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TRANSACTIONS

OF THE

AMERICAN

FISHERIES SOCIETY.

SEVENTEENTH ANNUAL MEETING.

HELD IN

ELK'S HALL, DETROIT, MICH.

MAY 15TH AND 16TH, 1888.

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Seventeenth Annual Meeting

—OF THE—

American Fisheries Society.

FIRST DAY.

The Seventeenth Annual Meeting of the Society was held in the room of the Detroit Lodge of Elks, No. 34, in Detroit, Mich., on Tuesday and Wednesday, May 15 and 16. The attendance was larger than usual and many States were represented, the result of a special invitation of United States Fish Commissioner McDonald to the different State Commissioners to meet him and devise some system of co-operation between the States having common fishery interests, and also between them and the general Government. There was a meeting of the Commissioners in the evening.

The meeting was called to order Tuesday morning, May 15, President W. L. May, of Nebraska, in the chair. Dr. R. O. Sweeny, of Minnesota, made a happy opening address in which he alluded to the call of Col. McDonald for a conference of Commissioners and pointed out the great benefits that would come to all by uniting and working in concert. The following new members were elected: Messrs. Henry C. Ford, James V. Long, and W. H. Powell, of the Pennsylvania Fish Commission; M. E. O'Brien, Superintendent Nebraska Commission ; Richard Rathbun, of the U. S. Commission ; Hon. C. V. Osborn, James C. Hofer, John H. Law and A. C. Williams, of the Ohio Commission ; Hon. J. J. Stranahan, of Chagrin Falls, O. ; and Daniel H. Fitzhugh, of Bay City, Mich.

An invitation to visit the Lake St. Clair Fishing and Shooting Club was tendered by its president, Mr. W. C. Colburn, and accepted for Wednesday afternoon. The Society then adjourned until 2 P. M. and visited the white-fish hatchery of the Michigan Commission, in the city, where several millions of the eggs of the pike-perch were to be seen in the jars, and some trout and adult grayling were shown in aquaria, the whitefish season being passed.

On assembling in the afternoon the following paper was read :

THE DISTRIBUTION OF FRESH-WATER FISHES.

BY PROF. DAVID STARR JORDAN.

When I was a boy and went fishing in the brooks of western New York, I noticed that the different streams did not always have the same kinds of fishes in them. Two streams in particular in Wyoming County, not far from my father's farm, engaged in this respect my special attention. Their sources are not far apart, and they flow in opposite directions, on opposite sides of a low ridge—an old glacial moraine, something more than a mile across. The Oatka creek flows northward from this ridge, while the East Coy runs toward the southeast on the other side of it, both flowing ultimately into the same river, the Genesee.

It does not require a very careful observer to see that in these two streams the fishes are not quite the same. The streams themselves are similar enough. In each the waters are clear and fed by springs. Each flows over gravel and clay, through alluvial meadows, in many windings, and with elms and alders "in all its elbows." In both streams we were sure of finding trout (*Salvelinus fontinalis* Mitchill), and in one of them the trout are still abundant. In both we used to catch the brook chub (*Semotilus atromaculatus* Mitchill), or, as we called it, the "horned dace"; and in both were large schools of shiners (*Notropis megalops* Rafinesque) and of suckers (*Catostomus teres* Mitchill). But in every deep hole, and especially in the mill-ponds along the East Coy creek, the horned pout (*Ameiurus melas* Rafinesque) swarmed on the mucky bottoms. In every eddy, or in the deep hole worn out at the root of the elm trees, could be seen the sunfish (*Lepomis gibbosus* Linnæus), strutting in green and scarlet, with spread fins keeping intruders away from its nest. But in the Oatka creek were found neither horned pout nor sunfish, nor have I ever heard that either has been taken there. Then besides these nobler fishes, worthy of a place on every school-boy's string, we knew by sight, if not by name, numerous smaller fishes, darters (*Etheostoma flabellare* Rafinesque) and minnows (*Rhinichthys atronasus* Mitchill), which crept about in the gravel on the bottom of the East Coy, but which we never recognized in the Oatka

There must be a reason for differences like these, in the streams themselves or in the nature of the fishes. The sunfish and the horned pout are home-loving fishes to a greater extent than the others which I have mentioned; still, where no obstacles prevent, they are sure to move about. There must be, then, in the Oatka some sort of barrier, or strainer, which keeping these species back permits others more adventurous to pass; and a wider knowledge of the geography of the region showed that such is the case. Farther down in its course, the Oatka falls over a ledge of rock, forming a considerable water-fall at Rock Glen. Still lower down its waters disappear in the ground, sinking into some limestone cavern or gravel-bed, from which they reappear, after some six miles, in the large springs at Caledonia. Either of these barriers might well discourage a quiet-loving fish; while the trout and its active associates have sometime passed them, else we should not find them in the upper waters in which they alone form the fish-fauna. This problem is a simple one; a boy could work it out, and the obvious solution seems to be satisfactory.

Since those days I have been a fisherman in many waters—not an angler exactly, but one who fishes for fish, and to whose net nothing large or small ever comes amiss; and wherever I go, I find cases like this.

We do not know all the fishes of America yet, nor all those well that we know by sight; still this knowledge will come with time and patience, and to procure it is a comparatively easy task. It is also easy to ascertain the more common inhabitants of any given stream. It is difficult, however, to obtain negative results which are really results. You cannot often say that a species does not live in a certain stream. You can only affirm that you have not yet found it there, and you can rarely fish in any stream so long that you can find nothing that you have not taken before. Still more difficult is it to gather the results of scattered observations into general statements regarding the distribution of fishes. The facts may be so few as to be misleading, or so numerous as to be confusing; and the few writers who have taken up this subject in detail have found both these difficulties to be serious. Whatever general propositions we may maintain must be stated with the modifying clause of "other things being equal"; and other things are never quite equal.

Still less satisfactory is our attempt to investigate the causes on which our partial generalizations depend—to attempt to break to pieces the "other things being equal" which baffle us in our search for general laws.

We now recognize about six hundred species of fishes as found in the fresh waters of North America, north of the Tropic of Cancer, these representing thirty-four of the natural families. As to their habits, we can divide these species rather roughly into the four categories proposed by Professor Cope, or, as we may call them—

(1) Lowland fishes; as the bow-fin, pirate perch, large-mouthed black bass, sunfishes and some catfishes.

(2) Channel fishes; as the channel catfish, the moon-eye, gar-pike, buffalo-fishes and drum.

(3) Upland fishes; as many of the darters, shiners and suckers, and the small-mouthed black bass.

(4) Mountain fishes; as the brook trout, and many of the darters and minnows.

To these we may add the more or less distinct classes of (5) Lake fishes, inhabiting only waters which are deep, clear and cold, as the various species of whitefish and the great lake trout; (6) Anadromous fishes, or those which run up from the sea to spawn in fresh waters, as the salmon, sturgeon, shad and striped bass; (7) Catadromous fishes, like the eel, which pass down to spawn in the sea; and (8) Brackish-water fishes, which thrive best in the debatable waters of the river-mouths, as most of the sticklebacks and the killifishes.

As regards the range of species, we have every possible gradation from those which seem to be confined to a single river, and are rare even in their restricted habitat, to those which are in a measure cosmopolitan,* ranging everywhere in suitable waters.

Still, again, we have all degrees of constancy and inconstancy in what we regard as the characters of a species. Those found only in a single river-basin are usually uniform enough; but the species having a wide range usually vary much in different localities. Continued explorations bring to light, from year to year, new species; but the number of new forms now discovered each year is usually less than the number of recognized species which are yearly proved to be intenable. Three complete lists of the fresh-water fishes of the United States have been published by the present writer. That of Jordan and Copeland,† published in 1876, enumerates 670 species. That of Jordan‡ in 1878 contains 665 species, and that of Jordan§ in 1885, 587 species, although upwards of 75 new species were detected in the nine years which elapsed between the first and the last list. Additional specimens from intervening localities are often found to form connecting links among the nominal species, and thus several supposed species become in time

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* Thus the chub-sucker (*Erimyzon sucetta*) in some of its varieties ranges everywhere from Maine to Dakota, Florida and Texas; while a number of other species are scarcely less widely distributed.

† Check List of the Fishes of the Fresh Waters of North America, by David S. Jordan and Herbert E. Copeland. Bulletin of the Buffalo Society of Natural History, 1876, pp. 133-164.

‡ A Catalogue of the Fishes of the Fresh Waters of North America. Bulletin of the United States Geological Survey, 1878, pp. 407-442.

§ A Catalogue of the Fishes known to inhabit the Waters of North America North of the Tropic of Cancer. Annual Report of the Commissioners of Fish and Fisheries for 1884 and 1885.

merged in one. Thus the common channel catfish (*Ictalurus punctatus* Rafinesque) of our rivers has been described as a new species not less than twenty-five times, on account of differences, real or imaginary, but comparatively trifling in value.

Where species can readily migrate, their uniformity is preserved ; but whenever a form becomes localized its representatives assume some characters not shared by the species as a whole.

Comparing a dozen fresh specimens of almost any kind of fish from any body of water with an equal number from somewhere else, one will rarely fail to find some sort of differences —in size, in form, in color. These differences are obviously the reflex of differences in the environment, and the collector of fishes seldom fails to recognize them as such ; often it is not difficult to refer the effect to the conditions. Thus, fishes from grassy bottoms are darker than those taken from over sand, and those from a bottom of muck are darker still, the shade of color being, in some way not well understood, dependent on the color of the surroundings. Fishes in large bodies of water reach a larger size than the same species in smaller streams or ponds. Fishes from foul or sediment-laden waters are paler in color and slenderer in form than those from waters which are clear and pure. Again, it is often true that specimens from northern waters are less slender in body than those from farther south ; and so on. Other things being equal, the more remote the localities from each other, the greater are these differences.

It is evident, from these and other facts, that the idea of a separate creation for each species of fishes in each river basin, as entertained by Agassiz, is wholly incompatible with our present knowledge of the specific distinctions or of the geographical distribution of fishes. This is an unbroken gradation in the variations from the least to the greatest—from the peculiarities of the individual, through local varieties, geographical sub-species, species, sub-genera, genera, families, super-families, and so on, until all fish-like vertebrates are included in a single bond of union.

It is, however, evident that not all American types of fishes had their origin in America, or even first assumed in America their present forms. Some of these are perhaps immigrants from Northern Asia, where they still have their nearest relatives. Still others are evidently modified importations from the sea; and of these some are very recent immigrants, land-locked species which have changed very little from the parent stock.

We can say, in general, that in all waters not absolutely uninhabitable there are fishes. The processes of natural selection have given to each kind of river or lake species of fishes adapted to the conditions of life which obtain there. There is no condition of water, of bottom, of depth, of speed of current, but finds some species with characters adjusted to it. These adjustments are, for the most part, of long standing; and the fauna of any single stream has, as a rule, been produced by immigration from other regions or from other streams. Each species has an ascertainable range of distribution, and within this range we may be reasonably certain to find it in any suitable waters.

But every species has beyond question some sort of limit to its distribution, some sort of barrier which it has never passed in all the years of its existence. That this is true becomes evident when we compare the fish-faunæ of widely separated rivers. Thus the Sacramento, Connecticut, Rio Grande and St. John's rivers have not a single species in common; and with one or two exceptions, not a species is common to any two of them. None of these has any species peculiar to itself, and each shares a large part of its fish-fauna with the water-basin next to it. It is probably true that the faunæ of no two distinct hydrographic basins are wholly identical, while, on the other hand, there are very few species confined to a single one. The supposed cases of this character, some twenty in number, occur chiefly in the streams of the South Atlantic States and of Arizona. All of these need, however, the confirmation of further exploration. It is certain that in no case has an entire river fauna originated independently from the divergence into separate species of the descendants of a single type.

The existence of boundaries to the range of species implies, therefore, the existence of barriers to their diffusion. We may now consider these barriers, and, in the same connection, the degree to which they may be overcome.

Least important of these are the barriers which may exist within the limits of any single basin, and which tend to prevent a free diffusion through its waters of species inhabiting any portion of it. In streams flowing southward, or across different parallels of latitude, the difference in climate becomes a matter of importance. The distribution of species is governed very largely by the temperature of the water. Each species has its range in this respect—the free-swimming fishes, notably the trout, being most affected by it; the mud-loving or bottom fishes, like the catfishes, least. The latter can reach the cool bottoms in hot weather, or the warm bottoms in cold weather, thus keeping their own temperature more even than that of the surface of the water. Although water communication is perfectly free for most of the length of the Mississippi, there is a material difference between the faunæ of the stream in Minnesota and in Louisiana. This difference is caused chiefly by the difference in temperature occupying the difference in latitude. That a similar difference in longitude, with free water communication, has no appreciable importance, is shown by the almost absolute identity of the fish-faunæ of Lake Winnebago and Lake Champlain. While many large fishes range freely up and down the Mississippi, a majority of the species do not do so, and the fauna of the upper Mississippi has more in common with that of the tributaries of Lake Michigan than it has with that of the Red river or the Arkansas. The influence of climate is again shown in the paucity of the fauna of the cold waters of Lake Superior, as compared with that of Lake Michigan. The majority of our species cannot endure the cold. In general, therefore, cold or Northern waters contain fewer species than Southern waters do, though the number of individuals of any one kind may be greater. This is shown in all waters, fresh or salt. The fisheries of the Northern seas are more extensive than those of the Tropics. There are more fishes there, but they are far less varied in kind. The writer once caught seventy-five species of fishes in a single haul of the seine at Key West, while on Cape Cod he obtained with the same net but forty-five species in the course of a week's work. Thus it comes that the angler, contented with many fishes of few kinds, goes to Northern streams to fish, while the naturalist goes to the South.

But in most streams the difference in latitude is insignificant, and the chief differences in temperature come from differences in elevation, or from the distance of the waters from the colder source. Often the lowland waters are so different in character as to produce a marked change in the quality of their fauna. These lowland waters may form a barrier to the free movements of upland fishes; but that this barrier is not impassable is shown by the identity of the fishes in the streams (for example, Elk river, Duck river, etc.) of the uplands of middle Tennessee with those of the Holston and French Broad. Again, streams of the Ozark Mountains, similar in character to the rivers of East Tennessee, have an essentially similar fish-fauna, although between the Ozarks and the Cumberland range lies an area of lowland bayous, into which such fishes are never known to penetrate. We can, however, imagine that these upland fishes may be sometimes swept down from one side or the other into the Mississippi, from which they might ascend on the other side. But such transfers certainly do not often happen. This is apparent from the fact that the two faunæ* are not quite identical, and in some cases the same species are represented by perceptibly different varieties on one side and the other. The time of the commingling of these faunæ is perhaps now past, and it may have occurred only when the climate of the intervening regions was colder than at present.

