musculium rosaceum* (Prime). Fig. 45, No. 30.

Found at one station on a bouldery exposed shore. It is rare. Reported from Traverse Bay. Not listed by Beauchamp.

Genus Pisidium Pfieffer.

20. *Pisidium ferrugineum* Prime. Not figured.

A single specimen of this species was collected at station XXXI, habitat I, C. This is an eastern species listed by both Letson and Beauchamp.

21. *Pisidium variable* Prime. Fig. 45, No. 25.

Collected at three stations, on a sandy bottom in partly protected bays. A widely distributed species, listed from Lake Michigan, Saginaw Bay and Isle Royale. Listed by Beauchamp.

22. *Pisidium compressum* Prime. Fig. 45, No. 27.

Collected at station III, habitat 2, on a sandy bottom in a protected bay. Widely distributed, and reported from Lake Michigan, Traverse Bay and Saginaw Bay. Listed by Beauchamp.

23. *Pisidium compressum lævigatum* Sterki. Fig. 45, No. 26.

Collected at four stations. Common at three, abundant at one. Widely distributed. Described after Beauchamp's list was published.

24. *Pisidium æquilaterale* (Prime). Fig. 45, No. 28.

Collected from two stations, one a sandy exposed bay, the other a protected bay with vegetation. It was very rare at both localities. Listed from New York by Letson but not by Beauchamp.

25. *Pisidium henslowanum* (Sheppard). Not figured.

This species was collected at the same stations as the last species, common at one and rare at the other. Dr. V. Sterki refers this *Pisidium* to this species with some doubt. They are peculiar in having a ridge or crest on the beak. The same form has been observed by Sterki from Ontario. Eaten by the Common Sucker.

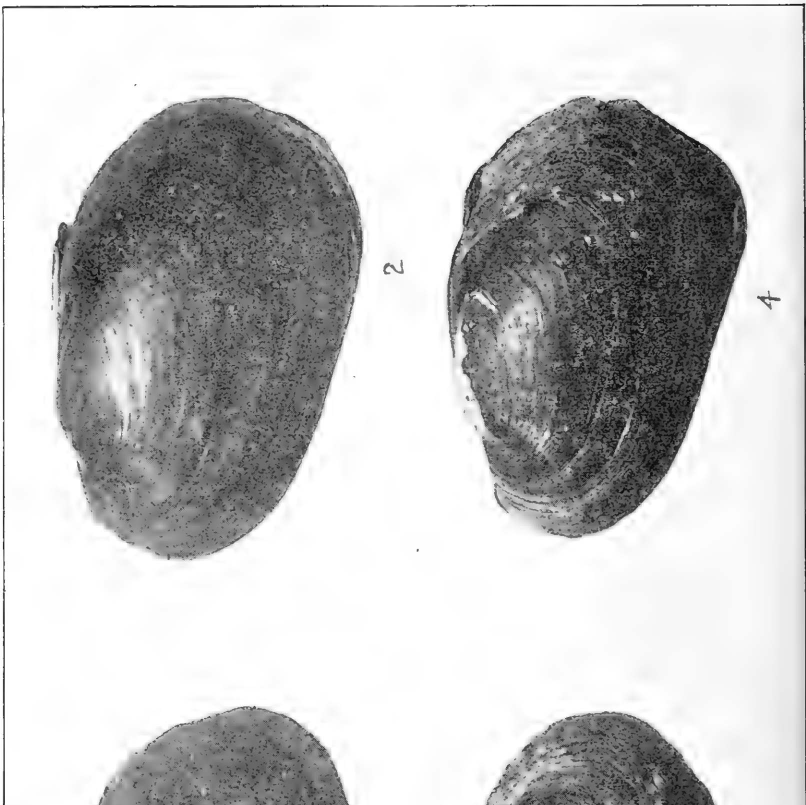

Fig. 43.

26. *Pisidium* species (field No. 252). Not figured.
Station III, habitat 2, uncommon.

27. *Pisidium* species (field No. 238). Not figured.
This undescribed species occurred at station XIX uncommonly.

28. *Pisidium* species (field No. 234). Not figured.
Station IX, rare.

29. *Pisidium* species (field No. 217). Not figured.
Station XXXI, habitat 1 c, rare.

The last four species are in the hands of Dr. V. Sterki awaiting the acquisition of additional material before they can be satisfactorily determined.

Fourteen species and races of Sphæriidæ are recorded from Oneida Lake in the preceding pages. Of the material sent for examination Dr. Sterki says: "As you see from the list, the material is interesting, but somehow insufficient for satisfactory study and determination, considering the great variation of most of the species. For many years it has been my desire to get good and ample material from that region, which must be very rich in Sphæriidæ — and other fresh-water mollusks. From the whole great State of New York, we know very little outside of what Dr. Jas. Lewis collected in the Mohawk. You should have 30 species or more of Sphæriidæ in your vicinity; eastern and more western species appear to meet there; and there ought to be more than 20 species (plus varieties) of *Pisidium*." It is quite probable that, as Dr. Sterki predicts, a much larger Sphærid fauna will be discovered after further examinations of the lake and surrounding country have been made.

Undetermined *Pisidia* are eaten by the following fishes: Common Whitefish, Common Bullhead, Fresh-water Killy, Pumpkinseed.

Fig. 43. 1, *Lampsilis luteola*, male; 2, *Lampsilis luteola*, female; 3, *Lampsilis radiata*, male; 4, *Lampsilis radiata*, female.

Class Gastropoda.

Order Prosobranchiata.

Family Viviparidæ.

Genus Vivipara Lamarck.

30. *Vivipara contectoides* W. G. Binney. Fig. 46, Nos. 1, 5.

This large, handsome snail was abundant at two stations and common at two other stations. All were sandy and protected from violent wave action. This snail is characteristic of the Mississippi Valley, extending from Michigan to Arkansas and from South Carolina to Florida. It is said by Lewis to have been colonized from Illinois (1874, p. 137). It is abundant in the Erie Canal at Rochester and Syracuse and is now known to inhabit Oneida Lake, doubtless brought there by way of the new Barge Canal and the Oneida River. It is not mentioned by Walton (1891), Letson (1905) does not give a locality, and Beauchamp fails to record it in the Onondaga list. It must, therefore, be a more or less recent addition to the Oneida Lake fauna. It will be interesting to know whether it is found in the eastern part of the lake. It was observed living only in the outlet and Oneida River. Females dissected in September were observed to contain young with fully formed shells, apparently ready for birth. The young of the Viviparidæ are born alive, unlike those of *Lymnæa,* and other snails, which develop from eggs deposited in the water and attached to some object. *Contectoides* is eaten by the Short-nosed Sturgeon. *Vivipara*, species not indicated, is eaten by: Dogfish, Small-mouth Buffalo, Common Red Horse, Short-headed Red Horse, Channel-cat, Yellow Bullhead, Common Bullhead, Bluegill.

Genus Campeloma Rafinesque.

31. *Campeloma decisum* (Say). Fig. 46, Nos. 6–8.

This large snail was collected only at two stations, one a pond the other a creek. It is widely distributed, and is recorded from Tomahawk Lake, Traverse Bay, Lake Michigan, Saginaw Bay, and Georgian Bay. It is abundant in New York State, and is noted by Beauchamp (under the old generic name *Melantho*) from Onondaga County. It is eaten by the Sheepshead. *Campeloma* (species not indicated) is eaten by the Dogfish, Common Red Horse, Channel-cat, Yellow Bullhead, Common Bullhead, and Sheepshead.

32. *Campeloma integrum* (DeKay). Fig. 46, Nos. 2–4.

Observed at thirteen stations, mostly on partly protected shores on a sandy bottom in shallow water. Occasionally a specimen or two occurs on a bouldery shore or point (as at station XX) but this is rare. It is abundant or common in many places. This species is as widely distributed as is *decisum*, and is an abundant species in the waters of New York State, from which it was first described by DeKay under the name of *heros* (1843, p. 85). Specimens occur which resemble both the variety *obesum* and *Campeloma rufum*. More extended search may be the means of discovering these forms. It was observed to contain fully formed young in September. *Integrum* is listed by Beauchamp.

Family Amnicolidæ.

Genus Gillia Stimpson.

33. *Gillia altilis* (Lea). Fig. 45, No. 39.

Collected at three stations on a sandy bottom in shallow water, in bays usually open to the waves. A common and widely distributed species in New York State, listed by Lewis, Walton, Letson, and by Beauchamp from Onondaga County.

Fig. 44.

Genus Somatogyrus Gill.

34. *Somatogyrus subglobosus* (Say). Fig. 45, No. 40.

Collected at four stations on a sandy shore in shallow water associated with *Gillia*. This characteristic snail is widely distributed from Lake Michigan eastward. Under the name of *isogonus* it is listed by most writers on New York mollusks. It is listed under this name by Beauchamp. *Somatogyrus* is eaten by the Common Red Horse.

Genus Bythinia Gray.

35. *Bythinia tentaculata* (Linné). Fig. 45, Nos. 22, 23.

Collected at thirteen stations. This snail seems to prefer a habitat where the water is in motion; it will thrive equally well on the sandy bottom of an exposed or partly sheltered bay, in thick vegetation in the outlet (where it was the most abundant) or on the stems of such water plants as Water Willow, Bulrush or Pickerel-weed (see Chapter III). Rarely found on an exposed bouldery point. This abundant species was found by Beauchamp at Oswego in 1879 (1886, p. 5). Since that time it has been reported from various parts of Western New York, principally in the Erie Canal (Walton, 1891). It was observed in Lake Michigan by the writer in 1893 (Baker, 1902, p. 330) and has been recorded from Michigan, Wisconsin, and Ohio. It has been thought to have been introduced from Europe but its wide distribution and great abundance point to its being a native species inhabiting both continents, like *Galba palustris, Margaritana margaritifera,* and *Helix nemoralis.* It is eaten by the Pumpkinseed.

It has been observed on the following plants:

Pickerel-weed (*Pontederia cordata*). On stem.
Water Willow (*Dianthera americana*). On stem.
American Bulrush (*Scirpus americanus*). On leaf.
Lake Bulrush (*Scirpus occidentalis*). On leaf.
White Water Lily (*Castalia odorata*). On stem.
Yellow Water Lily (*Nymphæa advena*). On stem.

Fig. 44. ***Lampsilis borealis.*** **1, 3. males; 2, 4, females.**

Genus Amnicola Gould and Haldeman.

36. *Amnicola limosa* (Say). Fig. 45, No. 19.

This little snail is not as common in Oneida Lake as is *lustrica*, and was observed at but four stations, in but one of which it was common. The usual habitat is a sheltered bay on a sandy bottom in shallow water. It is widely distributed throughout the eastern and central part of the United States and has been recorded from west of the Rocky Mountains. At Isle Royale it was found on the under side of water lily leaves (p. 294). In the Saginaw Bay region it was noted on lily leaves and pond-weed, and on a sandy and gravelly bottom in shallow water (p. 170). Listed by Beauchamp from Onondaga County. The snails from Oneida Lake are small and not typical in form.

Amnicola limosa has been observed in *Vaucheria,* probably using this alga as food. It is eaten by the Common Whitefish, the Pumpkinseed, the Yellow Perch.

37. *Amnicola lustrica* Pilsbry. Fig. 45, No. 20.

This tiny snail was collected from ten stations, mostly protected bays, on a sandy bottom in one to two feet of water or on vegetation, lily leaves, submerged vegetation, etc. Rarely it was found on a bouldery exposed point. It is widely distributed throughout the United States. At Isle Royale it was collected on a muddy bottom in three to five feet of water (p. 294). In the Saginaw Bay region (Rush Lake) it was found in great abundance on a sandy bottom in two to four feet of water, and in less abundance on a marly bottom (p. 136). In the Georgian Bay region, it was dredged in 20 or more fathoms of water. *Lustrica* varies greatly in form and may include, under this name, more than one species, as has been the case with *limosa*. In Dr. H. A. Pilsbry's monograph of New York Mollusca, now in preparation, this matter will doubtless be cleared up and this interesting genus straightened out and its true species distinguished. This *Amnicola* is eaten by the Common

Whitefish, Common Sucker, Pumpkinseed, Manitou Darter and Tessellated Darter.

38. *Amnicola lustrica* Pilsbry, variety. Fig. 45, No. 21.

A single very narrow *Amnicola* (field No. 217) was found among debris at station XXXI, habitat 2, C, associated with typical *lustrica*. It greatly resembles *Paludestrina nickliniana* in general form, and is an example of the statement expressed under the last species. Should more of this narrow form be collected it would need to be differentiated as a separate species.

Family Pleuroceridæ.

Genus Goniobasis Lea.

39. *Goniobasis livescens* (Menke). Fig. 47, Nos. 9–12.

Observed at fifteen stations where it lives on bouldery points in one to three feet of water, usually exposed to the full force of the waves. Young individuals, a few millimeters in length, have been noted on a sandy bottom. The young are strongly carinated on the whorls. This characteristic snail is distributed from New York to Lake Michigan and southward to Illinois. It is recorded from Lake Michigan and the Traverse Bay region, the Saginaw Bay region, where it lives on unprotected, rocky, shallow shores, and the Georgian Bay region where it occurs in similar habitats. It is very abundant in New York State and is listed by Beauchamp from Onondaga County. It has been observed to feed upon green filamentous algæ, and is said to eat dismids and diatoms.

Family Valvatidæ.

Genus Valvata O. F. Müller.

40. *Valvata tricarinata* (Say). Fig. 45, Nos. 10–12.