The effect of waterfalls and cascades as a barrier to the diffusion of most species is self-evident; but the importance of such obstacles is less, in the course of time, than might be expected. In one way or another very many species have

* There are three species of darters (*Etheostoma copelandi* Jordan; *Etheostoma evides* Jordan and Copeland: *Etheostoma scierum* Swain) which are now known only from the Ozark region or beyond and from the uplands of Indiana, not yet having been found at any point between Indiana and Missouri. These constitute perhaps isolated colonies, now separated from the parent stock in Arkansas by the prairie districts of Illinois, a region at present uninhabitable for these fishes. But the non-occurrence of these species over the intervening areas needs confirmation, as do most similar cases of anomalous distribution.

passed these barriers. The falls of the Cumberland limit the range of most of the larger fishes of the river, but the streams above it have their quota of darters and minnows. It is evident that the past history of the stream must enter as a factor into this discussion, but this past history it is not always possible to trace. Dams or artificial waterfalls now check the free movement of many species, especially those of migratory habits; while, conversely, numerous other species have extended their range through the agency of canals (thus, *Dorosoma cepedianum* Le Sueur, and *Clupea chrysochloris* Rafinesque, have found their way into Lake Michigan through canals).

Every year fishes are swept down the rivers by the winter's floods; and in the spring, as the spawning season approaches, almost every species is found working its way up the stream. In some cases, notably the Quinnat salmon (*Oncorhynchus tschawytscha* Walbaum) and the blueback salmon (*Oncorhynchus nerka* Walbaum), the length of these migrations is surprisingly great. To some species rapids and shallows have proved a sufficient barrier, and other kinds have been kept back by unfavorable conditions of various sorts. Streams whose waters are always charged with silt or sediment, as the Missouri, Arkansas, or Brazos, do not invite fishes; and even the occasional floods of red mud such as disfigure otherwise clear streams, like the Red river or the Colorado (of Texas), are unfavorable. Extremely unfavorable also is the condition which obtains in many rivers of the Southwest; as for example, the Red river, the Sabine, and the Trinity, which are full from bank to bank in winter and spring, and which dwindle to mere rivulets in the autumn droughts.

In general, those streams which have conditions most favorable to fish-life will be found to contain the greatest number of species. Such streams invite immigration; and in them the struggle for existence is individual against individual, species against species, and not a mere struggle with hard conditions of life. Some of the conditions most favorable to the existence in any stream of a large number of species of fishes are the following, the most important of which is the one mentioned first: connection with a large hydrographic basin; a warm climate;

clear water; a moderate current; a bottom of gravel (preferably covered by a growth of weeds); little fluctuation during the year in the volume of the stream or in the character of the water.

Limestone streams usually yield more species than streams flowing over sandstone, and either more than the streams of regions having metamorphic rocks. Sandy bottoms usually are not favorable to fishes. In general, glacial drift makes a suitable river bottom, but the higher temperature usual in regions beyond the limits of the drift gives to certain Southern streams conditions still more favorable. These conditions are all well realized in the Washita river in Arkansas, and in various tributaries of the Tennessee, Cumberland and Ohio; and in these, among American streams, the greatest number of species has been recorded.

The isolation and the low temperature of the rivers of New England have given to them a very scanty fish-fauna as compared with the rivers of the South and West. This fact has been noticed by Professor Agassiz, who has called New England a "zoölogical island." *

In spite of the fact that barriers of every sort are sometimes crossed by fresh-water fishes, we must still regard the matter of freedom of water communication as the essential one in determining the range of most species. The larger the river basin, the greater the variety of conditions likely to be offered in it, and the greater the number of its species. In case of the divergence of new forms by the processes called "natural selection," the greater the number of such forms which may have spread through its waters; the more extended any river basin, the greater are the chances that any given species may sometime find its way into it; hence the greater the number of species that actually occur in it, and, freedom of movement being assumed, the greater the number of species to be found in any one of its affluents.

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* "In this isolated region of North America, in this zoölogical island of New England, as we may call it, we find neither Lepidosteus, nor Amia, nor Polyodon, nor Amblodon (*Aplodinotus*), nor Grystes (*Micropterus*), nor Centrarchus, nor Pomoxis, nor Ambloplites, nor Calliurus (*Chænobryttus*), nor Carpiodes, nor Hyodon, nor indeed any of the characteristic forms of North American fishes so common everywhere else, with the exception of two Pomotis (*Lepomis*), one Boleosoma, and a few Catostomus."—Agassiz, *Amer. Journ. Sci. Arts*, 1854.

Of the six hundred species of fishes found in the rivers of the United States, about two hundred have been recorded from the basin of the Mississippi. From fifty to one hundred of these species can be found in any one of the tributary streams of the size, say, of the Housatonic river or the Charles. In the Connecticut river there are about eighteen species permanently resident ; and the number found in the streams of Texas is not much larger, the best-known of these, the Rio Colorado, having yielded but twenty-four species.

The waters of the Great Basin have not yet been fully explored. The number of species now known from this region is about seventy-five. This number includes the fauna of the upper Rio Grande, the Snake river, and the Colorado, as well as the fishes of the tributaries of the Great Salt Lake. This list is composed almost entirely of a few genera of suckers (*Catostomus*, *Pantosteus*, *Chasmistes*), minnows (*Squalius*, *Gila*, *Ptychocheilus*, etc.), and trout (*Salmo mykiss* and its varieties). None of the catfishes, perch, darters, or sunfishes, moon-eyes, killifishes, and none of the ordinary Eastern types of minnows (genera *Notropis*, *Chrosomus*, etc.) have passed the barrier of the Rocky Mountains.

West of the Sierra Nevada, the fauna is still more scanty, but fifty species being enumerated. This fauna, except for certain immigrants (as the fresh water surf-fish [*Hysterocarpus traski*] and the species of salmon) from the sea, is of the same general character as that of the Great Basin, though most of the species are different. This latter fact would indicate a considerable change, or "evolution," since the contents of the two faunæ were last mingled. There is a considerable difference between the fauna of the Columbia and that of the Sacramento. The species which these two basins have in common are chiefly those which at times pass out into the sea. The rivers of Alaska contain but few species, barely a dozen in all, most of these being found also in Siberia and Kamtschatka. In the scantiness of its faunal list, the Yukon agrees with the Mackenzie river, and with Arctic rivers generally.

There can be no doubt that the general tendency is for each species to extend its range more and more widely until all localities suitable for its growth are included. The various agencies of dispersal which have existed in the past are still in operation. There is apparently no limit to their action. It is probable that new "colonies" of one species or another may be planted each year in waters not heretofore inhabited by such species. But such colonies become permanent only where the conditions are so favorable that the species can hold its own in the struggle for food and subsistence. That various modifications in the habitat of certain species have been caused by human agencies is of course too well known to need discussion here.

We may next consider the question of water-sheds, or barriers which separate one river basin from another.

Of such barriers in the United States, the most important and most effective is unquestionably that of the main chain of the Rocky Mountains. This is due in part to its great height, still more to its great breadth, and most of all, perhaps, to the fact that it is nowhere broken by the passage of a river. But two species—the red-throated, or Rocky Mountain trout (*Salmo mykiss* Walbaum [=*purpuratus* Pallas],) and the Rocky Mountain whitefish (*Coregonus williamsoni* Girard)—are found on both sides of it, at least within the limits of the United States; while many genera, and even several families, find in it either an eastern or a western limit to their range. In a few instances representative species, probably modifications or separated branches of the same stock, occur on opposite sides of the range, but there are not many cases of correspondence even thus close.

It is easy to account for the separation of the faunæ; but how shall we explain the almost universal diffusion of the whitefish and the trout in suitable waters on both sides of the dividing ridge? We may notice that these two are the species which ascend highest in the mountains, the whitefish inhabiting the mountain pools and lakes, the trout ascending all brooks and rapids in search of their fountain-heads. In many cases the ultimate dividing ridge is not very broad, and we may imagine that at some time spawn or even young fishes may have been carried across by birds or other animals, or by man, —or more likely by the dash of some summer whirlwind.

Once carried across in favorable circumstances, the species might survive and spread.

I have seen an example of how such transfer of species may be accomplished, which shows that we need not be left to draw on the imagination to invent possible means of transit.

There are few water-sheds in the world better defined than the mountain range which forms the "backbone" of Norway. I lately climbed a peak in this range, the Suletind. From its summit I could look down into the valleys of the Lära and the Bägna, flowing in opposite directions to opposite sides of the peninsula. To the north of the Suletind is a large double lake called the Sletningenvand. The maps show this lake to be one of the chief sources of the westward-flowing river Lära. This lake is in August swollen by the melting of the snows, and at the time of my visit it was visibly the source of both these rivers. From its southeastern side flowed a large brook into the valley of the Bägna, and from its southwestern corner, equally distinctly, came the waters which fed the Lära. This lake, like similar mountain ponds in all northern countries, abounds in trout; and these trout certainly have for part of the year an uninterrupted line of water communication from the Sognefjord on the west of Norway to the Christianiafjord on the southeast,—from the North Sea to the Baltic. Part of the year the lake has probably but a single outlet through the Lära. A higher temperature would entirely cut off the flow into the Bägna, and a still higher one might dry up the lake altogether. This Sletningenvand,* with its two outlets on the summit of a sharp water-shed, may serve to show us how other lakes, permanent or temporary, may elsewhere have acted as agencies for the transfer

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* Since the above was written I have been informed by Professor John M. Coulter, who was one of the first explorers of the Yellowstone Park, that such a condition still exists on the Rocky Mountain Divide. In the Yellowstone Park is a marshy tract, traversable by fishes in the rainy season, and known as the "Two-Ocean Water." In this tract rise tributaries both of the Snake river and of the Yellowstone. Similar conditions apparently exist on other parts of the Divide, both in Montana and in Wyoming.

Professor John C. Branner calls my attention to a marshy upland which separates the valley of the La Plata from that of the Amazon, and which permits the free movement of fishes from the Paraguay river to the Tapajos. It is well known that through the Cassiquiare river the Rio Negro, another branch of the Amazon, is joined to the Orinoco river. It is thus evident that almost all the waters of eastern South America form a single basin, so far as the fishes are concerned.

of fishes. We can also see how it might be that certain mountain fishes should be so transferred while the fishes of the upland waters may be left behind. In some such way as this we may imagine the trout and the whitefish to have attained their present wide range in the Rocky Mountain region; and in similar manner perhaps the Eastern brook trout (*Salvelinus fontinalis* Mitchill) and some other mountain species (*Notropis rubricroceus* Cope; *Rhinichthys atronasus* Mitchill, etc.) may have been carried across the Alleghanies.

The Sierra Nevada constitutes also a very important barrier to the diffusion of species. This is, however, broken by the passage of the Columbia river, and many species thus find their way across it. That the waters to the west of it are not unfavorable for the growth of eastern fishes is shown by the fact of the rapid spread of the common eastern catfish (*Amciurus nebulosus* Le Sueur) or horned pout, when transported from the Schuylkill to the Sacramento. This fish is now one of the important food-fishes of the San Francisco markets. It has become in fact, an especial favorite with the Chinaman,—himself also an immigrant, and presenting certain analogies with the fish in question, as well in temperament as in habits.

The mountain mass of Mount Shasta is, as already stated, a considerable barrier to the range of fishes, though a number of species find their way around it through the sea. The lower and irregular ridges of the Coast Range are of small importance in this regard, as the streams of their east slope reach the sea on the west through San Francisco Bay. Yet the San Joaquin contains a few species, not yet recorded, from the smaller rivers of southwestern California.

The main chain of the Alleghanies forms a barrier of importance separating the rich fish-fauna of the Tennessee and Ohio basins from the scantier faunæ of the Atlantic streams. Yet this barrier is crossed by many more species than is the case with either the Rocky Mountains or the Sierra Nevada. It is lower, narrower, and much more broken, —as in New York, in Pennsylvania, and in Georgia there are several streams which pass through it or around it. The much greater age of the Alleghany chain, as compared with the

Rocky Mountains, seems not to be an element of any importance in this connection. Of the fish which cross this chain, the most prominent is the brook trout (*Salvelinus fontinalis*), which is found in all suitable waters from Hudson's Bay to the head of the Chattahoochee. A few other species are locally found in the headwaters of certain streams on opposite sides of the range. An example of this is the little red "fall-fish" (*Notrobis rubricroceus* Cope), found only in the mountain tributaries of the Savannah and the Tennessee. We may suppose the same agencies to have assisted these species that we have imagined in the case of the Rocky Mountain trout, and such agencies were doubtless more operative in the times immediately following the glacial epoch than they are now.

The passage of species from stream to stream along the Atlantic slope deserves a moment's notice. It is, under present conditions, impossible for any mountain or upland fish, as the trout or the miller's thumb (*Cottus richardsoni* Agassiz), to cross from the Potomac river to the James, or from the Neuse to the Santee, by descending to the lower courses of the rivers, and thence passing along either through the swamps or by way of the sea. The lower courses of these streams, warm and muddy, are uninhabitable by such fishes. Such transfers are, however, possible farther north. From the rivers of Canada and from many rivers of New England the trout does descend to the sea and into the sea, and farther north the whitefish does this also. Thus these fishes readily pass from one river basin to another. As this is the case now everywhere in the North, it may have been the case farther south in the time of the glacial cold. We may, I think, imagine a condition of things in which the snow-fields of the Alleghany chain might have played some part in aiding the diffusion of cold-loving fishes. A permanent snow-field on the Blue Ridge in western North Carolina might render almost any stream in the Carolinas suitable for trout, from its source to its mouth. An increased volume of colder water might carry the trout of the head-streams of the Catawba and the Savannah as far down as the sea. We can even imagine that the trout reached these streams in the first place through such agencies, though of this there is no positive evidence. For the presence of trout in the upper Chattahoochee, we must account in some other way.

It is noteworthy that the upland fishes are nearly the same in all these streams, until we reach the southern limit of possible glacial influence. South of western North Carolina, the faunæ of the different river basins appear to be more distinct from one another. Certain ripple-loving types* are represented by closely related but unquestionably different species in each river basin, and it would appear that a thorough mingling of the upland species in these rivers has never taken place.

With the lowland species of the Southern rivers it is different. Few of these are confined within narrow limits. The streams of the whole South Atlantic and Gulf Coast flow into shallow bays, mostly bounded by sand-spits or sand-bars which the rivers themselves have brought down. In these bays the waters are often neither fresh nor salt; or rather, they are alternately fresh and salt, the former condition being that of the winter and spring. Many species descend into these bays, thus finding every facility for transfer from river to river. There is a continuous inland passage in fresh or brackish waters, traversable by such fishes, from Chesapeake Bay nearly to Cape Fear; and similar conditions exist on the coasts of Louisiana, Texas, and much of Florida. In Perdido Bay I have found fresh-water minnows (*Notropis cercostigma; Notropis xænocephalus*), and silversides (*Labidesthes sicculus*), living together with marine gobies (*Gobiosoma molestum*) and salt-water eels (*Myrophis punctatus*). Fresh-water alligator gars (*Lepisosteus tristœchus*) and marine sharks compete for the garbage thrown over from the Pensacola wharves. In Lake Pontchartrain the

* The best examples of this are the following: In the Santee basin are found *Notropis pyrrhomelas*, *Notropis niveus*, and *Notropis chloristius*; in the Altamaha, *Notropis xænurus* and *Notropis callisemus*; in the Chattahoochee, *Notropis hypselopterus* and *Notropis eurystomus*; in the Alabama, *Notropis cæruleus*, *Notropis trichroistius*, and *Notropis callistius*. In the Alabama, Escambia, Pearl, and numerous other rivers, is found *Notropis cercostigma*. This species descends to the sea in the cool streams of the pine-woods. Its range is wider than that of the others, and in the rivers of Texas it reappears in the form of a scarcely distinct variety, *Notropis venustus*. In the Tennessee and Cumberland, and in the rivers of the Ozark range, is *Notropis galacturus*; and in the upper Arkansas *Notropis camurus*—all distinct species of the same general type. Northward, in all the streams from the Potomac to the Oswego, and westward to the Des Moines and the Arkansas occurs a single species of this type, *Notropis whipplei*. But this species is not known from any of the streams inhabited by any of the other species mentioned, although very likely it is the parent stock of them all.

fauna is a remarkable mixture of fresh-water fishes from the Mississippi and marine fishes from the Gulf. Channel-cats, sharks, sea-crabs, sunfishes, and mullets can all be found there together. It is therefore to be expected that the lowland fauna of all the rivers of the Gulf States would closely resemble that of the lower Mississippi ; and this, in fact, is the case.

The low and irregular water-shed which separates the tributaries of Lake Michigan and Lake Erie from those of the Ohio is of little importance in determining the range of species. Many of the distinctively Northern fishes are found in the head-waters of the Wabash and the Scioto. The considerable difference in the general fauna of the Ohio Valley as compared with that of the streams of Michigan is due to the higher temperature of the former region, rather than to any existing barriers between the river and the Great Lakes. In northern Indiana the water-shed is often swampy, and in many places large ponds exist in the early spring.

At times of heavy rains many species will move through considerable distances by means of temporary ponds and brooks. Fishes that have thus emigrated often reach places ordinarily inaccessible, and people finding them in such localities often imagine that they have "rained down." Once, near Indianapolis, after a heavy shower, I found in a furrow in a corn-field a small pike (*Esox vermiculatus* Le Sueur), some half a mile from the creek in which he should belong. The fish was swimming along in a temporary brook, apparently wholly unconscious that he was not in his native stream. Migratory fishes, which ascend small streams to spawn, are especially likely to be transferred in this way. By some such means any of the water-sheds in Ohio, Indiana, or Illinois may be passed.

It is certain that the limits of Lake Erie and Lake Michigan were once more extended than now. It is reasonably probable that some of the territory now drained by the Wabash and the Illinois was once covered by the waters of Lake Michigan. The cisco (*Coregonus artedi sisco* Jordan), of Lake Tippecanoe, Lake Geneva, and the lakes of the Oconomowoc chain, is evidently a modified descendant of the so-called lake herring

(*Coregonus artedi* Le Sueur). Its origin most likely dates from the time when these small deep lakes of Indiana and Wisconsin were connected with Lake Michigan. The changes in habits which the cisco has undergone are considerable. The changes in external characters are but trifling. The presence of the cisco in these lakes and its periodical disappearance—that is retreat into deep water when not in the breeding season—has given rise to much nonsensical discussion as to whether any or all of these lakes are still joined to Lake Michigan by subterranean channels. Several of the larger fishes, properly characteristic of the Great Lake region (as, *Lota lota maculosa; Percopsis guttatus; Esox masquinongy*), are occasionally taken in the Ohio river; where they are usually recognized as rare stragglers. The difference in physical conditions is probably the sole cause of their scarcity in the Ohio basin.

The similarity of the fishes in the different streams and lakes of the Great Basin is doubtless to be attributed to the general mingling of their waters which took place during and after the glacial epoch. Since that period the climate in that region has grown hotter and drier, until the overflow of the various lakes into the Columbia basin through the Snake river has long since ceased. These lakes have become isolated from each other, and many of them have become salt or alkaline and therefore uninhabitable. In some of these lakes certain species may now have become extinct which still remain in others. In some cases, perhaps, the differences in surrounding may have caused divergence into distinct species of what was once one parent stock. The suckers in Lake Tahoe (*Catostomus tahoensis*, in Lake Tahoe; *Catostomus macrocheilus* and *discobolus*, in the Columbia; *Catostomus fecundus*, *Catostomus ardens; Chasmistes liorus* and *Pantosteus generosus*, in Utah Lake) and those in Utah Lake are certainly now different from each other and from those in the Columbia. The trout (*Salmo mykiss*, et vars. *henshawi* and *virginalis*) in the same waters can be regarded as more or less tangible varieties only, while the whitefishes (*Coregonus williamsoni*) show no differences at all. The differences in the present faunæ of Lake Tahoe and Utah Lake must be chiefly due to influences which have acted since the glacial epoch, when the whole Utah Basin was part of the drainage of the Columbia.

To certain species of upland or mountain fishes, the depression of the Mississippi basin itself forms a barrier which cannot be passed. The black-spotted trout (*Salmo fario* L., in Europe; *Salmo labrax* Pallas, etc., in Asia; *Salmo gairdneri* Richardson, in streams of the Pacific Coast. *Salmo mykiss* Walbaum, in Kamtschatka, Alaska, and throughout the Rocky Mountain range to the Mexican boundary, and the headwaters of the Kansas, Platte, and Missouri), very closely related species of which abound in all waters of northern Asia, Europe, and western North America, has nowhere crossed the basin of the Mississippi, although one of its species finds no difficulty in passing Behring Strait. The trout and whitefish of the Rocky Mountain region are all species different from those of the Great Lakes or the streams of the Alleghany system. To the grayling, the trout, the whitefish, the pike, and to arctic and sub-arctic species generally, Behring Strait has evidently proved no serious obstacle to diffusion; and it is not unlikely that much of the close resemblance of the fresh-water faunæ of northern Europe, Asia and North America is due to this fact. To attempt to decide from which side the first migration came in regard to each group of fishes might be interesting; but without a wider range of facts than is now in our possession, such attempts would be mere guesswork and without value. The interlocking of the fish-faunæ of Asia and North America presents, however, a number of interesting problems, for numerous migrations in both directions have doubtless taken place.

I could go on indefinitely with the discussion of special cases, each more or less interesting or suggestive in itself, but the general conclusion is in all cases the same.

The present distribution of fishes is the result of long-continued action of forces still in operation. The species have entered our waters in many invasions from the Old World, or from the sea. Each species has been subjected to the various influences implied in the term natural selection, and under varying conditions, its representatives have undergone many different modifications.

Each of the 600 species we now know is making every year inroads on territory occupied by other species. If these colonies are able to hold their own in the struggle for possession, they will multiply in the new conditions and the range of the species will become widened. If the surroundings are different new species or varieties may be formed in time and these new forms may again invade the territory of the parent species. Again colony after colony of species after species may be destroyed by other species or by uncongenial surroundings.

The ultimate result of centuries on centuries of the restlessness of individuals is seen in the facts of geographical distribution. Only in the most general way can the history of any species be traced. Could we know it all, it would be as long and eventful a story as the history of the colonization and settlement of North America by immigrants from Europe.

By the fishes each river in America has been a hundred times discovered; its colonization a hundred times attempted. In these efforts there is no co-operation. Every individual is for himself, every struggle is a struggle of life and death. Each fish is a cannibal, and to each species each member of every other species is an alien and a savage. Now all this has a practical side to it, although the practical side has been as yet little developed.

A leading feature of the work of the Fish Commissions must be to help the fishes over the barriers, to assist nature in the direction of colonizing streams and lakes with fishes which are good to eat, to the exclusion of the kinds of which man can make no use.

This help may be given by the introduction of vigorous kinds of fishes into waters into which they had been unable to find an entrance before. The work judiciously done may be of the greatest value to the people of our country. Numerous as are the food fishes of the Mississippi valley, it must be confessed that the rank of the great bulk of them is not high. Our rivers ought to raise something better than suckers, paddle-fish, drum and buffaloes. To bring in better fishes with success, it is necessary for us to know something of the habits and necessities of the species in question, and also something definite as to the character of the waters which are to be stocked. It is of no use to plant brook trout in a muddy bayou, or channel-cat in mountain springs of ice-water, or codfish in Lake Michigan.

Most of our information in these respects is still very vague, and most attempts at the introduction of species into new waters are still of the most haphazard sort. The recent series of examinations of the Michigan lakes, lately undertaken by the Michigan State Fish Commission, ought to yield some results in this connection, yet as the character of the waters of the State is essentially uniform, what is true of one of the little lakes in the way of supporting fish life, must be largely true of all. For this reason, desirable as an extended exploration is from an economic standpoint, it can be made more important to the science of ichthyology, than to the art of fish-culture. To ichthyology, as has been said, a sculpin is as valuable as a codfish, but fish-culture prefers the codfish.

The results of a careful survey would give us facts regarding the distribution of minnows, darters and sunfish, facts of the greatest interest and importance in science, but of no value to fish-culture to which one minnow is as good as another and both useful only as food for bass, still a thorough survey in the hands of intelligent men, of the waters of any region cannot fail to throw much light on the habits and needs of the various food fishes, and we shall look with much interest for the final results of the work in Michigan.

The other work of the Fish Commission is in the direction of fish-hatching, the protection of the young of valuable kinds until they are able to take care of themselves. The value of this work is most great, now fortunately beyond question, and its methods are reaching a high degree of perfection.

I need only say that my deepest interest in science lies in the direction of the question of the distribution of organisms and in their adaptation to their surroundings and I should be glad if I were able to contribute even a little to making our knowledge of this subject practicably available in the direction of causing two big fish to grow where one little one grew before.

Indiana State University, Bloomington, Ind.

Dr. Sweeny said that the "dogfish" referred to by Prof. Jordan are considered a superior fish by the Hebrews of Minnesota, who call them "green bass." They are also called "lawyers," because they clean up everything.

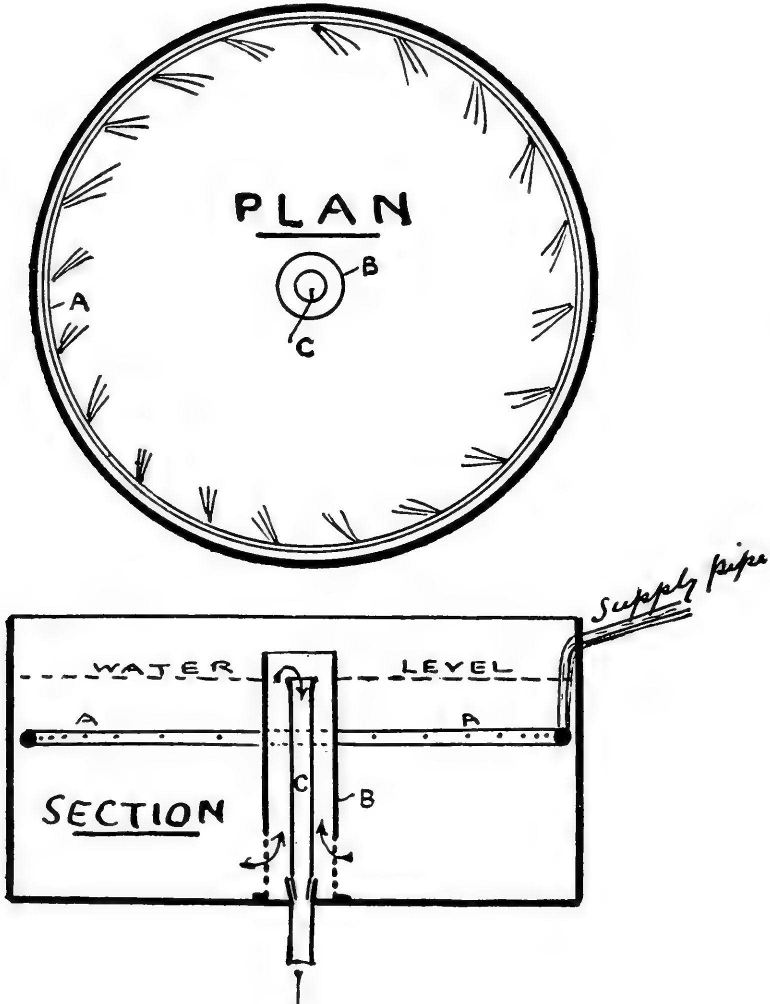
Dr. J. C. Parker had noted what Prof. Jordan said about the bullheads in East Coy creek. He had put his hands on them. They were transported from Silver Lake and placed in a horse trough at first and then escaped into the creek. There were no bullheads there during his boyhood.

Mr. Mather announced that he had received a private letter from Mr. W. Oldham Chambers, Secretary of the National Fish-culture Association of England, dated April 22, 1888, which contained some matters of public interest, and he would read such portions of it as related to the rearing of fishes. Mr. Chambers says: "I am looking forward to a visit to America, some time, for the express purpose of studying the vast advances you are making in our glorious science. I can conceive no greater treat than to exchange thoughts with my transatlantic friends. I think there is this difference, if I am not mistaken, in our methods; you devote all your energies to hatch out the greatest quantity of fry and then turn them out in the rivers and lakes, whereas we try to invent means of feeding and rearing them after the sac is absorbed, and then turn them out when they are capable of caring for themselves. I have never met with anything that approaches my "thorough" system of feeding. You can make a vase to bring up 100, or one large enough for 100,000 with the same ease, and on the same principle. The fish are bound to be on the move and are equally bound to feed, because the food is always held in suspension and has no chance to get to the bottom. I inclose a sketch, to scale similar to one in my hatchery that now has 15,000 rainbow trout in it. Oblige me by making one, which you can do at a small cost, and give me an opinion of the result. There is no patent on it, so do what you like with it. Be careful to follow the lines laid down in the inclosed diagram, especially in the case of the holes in the pipe which must be at the proper angle, for there rests the secret."

MR. CHAMBERS' "THOROUGH" VASE.

SCALE, 1 INCH TO THE FOOT.

(Cut loaned by *Forest and Stream.*)



A, Supply pipe.
B Guard cylinder with perforated bottom.
C, Standing waste, ground into fixed waste.

SPECIFICATIONS OF "THOROUGH" VASE.

"The outer casing can be an ordinary wooden tub, one three feet in diameter will hold 10,000 fry. The supply pipe to be one-half inch lead composition, to be fixed three-quarter inch away from inside of tub. This pipe to be perforated about every four inches with very fine holes, which must be at an angle as shown; the water as it enters this tub is forced round and round and the fish are in a small trout stream; the food is also kept in suspension by the circular motion.

"The guard cylinder is tacked to the bottom of the tub by a small flange. This cylinder is made with zinc, but the bottom four inches is perforated zinc, the waste water, dirt, etc., passes through the perforations.

"The standing waste to be one and one-quarter inch lead pipe, the top slightly bell-mouthed, the bottom soldered to a brass piece with ground face, which fits into a brass fixture standing up one inch from bottom of tub with corresponding ground face.

"In washing-out pull up the standing waste and with a feather stir up the bottom of tub and away goes the sediment down the waste. You seldom want to do this with care in feeding, not to give too much at a time.

"Remember that the entire invention depends upon the holes in circulating supply pipe being pierced at the proper angle."