Observed only at station XXXI, habitat, 1, C, where it occurred on a sandy bottom. It has been noted in algæ

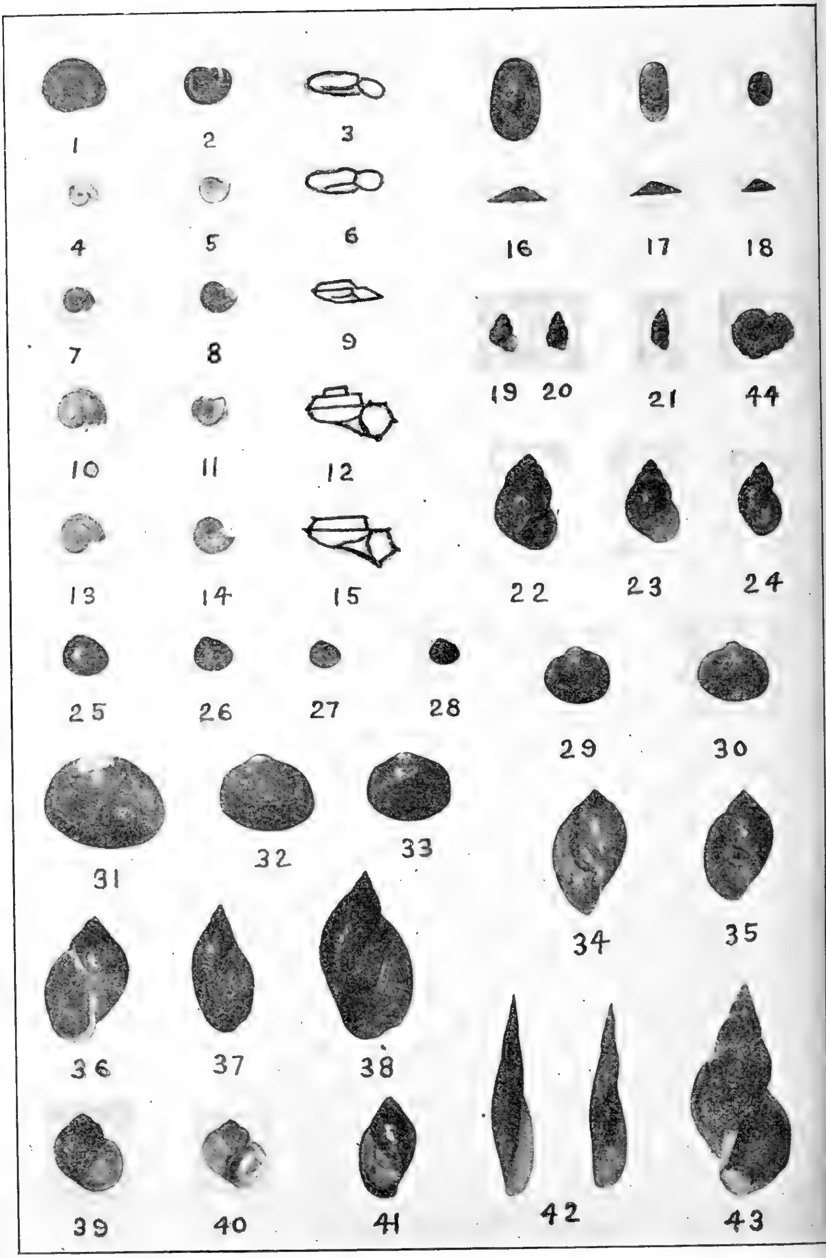
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Fig. 45.

(*Vaucheria*) upon which it was apparently feeding. Recorded by Beauchamp. Eaten by the Common Whitefish, Round Buffalo, Common Sucker, Common Red Horse, Placopharynx, Golden Shiner, Common Bullhead, Pumpkinseed, and Yellow Perch.

41. *Valvata bivarinata normalis* Walker. Fig. 45, Nos. 13–15.

Observed at five stations where it lives in shallow water on a sandy bottom in a more or less protected bay or in vegetation in a protected bay. It is eaten by the Pumpkinseed. *Bicarinata* is not listed by either Letson or Beauchamp.

The carinate Valvatas are widely distributed, occurring from New England to Iowa, and from Manitoba southward. *Tricarinata* was collected at Isle Royale in mud in deep water (p. 294), and varieties of *tricarinata* in the Saginaw Bay region in shallow water on a sandy, gravelly and marly bottom. In the Georgian Bay region, *tricarinata* is said to be common on sandy or muddy bottoms in weedy places and on sandy bottoms to a depth of 20 fathoms.

Fig. 45. 1–3, *Planorbis hirsutus*; 4–6, *Planorbis parvus*; 7–9, *Planorbis exacuous*; 10–12, *Valvata tricarinata*; 13–15 *Valvata bicarinata normalis*; 16, *Ancylus fuscus*; 17, *Ancylus parallelus*; 18, *Ancylus tardus*; 19, *Amnicola limosa*; 20, *Amnicola lustrica*; 21, *Amnicola lustrica*, var; 22, 23, *Bythinia tentaculata*; 24, *Succinea avara*; 25, *Pisidium variabile*; 26, *Pisidium compressum lævigatum*; 27, *Pisidium compressum*; 28, *Pisidium æquilaterale*; 29, *Musculium securis*; 30, *Musculium rosaceum*; 31, *Sphærium striatmum*; 32–33, *Sphærium vermontanum*; 34–35, *Physa ancillaria warreniana*; 36, *Physa integra*; 37, *Pseudosuccinea columella chalybea*; 38, *Pseudosuccinea columella*; 39, *Gillia altilis*; 40, *Somatogyrus subglobosus*; 41, *Physa gyrina*; 42, *Acelia haldemani*; 43, *Galba palustris*; 44, *Helicopsyche borealis*. 3, 6, 9, 12, 15, enlarged about twice natural size; 16–18, 25–33, slightly enlarged.

ORDER PULMONATA.

FAMILY PHYSIDÆ.

Genus PHYSA Draparnaud.

42. *Physa ancillaria warreniana* (Lea). Fig. 45, Nos. 34, 35.

One of the most abundant snails living in Oneida Lake, occurring at 28 stations. It lives in a variety of habitats from bouldery exposed points to protected bays filled with vegetation. The normal habitat, where the snail is most abundant and of larger size, is near the shore in shallow water (four to eight inches) among stones where it occurred in the majority of cases. In Tomahawk Lake this *Physa* occurred in either a protected bay or on an exposed shore, precisely as noted in Oneida Lake. The shells figured as *ancillaria* by Robertson (pl. XI, fig. 19) appear from the figures to belong to this race.

This characteristic *Physa* seems to have been noted by but few students and has doubtless been included under the all-embracing name of *heterostropha*. That species, however, is quite different from this as will be seen by comparing Binney's figure of Say's type (Binney, 1865, p. 84, fig. 144) with the figures on the plate. This race is related to both *ancillaria* and *sayii* (Binney, figs. 139, 136). It is much smaller than *sayii* and appears, as noted by the writer some years ago (F. C. Baker, 1911, p. 234), to vary toward *ancillaria* in the form of the shell, which becomes shouldered in some individuals. The surface is usually smooth and shining and the spiral sculpture is slight or entirely absent, hence its reference to *heterostropha*. The occurrence of this *Physa*, together with *Planorbis binneyi* and *Lymnæa stagnalis lillianæ*, in both Tomahawk Lake, Wisconsin, and Oneida Lake, New York, under similar ecological conditions, is a striking example of the result of environmental influences working in far separated regions on the same species. The same *Physa* has recently been observed by the writer on the shore of Lake Michigan at Chicago.

Physa ancillaria warreniana has been observed on the following vegetation, using it for either support or food, probably both:

Broad-leaved Arrow-head (*Sagittaria latifolia*).
Pickerel-weed (*Pontederia cordata*).
Water Willow (*Dianthera americana*).
American Bulrush (*Scirpus americanus*).
White Water Lily (*Castalia odorata*).
Yellow Water Lily (*Nymphæa advena*).
Green filamentous algæ.
Water Celery (*Vallisneria spiralis*).
Dead leaves used as food.

Probably feeds on desmids, diatoms, and green algæ, and is eaten by the Pumpkinseed and Golden Shiner. Under the generic name *Physa,* this type of snail is eaten by eleven kinds of fishes: Dogfish, Common Whitefish, Common Red Horse, Yellow Bullhead, Common Bullhead, Mud Minnow, Killifish, Top Minnow, Viviparous Minnow, Bluegill, and Pumpkinseed.

43. *Physa integra* Haldeman. Fig. 45, No. 36.

Observed at five stations, on a bouldery exposed point or in a sandy exposed bay. The species is here large and typical. It is widely distributed throughout the Great Lake and St. Lawrence River region. In the Saginaw Bay region it is found among algæ (*Vaucheria*) and on the under side of lily leaves in creeks and rivers, in contrast with the exposed habitats in Oneida Lake. In the Georgian Bay region the variety *niagarensis,* a smaller shell, occurs on exposed rocky shores. It is a common species in New York State where it seems to be better known under the name of its race *niagarensis,* under which name it is listed by Beauchamp.

44. *Physa gyrina* Say. Fig. 45, No. 41.

This *Physa* was observed only at two stations, both quiet water habitats. It is characteristic of swampy areas where the water is more or less stagnant. *Gyrina* is widely distributed over the central and eastern parts of the United

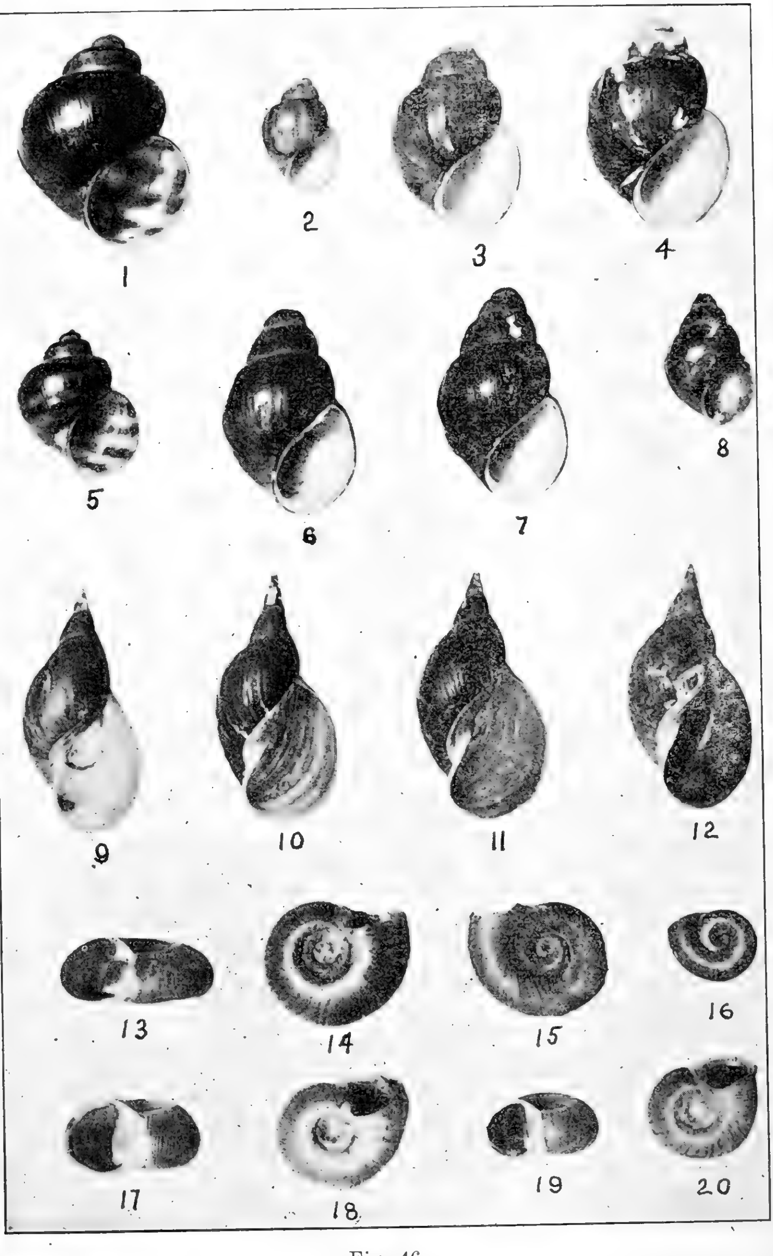

Fig. 46.

States. In the Saginaw Bay region it was noted on the under side of lily leaves. It is common in New York State, especially in ponds, ditches, swamps, and the quiet parts of lakes and rivers. Beauchamp lists it as from forest ponds in Onondaga County. *Gyrina* has been observed on the Yellow Water Lily (*Nymphæa advena*).

The genus *Physa* is in a chaotic state as regards the specific distinctness of a large number of its species. Authors following Binney have classed almost all species under the all-embracing name of *heterostropha* and it is therefore impossible to compare the distribution of any *Physa* under this name. The three forms listed above are quite distinct and need never be confounded.

Family Ancylidæ.

Genus Ancylus Geoffroy.

45. *Ancylus tardus* Say. Fig. 45, No. 18.

This small fresh-water limpet was observed only in Seriba Creek on stones in shallow, rapidly flowing water. It is widely distributed in the eastern and central parts of the United States and in Canada. It is common in New York State. Beauchamp lists it from Onondaga County on stones in rivers.

46. *Ancylus fuscus* Adams. Fig. 45, No. 16.

Observed at two stations, both sheltered habitats, and one a *Typha* marsh. Its habit of clinging to vegetation especially dead *Typha* leaves, is noteworthy. It is as widely distributed as is *tardus*. Recorded by Lewis from western New York but not included in Beauchamp's list of Onondaga County. It has been collected from dead leaves of Cat-tail (*Typha angustifolia*) upon which it feeds.

Fig. 46. 1, 5, *Vivipara contectoides;* 2–4, *Campeloma integrum,* 6–8, *Campeloma decisum;* 9–12, *Lymnæa stagnalis lillianæ;* 13–16, *Planorbis trivolvis;* 17–18, *Planorbis binneyi;* 19–20, *Planorbis trivolvis,* var.

47. *Ancylus parallelus* Haldeman. Fig. 45, No. 17.

Observed at three stations, always more or less protected. In the Saginaw Bay region it was observed, in quiet coves and ponds, on the under side of lily leaves. In the Georgian Bay region it was collected from the under side of lily leaves and on sticks. Beauchamp records it "on plants" from Onondaga County. It is as widely distributed throughout the United States as are the last two species. It has been collected from the following plants:

White Water Lily (*Castalia odorata*). Under surface.
Yellow Water Lily (*Nymphæa advena*). Under surface.
Bur-reed (*Sparganium eurycarpum*). Dead leaves used as food.

A species of *Ancylus* has been observed on two species of pond-weed (*Potamogeton americanus* and *P. amplifolius*). *Ancylus* is eaten by the Common Bullhead.

Family Planorbidæ.

Genus Planorbis Müller.

48. *Planorbis trivolvis* Say. Fig. 46, Nos. 13–16.