MR. MATHER said that all his trout were distributed or put out in the rearing ponds and he could not try this method the present year, but it may be worth while for others to do it. In 1880, when on the staff of Prof. G. Brown Goode, in charge of the American department at the fisheries exhibition in Berlin, a gentleman from Baltimore, whose name he had momentarily forgotten, sent some glass models of the Bell and Mather shad hatching cones which were designed to keep the food in suspension, just as the shad eggs are, and some fry were fed in the cones for a while, but not long enough to test the system of keeping food in suspension, nor to develop any difficulty which might arise from decaying food.

Reports of the Northern Fisheries Society of Japan were shown, and a translation of the headings of the articles read, as was also a letter from the president of that society, Mr. K. Ito, who called attention to some translated extracts from *Forest and Stream*, and to a portrait of Prof. G. Brown Goode, which adorned one of the reports.

A letter from Mr. Seth Green was read but was carried off by some of the reporters. He commended the work of the society and congratulated the Michigan Commission in having an able Superintendent in Mr. Walter D. Marks. He also announced that Jonathan Mason had succeeded in hatching the mascalonge at Chautauqua Lake, N. Y., the first of this species to be artificially hatched.

THE LATE PROF. SPENCER F. BAIRD.

DR. W. M. HUDSON moved that a committee be appointed to draft a resolution of regret at the death of Prof. S. F. Baird, and the president named Dr. Hudson, Dr. Sweeny and Mr. J. H. Bissell as such committee. Later on they reported the following, which was accepted by the Society :

IN MEMORY OF SPENCER F. BAIRD.

"Since the last meeting of this Society, our associate, Prof. Spencer F. Baird, United States Commissioner, has been removed from the scene of his labors by death. This Society hereby puts on record its appreciation of the great efficiency and admirable administrative qualifications by which he caused the position of U. S. Commissioner to be regarded as the first in the entire world, and mourns the loss of one who by his lovable qualities had endeared himself to all who came in contact with him."

MR. WILLIAM ALDEN SMITH, fish and game warden for the State of Michigan, spoke on the regulation of the fisheries, outlining the work of his 180 deputies and himself in executing the laws protecting fish and game. "We have generally had hearty and generous co-operation," he said. "In Eaton County four prominent citizens were convicted of violating the laws, despite the fact that the evidence was not conclusive, and they were given the full penalty of the law. In the County of Clare we were given the greatest opposition. A deputy came upon a man spearing fish. The violator refused to submit to arrest. The deputy lugged him off eight miles to a justice, where he was speedily acquitted. The work of enforcing the laws has been studiously carried on. The people demand their execution and the results are gratifying to all."

THE PROPAGATION OF NATURAL FOOD FOR FISH, WITH SPECIAL REFERENCE TO FISH-CULTURE.

BY M. E. O'BRIEN.

The subject "natural food of fish" is one that has received but meagre attention from the older naturalists, and our knowledge regarding this most important factor in fish-culture is but in its infancy, merely a passing glance having been bestowed on it by both naturalists and fish-culturists of the present day. Undoubtedly much good work has been done within the last five years towards investigating the food of the various species of marine food-fish, the result of examinations made on fish caught by steam trawlers and line boats; but in reference to fresh-water species, migratory and non-migratory, as far as I am aware, little effort has been made in this direction.

The present system of aiding the growth and development of fish by supplying them with various kinds of artificial foods, such as liver, coagulated blood, vegetables, etc., may produce results of a kind, but it is a system open to many objections.

First—It is unnatural.

Second—It has a tendency to render the water putrid, and consequently injurious to fish.

Third—It favors the introduction of disease.

Fourth—And last but not least, it entails a great deal of expense.

The results of such artificial feeding are found not to correspond to its cost, and this fact deters many people from engaging in the rearing of fish who would otherwise do so. All the results of artificial feeding are based more or less on hypothesis, because in making experiments the natural food, both animal and vegetable, has in most cases nowhere been investigated or taken into account. Now, I am sure no one will deny that it is better, if possible, to stick to the natural food, and give the powerful productions of nature a chance of exercising their beneficial influence. What I wish to bring before your immediate notice is this: "That at a comparatively small cost, conditions closely approximating those of nature can be established, under which conditions various forms of natural fish food will live, thrive and multiply, so as to afford a continual increasing supply of nutriment to the fish."

For the past two years I have been making investigations to find if possible some means by which fish, confined in small ponds could be supplied with natural food. My first step was to find out what the fish fed upon, and this led me to examine the stomach contents of numerous fish during the different seasons of the year. I confined my investigations to that most interesting class—the salmonidæ (*Salmo fontinalis* and *Salmo irideus*). What may be termed a post-mortem examination was performed—slitting the fish along its ventral or belly aspect, thus exposing the alimentary tract, I tied two ligatures, one around the gullet, the other round the intestine near the pyloric, or lesser end of the stomach. Removing the portion between the two ligatures, I opened the stomach and extracted the contents, placing them on a white plate. These I examined both by aid of the naked eye and microscope, then deposited them in a glass vial containing rectified spirits, and affixed a seal and label indicating the kind of food and date of examination. Thus at the end of the season I had quite an array of bottles containing different species of natural fish food.

The majority of the food belonged to the invertebrate type, including various species of crustacea, insecta, worms, leeches, and mollusca. Some of these the fish seemed to prefer at a certain season of the year to the exclusion of the others; thus I found the ordinary univalve shellfish (*Limnæa stagnalis*), a very frequent customer during the summer months, a decided favorite with both the *Salmo fontinalis* and *Salmo irideus.* This shellfish exists in enormous quantities in the lakes and quiet pools of rivers, and is greedily devoured by the trout. They feed on aquatic plants on whose stems they creep, and come occasionally to the surface to respire. In their reproduction the same limnæa is capable of serving at the same time as a male for a second, and as a female for a third, and by this connection of one individual with two others a continuous chain of some length is not unfrequently produced. The number of eggs is prodigious, and they are deposited on stones, stems of plants, etc., in elongated masses enveloped in a glary substance, very much similar in appearance to that which surrounds the ova of the frog. In their adult condition they love to crawl about on a gravelly bottom. Other genera, such as planorbis, cytilus and ancyllus, used to turn up on various occasions. These mollusca are a valuable source of nutriment to fish, having a double function, being composed of two parts, viz.: the fleshy portion or animal, which is a delicacy in itself, and its outer covering or shell, which, from its containing a large proportion of carbonate of lime, promotes the strength and growth of the fish.

Of crustacea, the common fresh water sand-hopper (*Gammarus pulex*) was invariably to be found. It abounds in almost all springs, ponds and rivulets, swimming near the bottom on its side. It feeds principally on dead material, and, like the limnæa, reproduces itseif in enormous quantities. As a diet, it seems to cause a deeper color in the flesh of the fish. Most of the larger trout like to feed on material more in proportion to their size; thus, in the summer months, the frog and tadpole are particularly sought after as a bill of fare. Various species of insecta both in their larval and adult conditions, worms and a small brownish black leech, are also in my list of stomach contents.

Now, as an adjunct to a fish pond, it seems to me that some of the above types could be reared in such quantities as to form a good and economical source of nutriment for fish. These lower types undoubtedly require certain conditions for their healthy existence, and what I propose is this: Trenches, or basins, should be dug in close apposition with the ponds, and, if necessary, communicating with them. These basins to be supplied with spring water by means of a pipe connected with the main spring. One should be devoted to Shell culture, another to Insect culture, and a third to Crustacea, and so on.

These various foods could be transferred by means of a fine net, or better still, by a running stream of water communicating with the fish pond, or means could be established whereby these forms could creep from the basin into the pond. By this method the fish-culturist would know exactly how much food the fish were getting, and he would also be able to arrive at some estimation as to the comparative nutritiousness of the various forms of natural food. Suitable conditions could be produced whereby insects about to deposit their eggs might be attracted, and soon the basins would swarm with larvæ, which form an excellent food, especially for young fish. As in human economy the food of the child requires to be different from that of the adult; so in like manner does the food of the young fish require to be different from that of the adult fish.

One word more, and that is regarding the frog. Should it be admitted into the arena of fish-culture? I think so. The damage it does to small fry can be kept within limits. A small pond could be constructed with an arrangement to prevent its escape, and in this pond the cultivation of the tadpole could be prosecuted, and for a time an abundant supply of stronger food would be afforded, for the large fish. Should the above experiments be tried and meet with success, they will establish the economic value of natural food as opposed to the artificial system of feeding; increase the number of fish culturists, and, in addition, afford a means of studying the life history of these lower forms, in connection with which are many points of great scientific interest requiring elucidation.

South Bend, Nebraska.

Mr. Mather remarked that he agreed with Mr. O'Brien that natural food was the best; but the trouble was to produce it in quantity sufficient for the daily food of a hundred thousand fry. He had a reservoir, about 300 by 30 feet, which supplied the hatching, and here he usually planted about 6,000 trout-fry, which found sufficient food during the summer, and outgrew those which were fed on clams and mussels, which, by the way, is the best food he ever used, and, in October, he drew this reservoir down and took out from 1,500 to 2,000 fine young trout; but it was doubtful if the water would grow many more.

SOME OBSERVATIONS ON THE BLACK BASS.

BY C. F. HOLT.

Having resided for the past thirty-five years on the bank of the Thornapple river, a favorite resort for that king of Michigan game fish, the small-mouthed black bass, I have had ample opportunities of studying their habits, and for the past few years have given the matter considerable attention.

They leave their winter quarters, usually under heaps of drift-wood or in hollow sunken logs, about the middle of April, and in a short time repair to their spawning grounds. I am quite sure that they pass the winter in hollow, sunken logs whenever they can, for, about the first of April, 1885, while removing some drift-wood from the river, we took out one hollow log that contained eighteen small-mouth black bass, weighing from two to three pounds each; and again this year, at about the same time, I found six more under the same conditions. The spawning season here begins the last week in April. The first bed seen in 1885 was on April 28; in 1886, April 24; and in 1887 and 1888, April 26. The places selected are in nearly still water, near the shore, and in water from one to two feet in depth.

The beds are circular in form, from eighteen inches to three feet in diameter, and are formed by cleaning from the bottom all sediment, sand, etc., leaving a bed of clean pebbles. This is the joint work of both male and female fish. The bed having been prepared, the female then moves slowly over it, depositing her ova, and the male impregnates them as fast as laid. The eggs, which are very small, are glued fast to the pebbles. The impregnation is almost absolutely perfect. In the past three years I have examined a large number of beds, by carefully removing one or more of the pebbles covered with eggs, and examining them with a microscope, and have never yet found more than one per cent. of unimpregnated eggs.

After the eggs are impregnated the male leaves to the female the whole care of the eggs and the young brood. She now passes constantly backwards and forwards over the bed, the motion of her fins and tail keeping the eggs clean, which the fact of their being glued fast permits her to do without washing them away. The following incident will illustrate the necessity for this constant care and attention on the part of the female, as well as point a moral, and furnish an illustration of how the greatest possible increase of this fish may be brought about: One evening in the spring of 1886 I noticed a "jack light" coming down the river, and I felt certain that some of my pets would have to suffer. I had endeavored to protect them as much as possible by requesting such neighbors as I could reach to respect my wishes, and to avoid the beds that I had under observation. Nearly all were willing to do so, but this time one of them made a mistake, as I expected they might, and when I went out in the morning the mother fish was gone. I thought I would secure the young fish (they were just hatched) and take them to the house and "bring them up by hand." So, putting on my wading boots, I walked out to the bed, and there I found, not the young fry, but three or four crayfish and some minnows, which had evidently devoured every fish on the bed. At another time, under similar circumstances, except that the eggs were not hatched, the crayfish had destroyed all the eggs. I took up every pebble without finding a single one.

The eggs are hatched in from five to ten days, according to the temperature of the water. When first hatched, the young fish are transparent, and so small as to be invisible to the naked eye. They have a much larger umbilical sac than the young brook trout, in proportion to the size of the body. At first they are unable to swim, or even move themselves from the bottom, but in from two to six weeks they begin to rise and swim, although they are from one to two months old before the sac wholly disappears and they become perfectly developed fish.

After the fish are hatched the mother seldom passes over the bed, as in their then helpless state the motion of her fins wouid scatter them; but instead she now swims in circles around it driving away all intruders, such as minnows, crawfish, etc. After the young begin to swim she enlarges the circle until it becomes from ten to fifteen feet in diameter, she then gradually drives them toward the shore into shallow water where she keeps them inside of a half circle, the shore forming the other side. From this half circle all of their natural enemies are carefully excluded, and the fish are allowed to develop. After that is done she scatters them along the shore among the weeds and grass, where, if pursued, they can find hiding places. Then, and only then, does she leave them to care for themselves. They are now from one-half to three-fourths of an inch in length, black in color and very lively, darting out of their hiding places and seizing their prey as readily as the older fish, and by the first of October following will be two inches in length.

I should estimate the average number of eggs in the beds at 4,000. Owing to the fact that some of the beds observed were near the mouths of cold spring brooks, where the temperature of the water in the river was much lower than where other beds were located, will account in a great measure, in my opinion, for the variation in the time taken for hatching the eggs and the development of the young fish; as in some seasons, and in some locations, I have found the young fish developed or weaned in one month from the time that the ova were deposited, and at other times two months were required for the same purpose.

I have been unable to procure both male and female fish at the proper time to try artificial impregnation, but have repeatedly taken part of the ova from the bed as soon as impregnated, and hatched them in dishes, and have kept them there until fully developed. I am of the opinion that very little can be done in the way of artificial impregnation or hatching, as nature has done for the black bass all that could be done.

All that the fish-culturist needs to do is to stock all suitable waters with them, where they do not now exist, and then protect them during the spawning season.

Cascade, Mich.

Mr. Fred Mather announced that the reports of salmon captures in the Hudson were increasing and that the river has been proved to have all the conditions necessary for a good salmon river, except fishways to enable the fish to surmount the dams and natural obstacles between Troy and the spawning grounds. In 1880 he had suggested to Prof. Baird that it was possible that this river was not a salmon river because the present fish had been debarred from the spawning grounds by natural obstructions before the settlement of the country, and that the trout streams near its source afford all the facilities for rearing young salmon, and in 1882 Mr. Mather hatched and planted 225,000 Penobscot salmon in Warren County. Every year since that plantings of increased numbers have been made from the Long Island hatchery under his supervision. This spring 440,000 were planted in the tributaries of the Hudson, in Warren County, and 20,000 on Long Island. In 1886 there was recorded ten salmon from the Hudson; in 1887 the number increased to between fifty and sixty, while this year over two hundred have already been taken, ranging in weight from six to twenty pounds. He had no doubt but the largest number of salmon taken were not heard of, but "North river salmon" was now a frequent sign in New York markets. While it is unlawful to capture these fish in the Hudson by any means excepting with hook and line, the fact that the gill-netters who drift for shad take many which are drowned before they reach them renders the law inoperative. Just before he left New York, Mr. Blackford told him of a fisherman at Yonkers who caught one but did not know what it was; he cut it open and it "looked red and unwholesome," and he threw it away. Now the fisherman is daily reminded of his mistake by his friends who ask if he has any red or diseased fish.

On motion, the meeting adjourned until the next day, and the members inspected the whitefish hatchery of the Michigan Fishery Commission, in the city, and although the whitefish hatching was over for the season, found interest in the eggs of wall-eyed pike and yellow perch, then in the hatching jars, and in the trout and grayling in the aquaria.

SECOND DAY'S PROCEEDINGS.

The meeting was called to order at 10 A. M., and the following was read :

NOTES ON THE FOOD OF THE FISHES OF THE MISSISSIPPI VALLEY.

BY PROF. S. A. FORBES.

There is a kind of insect in the South, called the agricultural ant, which is extremely fond of the seeds of certain grasses growing there spontaneously among the many species which make the prairie sod. Naturally, the agricultural methods of this ant are of a very primitive sort, and even fall below those of the native Indian. Besides collecting, wherever it can find them, the fallen seeds of many grasses and other plants, and storing these in its burrows, it also clears completely an area from six to twelve feet wide around its nest, and here either sows or permits to grow only one or two of the common grasses of whose seeds it is especially fond, harvesting the product and storing it for future use. It has not learned to cultivate the soil, or to introduce exotic plants of larger yield and better quality than those native to the sod, but it has advanced so far as to destroy on a little tract the competitors of the plants which bear its favorite food, and thus secures a larger and more convenient supply than would grow spontaneously. I mention this little ant because its agriculture seems to me to illustrate very well the aquaculture practiced by mankind at the present time. As this little insect collects the seeds of weeds wherever they happen to grow, so we fish the streams for whatever they happen to contain; and as it clears its little farm around its burrow, so we make our little fish ponds, seine out the worthless and destructive fishes, the snakes, frogs, and turtles, and throw the better species back to increase for our benefit. In two things our aquaculture is in advance of the agriculture of the ants,—we have successfully introduced two or three foreign species, and we have learned to take measures to maintain the fish supply wherever it has suffered from the effects of overpopulation. The first of these measures the ants have not thought of, and the second they probably do not need, because their numbers do not overrun their food supply. I believe it will pay us to inquire whether we can hope to get beyond this ant stage of aquaculture, and whether we may not learn to do at least as much to increase and improve the product of the waters of the country as the wild Indian did to cultivate the soil.

At present, four things are done, in general: First, we attempt to maintain or restore the relative numbers of our valuable aquatic animals—fish especially—defending the population of our waters against the evils growing out of civilized settlement. This is like trying to restore the native growth of trees and grasses to the surfaces deadened by travel and building, and by careless or unskillful usuage. Second, we try to increase the relative numbers of the most valuable of our native aquatic animals above the limit fixed originally by nature. This is as if we should collect and plant the nuts and acorns in the woods, and gather and sow abroad the seeds of the most valuable native grasses, in the hope that this artificial aid might enable our favorites to surpass their rivals. Third, we have aimed to introduce foreign with our native species in our natural waters. This is too much like sowing quantities of apple seeds and wheat and corn broadcast in the woods and on the prairies in the hope that if we use seed enough the plants we seek to introduce will crowd out the native vegetation. And, finally, we do, on a small scale, partly imitate actual agriculture by clearing or forming little patches of water here and there, and planting in them an exotic fish, protecting it from the competition of the native species. Here we approach the agricultural practice of the native Indian, who partly cleared his little patches in the river bottoms and planted and harvested the exotic corn and bean and pumpkin.

But it will not do to push this parallel too far. There are some things possible in agriculture which the aquaculturist cannot do. We cannot plow and till our lakes and rivers as the farmer does the prairie sod, ruthlessly exterminating all the native forms of life in order to substitute other sorts more useful to him. And even where we clear a little lake or start a pond, stocking it with carp or croppie, we cannot keep out the frogs and bullheads by any artificial tillage, as the farmer can the weeds. We are compelled, in other words, to work for improvement in the midst of things as they are. Not being able to destroy the native population of our waters, we have to take it into account and then make our adjustments to it. And right here, it has long seemed to me, is where the work is most needed. If we cannot get rid of the natural order, we certainly need to understand it. If we cannot destroy the native population, but must live and work with and through it, we certainly ought to know what it is like and what we can do with it; what we can do in spite of it, and what we cannot do because of it. It is because I have worked out some parts of an answer to these questions that I have ventured to appear here to-day, in a society of fish-culturists. If fish-culture is merely the culture of fishes, then I can have little or nothing to say, because I never raised a fish in my life; but if a scientific and rational fish-culture must finally merge in the broader science and art of aquaculture; if we must study to understand and improve the system of aquatic life into the midst of which we thrust our little fishes,—then I may perhaps claim some share in your deliberations.

What I have to report to-day is chiefly an answer to the question: What do our native fishes eat? This is only a single item of what we really need to know, and yet perhaps a larger one than might at first be supposed. Although fishes are the dominant class in every fairly permanent body of fresh water, they have no great variety of interests or occupations; but except for the relatively brief intervals devoted to their simple office of reproduction, they do little but to search for food and to eat, and avoid being eaten in turn; consequently, if we seek to measure or estimate their function in the general system of life in any region or locality, we are limited chiefly to their food relations, immediate and remote.

Among the purely practical results to be anticipated from such a study, are a more accurate knowledge of the conditions favorable to the growth and multiplication of the more important species; the ability to judge intelligently of 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 circumstance 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 and increase the supply of food and the incitement to healthful recreation afforded by the waters of the country.

As a contribution to the general subject, I present herewith a summary account of the food of twelve hundred and fifteen fishes, obtained from the waters of the State of Illinois at intervals from 1876 to 1887, and in various months from April to November. These fishes belonged to eighty-seven species of sixty-three genera and twenty-five families. They were taken from waters of every description, ranging from Lake Michigan to weedy stagnant ponds and temporary pools, and from the Mississippi and Ohio rivers to the muddy prairie creeks, and the rocky rivulets of the hilly portions of the State. Nine hundred and fourteen of the examples studied were practically adult, so far as the purposes of this investigation are concerned, the remaining three hundred and one being young, in the first stage of their food and feeding habits. More than half these young belonged to a single species—the common lake whitefish—but the remainder were well distributed.

I have arranged the matter under the following general heads: (1) a general account of the food of the most important species and families of our native adult fishes; (2) a brief account of the food of the young; and (3) a summary statement of the food, so made as to exhibit (*a*) the kinds and relative importance of the principal competitions among fishes, and (*b*) the relative value to the principal species of fishes of the major elements of their food.

First, then, I will attempt to give you very briefly, and in the most general way, the facts relating to the food of the most important fishes, those which I think most likely to interest you as fish-culturists, taking the species in their zoölogical order rather than in the order of their economic importance.

FOOD OF ADULTS.

The abundant *white perch* or *sheepshead* of the larger rivers and lakes, now commonly marketed, I find feeding, when full grown, almost exclusively upon the bivalve mollusks known in the West as clams, whose heavy shells this fish is enabled to crush and grind by a special apparatus in the throat. The shells are swallowed with the bodies and pass, in part at least, through the intestine. Half-grown specimens feed in much larger ratio upon aquatic insects, especially the larvæ of May flies, but take likewise the smaller mollusks with spiral shells, commonly known as water snails, the food in my examples being about equally divided between these two elements. The youngest specimens feed, like the young of fishes in general, upon the smallest of the Crustacea.

The *common perch* or "*ring perch*," excessively abundant throughout the northern part of the country, varies in food according to the waters it inhabits, those in the great lakes feeding almost wholly upon small fishes (especially of the minnow family), and upon crayfishes—five or six times as many of the former as of the latter. River specimens, however, eat few fishes, but find nearly half their food among the Crustacea, partly crayfishes, but chiefly the smaller kinds, known to zoölogists as amphipods and isopods, and in common speech as water wood-lice and brook shrimps. Aquatic insect larvæ, especially those of day-flies, and small spiral-shelled mollusks are eaten in about equal ratio.

The two *pike-perch* or "*wall-eyed pike*," are exclusively piscivorous, if we may judge from twenty-six specimens whose food I studied. More than a fourth of the fishes taken consisted of the spiny-finned species, including eight per cent. of catfishes, but nearly half were the common gizzard shad.

We shall find accumulating evidence that this shad, not used with us for food, is, notwithstanding, one of the most valuable fishes in our streams. Nevertheless, not the slightest attention is paid to its preservation, much less to its encouragement. The fishermen commonly regard these fishes as a mere nuisance, and leave them to die on the bank by hundreds, rather than take the trouble to return them to the water. They are a very delicate species, and are easily killed by rough handling in the seine, but the majority of those captured might be saved with a little care.

Their abundance as compared with some other species in our rivers might seem to indicate that they are common enough as it is. Few realize, however, the number of fishes needed to feed a pike-perch to maturity. Two or three items from my notes will furnish the basis for an intelligent estimate.

From the stomach of a pike-perch caught in Peoria Lake, October 27, 1878, I took ten well-preserved specimens of gizzard shad, each from three to four inches long; and from another I took seven of the same species, none under four inches in length. As the gizzard shad is a very thin, high fish, with a serrate belly, these were as large as a pike-perch can well swallow; and we may safely suppose that not less than five of this shad would make a full meal for that fish. The pike-perch is a very active hunter, and it is not at all probable that one can live and thrive on less than three such meals a week. The specimens above mentioned were taken in cold autumn weather, when most other fishes were eating but little; but since fishes generally take relatively little food in winter, we will suppose that the pike-perch eats, during the year, on an average, at this rate per week for forty weeks, giving us a total *per annum* of six hundred gizzard shad destroyed by one pike-perch. We cannot reckon the average life of a pike-perch at less than three years, and it is probably nearer five. The smallest estimate we can reasonably make of the food of each pike-perch would therefore be somewhere between eighteen hundred and three thousand fishes like the gizzard shad. A hundred pike-perch, such as should be taken each year along a few miles of a river like the Illinois, would therefore require from one hundred and eighty thousand to three hundred thousand fishes for their food. Finally, when we take into account the fact that a number of other species also prey upon the gizzard shad, and that the whole number destroyed in all ways must not exceed the mere *surplus* reproduced—otherwise the species would soon be extinguished—we can form an approximate idea of the multitudes in which the food species must abound if we would support any great number of predaceous fishes. The gizzard shad, being a mud-eater and a vegetarian, taking little animal food except when very young, can probably be more readily maintained in large numbers in our muddy streams than any other fish.

The two species of *black bass* differ, according to my observations, in the character of their food, the large-mouthed species eating more fishes, and the small-mouthed more crayfishes. Here, also, the gizzard shad made more than half the food.

The *common sunfishes* are readily divisible into four groups, based on their feeding structures and their food ; one characterized especially by the wide mouth, including the black warrior and the blue-cheeked sunfish, took a noticeable amount of fishes, the ratio varying from a third to a half, the remainder of the food being chiefly insects, crayfishes, and smaller crustaceans. Those with small mouths, pointed teeth in the throat, and short gill-rakers, like the most abundant of the river species, took scarcely any fishes, but fed chiefly on insects and crustaceans, the latter principally the forms of medium size (amphipods and isopods). Some of this group likewise took a large amount of vegetation, amounting to a third or fourth of the whole.

A group with small mouths, and blunt conical teeth in the throat, illustrated by the common bream or pumpkin seed, was distinguished especially by the number of small snail-like mollusks eaten, these making, in my specimens, more than a third of the food. The remainder was chiefly aquatic insect larvæ, the medium-sized Crustacea, and water plants.

The fourth group, illustrated by the croppies, have the mouth long but narrow, and the gill-rakers numerous and long. By these a few fishes are taken, but the food is chiefly insects and the smallest crustaceans—those commonly referred to as Entomostraca, a food resource which they are enabled to draw upon by the straining apparatus in the gills.

Passing to the pike or pickerel of our western rivers, I find that the common large *river pike*, *Esox lucius*, is almost wholly piscivorous, a single specimen only out of the thirty-seven examined, having taken a number of dragon flies. About a fifth of the fishes were sunfishes (half of them croppies) and black bass. Twenty of these thirty-seven pike had taken gizzard shad, which made, in fact, nearly half of the food of the entire group. Minnows were found in only two, and three had eaten buffalo fish.

The striking features of this record are the importance of the gizzard shad, the abundance of the spiny-finned fishes, including some of the most valuable kinds, and the insignificant number of minnows and suckers taken.

The "*grass pickerel*," a species which rarely reaches a foot in length, had eaten tadpoles of frogs, and fishes, and insects, the latter making more than a third of the food, and consisting chiefly of larvæ of dragon flies.

The *gizzard shad*, mentioned above as an especially valuable element of the food of the higher fishes, feeds itself almost wholly upon mud, with which the long and coiled intestine of every specimen was filled from end to end. This mud contained, on an average, about twenty per cent. of minute vegetable *débris*, with occasionally a little animal matter.

The great *minnow family* I can scarcely pass by, since it contributes so largely to the food of other fishes, although itself of little or no direct advantage to mankind. I found this family dividing into several groups based upon the length of the intestine and the form of the pharyngeal teeth. In the first of these groups, containing several of the more abundant sorts, about three fourths of the food consisted of soft black mud, the remainder being both animal and vegetable matter, chiefly the latter. These fishes all had very long intestines and smooth grinding teeth in the throat. In another group quantities of mud are also taken, but with it many Entomostraca; while in groups three and four, containing by far the greater portion of the family, the food is essentially different, about three fourths of it being insects and small crustaceans, and the remainder vegetation. I note especially here the value of the mud-eating minnows as food for larger fishes, since while abundant and easily maintained, they do not compete with the young of the larger fishes to whose sustenance they may be applied.

One of the most striking characteristics of the fish-fauna of the Mississippi Valley is the prominence of the *sucker family*, several of which are among the most abundant of our larger fishes. About one tenth the food of this family taken as a whole consisted of vegetation, eaten chiefly by the buffalo fishes, and in them composed largely of distillery slops. The family is, however, essentially carnivorous, mollusks and insects appearing in nearly equal ratio in the food. The former are taken much the more generally by the cylindrical suckers, and the latter about equally by all except the stone roller, which collects great quantities of insect food by pushing about the stones in running water. A large proportion of the insects eaten are small larvæ of gnats (Chironomus). Some of the deeper-bodied species with long gill-rakers, especially the river carp, feed largely on Entomostraca, this latter species swallowing also considerable quantities of mud.

The *catfishes*, taken together, are nearly omnivorous in habit, and their feeding structures have a correspondingly general character. The capacious mouth, wide gullet, and short, broad stomach admit objects of large size and nearly every shape. The jaws, each armed with a broad pad of fine, sharp teeth, are well calculated to grasp and hold soft bodies as well as hard. The gill-rakers are of average number and development, and crushing jaws in the throat, broad, stout arches below, and oval pads above, covered with minute pointed teeth, serve fairly well to break the crusts of insects and the shells of the smaller mollusks, and to squeeze and grind the vegetable objects which occur in the food. The most peculiar feeding habit relates to the larger bivalve mollusks, the bodies of which are frequently found almost entire in the stomachs of these fishes and always without a fragment of a shell. I have been repeatedly assured by fishermen that the catfish seizes the foot of the mollusk while the latter is extended from the shell, and tears the animal loose by vigorously jerking and rubbing it about. One intelligent fisherman informed me that he was often first notified of the presence of catfishes in his seine, in making a haul, by seeing the fragments of clams floating on the surface, disgorged by the struggling captives. Finally, these are the only habitual scavengers among our common fishes. The larger deep-water species from the great rivers are strictly piscivorous, so far as known. Very small stone-cats feed on the smaller insect larvæ and the medium-sized crustacea. The spotted cat, blue Fulton, or fiddler, feeds largely on mollusks, but is, nevertheless, chiefly insectivorous. It differs from most of the river catfishes by eating water-plants to a considerable extent. The common bullhead is more strictly omnivorous than any other kind, its food being composed about equally of fishes, mollusks, aquatic insects, and vegetable structures, with a very considerable ratio of crustaceans added. The great mud-cat or Morgan cat, reaching a weight of over one hundred pounds, seems to feed entirely upon fishes.