Collected from eight stations, all protected, where the mollusks were usually among vegetation. This, the commonest of all "wheel snails," is widely distributed from the Rocky Mountains to the Atlantic Ocean and from Canada southward. As observed in other places *trivolvis* is always an inhabitant of quiet, even swampy and stagnant, pools and water bodies. At Isle Royale it was found in a pool in a tamarack swamp (p. 292). In the Saginaw Bay region, it occurred on lily leaves, among dead vegetation, on driftwood, etc., in pools, marshes and swamps. It was noted that the shells from the Bay were larger and heavier than those from inland waters (p. 165). In the Georgian Bay region it was observed in protected bays, along the shore in water less than two feet deep (p. 100). *Trivolvis* is the commonest shell in many parts of New York State. Listed by Beauchamp. Observed on the following plants:

White Water Lily (*Castalia odorata*). On leaves and stem.
Yellow Water Lily (*Nymphæa advena*). On leaves and stem.
Cat-tail (*Typha angustifolia*). Dead leaves used as food.

It is believed to feed on filamentous algæ, desmids, and diatoms, and is eaten by the Short-nosed Sturgeon.

49. *Planorbis trivolis* Say, variety. Fig. 46, Nos. 19–20.

A form of *trivolvis* occurs at five stations, where the habitat is not as protected as those occupied by typical *trivolvis*, several of them, as V and XXX, 2, being fully exposed to wave action. The shell is smaller than *trivolvis*, the whorls are wider and the shell in general seems to stand midway between *trivolvis* and *binneyi*. Walker has expressed the opinion that *binneyi* is a variety of *trivolvis* and the presence of these intermediate forms seems to point in that direction. This may be the form called *lentus* by New York conchologists and listed as such by Beauchamp. This *Planorbis* has been observed on the following plants:

Broad-leaved Arrow-head (*Sagittaria latifolia*).
Pickerel-weed (*Pontederia cordata*).
Water Willow (*Dianthera americana*).
Lake Bulrush (*Scirpus occidentalis*).
American Bulrush (*Scirpus americanus*).
Green filamentous algæ.

50. *Planorbis binneyi* Tryon. Fig. 46, Nos. 17–18.

This handsome *Planorbis* was noted at seven stations, the habitat always being a more or less exposed bouldery point or bay. A favorite location was noted to be at the shore edge, in a few inches of water, the snails feeding on the green algæ on the rocks. This species was noted in Tomahawk Lake in both sheltered bays and on exposed shores. It is an abundant species, extending from Massachusetts west to Oregon (F. C. Baker, 1911, p. 237). It has been identified by local conchologists as a wide form of *trivolvis*. It is not in Beauchamp's list and has not been recorded in any of the catalogs of New York shells.

51. *Planorbis antrosus* Conrad. Fig. 47, Nos. 17–20.

This *Planorbis*, long known under the name of *bicarinatus* (which is preoccupied), was obtained from ten

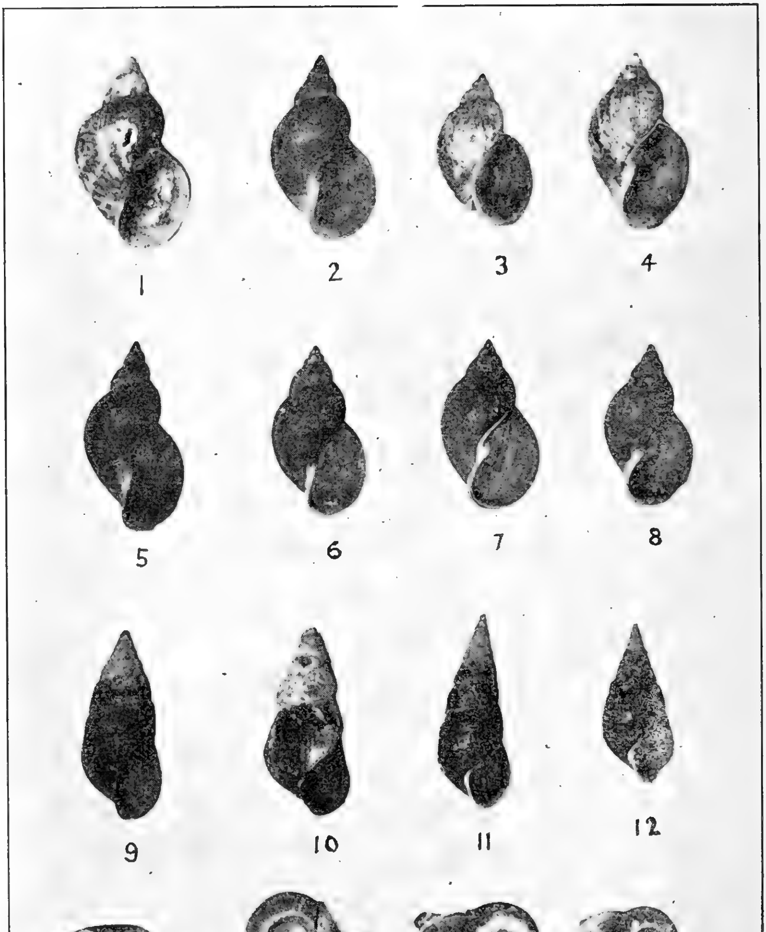

Fig. 47.

stations, all more or less exposed points, bays, and shores. In the Saginaw Bay region it was found along the shores of the Pigeon River among algæ, principally *Vaucheria;* also dredged in deep water (H. B. Baker, 1911, p. 164); in the Georgian Bay region it occurs in weedy sand runs and weedy muddy bays and on rocks (p. 100); at Isle Royale it was found on a mud bottom in three to five feet of water (p. 292). Listed by Beauchamp (as *bicarinatus*) from Onondaga County and commonly distributed in New York State.

Antrosus has been observed on the following plants:

Pickerel-weed (*Pontederia cordata*).
Water Willow (*Dianthera americana*).
Lake Bulrush (*Scirpus occidentalis*).

Observed to feed upon green algæ, and is eaten by the Pumpkinseed.

52. *Planorbis campanulatus* Say. Fig. 47, Nos. 13–16.

This is one of the most abundant mollusks in the lake, being found at 32 stations. It occurs in all kinds of habitats from the wave-beaten shore to the quiet, protected bay. It clings to stones, the sandy bottom, and to any kind of vegetation. In the Saginaw Bay region, *campanulatus* lives in pond-like bodies of water on lily leaves and *Potamogeton* (p. 165); in the Georgian Bay region it occurs in weedy places, both muddy and sandy, up to the depth of at least three fathoms (p. 100); at Isle Royale it occurred in mud and among loose stones at a depth of about one foot and in small pools among sedge (p. 293). In Tomahawk Lake it lived on both a protected and an exposed habitat in much the same manner as in Oneida Lake (p. 236). A single specimen was found in Oneida Lake which had the elevated apical whorls characteristic of the variety *rudentis* Dall. *Campanulatus* is abundant in New York State, and is listed

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Fig. 47. 1, 3, *Galba emarginata;* 2, 4–8, *Galba catascopium;* 9–12, *Goniobasis livescens;* 13–16, *Planorbis campanulatus;* 17–20, *Planorbis antrosus.*

from Onondaga County by Beauchamp. *Campanulatus* has been observed on the following plants:

Broad-leaved Arrow-head (*Sagittaria latifolia*).
Pickerel-weed (*Pontederia cordata*).
Water Willow (*Dianthera americana*).
Lake Bulrush (*Scirpus occidentalis*).
American Bulrush (*Scirpus americanus*).
White Water Lily (*Castalia odorata*). On leaves and stem.
Yellow Water Lily (*Nymphæa advena*). On leaves and stem.

It feeds on filamentous algæ, desmids, diatoms, and on the dead leaves of Water Celery (*Vallisneria spiralis*). It is eaten by the Pumpkinseed.

53. *Planorbis parvus* Say. Fig. 45, Nos. 4–6.

This small *Planorbis* was observed only at three stations, a protected habitat in vegetation. As recorded from other places, *parvus* is found in protected places on lily pads, drift-wood, and debris of various kinds (Saginaw Bay, p. 166; Tomahawk Lake, p. 235; Isle Royale, p. 293). It feeds upon the dead leaves of Cat-tail (*Typha angustifolia*) and has been observed in algæ (*Vaucheria*); it is eaten by the Common Whitefish and the Pumpkinseed.

54. *Planorbis hirsutus* Gould. Fig. 45, Nos. 1–3.

This characteristic little wheel-snail was found at eleven stations but was common at only two. Under the names of *hirsutus* and *albus* (a European species which the American shell closely resembles) it is widely distributed in the United States. In the Saginaw Bay region (p. 166) it lives on lily pads and driftwood, always in protected situations. In the Georgian Bay region (p. 101) it occurs in muddy channels and muddy bays on smooth rocks covered with a light deposit of sediment. At Tomahawk Lake it was collected in quiet water habitats.

Observed on the following plants:

White Water Lily (*Castalia odorata*). Under side.
Yellow Water Lily (*Nymphæa advena*). Under side.

It was observed feeding upon dead leaves of Water Celery (*Vallisneria spiralis*), and is eaten by the Common Sucker and the Manitou Darter.

55. *Planorbis exacuous* Say. Fig. 45, Nos. 7–9.

Observed at only one station, XXXI, and two habitats, 1, C, and 2, both with thick vegetation; in the latter place feeding on dead *Typha* leaves, floating on the surface of the water. At Isle Royale it was found on the muddy bottom of a small stream, at a depth of two to five feet (p. 293); in the Saginaw Bay region (p. 165) it was found on drift-wood, lily pads, and on dead leaves; in the Georgian Bay region (p. 101) it was found in protected weedy places, and was noted to be light colored in sandy places and brown in muddy places. *Exacuous* is eaten by the Pumpkinseed.

Under the generic name of *Planorbis* upwards of thirteen fish are noted as using this genus as food. These are Dog-fish, Small-mouth Buffalo, Common Red Horse, Channel-cat, Brook Trout, Mud Minnow, Fresh-water Killy, Killifish, Viviparous Minnow, Bluegill, Heros Sunfish, Pumpkinseed, and Sheepshead.

FAMILY LYMNÆIDÆ.

Genus LYMNÆA Lamarck.

56. *Lymnæa stagnalis lillianæ* F. C. Baker. Fig. 46, Nos. 9–12.

This large pond snail was observed at thirteen stations, at four of which it was abundant, at four common, and rare or uncommon at the rest. It lives in a variety of habitats, the most characteristic and perhaps the normal one being near the shore, where there are many boulders, in from six to eight inches of water, where it feeds on the green filamentous algæ covering the rocks. It seems to be rare on shores where the force of the waves is not diminished by off shore vegetation, Water Willow, or bulrush.

The discovery of this race of *Lymnæa* in Oneida Lake was a surprise as was also the presence of *Planorbis binneyi* and *Physa ancillaria warreniana*. This *Lymnæa* lives under similar conditions in both Oneida Lake and Tomahawk Lake. It has not before been reported from New York State (though probably included by Beauchamp under the name *stagnalis*) and was previously known only from Minnesota, Wisconsin, and Michigan (F. C. Baker, 1911, p. 155). At Isle Royale a *Lymnæa* occurs which seems referable to this race, though not exactly typical. It is found in protected harbors where the water is quiet (p. 289).

The increase in the size of the aperture and the decrease in the height of the spire is due to a rough water habitat, which makes it necessary to have a larger foot surface to enable the mollusk to retain its hold on the rocks. This feature is carried to the extreme in the race *sanctæmariæ* of Walker (Walker, 1908, p. 289, fig. 2–3; F. C. Baker, 1911, p. 156), in which the spire is still farther reduced and the aperture enlarged. This race lives on shores where the waves are violent. Egg capsules were noted in nearly all habitats attached to lily leaves, *Typha* leaves (dead), *Potamogeton natans* leaf, and on bottom debris. *Lillianæ* has been observed on the following plants:

Pickerel-weed (*Pontederia cordata*). On stems.
Water Willow (*Dianthera americana*). On stems.
American Bulrush (*Scirpus americanus*).
White Water Lily (*Castalia odorata*). On leaves and stems.
Yellow Water Lily (*Nymphæa advena*). On leaves and stems.

Observed feeding on filamentous green algæ and dead leaves of Cat-tail (*Typha angustifolia*). A study of the stomach contents showed it to feed on bryozoan statoblasts (*Plumatella*), *Planorbis campanulatus*, and algæ and plant fragments. Under the generie name of *Lymnæa*, three species of fish are listed as using this group of mollusks as food; Dog-fish, Common Whitefish, and Steel-colored Minnow.

Genus Pseudosuccinea Baker.

57. *Pseudosuccinea columella* (Say). Fig. 45, No. 38.

Observed at three stations where the habitat was a protected bay filled with floating and submerged vegetation. Common on the upper and rare on the lower surface of pond lily leaves (*Castalia* and *Nymphæa*). This *Lymnæa* is widely distributed in the United States and Canada from Minnesota eastward and from Manitoba south to Florida and Texas. Abundant in New York State, and recorded by Beauchamp from Onondaga County. For the use of the generic name see F. C. Baker (1911, p. 162). The habitat of *columella* appears to be universally the same, as noted by other ecologists. In Tomahawk Lake (p. 239) it was observed on lily-pads; in the Georgian Bay region on lily-pads; lives also in shallow water clinging to cat-tails and reeds (F. C. Baker, 1911, p. 170). It is said to feed on desmids, diatoms and green algæ.

58. *Pseudosuccinea columella chalybea* (Gould). Fig. 45. No. 37.

Observed at one station associated with typical *columella* on lily leaves. It is distinguished by its narrower shell and higher spire (see F. C. Baker, 1911, p. 171). Not definitely recorded from New York previously. The figures of Robertson (pl. XI, fig. 15) represent this race.

Genus Acella Haldeman.

59. *Acella haldemani* (Deshayes' Binney). Fig. 45, No. 42.