The abundant and peculiar *dogfish*, or "*grindle*," is strictly carnivorous, about one third of the food being fishes, a fourth of it small mollusks, and nearly half crustaceans, chiefly crayfish.

The *gars* are all strictly piscivorous, feeding especially upon the gizzard shad.

The most remarkable of our fishes, in structure and feeding habit, is the *shovel-fish*, or "*spoonbill*," of the Mississippi and its larger tributaries. It is a large species, reaching a weight of thirty pounds and upwards and a length of six feet or more, including the paddle-like snout. Although so large, the greater part of its food consists of the smallest aquatic Crustacea and insect larvæ, strained from the water by means of an extraordinary apparatus in the gills, composed of long and slender gill-rakers, a double series on each arch, and over five hundred in a series. Interlocking as these do when the gill apparatus is extended, they form a strainer sufficient to arrest the smallest living forms above the Protozoa, and with the immense opening of the mouth and equally free provision for the exit of water from the gill chamber, enable this fish to strain out enormous quantities of these minute animal forms, especially those most commonly reserved for young fishes. It takes also, in mid-summer, insect larvæ of medium size, but evidently avoids vegetation, and never swallows mud.

FOOD OF THE YOUNG.

By an examination of three hundred and one specimens, representing twenty-seven species, twenty-six genera, and twelve families of Illinois fishes, I learn that the food of many species of fishes differs greatly according to age; and that, in fact, the life of most of our fishes divides into at least two periods, and that of many into three, with respect to the kinds of food chiefly taken. Further, in the first of these periods a remarkable similarity of food was noticed among species whose later feeding habits are widely different. The full-grown black bass, for example, feeds principally on fishes and crayfishes, the sheepshead on mollusks, and the gizzard shad on mud and Algæ, while the catfishes are nearly omnivorous; yet all these agree so closely in food when very small, that one could not possibly tell from the contents of the stomachs which group he was dealing with.

In the earliest stage, all the fishes studied, except suckers and minnows, depend for food on the smallest crustaceans, commonly called Entomostraca, and on certain small worm-like larvæ of gnats or gnat-like flies scarcely larger than these crustaceans, and usually occurring with them. By far the most abundant of these insect larvæ was that known as Chironomus. The suckers and minnows differ from our other fishes by being toothless while very young, as well as when adult, while our other toothless fishes, gizzard shad, whitefish, etc., have in youth a set of evanescent teeth. These toothless young I found feeding in part on still smaller prey than the others, taking the smallest animal forms (wheel animalcules), various Protozoa, and Algæ so minute that the whole plant consists of a single vegetable cell. The food of the whitefish fry was determined by keeping several hundred of them in a large aquarium kept constantly supplied with all the living objects which a fine gauze net would separate from the waters of Lake Michigan.*

While small fishes of all sorts are evidently competitors for food, this competition is relieved to some extent by differences of breeding season, the species dropping in successively to the banquet, some commencing in very early spring, or even, like the whitefish, depositing their eggs in fall, that their young may be the first at the board, while others delay until June or July. The most active breeding period coincides, however, with that of the greatest evolution of Entomostraca in the backwaters of our streams; that is, the early spring. That large adult fishes with fine and numerous rakers on the gills—like the shovel fish and the river carp—may compete directly with the young of all other species, and tend to keep their numbers down by diminishing their food supply—especially in times of scarcity—is very probable, but is not certainly true as a general thing; for these larger fishes have other food resources, also, and may resort to Entomostraca only when these are superabundant, thus appropriating the mere excess above what are required for the young of other groups. Of the fishes which emerge from this earliest stage through increase in size with failure to develop alimentary structures especially fitted to the appropriation of minute animal forms, some become mud-eaters, like the Campostoma and the gizzard shad; a few apparently become vegetarians at once; but most pass into or through an insectivorous stage. After this a few become nearly omnivorous,

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* See note following this paper.

like the bullheads ; others learn to depend chiefly on molluscan food—the sheepshead and the red horse species; but many become essentially carnivorous. In fact, unless the gars are an exception, as they now seem to be (attacking young fishes almost as soon as they can swallow), all our specially carnivorous fishes make a progress of three steps, marked, respectively, by the predominance of Entomostraca, insects, and fishes in their food ; and the same is true of those strictly fitted for a molluscan diet.

PRINCIPAL ELEMENTS OF THE FOOD.

An analysis of the facts made with reference to the kinds of fishes eating each of the principal articles in the dietary of the class, and showing the relative importance of these elements in the food of the various species, will have its separate interest for us, especially as it will exhibit the competitions of fishes for food, and also the nature and the energy of the restraints imposed by fishes on the multiplication of their principal food species.

The principal *fish-eaters* among our fishes—those whose average food in the adult stage consists of seventy-five per cent., or more, of fishes—are the burbot, the pike-perch or wall-eyed pike, the common pike or pickerel, the large-mouthed black bass, the channel-cat, the mud-cat, and the gars. Possibly, also, the golden shad will be found strictly ichthyophagous, this being the case with the four specimens which I studied. Those which take fishes in considerable but moderate amount—the ratios ranging in my specimens from twenty-five to sixty-five per cent.—are the war-mouth (Chænobryttus), the blue-cheeked sunfish, the grass pickerel, the dog-fish, the spotted cat, and the small miller's thumb. The white and the striped bass, the common perch, the remaining sunfishes (those with smaller mouths), the rock bass, and the croppie, take but few fishes, these making, according to my observations, not less than five nor more than twenty-five per cent. of their food. Those which never capture living fishes, or, at most, to a merely trivial extent, are the white perch or sheepshead, the gizzard shad, the suckers, and the shovel fish among the larger species; and the darters, the brook silversides, the stickleback, the mud minnows, the top minnows, the stone-cats, and the common minnows generally, among the smaller kinds. Our eight specimens of the toothed herring had taken no fishes whatever; while our nineteen examples of the pirate perch had eaten only two per cent.

Rough-scaled fishes with spiny fins were eaten by the miller's thumb, the common pike, the wall-eyed pike, the large-mouthed black bass, the croppies, the dog-fish, the common perch, the burbot, the bull-head, the common sunfish (*Lepomis pallidus*), the small-mouthed black bass, the grass pickerel, the gar, and the mud-cat (Leptops). Among these, the common perch and the sunfishes were most frequently taken—doubtless owing to their greater relative abundance—the perch occurring in the food of the burbot, the large-mouthed black bass, and the bullhead; and the sunfishes in both species of wall-eyed pike, the common pike, the gars, pickerel, bullheads, and mud-cat. Black bass were taken from the common pike (Esox), the wall-eyed pike (Stizostedion), and the gar. Croppie and rock bass I recognized only in the pike. Even the catfishes with their stout, sharp, and poisoned spines were more frequently eaten than would have been expected—taken, according to my notes, by the wall-eyed pike, both black bass, and a fellow species of the family, the *goujon* or mud-cat.

The soft-finned fishes were not very much more abundant, on the whole, in the stomachs of other species, than those with ctenoid scales, spiny fins, and other defensive structures, an unexpected circumstance which I cannot at present explain, because I do not not know whether it expresses a normal and fixed relation, or whether it may not be due to human interference.

Only the catfishes seem to have acquired defensive structures equal to their protection, the predatory apparatus of the carnivorous fishes having otherwise outrun in development the protective armor of the best-defended species.

Among the soft-finned species the most valuable as food for other fishes is the gizzard shad, Dorosoma, this single fish being about twice as common in adults as all the minnow family taken together. It made forty per cent. of the food of the wall-eyed pike ; a third that of the black bass ; nearly half that of the common pike or "pickerel" ; two thirds that of the four specimens of golden shad examined ; and a third of the food of the gars. The only other fishes in whose stomachs it was recognized were the yellow cat, *Ictalurus natalis*, and young white bass, Roccus. It thus seems to be the especial food of the large game fishes and other particularly predaceous kinds.

The minnow family (Cyprinidæ) are in our waters especially appropriated to the support of the half-grown game fishes, and the smaller carnivorous kinds. They were found in the wall-eyed pike, the perch, the black bass, the blue-cheeked sunfish, the croppie, the pirate perch, the pike, the little pickerel, the chub minnow, the yellow cat, the mud-cat, the dog-fish, and the gar.

Suckers, Catostomatidæ, I determined only from the pike, the sheepshead, the blue-cheeked sunfish (*cyanellus*), the yellow cat, and the dog-fish (*Amia*). Buffalo and carp occurred in the pike, the dog-fish, and the above sunfish.

The ponds and muddy 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 groups 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. The class as a whole makes about one fourth of the food of the dog-fish and the sheepshead—taking the latter as they come, half-grown and adults together—about half that of the cylindrical suckers—rising to sixty per cent. in the red horse—and a considerable ratio (fourteen to sixteen per cent.) of the food of the perch, the common catfishes (Amiurus and Ictalurus), the small-mouthed sunfishes, the top minnows, and the shiner (Notemigonus). Notwithstanding the abundance of the fresh-water clams or river mussels (Unio and Anodonta), only a single river fish is especially adapted to their destruction, viz., the white perch or sheepshead, and this species derives, on the whole, a larger part of its food from univalve than from bivalve mollusks, the former eaten especially by half-grown specimens, and the latter being the chief dependence of the adults. The ability of the catfishes to tear the less powerful clams from their shells has been already mentioned. Large clams were eaten freely by the full-grown sheepshead—whose enormous and powerful pharyngeal jaws with their solid pavement teeth are especially adapted to crushing the shells of mollusks—and by the bull-heads (Amiurus), especially the marbled cat. The small and thin-shelled Sphæriums are much more frequent objects in the food of mollusk-eating fishes than are the Unios. This genus alone made twenty-nine per cent. of the food of our one hundred and seven specimens of the sucker family, and nineteen per cent. of that of a dozen dog-fishes. Among the suckers it was eaten greedily by both the cylindrical and the deep-bodied species, although somewhat more freely by the former. Even the river carp, with its weak pharyngeal jaws and delicate teeth, finds these sufficient to crush the shells of Sphærium, and our nineteen specimens had obtained about one fourth of their food from this genus. Besides the above families, smaller quantities of the bivalve mollusks occurred in the food of one of the sunfishes (*Lepomis pallidus*), and—doubtless by accident only—in the gizzard shad. The gasteropod mollusks (snails of various descriptions) were more abundant than bivalve forms in the sheepshead, sunfish, and all the smaller fishes which feed upon Mollusca, but less abundant in the suckers and the catfishes. In the sheepshead they made one fifth of the food of the twenty-five specimens examined, but the greater part of these had not yet passed the insectivorous stage, this being much longer continued in the sheepshead than in many other fishes. A few of these univalve Mollusca occurred in the food of the common perch and in certain species of sunfishes—especially the superabundant bream or pumpkin-seed. They made fifteen per cent. of the food of the minute top minnows, and occurred in smaller quantities among the darters, the little pickerel, the mud minnows and the cyprinoids. The heavier river snails, Vivipara and Melantho, were eaten especially by the cylindrical suckers and the catfishes. The delicate pond snails (Succinea, Lemna, and Physa) were taken chiefly by the smaller mollusk-eating fishes—a few of them also by the catfishes and the suckers.

It is from the class of *insects* that adult fishes derive the most important portion of their food ; and, taken as a whole, this class furnishes thirty-eight per cent. of the food of all which I examined. The principal insectivorous fishes are the smaller species, whose size and food structures, when adult, unfit them for the capture of Entomostraca and yet do not bring them within reach of fishes or Mollusca. Some of these fishes have peculiar habits which render them especially dependent upon insect life—the little minnow, Phenacobius, for example, which, according to my studies, makes nearly all its food (ninety-eight per cent.) from insects found under stones in running water. Next are the pirate perch, Aphredoderus (ninety-one per cent.), then the darters (eighty-seven per cent.), the croppies (seventy-three per cent.), half-grown sheepshead (seventy-one per cent.), the shovel fish (fifty-nine per cent.), the chub minnow, Semotilus (fifty-six per cent.), the black warrior sunfish (Chænobryttus) and the brook silversides (each fifty-four per cent.), and the rock bass and the cyprinoid genus Notropis (each fifty-two per cent).

Those which take few insects or none are mostly the mud feeders and the ichthyophagous species, Amia (the dog-fish) being the only exception to this general statement. Thus we find insects wholly or nearly absent from the adult dietary of the burbot, the pike, the gar, the black bass, the wall-eyed pike, and the great river catfish, and from that of the hickory shad and the mud-eating minnows (the shiner, the fat-head, etc.). It is to be remembered, however, that the larger fishes all go through an insectivorous stage, whether their food when adult be almost wholly other fishes, as with the gar and the pike, or mollusks, as with the sheepshead. The mud-feeders, however, seem not to pass through this stage, but to adopt the limophagous habit as soon as they cease to depend upon Entomostraca.

Terrestrial insects, dropping into the water accidentally or swept in by rains, are evidently diligently sought and largely depended upon by several species, such as the pirate perch, the brook minnow, the top minnows or killifishes (Cyprinodonticlæ), the toothed herring and several cyprinoids (Semotilus, Pimephales, and Notropis).

Among aquatic insects, minute, slender dipterous larvæ are of remarkable importance, making, in fact, nearly one twelfth of the food of all the fishes studied. They amounted to about one third the food in fishes as large and important as the red horse and the river carp, and made nearly one fourth that of fifty-one buffalo fishes. They appear further in considerable quantity in the food of a number of the minnow family (Notropis, Pimephales, etc.), which habitually frequent the swift water of stony streams. Aquatic beetles and larvæ, notwithstanding the abundance of some of the forms, occurred in only insignificant ratios, but were taken by fifty-six specimens. The adult surface beetles, whose zig-zag darting swarms no one can have failed to notice, were not once encountered in my studies.

The almost equally well-known slender water-skippers seem also completely protected by their habits and activity from capture by fishes, only one occurring in the food of all our specimens.

It is from the order Neuroptera that fishes draw a larger part of their food than from any other single insect group. In fact, nearly one sixth of the entire amount of food consumed by all the fishes examined by me consisted of aquatic larvæ of this order, the greater part of them larvæ of day flies. These Neuroptera larvæ were eaten especially by the miller's thumbs, the sheepshead, the white and striped bass, the common perch, thirteen species of the darters, both the black bass, seven of the sunfishes, the rock bass and the croppies, the pirate perch, the brook silversides, the sticklebacks, the mud minnow, three top minnows, the gizzard shad, the toothed herring, twelve species each of the true minnow family and of the suckers and buffalo, five catfishes, the dog-fish and the shovel-fish—seventy species out of the eighty-seven which I studied.

Of the four principal classes of the food of fishes, viz., fishes, mollusks, insects, and *Crustacea*, the latter stand third in importance according to my observations, mollusks alone being inferior to them. That insect larvæ should be more abundant in the food of fresh-water fishes than are crustaceans, is a somewhat unexpected fact, but while the former make about twenty-five per cent. of the food of our entire collection, the crustaceans amount to only fourteen per cent. Crayfishes made about a sixth of the food of the burbot, about a tenth that of the common perch, a fourth that of half a dozen gars, and not far from a third that of the black bass*, the dog-fish, and our four rock bass. Young crayfishes appeared quite frequently in some of the larger minnows (Semotilus and Hybopsis), and also in catfishes, especially the pond and river bull-heads, averaging nearly fifteen per cent. of the entire food of the two most abundant species.

The minute crustaceans commonly grouped as Entomostraca are a much more important element. Among full-grown fishes, I find them especially important in the shovel-fish—where they made two thirds of the food of the specimens studied—and in the common lake herring. Among the sunfishes at large they were present in only insignificant ratio; but the croppies, distinguished by long and numerous rakers on the anterior gill, had derived about a tenth of their food from these minute crustaceans. In the early spring, especially, when the back-waters of the streams are filled with Entomostraca, the stomachs of these fishes are often distended with the commonest forms. Ten per cent. of the food of the sucker family consisted of them, mostly taken by the deep-bodied species, in which they made a fourth or a fifth of the entire food. This fact is explained, it will be remembered, by the relatively long, slender, and numerous gill-rakers of these fishes. Large river buffalo were occasionally crammed with the smallest of these Entomostraca, only a twenty-fifth of an inch in length.

I have several times remarked the peculiar importance of Entomostraca to the shovel-fish—one of the largest of our fresh-water animals—a fact accounted for by the remarkable branchial strainer of this species, probably the most efficient apparatus of its kind known to the ichthyologist. Here, again, the smallest forms were the most abundant.

* Our specimens—especially of the small-mouthed black bass—were too few in number to make this average reliable.

Probably to those accustomed to the abundance of true *worms* in marine situations, no feature of the poverty of fresh-water life will be more striking than the small number of this subkingdom occurring in the course of miscellaneous aquatic collections in the interior. Similarly, we notice that in the food of fishes the occurrence of Vermes is so rarely noticed that they might be left out of account entirely without appreciably affecting any of the important ratios. Catfishes alone seem purposely to eat leeches, these occurring in nine specimens of three different species of this family, and also in one common sucker and in a single shovel-fish. One of the fresh-water *Sponges* (Spongilla) had been eaten in considerable quantities by two examples of the spotted cat taken in September, but this element was not encountered elsewhere in my studies.

That the minutest and simplest of all the animal forms, far too small for the eye of a fish to see without a microscope, should have been recognized in the food of seventeen species of fishes is, of course, to be explained only as an incident of the feeding habit. It is possible, however, that these *Protozoa*, where especially abundant, may be recognized in the mass by the delicate sensory structures of the fish; and they seem in most cases to have been taken with mud and slime, rich in organic substances. As most of them are extremely perishable, and can scarcely leave a trace a few seconds after immersion in the gastric juices of the fish, it is probable that they contribute much more generally than our observations indicate to the food of some fishes, especially to those which feed upon the bottom.

Young suckers under six inches in length clearly take them purposely, substituting them in great part for the Entomostraca taken by other fishes of their size and age.

I detected Protozoa in the food of several genera of Cyprinidæ, in the young of buffalo, the river carp, the chub sucker, the red-horse, the stone roller, in the common sucker, in a single gizzard shad, in a stone-cat, and in a top minnow.

The only *scavenger* fishes of our collection were three species of the common catfishes; the spotted cat, the yellow cat, and the marbled cat—all of which had eaten dead animal matter, including pieces of fish, ham, mice, kittens, and the like. A single large-mouthed black bass had likewise eaten food of this description.

Considering the wealth of *vegetation* accessible to aquatic animals, and the fact that few other strictly aquatic kinds have the vegetarian habit, it is indeed remarkable that fishes draw from plants an unimportant part of their diet. Taking our nine hundred specimens together, the vegetation eaten by them certainly would have amounted to less than ten per cent. of their entire food, and excluding vegetable objects apparently taken by chance, it probably would not reach five per cent.

The greatest vegetarians are among the minnow family. Counting each genus as a unit, I find that the family as a whole obtained from plants about twenty-three per cent. of its food. The little Phenacobius, already reported as strictly insectivorous, was the only one studied in which vegetation can scarcely be said to occur.

Certain of the sunfishes evidently take plant food purposely on occasion, this making, for example, nearly a tenth of the food of forty-seven specimens of Lepomis. Among the larger fishes, the principal vegetarians are the gizzard shad, in which this element was reckoned at about a third, taken, however, not separately, but with quantities of mud. A considerable part of the vegetation here included, consisted of distillery slops obtained near towns. The buffalo fishes are likewise largely vegetarians, more than a fourth of their food coming from the vegetable kingdom; about a third of this in our specimens being refuse from distilleries. Vegetation made a tenth of the food of the larger genera of catfishes (Amiurus and Ictalurus)—some of it distillery refuse—and nearly as large a ratio of the great Polyodon.

Not infrequently, terrestrial vegetable rubbish—seeds of grasses, leaves of plants, and similar matter—was taken in quantity to make it certain that its appropriation was not accidental. The principal *mud-eating* fishes are the gizzard shad, the common shiner, and certain genera of minnows with elongate intestines and cultrate pharyngeal teeth. Much mud was also taken by the cylindrical members of the sucker family, but apparently as an incident to their search for mollusks.

CONCLUSION.

I cannot attempt to discuss the practical bearing of the mass of data here presented, or of the much greater number which I have withheld, partly because the time is lacking, and partly because I know too little of practical fish-culture ; and I will merely call attention to a few illustrative points which have occurred to me in writing.

It would seem that the fact that all young fishes compete, at first, for food must have important practical results tending in various directions. It is probable that all fishes which are not especially adapted to the food requirements of the more valuable fishes are hurtful to them, because they limit the food available for their young. It seems possible that even the food species of the predaceous fishes may multiply to an extent injurious to the latter, since both robber and prey compete while young for the same elements of food. It would seem entirely likely that large fishes, like the shovel-fish, which destroy when adult immense quantities of the proper food of the young, must be reckoned as injurious.

Again, it is evident that the fishes most desirable as food for other kinds are those whose own food is not eaten by valuable species, but exists in practically inexhaustible supplies. The gizzard shad and the mud-feeding minnows are examples of this sort; while the red-horse and other cylindrical suckers answer the purpose almost equally well, since no valuable fishes feed upon mollusks (especially preferred by the suckers), and these are among the most abundant animals in our western streams. The fact that they have likewise adapted themselves to civilization, so far at least as to relish distillery slops, is, perhaps, an additional recommendation from this point of view.

The smaller catfishes, being practically omnivorous, are the rivals of every other kind ; and being almost perfectly protected from capture by their stout, sharp, poisoned spines, they contribute little to the food supply of other fishes. The common sunfishes are almost equally worthless and injurious from this point of view.

I need scarcely say that the fish-culturist should examine the waters in which young fishes are planted, in order to determine the amount of their appropriate food available. It is not impossible that myriads of whitefish have been set free to perish by starvation before the feeble fry could disperse widely enough to secure a single meal. It seems to me also, that in every case where it is proposed to introduce a new fish into waters already populated, the first question to be asked should be, what fishes do these waters already contain—and in what numbers—whose food and whose relations to nature generally are substantially the same as those it is intended to introduce?

And, finally, I would call attention to the necessity of keeping continuous watch of the balance and abundance of plant and animal life in its various leading forms in any body of water in which it is thought desirable to maintain especial kinds of fishes in the greatest number possible. The owner of a fish pond especially, who makes himself acquainted with the entire collection of animals and plants which his pond contains, and keeps the run of these in their variations of number and habit, from season to season and from year to year, will not only get some practical hints thereby, which will aid him in the multiplication and preservation of his fish, but will derive no small amount of pleasure from his observations, and from the reasonings and reflections to which they will give rise.

NOTE ON THE FIRST FOOD OF THE WHITEFISH.

An elaborate account of this research was published in 1883, in the first volume of the Bulletin of the Illinois State Laboratory of Natural History; but as this article was not widely distributed among fish-culturists, the great practical importance of the subject, will perhaps, justify the following extracts from it: More light was thrown upon the earliest food habits of these fishes by the discovery of raptatorial teeth upon the lower jaw, than by the dissections of their alimentary canals. All the families of fishes which I had previously studied whose young were provided with teeth, were found strictly dependent at first upon Entomostraca and the minuter insect larvæ; while only those whose young were toothless fed to any considerable extent upon other forms. The discovery of teeth in the young whitefish, therefore, placed this species definitely in the group of those carnivorous when young. The fact that the adult was itself toothless interfered in no way with this inference, because other toothless fishes (Dorosoma) whose young were furnished with teeth, had been found carnivorous at an early age.

The inconclusive character of the results thus far obtained, made it necessary to attempt to imitate more closely the natural conditions of the young when hatched in the lake. In February, 1881, I obtained, through the kindness of Mr. Clarke, twenty-five specimens of living young whitefish, saved from a lot which he was planting in the waters of Lake Michigan, off Racine, Wisconsin. I succeeded in conveying them to the laboratory without loss, and there kept them for several days in a glass aquarium and supplied them with an abundance of the living objects to be obtained by drawing a fine muslin net through the stagnant pools of the vicinity. These consisted of many diatoms and filamentous fresh-water Algæ, of two or three species of Cyclops, of *Canthocamptus illinoisensis*, and *Diaptomus sanguineus* among the Copepoda, and of two rather large Cladocera, *Simocephalus vetulus* and *S. americanus*. These little fishes were kept under careful observation for several days, the water in the aquarium being frequently aërated by pouring. Many of them had, however, been injured by handling, and eleven of the specimens died without taking food. It was soon evident that the larger Entomostraca (the *Simocephalus*, and even the *Diaptomus*) were quite beyond the size and strength of these little fishes, and that only the smaller Copepoda, among the animals available, could afford them any food at first. These they followed about from the beginning with signs of peculiar interest, occasionally making irresolute attempts to capture them. Two days after their arrival, one of the young whitefish had evidently taken food, which proved, on dissection, to be a small Cyclops. During the next two days nine others began to eat, dividing their attentions between the Cyclops above mentioned and the Canthocamptus, and on the 22d two other took a Cyclops each and a third a Canthocamptus.

One of these fishes contained still a large remnant of the egg-sac, showing that the propensity to capture prey must antedate the sensation of hunger. On the 25th the fourteenth and last remaining fish captured its Cyclops, and was itself sacrificed in turn. As an indication of the efficiency of the raptatorial teeth, it may be worth while to note that I saw one of the smallest fishes make a spring at a Cyclops, catch it, give three or four violent wriggles, and drop it dead to the bottom of the tank.

As a general statement of the result of the observations made on these fourteen fishes, we may say that eight of them ate a single Cyclops each, that one took two, and another three of the same, that one took a single Canthocamptus, that two specimens captured two each of this genus, and that finally, a single fish ate Cyclops and Canthocamptus both. The final conclusion was a highly probable inference that the smallest Entomostraca occurring in the lake would prove to be the natural food of the species.

In order to test this conclusion with precision, I arranged a similar experiment on a larger scale, and under more natural conditions. Through the generosity of the Exposition Company, of Chicago, I was allowed the use of one of the large aquarium tanks in the Exposition building, on the lake shore, and by the repeated kindness of Mr. Clarke, of Northville, Michigan, I was furnished with a much larger number of living whitefish. Five thousand fry were shipped to me in a can of water, but through unfortunate delays in changing cars at intermediate points, about two-thirds of these were dead when they reached my hands. Those living were immediately transferred to the tank, through which the water, taken from the city pipes, had already been allowed to run for several hours. As this water is derived from Lake Michigan at a distance of two miles from the shore, and had at this time the exact temperature of the open lake, the conditions for experiment were as favorable as artificial arrangements could well be made.

Sending a man with a towing-net out upon the lake with a boat, or upon the remotest breakwaters, immense numbers of all organic objects in the waters were easily obtained. After enclosing the exit of the tank with a fine wire screen, to prevent the escape of objects placed in it, we poured these collections of all descriptions indiscriminately into the water from day to day, thus keeping the fishes profusely supplied with all the various kinds of food which could possibly be accessible to them in their native haunts. From this tank one hundred fishes were taken daily and placed in alcohol for dissection and microscopic study, to determine precisely the objects preferred by them for food. These were examined at a later date, and all contents of the intestines were mounted entire as microscopic slides, and permanently preserved. A careful study was, of course, made of the organisms of the lake, as shown by the product of the towing-net, and when the experiment was finally ended, it was followed by an equally careful examination of the living contents of the water of the tank at that time.

These fishes, like those previously described, had already reached the age and condition at which it is customary to "plant" them in the lake. The ventrals were still undeveloped, the egg sac had nearly disappeared, the four mandibular teeth were present, and the median fin extended from the tips of the pectorals on the belly to a point opposite the middle of the same fins on the back. In most the egg-sac did not protrude externally, being reduced in some to a droplet of oil, but remaining in a few of a size at least as great as that of the head. The alimentary canal was, of course, a simple, straight tube, without any distinction of stomach and intestines.

The sufferings of these fry in transit had doubtless weakened the vitality of the survivors, and although every care was taken to keep the water of the tank fresh and pure, about one-third of those remaining died during the progress of the experiment. The aquarium in which they were confined was built of glass, and had a capacity of about one hundred cubic feet. The temperature, tried repeatedly, stood at forty-two Fahrenheit. A steady current of the water of the lake was maintained through this tank, entering through a rose, from which it fell in a spray, thus insuring perfect aëration.

By far the greater part of the organic contents of the water of the lake, as shown by the product of the towing-net, consisted of diatoms in immense variety, which formed always a greenish mucilaginous coating upon the interior of the muslin net. In this were entangled a variety of rotifers, occasional filamentous Algæ, and many Entomostraca, the latter belonging chiefly to the genera Cyclops, Diaptomus and Limnocalanus among the Copepoda, and to Daphnia among the Cladocera.

As the Entomostraca proved to be far the most important elements of this food supply, the particulars respecting them may be properly more fully given. The smallest of all was a Cyclops, then new, but since described by me under the name of *Cyclops thomasi.** This little Entromostracan is only .04 inch long by .011 wide. The next in size, and by far the most abundant member of this group, was a Diaptomus, likewise new, described in the paper just cited, under the name of *Diaptomus sicilis.* This appears in two forms, one, evidently young, in the stage just preceding the adult. Full-grown individuals were .065 inch long by one-fourth that depth. The Limnocalanus was a much larger form, evidently preying, to a considerable extent, upon the two just mentioned. All the Cladocera noticed were *Daphnia hyalina*, an elegant and extremely transparent species, occurring likewise in the lakes of Europe. A single insect larval form (Chironomus) should likewise be mentioned in this connection, since it had about the same size and consistence of the Entomostraca, and was consequently available for food. The specimens of each of the above species from a certain quantity of these collections were counted, in order to give a definite idea of their relative abundance in the lake; the Diaptomus numbered 225, the Cyclops 75, Limnocalanus 7, Daphnia 3, and Chironomus larvæ 1. It was a curious fact, however, that when the water was drawn off at the end of the experiment, more than half the Entomostraca were Limnocalanus; a fact partly to be explained by the predaceous habit of the latter, and partly by the facts relating to the food of the fishes themselves, which are presently to be detailed. The fry were placed in the tank and supplied with their first food on the evening of the 12th of March. On the

* "On some Entromostraca of Lake Michigan and Adjacent Waters." American Naturalist, Vol. XVI., No. VIII. (August, 1882), pp. 640 and 649.