This rare and peculiar Lymnæid occurred at four stations, always in a protected bay where the growth of vegetation was luxuriant. Though distributed from Minnesota eastward to Vermont and from Ontario south to Ohio, this delicate snail has been but little known, especially as regards its ecology. Dr. R. J. Kirtland collected it in great numbers in Reed Lake, near Grand Rapids, Michigan, and found it, as late as November 25th, when the water was covered with ice. It was observed on reeds and rushes in water one to three feet deep, invariably from six to eight inches from the bottom, on the side of the reed facing deep water, the apex of the shell pointing downward. In this lake the colony of snails occupied an area of a few square rods, and the location of this area has not varied a hundred feet in either direction in ten years. Kirtland believes that it is a deep water species that migrates shoreward in the fall to spawn. Sargent noted *Acella* on lily leaves in the fall. (F. C. Baker, 1911, pp. 197–198). In the Georgian Bay region (p. 99) *Acella* is also found on the lower surface of lily leaves in sheltered bays. All records of the collecting of this species are in the fall and its location in Spring and Summer is not yet known. This fact indicates another reason for all the year round field work.

Acella is known from but six localities in New York State: Strawberry and Squaw Islands, Niagara River; Mohawk River; Herkimer County; Little Lakes, Schuyler's Lake, and Lake Canadarago, Otsego County. A seventh locality may now be added, Oneida Lake, Oswego County. It will doubtless be found in other parts of the lake. Not listed by Beauchamp.

Acella feeds upon green algæ and has been observed on the following plants:

Smith's Bulrush (*Scirpus smithii*). On stem.
Floating Pond-weed (*Potamogeton natans*). On leaves and stem.
White Water Lily (*Castalia odorata*). On leaves and stem.
Yellow Water Lily (*Nymphæa advena*). On leaves and stem.

Genus Galba Schrank.

60. *Galba catascopium* (Say). Fig. 47, Nos. 2, 4–8.

Observed at 24 stations, the habitat being usually an unprotected rocky point or bay, in one to four feet of water. It was common on sandy bottoms, though mostly young or immature, and rare in protected situations. It was almost always associated with *Goniobasis*. At Isle Royale (p. 291) it was most frequent in shallow water in habitats sheltered from the waves. In the Delaware River it is subject to the ebb and flow of the tide, which leaves stretches of the river shore bare, and this fresh-water species has here been compelled to adapt itself to this periodic exposure, as have the marine Littorinas, and for this purpose a thick shell has been evolved.* The *catascopium* of Oneida Lake also has a rather thick shell, caused probably by its normal station in a rough water habitat. It is widely distributed in the eastern part of the United States and is one of the most abundant snails in New York State. Listed by Beauchamp from Onondaga County. This snail has been observed on the following plants:

Broad-leaved Arrow-head (*Sagittaria latifolia*). On stem.
Pickerel-weed (*Pontederia cordata*). On stem.
Water Willow (*Dianthera amrericana*). On stem.
American Bulrush (*Scirpus americanus*). On leaf.
Lake Bulrush (*Scirpus occidentalis*). On leaf.

It has been noted feeding upon dead Water Celery leaves (*Vallisneria spiralis*) and is used as food by the Short-nosed Sturgeon, Common Whitefish, and Pumpkinseed.

61. *Galba emarginata* (Say). Fig. 47, Nos. 1, 3.

Observed, rarely, at four stations, always on a bouldery point or in a sandy, exposed bay. Nearly all of the specimens found, however, were dead shells. At Isle Royale (pp. 60–61, 290) *emarginata* occurs on sandy and rocky shores where wave action is light; a variety, *ontarioensis,* is abundant in the Saginaw Bay region (p. 162) on a rocky shore unprotected from the waves; another variety, *canadensis,* occurs in the Georgian Bay region (p. 99) on rocky and sandy shores, in exposed situations. The distribution and interesting ecology of this species is extensively described by F. C. Baker (1911, pp. 408–433). Recorded by Beauchamp. A variety of *emarginata* (variety *canadensis*) is eaten by the Common Whitefish.

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*For notes on ecology of *catascopium,* see F. C. Faker, 1911, pp. 387–388.

62. *Galba palustris* (Müller). Fig. 45, No. 43.

This common pond-snail was observed at but one station, a Typha habitat, and was here rare. It doubtless occurs abundantly in swampy ponds and streams in the vicinity of Oneida Lake. Recorded by Beauchamp under the name of *elodes.* It is said to feed on filamentous algæ, desmids, and diatoms, and has been observed eating rotten fruit, decaying vegetables and dead animals, and has been known to attack a living leech. *Palustris* is eaten by the Common Whitefish.

Family Succineidæ.

Genus Succinea Draparnaud.

63. *Succinea avara* Say. Fig. 45, No. 24.

Observed only in the Oneida River on cat-tail leaves (*Typha angustifolia*). Listed by Beauchamp.

64. *Succinea retusa* Lea. Not figured.

Observed only in a pool on Frenchman Island, on leaf of Water Willow (*Dianthera americana*). A species of *Succinea* has been noted in the stomach of the Yellow Perch. *Retusa* is not listed by Beauchamp.

Family Helicidæ.

Genus Polygyra (Say) Pilsbry.

65. *Polygyra thyroides* (Say). Not figured.

This land snail was abundant on Frenchman Island, along the shore near the water, in damp or wet spots. It was observed feeding upon the nettle (*Urtica*). Listed by Beauchamp.

2. Identification by Opercula.

When the stomach contents of fishes are examined it is often noted that the shells of the mollusks are badly broken and unrecognizable, but that the opercula (attached to the foot of the snail and serving to close the aperture of Prosobranchiate mollusks when the animal withdraws into the shell)

TABLE NO. 18. SHOWING DISTRIBUTION OF SPECIES IN ALL HABITATS.

Species (Station / Substation — Character of Habitat)	I-1 Sandy, protected point	I-2 Vegetation, protected bay	II Bouldery, exposed point	III-1 Vegetation, protected bay	III-2C Sandy, partly protected bay	III-2D Sandy, partly protected bay	III-3A Sandy, exposed shore	III-3B Bouldery, exposed shore	IV Bouldery, exposed point	V-1 Bouldery, partly protected bay	VI Vegetation, protected bay	VII-B Vegetation, mouth of creek	VIII Sandy, protected point	IX-B Silty, protected shore	X-B Vegetation, protected bay	XI Bouldery, exposed point	XII Sandy, exposed shore	XIII Sandy, exposed shore	XIV Bouldery, exposed point	XV Bouldery, exposed point
1 *Margaritana margaritifera*																R		R		R
2 *Elliptio complanatus*	C		A			C		C	C	C			C			C	C	C	C	C
3 *Anodonta marginata*																	R			
4 *Anodonta cataracta*								U		C							C			
5 *Anodonta implicata*			C																	C
6 *Anodonta grandis*																				
7 *Anodonta grandis footiana*			C														C			C
8 *Alasmidonta undulata*																				
9 *Strophitus edentulus*																				
10 *Strophitus undulatus*																				
11 *Lampsilis luteola*																		R		
12 *Lampsilis radiata*	C		C					U	C									C		
13 *Lampsilis borealis*																				
14 *Lampsilis iris*																		R		
15 *Nephronaias ligamentina*																				
16 *Sphærium striatinum*																	U			
17 *Sphærium vermontanum*			C		C	C							C	C				C		
18 *Musculium securis*																				
19 *Musculium rosaceum*																				
20 *Pisidium ferrugineum*																				
21 *Pisidium variabile*					C															
22 *Pisidium compressum*						R														
23 *P. compressum* [illegible]					C									C						
24 *Pisidium æquilaterale*																				
25 *Pisidium henslowanum*																				
26 *Pisidium* species					C															
27 *Pisidium* species														U						
28 *Pisidium* species																				
29 *Pisidium* species																				
30 *Vivipara contectoides*																				
31 *Campeloma decisum*																				
32 *Campeloma integrum*					U	U	A						C	C				R		
33 *Gillia altilis*					C	C												C		
34 *Somatogyrus subglobosus*					R												C	C		
35 *Bythinia tentaculata*																	U	C		
36 *Amnicola limosa*																				
37 *Amnicola lustrica*		R			C	R								C	R					
38 *Amnicola lustrica*, variety																				
39 *Goniobasis livescens*			A					A	C	A								C	C	
40 *Valvata tricarinata*																				
41 *Valvata bicarinata normalis*					C															
42 *Physa ancillaria warreniana*		C		C		U	R			C	C	C					U	C	C	
43 *Physa integra*			C															C		
44 *Physa gyrina*												R								
45 *Ancylus tardus*																				
46 *Ancylus fuscus*																				
47 *Ancylus parallelus*															C					
48 *Planorbis trivolvis*		C																		
49 *Planorbis trivolvis*, variety										C								R		
50 *Planorbis binneyi*							C										U		C	
51 *Planorbis antrosus*	C								R								U	R		
52 *Planorbis campanulatus*	C	C		C	C			C	R	C		C	U	C			C	C	C	
53 *Planorbis parvus*																				
54 *Planorbis hirsutus*		U			R			R											C	
55 *Planorbis exacuous*																				
56 *Lymnæa stagnalis lillianæ*							R			R									C	
57 *Pseudosuccinea columella*		C		C								C								
58 *P. columella chalybea*		C																		
59 *Acella haldemani*		A		C											C					
60 *Galba catascopium*			A			U	R	A	C	A			C				C	C		
61 *Galba emarginata*										R						R	R			
62 *Galba palustris*																				
63 *Succinea avara*																				
64 *Succinea retusa*																				
65 *Polygyra thyroides*																				
Total species in each station	4	8	8	4	11	8	5	7	6	9	1	4	5	6	3	3	13	17	7	4

Species (Station / Substation — Character of Habitat)	XVI-1 Creek, stony, running water	XVI-2 Creek, muddy pool	XVII Creek, muddy	XVIII Pond	XIX Sandy, exposed bay	XX Bouldery, exposed point	XXI-1 Bouldery, exposed point	XXI-2 Sandy, partly sheltered bay	XXI-3B Sandy, partly sheltered bay	XXII Bouldery, exposed point	XXIII Bouldery, exposed point	XXIV Vegetation, protected bay	XXV Bouldery, exposed point	XXVI Bouldery, exposed point	XXVII-1 Bouldery, sheltered cove	XXVII-2 Sandy, exposed bay	XXVIII Bouldery, exposed bay	XXIX Sandy, exposed	XXX-1 Silty, protected pool	XXX-2 Bouldery, exposed shore
1 *Margaritana margaritifera*					R															
2 *Elliptio complanatus*			C		A	A	A	A		C	C	C	C	C		A		A	R	A
3 *Anodonta marginata*								R							R					C
4 *Anodonta cataracta*							C	C	R	C				C						C
5 *Anodonta implicata*						C	C	C		C				R						C
6 *Anodonta grandis*				C																
7 *Anodonta grandis footiana*							R	C					U							
8 *Alasmidonta undulata*								1												
9 *Strophitus edentulus*			1																	
10 *Strophitus undulatus*						R														
11 *Lampsilis luteola*							R						R					A		R
12 *Lampsilis radiata*							A						C	C		C				C
13 *Lampsilis borealis*																C				C
14 *Lampsilis iris*						R														
15 *Nephronaias ligamentina*																				1
16 *Sphærium striatinum*									U											
17 *Sphærium vermontanum*					C		R	C		R				U		C				
18 *Musculium securis*																				R
19 *Musculium rosaceum*																				R
20 *Pisidium ferrugineum*																				
21 *Pisidium variabile*					C															
22 *Pisidium compressum*																				
23 *P. compressum* [illegible]					C															
24 *Pisidium æquilaterale*					R															
25 *Pisidium henslowanum*					C															
26 *Pisidium* species																				
27 *Pisidium* species																				
28 *Pisidium* species					R															
29 *Pisidium* species																				
30 *Vivipara contectoides*																				
31 *Campeloma decisum*			A	A																
32 *Campeloma integrum*						R		C								C				
33 *Gillia altilis*																C				
34 *Somatogyrus subglobosus*																C				
35 *Bythinia tentaculata*					C	R									A	C				
36 *Amnicola limosa*					R															
37 *Amnicola lustrica*					A		R		C							C				
38 *Amnicola lustrica*, variety																				
39 *Goniobasis livescens*					R	A	A			C	A		A	A						A
40 *Valvata tricarinata*																				
41 *Valvata bicarinata normalis*																C				
42 *Physa ancillaria warreniana*					R	U	R			R			A	C		C			U	C
43 *Physa integra*															U	R				
44 *Physa gyrina*		C																		
45 *Ancylus tardus*	A																			
46 *Ancylus fuscus*																				
47 *Ancylus parallelus*																				
48 *Planorbis trivolvis*		C													A					
49 *Planorbis trivolvis*, variety																			A	A
50 *Planorbis binneyi*						R														C
51 *Planorbis antrosus*					C	R								R		R				
52 *Planorbis campanulatus*					R	A	R		C			C	A	C		A			U	
53 *Planorbis parvus*																				
54 *Planorbis hirsutus*		C			U		R						U							
55 *Planorbis exacuous*																				
56 *Lymnæa stagnalis lillianæ*						R							A	R			A		C	C
57 *Pseudosuccinea columella*																				
58 *P. columella chalybea*																				
59 *Acella haldemani*																				
60 *Galba catascopium*					A	A	C			A	A		A			A			C	A
61 *Galba emarginata*							R													
62 *Galba palustris*																				
63 *Succinea avara*																				
64 *Succinea retusa*																			R	
65 *Polygyra thyroides*																				
Total species in each station	1	3	3	2	17	13	14	8	4	7	3	2	10	10	4	15	1	2	7	16

Species (Station / Substation — Character of Habitat)	XXXI-1B Vegetation, sheltered bay	XXXI-1C Vegetation, more exposed than B	XXXI-2 Typha, protected shore	XXXI-3 Vegetation, protected shore	XXXI-4 Bouldery, protected shore	XXXII Shore, 20 feet from water	XXXIII Bouldery, exposed shore	XXXIV Sandy, protected shore	XXXV Vegetation, sand, exposed	XXXVI Typha, protected shore	XXXVII Sandy, outlet to river	XXXVIII Oneida River	XXXIX Outlet, dredgings	XL Big Bay, dredgings	XLI Open lake	Other localities for comparison: … Lake, Wisconsin	Isle Royale, Lake Superior	Saginaw Bay, Michigan	Georgian Bay, Ontario
1 *Margaritana margaritifera*							R												
2 *Elliptio complanatus*		U					A		C		C	C			A				x
3 *Anodonta marginata*																x	x	x	
4 *Anodonta cataracta*			1																
5 *Anodonta implicata*																x			
6 *Anodonta grandis*																		x	x
7 *Anodonta grandis footiana*		1														x	x	x	x
8 *Alasmidonta undulata*																			
9 *Strophitus edentulus*																x			
10 *Strophitus undulatus*																			
11 *Lampsilis luteola*											C					x	x		x
12 *Lampsilis radiata*			1				C								C				
13 *Lampsilis borealis*												R			C				
14 *Lampsilis iris*																			
15 *Nephronaias ligamentina*																x			
16 *Sphærium striatinum*																x		x	x
17 *Sphærium vermontanum*		C																	
18 *Musculium securis*		C														x	x	x	x
19 *Musculium rosaceum*																x			
20 *Pisidium ferrugineum*		1																	
21 *Pisidium variabile*		C															x	x	
22 *Pisidium compressum*																		x	
23 *P. compressum* [illegible]		A																	
24 *Pisidium æquilaterale*		R																	
25 *Pisidium henslowanum*		R															x		
26 *Pisidium* species																			
27 *Pisidium* species																			
28 *Pisidium* species																			
29 *Pisidium* species		R																	
30 *Vivipara contectoides*								A	C		A	C							
31 *Campeloma decisum*																x		x	x
32 *Campeloma integrum*		R			1			R			R	C						x	
33 *Gillia altilis*																			
34 *Somatogyrus subglobosus*																			
35 *Bythinia tentaculata*	U	A	3		A				A			C	A						
36 *Amnicola limosa*	R	C									C						x	x	x
37 *Amnicola lustrica*		A			A						C						x	x	x
38 *Amnicola lustrica*, variety		1																	
39 *Goniobasis livescens*								R										x	x
40 *Valvata tricarinata*		A															x	x	x
41 *Valvata bicarinata normalis*		R	1										R					x	
42 *Physa ancillaria warreniana*	R	R			C		C		C		R	1	A	C		x			
43 *Physa integra*		U																x	
44 *Physa gyrina*																x	x	x	x
45 *Ancylus tardus*																			
46 *Ancylus fuscus*	C		A															x	
47 *Ancylus parallelus*					C								U			x		x	x
48 *Planorbis trivolvis*	C	U	A	A								C				x	x	x	x
49 *Planorbis trivolvis*, variety		C																	
50 *Planorbis binneyi*					R		C									x		x	
51 *Planorbis antrosus*		C			R												x	x	x
52 *Planorbis campanulatus*	C	A			U		C	R	C		R	C	C	C		x	x	x	x
53 *Planorbis parvus*		C	C										R			x	x	x	
54 *Planorbis hirsutus*		R			1						R					x	x	x	x
55 *Planorbis exacuous*		R	C														x	x	x
56 *Lymnæa stagnalis lillianæ*	A		U	C			A									x			
57 *Pseudosuccinea columella*																x			
58 *P. columella chalybea*																			x
59 *Acella haldemani*	C																	x	x
60 *Galba catascopium*	R	C			C		C				C	1					x	x	
61 *Galba emarginata*																	x		
62 *Galba palustris*										R								x	x
63 *Succinea avara*												U						x	
64 *Succinea retusa*																x	x	x	
65 *Polygyra thyroides*						C												x	
Total species in each station	9	27	9	2	10	1	8	4	5	1	10	10	6	2	3	20	18	28	21
Total species reported from locality (fresh water)																44	49	84	37
Percentage common to both localities																45	37	33	57

Symbols used. A, abundant; C, common; U, uncommon; R, rare; 1, 3, etc., number of specimens found.

are intact and from these the genera may be distinguished. To aid in the identification of snails by this means the opercula of several genera are figured on this page (fig. 48). The four genera are: 1, *Goniobasis;* 2, *Bythinia;* 3, *Amnicola;* and 4, *Valvata.*

The number of individuals eaten by a fish may often be known by the number of opercula present.

3. Table of Distribution of Species.

In the table at the end of this chapter the 62 species and varieties of fresh water mollusks are so arranged as to indicate their distribution throughout the 54 stations and substations. It will be noted that the habitats producing the largest number of species are those with a *sandy or rocky bottom in an exposed situation.* Of those habitats, having 10 or more species, eight are exposed points or shores where

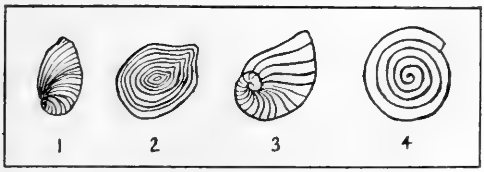

Fig. 48. Opercula of small gastropods, 1, *Goniobasis;* 2, *Bythinia;* 3, *Amnicola;* 4, *Valvata.* All are enlarged.

the number of species ranges from 10 to 17. One is a sandy, protected bay, with 16 species and another has a sandy shore, partly protected, with an abundance of vegetation such as Water Willow, Bulrush and Pickerel-weed, and is inhabited by 27 species. The variation in the number of species found in each habitat is shown on the table and need not be dwelt upon farther.

Comparison is made with four localities outside of the State: Isle Royale, Lake Superior (Walker, 1908), Saginaw Bay, Mich. (H. B. Baker, 1911), Tomahawk Lake, Wis. (F. C. Baker, 1911), and Georgian Bay, Ontario (Robertson, 1915). The number of species common to all five localities are shown and the percentage of the widely distributed species as compared with the total number listed from the locality. It will be noted that only one locality (Saginaw Bay) has a larger number of species (84), exceeding Oneida Lake by 22 species. It is probable that this percentage of difference will entirely disappear when Oneida Lake is more thoroughly searched in locations not reached by the 1915 field work.

4. Mollusks from Fish Hatcheries.

Lists of mollusks collected in or near fish hatcheries are not common. Some years ago, before the present Caledonia hatchery was established, a biological survey was undertaken of Caledonia Creek. The fresh-water mollusks noted are listed below (Lintner, 1878, p. 25):

Limnæa catascopium
Limnæa desidiosa (now *obrussa*).
Limnæa humilis (now *humilis modicella*).
Physa heterostropha.
Planorbis parvus.
Amnicola obtusa (now *Amnicola emarginata*).
Sphærium species.
Pisidium abditum.

It is interesting to compare the mollusks living in Chautauqua Lake with those recorded from Oneida Lake. In 1902 Evermann and Goldsborough (p. 175) published a list of the fishes and mollusks of Chautauqua Lake, 15 in number; all but four of the mollusks live in Oneida Lake. The list is given below, those species represented in the Oneida list being marked with an *:

Campeloma decisum Say.
Valvata tricarinata Say.
Planorbis trivolvis Say.
Planorbis campanulatus Say.
Planorbis bicarinatus Say (now *antrosus* Conrad).
Lymnæa palustris Müller.
Physa ancillaria Say.
Sphærium rhomboideum Prime.
Sphærium striatinum Lamarck.
Sphærium sulcatum Lamarck.
Anodonta grandis footiana Lea.
Unio gibbosus Barnes.
Lampsilis luteola Lamarck.
Strophitus undulatus Say.
Strophitus edentulus Say.

Needham (1901, p. 402) lists three species of snails from Clear Creek, situated at the fish hatchery, Saranac Inn, in the Adirondack mountains.

Physa heterostropha Say.
Galba desidiosa Say.
Sphærium simile Say (=*sulcatum* Lamarck).

Embody, in his interesting paper on "The Farm Fish Pond" (1915, p. 238) recommends the introduction of mollusks into bodies of water used for the culture of fishes. These mollusks appear, from the illustrations, to represent the American species noted below, reading from upper to lower figure. They are all valuable as fish food:

1. *Lymnæa (Galba) palustris* Müller, upper two figures.
   Lymnæa (Galba) humilis modicella Say, lower figure.
2. *Physa gyrina* Say, upper figure.
   Physa integra Hald., middle figure.
   Physa gyrina Say, lower figure.
3. *Campeloma decisum* Say, three figures.
4. *Planorbis trivolvis* Say, upper two figures.
   Planorbis antrosus Conrad, lower two figures.
5. *Sphærium sulcatum* Lam., upper figure.
   Sphærium sp., second figure.
   Sphærium occidentale Prime, fourth figure.
   Musculium securis Prime, third figure.

5. Summary.

The western end of Oneida Lake supports a molluscan fauna embracing 62 species and varieties, very evenly distributed on all shores of the lake and its islands. The studies of the 1915 season cover about one-third of the shore line of the lake. The bouldery points and sandy bays, usually unprotected, are usually the best habitats, although one protected, sandy shore, protected by aerial vegetation, produced the largest number of species, 27. Four types of shells may be noted: The naiades or clams, with 15 species; the small bivalves, Sphæriidæ, with 14 species; the Prosobranchiates, or gill-breathers, with 12 species; and the Pulmonates, or air-breathers, with 21 species. The number of species will probably be largely increased with additional collecting.

CHAPTER VIII. PLANTS AND ANIMALS ASSOCIATED WITH THE MOLLUSCA.

In the study of the mollusks of Oneida Lake the fact, which is really very evident upon reflection, stands out clearly that no one class of animals can be studied intelligently to the exclusion of all others. There is an interrelation between the Mollusca and all other animals, as well as plants, some phases of which have been brought out in the chapters on "Mollusks as Food of Fishes" and "The Enemies of Fresh-water Mollusks." In the field studies, also (Chapter II), it was noted that many animals lived in the same environment and that the vegetation had a most intimate relation to the Mollusca. In the present chapter all of the animals and plants are listed which were noted either in the same station and habitat with the Mollusca, or that were obtained from the stomachs of fishes caught in the west end of the lake. A part of this material has been submitted to competent specialists for identification. These are noted under each group. References to a few notable papers on each group are also made to enable the student to look more closely into the habits and structure of these animals and plants, and their relation to animals of an economic character.

A. PLANTS.

Plants, says Davis (1908, p. 217) "are the organisms which stand between the higher specialized and complicated animal world and the inorganic or mineral kingdom, converting the gases and mineral matter of the latter into substances which can be assimilated by the former. Plants, then, may be termed the primary food of animals, even when these, as is the case with many fish, do not use them directly for food, for, if the history is traced far enough, it will be found that there is one or more vegetable feeding organisms constituting the intermediate from the mineral world to the animal."

In addition to supplying food material, plants perform another office, of nearly equal importance in many ways, that of providing support for animal food organisms, protection for breeding fishes, and a binding medium for the more or less shifting bottom material. As has been well stated by Petersen (1911), Pieters (1901), and J. E. Reighard (1894), the abundance of the larger plants is wholly dependent on the *amount of shallow water in the lake,* and it has been noted that only in the shallow areas, called lake terraces. bordering the shores of the lake, do the plants find sufficient soil for attachment and light and heat for their development. There is an intimate interrelation between plants and this shallow area, the latter forming the necessary depth and soil while the former, with their extensive root system, hold the soil in place and prevent excessive erosion. In Oneida Lake it is noteworthy that there is a wide zone of water, 1 to 6 feet in depth, bordering the shore, which is especially well developed in the western end, and that coincident with this shallow area there is a luxuriant growth of vegetation. The bottom soil is mostly sand or boulders, mud being reduced to a few small spots, and the plants are mostly of the types living in a sandy soil. The development of Bulrushes and Water Willow, therefore, is significant. In Lake Erie, Pieters (1894, p. 15) noted that the plants disappeared when the water reached a depth of fifteen feet, and were scarce in water ten feet deep. The same relation of plants to depth was noted in Oneida Lake. Deep lakes do not have an abundant development of vegetation and so far as the abundance of life is concerned, are comparable to land deserts.

The zonal arrangement of plants in some of the habitats is noteworthy. These are described in Chapter II under Field Stations. The plants listed in the following pages form but a small part of the vegetation living in and about the lake. Those species mentioned are intimately connected with the animal life, hence their selection from among the large number of species present. The majority of the species have been identified by Dr. Wm. L. Bray of the Department of

Botany, Syracuse University and Dr. Harry P. Brown of the College of Forestry. The classification is that of Gray's Manual (Robinson and Fernald, 1908). The relation of the flora to the environment and to the animal life is well discussed by Pieters (1894, 1901), J. E. Reighard (1894), Davis (1908), and Moore (1915).

ALGÆ.

The algæ of the lake were not identified. Two genera were observed *Vaucheria* and *Rivularia*. Some of the algæ found on the shells of mollusks have been submitted to Mr. F. S. Collins for study.

CHARACEÆ.

Chara. Stoneworts, species not determined were plentiful at Stations I, III, XXI, XXIV, XXXV, XXXVI, XXXIX, and XL.

SPERMATOPHYTA.

MONOCOTYLEDONÆ.

Family Typhaceæ.

Typha angustifolia Linn. Narrow-leaved Cat-tail.

Observed at stations I, II, III, IX, X, XXIV, XXXI, XXXVI, XXXVIII.

Family Sparganaceæ.

Sparganium eurycarpum Engelm. Bur-reed.

Observed at stations II, III, IX, XXI, XXIV, XXXI.

Family Najadaceæ.

Potamogeton natans Linn. Floating Pond-weed.

Observed at stations II, III, VI, VII, X, XXIV, XXXV.

Potamogeton perfoliatus Linn. Clasping-leaved Pond-weed.

Stations II, III, V, VII, X, XXIV, XXXV, XXXIX, XL.

Potamogeton heterophyllus Schreb. Various-leaved Pondweed.

Station XXXIX.

FAMILY ALISMACEÆ.

Sagittaria latifolia Willd. Broad-leaved Arrow-head.

Stations II, III, V, VII, IX, X, XXIV, XXX, XXXI, XXXIV, XXXV, XXXVI, XXXVIII.

FAMILY HYDROCHARITACEÆ.

Elodea canadensis Michx. Water Weed.

Stations I,[2] III,[1], VI, X, XXIV, XXXV, XXXIX, XL.

Vallisneria spiralis Linn. Eel Grass, Water Celery.

Stations III, V, X, XXIV, XXXV, XXXIX, XL.

FAMILY GRAMINEÆ.

Spartina cynosuroides (L). Roth. Salt Reed Grass.
Station V.

FAMILY CYPERACEÆ.

Scirpus Smithii Gray. Smith's Bulrush.

Stations II, III, V, IX, XIX, XXX, XXXI.

Scirpus americanus Pers. American Bulrush.

Stations II, III, IV, IX, XII, XIII, XIV, XIX, XXI, XXV, XXVI, XXXI, XXXIII.

Scirpus occidentalis (Wats.) Chase. Lake Bulrush.

Stations I, III, V, VI, VIII, IX, X, XII, XIII, XIX, XX, XXI, XXIV, XXVI, XXXI, XXXIII, XXXV.

Carex trichocarpa Muhl. Sedge.

Stations I, II, III, X, XXX, XXXI, XXXIII, XXXIV. XXXV, XXXVI.

Family Lemnaceæ.

Spirodela polyrhiza (L). Schleid. Greater Duck Weed.
,Observed only at station XXXI.

Family Pontederiaceæ.

Pontederia cordata L. Pickerel-weed.

Stations II, III, V, VI, IX, X, XIX, XXI, XXIV, XXXI.

Family Iridaceæ.

Iris versicolor L. Larger Blue Flag.

Stations XXX, XXXVIII.

DICOTYLEDONÆ.

Family Salicaceæ.

Salix nigra falcata (Pursh) Torr. Black Willow.

Stations III, XIX, XXI.

Family Ceratophyllaceæ.

Ceratophyllum demersum L. Hornwort.

Stations I, III, VI, X, XXIV, XXXV, XXXIX, XL.

Family Nymphæceæ.

Nymphœa advena Ait. Cow Lily.

Stations II, III, VI, VII, X, XXIV, XXXI, XXXV. *Nymphœa americana* (Prov.) M. & S. has been reported from Fish Creek at the eastern end of Oneida Lake, but none were observed in the western end (Miller and Standley, 1912, p. 79).

Castalia odorata (Ait.). Woodville and Wood, Sweet-scented Water Lily. Stations II, III, VI, X, XXIV, XXXI, XXXV. *Castalia tuberosa* (Paine) Green, should also be found in the lake.

FAMILY LYTHRACEÆ.

Decodon verticillatus (L) Ell. Swamp Loosestrife.

Stations II, III, VI, X, XIX, XXX, XXXI, XXXIV, XXXV, XXXVI.

FAMILY HALORAGIDACEÆ.

Myriophyllum spicatum L. Spiked Water Milfoil.

Stations I, III, VI, X, XXIV, XXXV, XXXIX, XL.

FAMILY RUBRIACEÆ.

Cephalanthus occidentalis L. Buttonbush.

Stations II, III, X, XXX, XXXI.

FAMILY ACANTHACEÆ.

Dianthera americana L. Water Willow.

Stations I, III, IV, V, VI, IX, XII, XIII, XIX, XX, XXI to XXVI, XXX, XXXIII to XXXV.

B. ANIMALS.

There are without a doubt a large number of species of Protozoa, principally belonging to the classes Rhizopoda and Infusoria, living in Oneida Lake, but no attempt was made to collect them. The same may be said of the fresh-water sponges (Porifera), several species of which probably occur in this lake. Of the Cœlenterata, the fresh-water *Hydra* without doubt is an inhabitant of the lake but none were observed.

PHYLUM PLATYHELMINTHES.

This group of worms is represented by the free triclads (*Planaria*) belonging to the class Turbellaria, and by the parasitic classes Trematoda and Cestoda, both of which affect the external or internal parts of fishes. Worms of this group were observed in Perch (Field Nos. 145, 309) and in a specimen of the Ling purchased in the Syracuse market.

PHYLUM NEMATHELMINTHES.

Class Nematoda.

This class of worms (represented by the common Round-worm or Hair-worm, *Gordius aquaticus*) are common as parasites, but are also well-known in fresh water as free worms. Such were observed in the intestine of the Chain Pickerel (No. 54 [1]) and the Common Sculpin (No. 23[2]).

PHYLUM MOLLUSCOIDEA.

Class Polyzoa.

To this class belong the animals known as moss animals or bryozoans. They are mostly marine organisms, but a few genera (about seven) live in fresh-water streams and ponds. These belong to the order *Phylactolæmata.* None of the animals were observed but the "winter eggs" or statoblasts of *Plumatella* were common in the stomach of snails (*Lymnæa stagnalis lillianæ*) and in the stomachs of the Common Sucker, Brook Silversides, Rock Bass, and Pumpkinseed. These statoblasts are well figured by Whipple (1899, plate 18, fig. 6) and Stokes (1896, p. 253, fig. 174). A good account of the North American fresh-water group is given by Davenport (1904).

PHYLUM ANNULATA.

Class Hirudinea.

A number of leeches were collected and have been identified by Professor J. Percy Moore. Ten species were obtained, being nearly half of the number recorded from Minnesota (22, Moore, 1912), and nearly as many as recorded from Illinois (11, Moore, 1901). Fifteen species are recorded from the Great Lakes Region (Moore, 1906). The leeches are abundant in Oneida Lake, and special attention given to this group of animals would doubtless add several species to the list herein presented. The leeches are described, and in two cases beautifully figured by Moore (1901, 1906, 1912).

Family Glossiphonidæ.

Glossiphonia stagnalis (Linn.) Johnston.

Station I, habitat 2, on leaves of Water Lily (*Nymphæa* and *Castalia*). Known to feed on *Pisidium*, and itself eaten by the larger leeches, sunfish, perch, and other small carnivorous fishes (Moore, 1912, p. 79).

Glossiphonia fusca Castle.

Station I, habitat 2, on leaves of Water Lily (*Nymphæa* and *Castalia*). Said to live almost exclusively on the smaller snails. It frequently attaches itself to the shells of *Lymnæa* and other large snails (Moore, 1912, p. 81).

Glossiphonia complanata (Linn.) Johnston.

Station III, habitat 3, under stones. This species is known as the snail leech, and feeds on small snails, worms, etc.

Placobdella parasitica (Say) Moore.

Station VII, on the back of turtles (Snapping Turtle and Painted Terrapin) upon the blood of which it feeds. At station XXXIII it was found on stones near shore.

Placobdella rugosa (Verrill) Moore.

Station III, habitat 3, clinging to stones.

Placobdella phalera Graf.

Young leeches thought to be this species were collected at station XXI, habitat 2.

Placobdella picta Verrill

Station I, habitat 2, and station XL, in submerged vegetation.

Family Hirudinidæ.

Hæmopis marmoratis (Say) Moore.

Stations XXXIII and XXIII, on rocks and debris on shore at edge of water. In Maple Bay, Adams and Hankinson found this leach on dead catfish which had been killed by the Lamprey Eel, the leeches being on and inside of the injured spot. This leech, known as the Horse Leech, besides being a scavenger, eats earthworms, insects, mollusks, etc., as well as large quantities of mud containing organic matter (Moore, 1912, p. 112).

Hæmopis grandis (Verrill).

This largest of American leeches was found in a rowboat at Brewerton by Adams and Hankinson. It is known to feed on snails.

Family Erpobdellidæ.

Erpobdella punctata (Leidy) Moore.

Station I, habitat 2, station III, habitat 2, and station XXX, habitat 2, on vegetation and on stones near the shore (station XXX).

PHYLUM ARTHROPODA.

Class Crustacea.

SUBCLASS ENTOMOSTRACA.

Entomostraca are abundant in the plankton of Oneida Lake. As has already been stated no attempt was made in 1915 to study the plankton, and the following list is based on the stomach contents of fishes caught in the lake. Species listed in the report of the Conservation Commission (see Bean, 1914, p. 352) from the ponds of the Oneida hatchery at Constantia, named by Mr. A. A. Doolittle, are also included.

It is interesting to note the relative abundance of these Entomostraca in the hatchery pond. These were counted by Mr. Doolittle and his results are noted below:

Cyclops ater	2 in vial,	0.045 per cent of whole
Cyclops serrulatus	2 in vial,	0.045 per cent of whole
Sida crystallina...............	3 in vial,	0.068 per cent of whole
Simocephalus vetulus	3 in vial,	0.068 per cent of whole
Scapholeberis mucronata	1565 in vial,	35.712 per cent of whole
Bosmina obtusirostris	2 in vial,	0.045 per cent of whole
Chydorus sphæricus	5 in vial,	0.114 per cent of whole
Polyphemus pediculus	2800 in vial,	63.900 per cent of whole
Totals.................	4382 in vial,	99.997 per cent of whole

It was noted that 50 young Small-mouthed Black Bass ate one per cent. of *Scapholeberis.*

ORDER PHYLLOPODA.

SUBORDER CLADOCERA.

FAMILY SIDIDÆ.

Sida crystallina Mueller. Oneida hatchery ponds (Bean, 1914, p. 352).

FAMILY DAPHNIDÆ.

Daphnia hyalina Leydig. From stomach of Perch.

Simocephalus vetulus Mueller. Oneida hatchery ponds. (Bean, p. 352).

Scapholeberis mucronata Mueller. Oneida hatchery ponds. (Bean, p. 352).

FAMILY BOSMINIDÆ.

Bosmina obtusirostris Sars. Oneida hatchery ponds (Bean, p. 352).

Bosmina longirostris Mueller. From stomachs of Perch, Brook Silversides, and Golden Shiner.

FAMILY LYNCEIDÆ.

Alona species. From stomachs of Common Sucker, Common Bullhead, Pumpkinseed and Manitou Darter.

Chydorus sphæricus Mueller. Oneida hatchery ponds (Bean, p. 352).

SUBORDER GYMNOMERA.

FAMILY POLYPHEMIDÆ.

Polyphemus pediculus Linn. Oneida hatchery ponds (Bean, p. 352).

FAMILY LEPTODORIDÆ.

Leptodora hyalina Lilljeborg. In stomach of Tullibee.

The individuals in the stomach of this whitefish were very large and the fish had eaten almost entirely of this one species. The Tullibee, judging by the contents of this stomach, takes its food from near the surface, at least at some seasons. Determined by Dr. C. D. Marsh.

ORDER COPEPODA.

The copepods were determined by Dr. C. D. Marsh.

FAMILY CALANIDÆ.

Epischura lacustris Forbes. From stomach of Yellow Perch. One male and one female were represented.

FAMILY CYCLOPIDÆ.

Cyclops ater Herrick. Oneida hatchery pond.

Cyclops serrulatus Fischer. Oneida hatchery pond.

Cyclops strenuus Fischer. From stomachs of Manitou Darter and Tessellated Darter.

Cyclops vividis Jurine. From stomach of Manitou Darter.

Cyclops, species not identified, were noted in the stomachs of the Common Sucker, Common Bullhead and Pumpkinseed. *Cyclops strenuus* provides the second record for America, the first being at Axton, New York, where it was collected by Dr. B. W. Evermann, in Rock Pond, on April 30 (Marsh, 1912, p. 253). It is known to be a cold water form, and the fish from which it was taken was collected by Dr. C. C. Adams, on October 12, 1915, in shallow water.

Family Harpacticidæ.

Canthocamptus northumbricus Brady. From stomach of Manitou Darter.

Canthocamptus staphylinus Claus. From stomach of Manitou Darter.

The various groups of Entomostraca are more or less extensively treated, and illustrated, in the following papers, the full references of which will be found in the bibliography: Herrick and Turner, 1895; Marsh, 1895, 1910; Birge, 1895. 1897; Forbes, 1897; Sharpe, 1903.

Class Malacostraca.

ORDER DECAPODA.

SUBORDER MACRURA.

Family Astacidæ (Crawfishes).

The crawfishes were determined by Dr. A. E. Ortmann.

Cambarus bartoni robustus (Girard).

Young and half-grown specimens were common at station XVI. These were males and females of the II form. Found also in the stomachs of Pickerel and Ling. This is apparently the first record of this race from Oneida Lake. Typical *bartoni* is a form living in small streams and springs, but the race *robustus* prefers creeks, and larger streams. In Lake Huron and Georgian Bay it is found in the lake, in situations similar to those of Oneida Lake.

Cambarus propinquus Girard.

Young specimens, mostly males of the I form were common at station III, habitats 2 and 3, and stations XVI, XX and XXXIII. This species was also found in the stomach of the Ling. The remains of crawfishes, either *propinquus* or *bartoni robustus,* were noted in the stomachs of the Rock Bass, Yellow Perch, Manitou Darter, Pickerel, and Horned Dace. Both species were abundant under and among stones and boulders. The crawfishes are described and figured by Ortmann (1905, 1906), Faxon (1885, 1898), and Pearse (1910).

ORDER ARTHROSTRACA.

SUBORDER AMPHIPODA.

The amphipods were determined by Miss Ada L. Weckel.

FAMILY GAMMARIDÆ.

Gammarus fasciatus Say.

Stations XXXIX and XL. From stomachs of Manitou Darter and Tessellated Darter.

Hyalella knickerbockeri (Bate).

Stations X, XVI. From stomachs of Golden Shiner, Common Bullhead, Rock Bass, Pumpkinseed, Yellow Perch, Manitou Darter and Tessellated Darter. An account of the freshwater amphipods will be found in Weckel's paper (1907).

SUBORDER ISOPODA.

FAMILY ASELLIDÆ.

Asellus aquaticus (Linn).

From stomach of Tessellated Darter. Fragments of an *Asellus* were observed in the Pumpkinseed. This *Asellus* is large and agrees with the description and figures of *aquaticus* (Richardson, 1905, p. 430).

CLASS HEXAPODA (Insects).

ORDER EPHEMERIDA (May-flies).

The *Ephemerida, Odonata* and *Plectoptera* were determined by Dr. J. G. Needham.

FAMILY EPHEMERIDÆ.

Hexagenia bilineata Say.

The nymphs of this May-fly were observed in the stomachs of the Common Red-horse and Yellow Bullhead. A good figure of this and other May-fly larvæ may be seen in Clemens (1915, plate XV, fig. 1). See also Needham (1901, p. 418).

Ephemerella species.

Several nymphs of this genus were obtained from the stomach of the Manitou Darter.

Ephemera species.

Nymphs of this genus were observed in the stomach of the Manitou Darter.

Cænis species.

Nymphs of this species were obtained from the stomachs of the Manitou Darter and the Chain Pickerel.

Callibætis species.

Several nymphs were observed in the stomach contents of the Painted Terrapin and the Chain Pickerel.

ORDER ODONATA (Dragon-flies).

FAMILY AGRIONIDÆ (Damsel-flies).

Enallagma signatum Hagen.

Nymphs of this species were obtained at station XL.

Enallagma species.

Nymphs of several species of this genus were observed at stations XVI,[1] XXX,[1] and XXXIX. Also in the stomachs of the Painted Terrapin, Chain Pickerel, and Manitou Darter.

FAMILY ÆSCHNIDÆ.

Gomphus sordidus Hagen.

Collected from stations IX, and XXX.[1] All nymphs.

Basiæschna janata Say.

Nymphs of this species were secured at station I.[2]

Æschna species.

Nymphs were secured from station XXX.[1]

Æschna species.

Nymphs were secured from station XIX.

Anax junius (Drury) Selys.

Nymphs of this dragon-fly were obtained from the stomach of the Painted Terrapin.

Good accounts of the Odonata, as well as other fresh-water insects, will be found in Needham, 1901 and 1903.

FAMILY LIBELLULIDÆ.

Tetragoneuria cynosura Say.

Two specimens of this species were obtained from station I.[2]

Fragments of both dragon-fly and damsel-fly nymphs were noted in the stomach contents of the Common Perch.

ORDER PLECOPTERA (Stone-flies).

FAMILY PERLIDÆ.

Perla species.

Several nymphs of a species of this genus were obtained at station XVI.

Acroneuria species.

Nymphs were obtained at station XVI in company with the last species.

ORDER HEMIPTERA (Bugs).

The Hemiptera were determined by Mr. W. J. Gerhard.

FAMILY CORIXIDÆ (Water-boatmen).

Corisa undulata Say.

This common water-boatman was observed in several of the protected bays among the water plants.

Corisa species. From stomach of Painted Terrapin.

FAMILY NOTONECTIDÆ (Back-swimmers).

Notonecta undulata Say.

Station XXX, habitat 1, common.

Plea striola Fab. From stomach of Painted Terrapin.

FAMILY NEPIDÆ (Water-scorpions).

Ranatra species.

Observed in Nicholson Bay, in the submerged vegetation.

FAMILY BELOSTOMIDÆ (Giant Water-bugs).

Belostoma flumineum Say. Nymph.

Station XXX, habitat 1, rare.

FAMILY GERRIDÆ (Water-striders).

Gerris buenoi Kirk.

Station XXX, habitat 1, common.

ORDER TRICHOPTERA (Caddis-flies or Caddis-worms).

The caddis-flies were determined by Dr. C. Betten. The long tubes and spiral cases of the larval stages of these interesting insects were abundant in nearly all parts of the lake. Upwards of ten species, of five families, are represented. See Betten (1901, p. 561) and Needham (1908, p. 252) for accounts of the members of this order.

FAMILY LIMNEPHILIDÆ.

Neophylax species.

Empty cases were common at station XVI.

Platycentropus maculipennis (Kol.).

Station XXXI, habitat 1, B. Several empty cases from station IX are referred to this family.

Family Sericostomatidæ.

Helicopsyche borealis Hagen. Fig. 45, No. 44.

Common at stations II, III, IV, V, X, XII, XVI, XIX, XXI, XXII, XXX, habitat 2, and station XXXI. It has been noted in the stomach of the Pumpkinseed.

This caddis-fly larva forms a spiral case in form so nearly like the shell of a mollusk as to have deceived such expert conchologists as Lea and Bland. Many years ago Lea (1834, p. 104) described the hard case of this insect as *Valvata arenifera,* supposing it to be a mollusk and remarks that "It has the singular property of strengthening its whorls by the agglutination of particles of sand, etc., by which it is entirely covered." The spiral case and the habit of clinging to rocks like the Valvatas perhaps explains, in a measure, the error of the early students. They are to-day frequently mistaken for snails by amateurs and laymen. This interesting case is discussed at length by Bland (1865, p. 144).

Family Hydroptilidæ.

Hydroptila species.

Station IX, small kidney-shaped case, not common.

Family Leptoceridæ.

Molanna species.

Characteristic larval cases were collected at stations XIX, and XXXI, habitat 1, c.

Oecetis resurgens Walker.

A few specimens were secured at station XXXIX.

Leptocella species.

The long, slender, larval cases of this caddis-fly were common at stations II, VIII, XII, XIX, XXXI, habitat 1, B, 1, C, 4, stations XXXIX, XL. It has been found in the stomach of the Golden Shiner.

Leptocerus species.

A large empty case of this genus was found at station IX.

Family Hydropsychidæ.

Polycentropus species.

Observed at stations XXXIX and XL.

Phylocentropus species.

One slender sand tube was found at station XIX.

Order Lepidoptera (Butterflies and Moths).

Family Pyralidæ.

Nymphula sp. (= *Paraponyx*).

The specimens from Oneida Lake were folded in the leaves of *Potamogeton natans*. They were collected at stations X and XL. The larva of *Bellura melanopyga* (Grote) (Noctuidæ) departs radically from the habits of the larvæ (caterpillars) of other members of the order. The eggs are probably laid on a pond lily leaf which the newly hatched caterpillars proceed to mine and feed upon. The last aquatic period (petiole period) is passed in the petiole of the leaf. Sunfish are said to feed upon this larvæ when the latter is swimming on the surface of the water (Welch, 1914, p. 112). Determined by Dr. P. S. Welch.

Order Diptera (Flies).

Family Chironomidæ (Midges).

Chironomus species.

Larvæ and pupæ of species of this genus were in the stomachs of the Manitou Darter and the Chain Pickerel.

Family Culicidæ (Mosquitos).

Corethra species.

Larvæ of this genus were found in the stomach of the Chain Pickerel.

Mr. John R. Malloch, of Urbana, Illinois, is at work on the larval Diptera obtained from the stomachs of fishes, and the result of his studies will be published in a later paper. In the percentages the small flies are given provisionally as "chironomid larvae." The papers by Malloch, Needham and Johannsen, listed in the bibliography, contain a large amount of information on these insects, so important as food for many fishes.

ORDER COLEOPTERA (Beetles).

The Coleoptera were identified by Mr. W. J. Gerhard.

FAMILY DYTISCIDÆ (Predaceous Diving-beetles).

Laccophylus maculosus Germ.
Station XXX, habitat 1.

Hydrovatus pustulatus Mels. From stomach of Painted Terrapin.

FAMILY GYRINIDÆ (Whirligig-beetles).

Gyrinus ventralis Kirby.
Very common at station IV.

Dineutes hornii Roberts.
Station I.

Dineutes assimilis Aube.
Station IV.

Gyrinid larvæ.
Station XIII.

FAMILY HALIPLIDÆ.

Cnemidotus sp.
Larva from stomach of Painted Terrapin.

FAMILY HYDROPHILIDÆ (Water-scavenger Beetles).

Tropisternus glaber Herbst.
Stations XVI, common; XXX, habitat 1, common.

Philhydrus cinctus Say.
Station XXX, habitat 1, common.

FAMILY PARNIDÆ (Water-penny Beetles).

Psephenus lecontei Lec.

The larva of this beetle lives on stones in running water and on exposed shores subject to violent wave action. It was very abundant at stations XVI, XXX, habitat 2, and station XXXIII.

SUMMARY.

The study of the biota associated with the Mollusca indicates that the various groups represented are fully as well developed as is the Mullusca. Comparisons of groups cannot be made at this time as in the majority of cases only such species were collected as were observed while collecting mollusks. The number of leeches (10) and caddis-flies (10) is noteworthy, indicating an unusually large development of these groups. The use of Entomostraca as well as the larvæ of flies and May-fly and dragon-fly nymphs in large numbers by fishes as food indicates a great abundance of these animals. Seventy-seven aquatic species are recorded, but this number will without doubt be very largely increased when systematic search is made. A rich harvest of invertebrate life awaits the student who can give the time necessary for its collection and study.

CHAPTER IX. SUMMARY AND CONCLUSIONS.

The facts brought out in the study of the 1915 field work may be summarized as follows:

I. Oneida Lake is the largest body of inland water wholly within the State of New York. It is very shallow, the maximum depth being 55 feet, and its origin is different from that of the finger lakes, which are upwards of 600 feet in depth and occupy ancient, rock-cut river valleys. A shallow area borders the shore of Oneida Lake, approximating 4,349 acres in extent. It varies from 200 to 1600 feet in width and from 2 to 6 feet in depth. Within the 12-foot contour is an approximate area of 8,343 acres which affords breeding and feeding grounds for fish.

II. The shallowness of the lake is coincident with a luxuriant growth of shoreward vegetation which in turn affords food and lodgement for a host of bottom-inhabiting animals, such as insects, mollusks, crustaceans, and leeches.

III. The bottom of the shallow area bordering the shore is composed of sand, gravel or boulders, mud being confined to a few small isolated spots. The habitats are divisible into *three* main types; bouldery, mostly on exposed points; sandy, usually in bays more or less protected; and vegetation covered, the latter being in sheltered and protected bays.

IV. A rich and varied molluscan fauna is present, is widely distributed, and includes upwards of 62 species and varieties, forming an animal population excelled in number of species and abundance of individuals by but few other American lakes. Thirty-three species of gastropods (snails) and 29 species of pelecypods (bivalves) are represented.

V. There was found to be an abundant supply of fish food of all kinds, including Entomostraca, insects and insect larvæ, crawfish, in addition to mollusks. The examination of the stomach contents of 130 fishes add new information on the food of these animals. The fact of the change of food habits coincident with growth, first elaborated by Forbes, was clearly indicated by the examination of fishes of various ages, from infancy to maturity. Of the 41 species of fish in the lake, 18 are mollusk-eaters, more or less, or about one-half. The Pumpkinseed consumes mollusks to the extent of 66 per cent., the Common Sucker 30 per cent., and the Yellow Perch 10 per cent. The fishes naturally divide themselves into types characteristic of certain feeding habits: as bottom-feeders, eating mollusks, insects and other animals inhabiting this region, and plankton-eaters, including nearly all young fish and some adults, taking the food near the surface or in the water above the bottom. This analysis may be carried further to include peculiarities of food, as mollusk-eaters, insect-eaters, plankton-eaters, fish-eaters, plant-eaters, mud-eaters, scavengers, and lastly those which are omnivorous.

VI. A summary of our knowledge concerning the use of mollusks as food by fish shows that 46 out of 225 (about one-fifth) species of fresh-water fishes inhabiting New York and Illinois consume mollusks more or less, the ratios running from 1 to 100 per cent., and being 31.50 per cent. for 25 of the most important food and game fishes. Several valuable food and game fishes, as the pike, feed upon other mollusk-eating fishes which are of themselves of little direct value, but which become economically valuable when they furnish food for these valuable food and game fishes. This indirect molluscan food supply forms 15 per cent. or about one-sixth of the food of the important fish-eating food and game fishes.

VII. It was found that representatives of nearly all classes of animals prey upon mollusks, thus entering into competition with the mollusk-eating fishes for the food supply. It is noteworthy that many of these predatory animals, as insects and leeches, form the food of fishes, thus again indicating the interrelation between the different forms of life in the lake.

Fig. 49. A flat-bottomed dredging boat rigged with two crowfoot dredges, with typical fisherman, McGregor, Iowa. Note the shore strewn with dead shells. This is an example of the waste of raw material which has now largely ceased following the educational movement inaugurated by the U. S. Bureau of Fisheries through the biological station at Fairport, Iowa. Photograph by Frank M. Woodruff.

Fig. 50. Summer Fleld Laboratory at the outlet near Brewerton.

VIII. Provisional quantitative studies on the amount of mollusk food present in the lake were made by counting the number of individuals in a unit area about one foot square. The number ranged from 4 to 163. In the thick vegetation in the outlet to the Oneida River an area of fifty-five acres was estimated to contain 435 million individuals of the small snail *Bythinia tentaculata*, which is eaten by the Pumpkinseed and possibly by other fishes.

IX. The layer of dead organic matter covering the bottom, described by Petersen as the dust-fine detritus, is believed to furnish food for a number of mollusks, and possibly some fish (see Forbes, 1888, b, p. 491, mud-eaters) such as Pumpkinseed, suckers and catfishes, which are bottom feeders. This material is said by Petersen (1911, p. 27) to form a large proportion of the organic substance held in suspension in the water and is probably used, together with the protophyta, to a greater extent than the animal plankton by the pelecypods or clams. Its use by some snails and other animals cannot be doubted.

Conclusions.

The point which stands out clearly, after completing the studies outlined in the previous pages, is that to understand the fish life of any body of water it is absolutely necessary to know the entire fauna and flora of this body of water and the relation of the biota to the fish under investigation. This point of view was clearly indicated by Forbes over thirty-five years ago (1880, p. 18) when he stated that "Nowhere can one see more clearly illustrated what may be called the *sensibility* of such an organic complex — expressed by the fact that whatever effects any species belonging to it, must speedily have its influence of some sort upon the whole assemblage. He will thus be made to see the impossibility of studying any form successfully out of relation to the other forms — the necessity for taking a comprehensive survey of the whole as a condition to a satisfactory understanding of any part. If one wishes to become acquainted with the black bass, for example, he will learn but little if he limits himself to that species. He must evidently study also the species upon which it depends for its existence, and the various conditions upon which *these* depend. He must likewise study the species with which it comes in competition, and the entire system of conditions affecting their prosperity. Leaving out any of these, he is like one who undertakes to make out the construction of a watch, but overlooks one wheel; and by the time he has studied all these sufficiently, he will find that he has run through the whole complicated mechanism of the aquatic life of the locality, both animal and vegetable, of which his species forms but a single element."

"In such a general survey of the plants and animals of a region, the study of their food relations will be found to afford an admirable objective point. Doubtless, of all the features of the environment of an individual, none affect it at the same time so powerfully, so variously and so intimately as the elements of its food. Even climate, season, soil, and the inorganic circumstances generally, influence an animal through its food quite as much as by their direct action. It is through the food relation that animals touch each other and the surrounding world at the greatest number of points, here they crowd upon each other the most closely, at this point the struggle for existence becames sharpest and most deadly; and, finally, it is through the food relation almost entirely that animals are brought in contact with the material interests of man. Both for the student of science and for the economist, therefore, we find this subject of peculiar interest and value. It includes many of the most important relations of a species, and may properly be made the nucleus about which all the facts of its natural history are gathered."

If the statement of Forbes be true, and all who have studied the subject even slightly will assuredly agree that it is, then there is a large amount of work still to be done before our knowledge of the food habits of fishes is complete. There are many species the food of which is unknown, and of those species that have been given some study much remains to be learned. A fact brought out in the chapter on "Mollusks as Food of Fishes" was that a species may feed upon a class of animals, as the mollusks, in one body of water and the same species may prefer a totally different kind of animals, as the Entomostraca, in another body of water. The food of the Common Whitefish in the Charlevoix region and in Walnut Lake is an example of this variation in food habits.

It is the culture of these animals that demands the greatest amount of reliable information. In the past some of the fish culture has been haphazard, fish fry and fingerlings being introduced into bodies of water without knowing whether the natural conditions were favorable or the food supply sufficient and of the right variety for their growth and multiplication. Before a planting is undertaken, it would seem the part of wisdom to know the food habits of the fish to be introduced and the general biology of the aquatic medium into which the fishes are to be placed. Thus we should know that the body of water contains plants for protection and suitable grounds for breeding, food sufficient in quantity and of the right kind, and the presence or absence of natural enemies which might seriously affect the increase of the planted fish. In other words there must be as nearly as possible a balance between the vegetation — the fish — and the food supply. Fish will be present and will persist in a body of water in proportion as the food supply is abundant or meagre and as the enemies are abundant or few in number. This interrelation and interdependence of animals, as regards their food, is illustrated by the appended tables showing the food of several familar fishes (see end of chapter). The primitive food of all animals is the inorganic matter in solution in the soil, water or air, which the plants convert into available food for animals, which are either herbivorous or carnivorous. The microscopic plants and the dust-fine detritus form the basal food which is eaten by a host of small animals — Protozoa, Rotifera, Crustacea, and Mollusca. The protophyta and detritus increases with marvelous rapidity under favorable conditions and are thus able to form an extensive food supply. All animals may be divided into producers and consumers, the former including those animals that feed on the detritus, the protophyta and the higher plants, and the latter consisting of all predatory animals, which include the majority of fishes. From the limited studies made in 1915 it would seem that there is an adequate food supply sufficient to support a large animal population, and as the lake is free from extensive sewage and chemical pollution it is favorable for the propagation and growth of an extensive fish fauna.

Suggestions for Further Study of the Lake.

There should be made a series of year-round observations on the aquatic life of Oneida Lake. These should be by months and should include the winter season as well as the more favorable summer, spring and fall seasons. That the fish life in the lake is more or less active through the winter season is known, but what these animals use for food is not well known. Little is known concerning the winter habits of the bottom fauna. How do the mollusks spend the winter? *Campeloma, Goniobasis, Amnicola,* and some of the clams are believed to burrow in the bottom. But in the Mississippi River, the mussel fishermen gather clams all winter and the mussels are apparently in an active condition. *Physa, Lymnæa,* and other snails have been seen active in brooks and streams when the surface of the water was frozen over. Winter studies would be of great interest and value.

The biological survey, especially as it relates to the Mollusca, should be extended to cover the shallow area around the center and east end of the lake. Dredgings should also be made in the deeper parts of the lake with the crowfoot and other dredges (Figs. 49, 50). Quantitative studies of the food supply should be conducted by the Petersen method as outlined in Chapter III. Experiments should be made to ascertain the rate of consumption of the food supply by mollusks and other animals. A large number of examinations of the stomach contents of fish should be made,* and if possible, the amount of food taken per day should be ascertained. To accurately determine the relation between the amount of food and its rate of consumption by fishes some exact data of this kind is necessary.

The study of a body of water such as Oneida Lake brings out certain fundamental facts of great significance, which have nowhere been better stated than by Forbes in an address printed many years ago (1887, p. 1), and his terse description may fittingly close this report. "The animals of such a body of water are, as a whole, remarkably isolated,—closely related among themselves in all their interests, but so far independent of the land about them that if every terrestrial animal were suddenly annihilated, it would doubtless be long before the general multitude of the inhabitants of the lake would feel the effects of this event in any important way. One finds in a single body of water a far more complete and independent equilibrium of organic life and activity than on any equal body of land. It is an islet of older, lower life in the midst of the higher, more recent life of the surrounding region. It forms a little world within itself,— a microcosm within which all the elemental forces are at work and the play of life goes on in full, but on so small a scale as to bring it easily within the mental grasp."

* In this connection it may be said that fish caught in fyke or trammel nets are usually worthless for study if allowed to remain in the net too long, digestion having proceeded to such an extent before they are released that the food contents are almost wholly unrecognizable.

Food Tables of Four Common Fishes.

In these tables only the commonest food species are listed to illustrate the interdependence of all organisms. A complete list of all food interrelations of a single species would occupy several pages. Table 23, illustrating the principal food relations of aquatic organisms, is modified from that of Forbes (1914). Suggestions for tables 19–22 have been received from the food table by J. E. Reighard (1894, page 24).

TABLE NO. 19. SHOWING INTERRELATION OF FOOD OF PICKEREL (*Esox reticulatus*).

Primary food.	*Plants.*		*Intermediate food.*		*Immediate food.*
Minerals in soil and water H_2O CO_2	....		Plants		*Cambarus.*
	Algæ Higher plants	Chironomid larvæ	Caddis-fly larvæ Worms Insects	....	*Cambarus.*
	Detritus.......	Chironomid larvæ..			May-fly nymphs. Damsel-fly nymphs
		....			Chironomid larvæ.
	Higher plants Algæ Detritus	....	Chironomid larvæ Mollusks	....	Dragon-fly nymphs
	Algæ..........	Copepods..			Young fish.
	....		Plants	Crawfishes Worms	Frog.
	Higher plants Algæ Detritus	Chironomid larvæ	Caddis-fly larvæ Worms Insects	Crawfishes Worms	Frog.
		Chironomid larvæ, etc..................		Insect-larvæ	Frog.
		....		Mollusks (snails)	Frog.
	Algæ..........	Entomostraca........................		Fishes (young)	Frog.
	....			Algæ	Frog.

TABLE NO. 20. SHOWING INTERRELATIONS OF FOOD OF YELLOW PERCH (*Perca flavescens*) ADULT AND YOUNG.

Primary food.	*Plants.*	*Intermediate food.*		*Immediate food.*
Minerals in soil and water H_2O CO_2	Algæ			*Amnicola.*
	Algæ Detritus			*Musculium.*
	Higher plants Detritus Algæ	Chironomid larvæ	Plants Caddis-fly larvæ Worms Insect larvæ	*Cambarus.*
	Algæ	Entomostraca		Small fish.
	Algæ			Entomostraca.
	Higher plants Detritus Algæ			Chironomid larvæ.
	Algæ Detritus Higher plants	Entomostraca Chironomid larvæ Ephemeridæ		Young fish.

TABLE NO. 21. SHOWING INTERRELATIONS OF FOOD OF PUMPKINSEED (*Eupomotis gibbosus*)

Primary food.	*Plants.*	*Intermediate food.*	*Immediate food.*
Minerals in soil and water H_2O CO_2	Filamentous algæ Desmids Diatoms Higher plants		*Mollusca*, gastropods. *Bythinia tentaculata.* *Amnicola lustrica.* *Amnicola limosa.* *Valvata tricarinata.* *V. bicarinata normalis.* *Planorbis exacuous.* *Planorbis antrosus.*
	Algæ Detritus		*Mollusca*, pelecypods. *Pisidium* species. *Sphærium vermontanum.*
	Algæ	Copepoda	*Crustacea*, amphipod. *Hyalella knickerbockeri.*
	Algæ		*Insects*, caddis-fly. *Helicopsyche borealis.*
			Plants. *Vallisneria spiralis.*
	Algæ	Entomostraca	Young Fish.

TABLE NO. 22. SHOWING INTERRELATIONS OF FOOD OF ADULT SUCKER (*Catostomus commersonii*).

Primary food.	*Plants.*	*Intermediate food.*	*Immediate food.*
Minerals in soil and water H_2O CO_2	Filamentous Algæ Desmids Diatoms Higher plants		*Mollusca*, gastropods. *Valvata tricarinata.* *Amnicola limosa.* *Galba catascopium.*
	Algæ Detritus		*Mollusca*, pelecypods. *Pisidium henslowanum.* *Sphærium vermontanum.*
	Detritus Decaying vegetation	Chironomid larvæ	*Hexapoda*, insects. Chironomid larvæ. *Hexagenia* nymph.
	Algæ		*Helicopsyche borealis.*
	Detritus Algæ, higher plants	Chironomid larvæ Mollusks, snails	Odonata nymphs.
	Algæ		*Bryozoa.* *Plumatella* statoblasts.
			Mud and plants.
	Algæ	Copepoda, Isopoda	*Hyalella.*
	Algæ, detritus		Entomostraca.

TABLE NO. 23. PRINCIPAL FOOD RELATIONS OF AQUATIC ORGANISMS.*
(Adapted from Forbes.)

	Mineral compounds.	Detritus.	Bacteria.	Algæ.	Higher plants.	Protozoa.	Rotifers.	Entomostraca.	Worms.	Crawfishes.	Insects.	Mollusks	Fishes.	Frogs and Tadpoles.	Salamanders.	Turtles.	Serpents.	Birds.	Mammals.
Bacteria	x																		
Algæ	x																		
Higher plants	x																		
Protozoa		x	x	x		x	x												
Rotifers		x	x	x		x		x											
Entomostraca		x	x	x		x	x	x					x						
Worms		x	x	x		x		x		x		x	x						
Crawfishes		x			x				x	x	x	x	x	x					
Insects		x	x	x	x			x	x		x	x	x	x					
Mollusks		x	x	x	x	x	x					x							
Fishes		x	x	x	x	x	x	x	x	x	x	x	x	x	x				
Frogs				x					x	x	x	x	x	x					
Turtles		x			x			x	x		x	x	x	x				x	
Serpents										x	x	x	x	x					
Birds					x				x	x	x	x	x	x	x		x		
Mammals					x				x	x	x	x	x	x			x	x	x
Man					x					x			x	x		x		x	x

*Food eaters in the right-hand column. Food eaten in the upper column.

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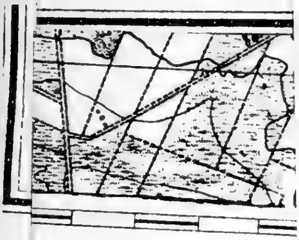
INDEX



58

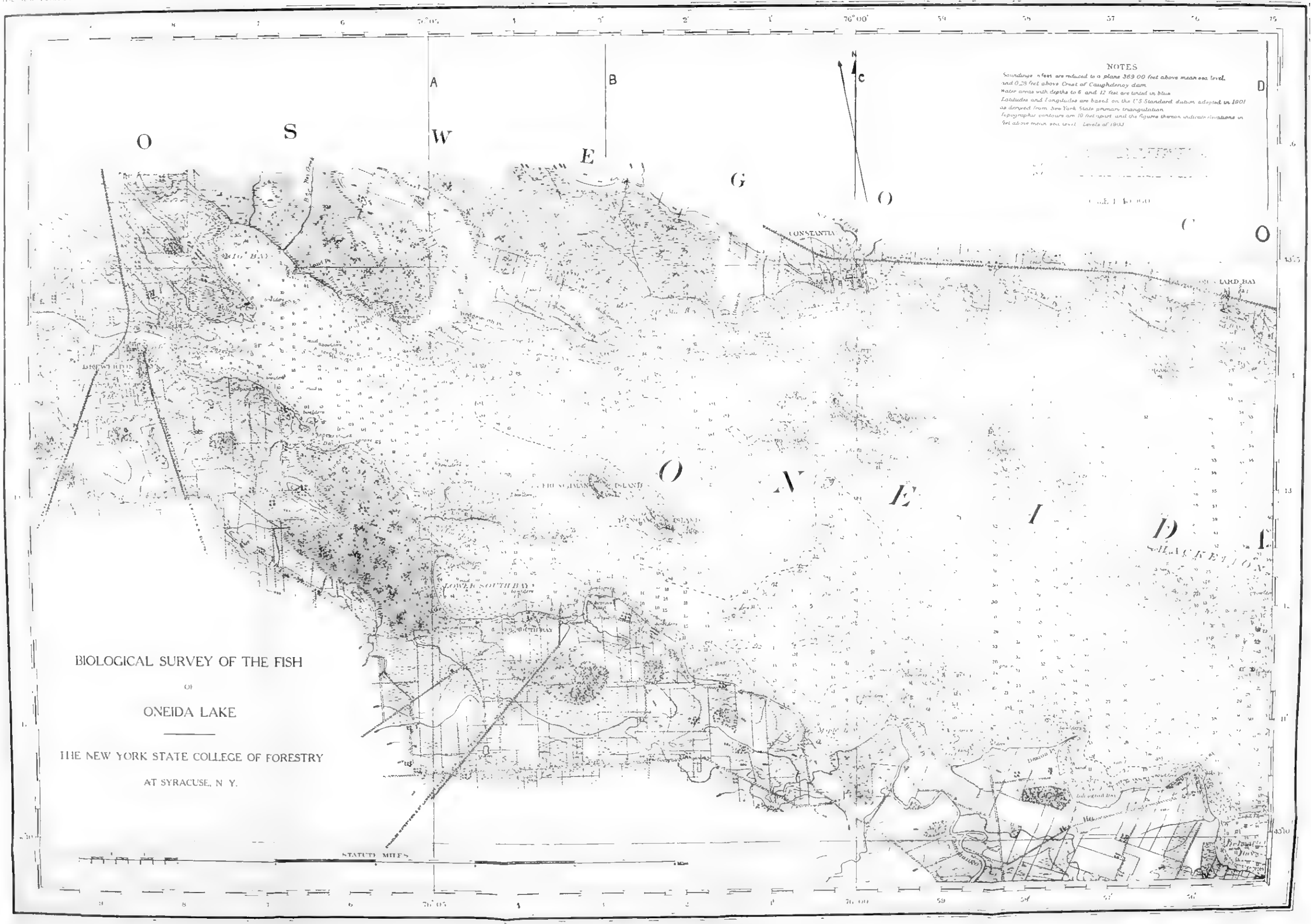


FIG. 1. MAP OF THE WEST END OF ONEIDA LAKE (ADAPTED FROM U. S. LAKE SURVEY MAP)