14th, one hundred specimens were removed, and twenty-seven of these were dissected. Twenty were empty, but the remaining seven had already taken food, all Cyclops or Diaptomus. Three had eaten Cyclops only, and six Diaptomus, while two had eaten both. Fourteen of these Entomostraca, seven of each genus, were taken by these seven fishes. From those captured the next day, twenty-five specimens were examined, of which nineteen were without food. Of the remaining six, three had eaten Diaptomus and three Cyclops; five of the former being taken in all, and ten of the latter. Three specimens were next examined from those caught on the 19th of March, two of which had devoured Diaptomus, and a third a single *Cyclops thomasi* and a shelled rotifer, *Anuræa striata.* The character of the food at these earliest stages was so well settled by these observations that I deemed it unnecessary to examine the subsequent lots in detail, but passed at once to the specimens taken on the 23d. Twenty-six of these were examined, and found to have eaten thirty-three individuals of *Cyclops thomasi*, fourteen of *Diaptomus sicilis*, and fourteen of the minute rotifer already mentioned (*Anuræa striata*). Two had taken a few diatoms (Bacillaria), and one had eaten a filament of an Alga. Cyclops was found in sixteen of the specimens, Diaptomus in nine, and Anuræa in eight, only two of them being empty. The amount of food now taken by individual fishes was much greater than before, one specimen dissected having eaten two Cyclops and six *Diaptomus sicilis*, male and female. Another had taken five Cyclops, one Diaptomus, and five examples of *Anuræa* striata. Still another had eaten four of the Cyclops, four Diaptomus, and one Anuræa.

Twenty-five specimens were examined from those removed on the 24th of the month, at which time the water of the tank was drawn off and all the remaining fishes bottled. Four of these had not eaten, but the twenty-one others had devoured fifty specimens of *Diaptomus sicilis*, forty-seven of *Cyclops thomasi*, fourteen of Anuræa striata, and a single *Daphnia hyalina*, the latter being the largest object eaten by any of the fishes. A few examples of their capacity may well be given. The ninth example had eaten six Diaptomus, two *Cyclops* *thomasi*, and one Anuræa; the tenth had taken eight Diaptomus, two Cyclops, and an Anuræa; and the twentieth, seven Diaptomus and three *Cyclops thomasi*. In two of these examples were small clusters of orange globules, probably representing unicellular Algæ.

Summarizing these data briefly, we find that of the one hundred and six specimens dissected, sixty-three had taken food, and that the ratio of those which were eating increased rapidly, the longer the fishes were kept in the aquarium. Only one-fourth of those examined on the fourteenth of the month had taken food, while more than five-sixths of those bottled ten days later had already eaten. The entire number of objects appropriated by these sixty-three fishes was as follows: *Cyclops thomasi*, ninety-seven; *Diaptomus sicilis*, seventy-eight; *Anuræa striata*, twenty-nine; *Daphnia hyalina*, one. Seven of the fishes had eaten unicellular Algæ, two had eaten diatoms, and one, filamentous Algæ.

From the above data we are compelled to conclude that the earliest food of the white-fish consists almost wholly of the smallest species of Entomostraca occurring in the lake, since the other elements in their alimentary canals were evidently either taken accidentally, or else appeared in such trivial quantity as to contribute nothing of importance to their support. In fact, two species of Copepoda, *Cyclops thomasi* and *Diaptomus sicilis*, are certainly very much more important to the maintenance of the whitefish in this earliest stage of independent life than all the other organisms in the lake combined. As the fishes increase in size, vigor, and activity, they doubtless enlarge their regimen by capturing larger species of Entomostraca, especially Daphnia and Limnocalanus.

A few words respecting the relative abundance of these species at different seasons of the year and their distribution in the lake will have some practical value. We may observe here an excellent illustration of the remarkable uniformity of the life of the lake as contrasted with that of smaller bodies of water. While in ponds minute animal life is largely destroyed or suspended during the winter, the opening spring being attended by an enormous increase in numbers and rate of multiplication, in Lake Michigan there is but little difference in the products of the collecting apparatus at different seasons of the year.* There is a slight increase in the number of individuals during spring and early summer, but scarcely enough appreciably to affect the food supply of fishes dependent upon them. They are not by any means equally distributed, however, throughout the lake, my own observations tending to show that there are relatively very few of these minute crustaceans to be found at a distance of a few miles from shore, and that, in fact, by far the greater part of them usually occur within a distance of two or three miles out. Indeed, the mouths of the rivers flowing into the lake are ordinarily much more densely populated by these animals than the lake itself, as has been particularly evident at Racine and South Chicago. Neither are they commonly equally distributed throughout the waters in which they are most abundant, but like most other aquatic animals, occur in shoals. In the deeper portions of the lake, many species shift their level according to the time of day, coming to the surface by night and sinking again when the sun is bright.

These facts make it important to the fish-culturist that the particular situation when it is proposed to plant the fry should be searched at the time when these are to be liberated, to determine whether they will find at once sufficient food for their support. A little experience will easily enable one to estimate the relative abundance of the Entomostraca at any given time and place, and they require nothing for their capture more complicated or difficult of management than a simple net of cheese-cloth or similar material, towed behind a boat. This may be weighted and sunk to any desired depth, so that the contents of the water either at the surface or at the bottom, may be ascertained by a few minutes' rowing.

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* For definite assurance of this fact I am indebted less to my own observations (which are, however, consistent with it so far as they go), than to the statements of B. W. Thomas, Esq., of Chicago, who, while making a specialty of the Diatomaceæ of the lake, has collected and studied all its organic forms for several years, obtaining them from the city water by attaching a strainer to a hydrant many times during every month throughout the year.

Dr. Sweeny had seen catfish jerk snails out of their shells by getting hold of the animal and drawing it out bodily. He had also noticed thousands of shells of the fresh-water mussel, or Unio, popularly known as the "hydraulic clam," with a hole through on each side as large as a half-dollar, and the meat gone. Doubtless this was the work of some of the fishes that Prof. Forbes has examined.

Mr. Mather had fed the salt-water mussel, *Mytilis*, to the marine sheepshead, *Diplodus* or *Archosargus*, as the scientists have it, while he was connected with the New York Aquarium, and had observed that this fish used its sheep-like incisors to nip off the byssus which held the mussel to its anchorage, and then crushed it with its pavement of teeth back of the jaws. After extracting the meat the shells were expelled from the mouth, and he had never noticed fragments of shell in the exuvæ. He had fed the fish hard clams also, but these required cracking with a hammer, and the shells were ejected after the meat was devoured as in the case of the mussels.

Dr. Parker asked what the food of the lake whitefish consists of.

Prof. Forbes answered that he had made no study of the food of this fish, except in the fry, and he had fully reported on their food. The United States Fish Commission has shown that crustacæa form the principal diet of the adult fish.

Mr. Clark had examined some of the whitefish taken February, and found nothing but small crustaceans in their stomachs.

SOME EXPERIMENTS WITH THE FRY OF WHITEFISH.

BY DR. J. C. PARKER.

The question as to whether the young of the whitefish would find food and live when planted out of season much earlier than at the time at which they usually mature had been one of much discussion amongst those interested in fish-culture in Michigan, it being generally thought that while the lakes were filled with ice that the temperature of the water would be so low that there would be no organisms upon which the young fish could feed, and, consequently, starvation would ensue. To test this question Superintendent Marks directed the overseer, Mr. A. W. Marks, of Petoskey Station, of the Michigan Fish Commission, to institute certain experiments and to report the same to the Board. The report is as follows:

On March 1, 1887, a small screen or crate made of wood and wire netting, three feet long and four and a half in diameter, in the form of a cylinder, was placed through the ice in Little Traverse Bay, in 100 feet of water, and 10,000 whitefish placed in the crate and lowered to the bottom with a strong rope. On March 5 the crate was raised and the young fry were nearly all alive, only six dead ones found. On March 10 the crate was raised again and twelve dead fish were found. The fry had turned to a light brown, the yolk sac was nearly absorbed and the fish seemed in good health. On March 12 the crate was again raised and some of the fry taken out and brought home; also a jug of water from the bottom and another from the top was taken. One drop of this was placed under a strong glass and life could be seen very plentiful. The stomach of one of the small fish and a drop of the water was placed under the glass and it was found to be full of diatoms and vegetable matter. The diatoms seemed to be working around the small pieces of vegetable matter; the sac of the fry had been absorbed and they were feeding upon the vegetable matter and the animalcule. On March 14 the crates were again lifted, and the fish seemed to be doing well in about the same condition as on the 12th. About 100 dead fish were found on the 14th. The crate was lifted on the 18th; no change could be seen. On the 24th the crate was again lifted, and some of the young had turned to a light green, the color of a herring a year old. On March 24 another crate was sunk, containing 5,000 fry. This was lifted on the 28th, and two dead fish were found in the crate. At this date the first crate sunk contained fish forty-five days old that had been under the ice twenty-eight days. About the last of March the ice moved out of the bay, thus preventing any further systematic observations. Later on the submerged crates were recovered, but the wire screens had become filled with sediment, caused by the roiling of the water consequent upon the breaking up of the ice, and no live fish were found in them. This closed the experiments for that year, and circumstances prevented their continuance this spring.

Grand Rapids, Mich.

THE DIGESTIBILITY OF FISH.

BY PROF. W. O. ATWATER.

In the course of an investigation upon the Chemistry and Food-economy of Fish, which has been in progress for a number of years, under the auspices of the U. S. Fish Commission, a study of the digestibility of fish has seemed desirable, and a beginning has been made in the form of experiments upon the comparative digestibility of the flesh of fish and lean meat. The object of the present paper is to give a brief outline of the main results. These confirmed by quantitative test the general impression that in fish we have one of the most completely digestible of food-materials.

THE DIGESTIBILITY OF FOOD IN GENERAL.

The question of the digestibility of foods is very complex, and it is noticeable that the men who know most about the subject are generally the least ready to make definite and sweeping statements concerning it. One of the most celebrated physiologists of the time, an investigator who has, I suppose, devoted as much experimental study to this particular subject as any man now living, declares that aside from the chemistry of the process and the quantities of nutrients that may be digested from different foods, he is unable to affirm much of anything about it. The contrast between this and the positiveness with which many people discourse about the digestibility of this or that kind of food, is very marked and has its moral.

Our source of confusion is the fact that what people commonly call the digestibility of food includes several very different things, some of which, as the ease with which a given food-material is digested, the time required for the process, and the effect of different substances and conditions upon digestion, are so dependent upon individual peculiarities of different people and so difficult of measurement as to make the laying down of hard and fast rules impossible. Why it is, for instance, that some are made seriously ill by so wholesome a material as milk, and others find that certain kinds of meat or vegetables or sweetmeats "do not agree with them," neither chemist nor physiologist can exactly tell.* Late investigations, however, suggest the possibility that the ferments in the digestive canal may cause particular compounds to be changed into injurious forms, so that it may sometimes be literally true that "one man's meat is another man's poison." But digestion proper, by which we understand the changes which the food undergoes in the digestive canal in order to fit the digestible portion to be taken into the blood and lymph and do its work as nutriment, is essentially a chemical process. About this a great deal has been learned within a comparatively few years, so that here we have many important facts that have not yet got into current literature.

The average man swallows, say six pounds of food and drink, meat, fish, potatoes, bread, coffee, milk, water, and what not, per day. Every twenty-four hours, then, all the solid substance, all the protein, fats, carbohydrates and mineral matter

* Things do not always or, indeed, often come to hand exactly when they fit best, but, oddly enough, just as I am writing this the postman brings a letter from the Recording Secretary of the American Fisheries Society with the following statement: "By the way, I cannot digest oysters, raw or cooked, but can eat clams (both Venus and Mya) and can go to bed on the outside of a lobster mayonaise. Coffee ties a hard knot in the interior department, buckwheat cakes start my 'vinegar factory' to work on full time, beans cause the 'gas works' to be put in operation. This merely proves the adage about 'one man's meat, etc.'" The learned gentleman follows this by the statement that he has already passed the age of forty, at which a man is said to become "either a fool or a physician"; and gives a physiological explanation of his digestive temperament which he attributes to dyspepsia "aggravated by nine months' diet on corn meal, ground cob and all, and sorghum syrup, in Confederate prisons." Of course it would be wrong to affirm that in this especial case it is the microbe that causes the protein of the oysters to be changed into compounds which make them disagree, or produces the disagreeable fermentations in the buckwheat cakes and beans, but some how or other different food-materials do produce very disagreeable effects in the digestive apparatus of different people, and the science of to-day explains this in part by the action of the digestive ferments, among which microbes play an important role.

of this quantity of food, except the small portion that passes through the alimentary canal undigested, must be either dissolved or divided into such minute particles as to be able to get through the microscopic passages that permeate the walls of the canal and thus find their way to the blood. To judge accurately of the nutritive value of our food, then, we must know not simply how much of the different nutritive ingredients, the protein and fats and carbohydrates, it contains, but how much of each of these nutrients will be digested. This is a matter that can be determined more or less accurately by experiment. But a great deal of labor is needed to make the experiments accurate, the line of research is new, the methods are not yet perfectly matured, and the results thus far obtained, though extremely interesting and valuable, are still far from complete. The side questions, such as differences in the digestive apparatus of different persons; the effects of exercise and rest, or mode of preparation of the food, and of the flavoring materials and beverages taken with it, tend to complicate the problem of digestibility, yet even here experimental research has something to tell us. In brief, we have to-day a tolerably fair idea as to what proportions of the ingredients of a good many of the more common kind of animal and vegetable food-materials, meats, milk, butter, cheese, eggs, bread, potatoes, are ordinarily digested by healthy people. But the list of materials the digestibility of which has been accurately tested is far from including all the more common kinds of food, and more experiments are needed, even with the foods that have been tested, to show the variations in digestibility by different classes of people, and under different conditions. The only direct experiments on the digestibility of fish by men or other animals, so far as I know, are those described in this paper.

THE CONSTITUENTS OF FOOD.

But before going farther I ought, perhaps, to say a few words about the nutritive ingredients of fish and other food materials and the technical terms which we are coming to apply to them in the chemical laboratory. Fish, like meats and other food, are made up of different constituents. These we may classify as follows :

1. Edible substance, *e. g.*, the flesh of meats and fish, the shell contents of oysters, wheat flour. 2. Refuse, *e. g.*, bones of meat and fish, the shells of oysters, bran of wheat.

The edible substance consists of: 1. Water. 2. Nutritive substance or nutrients. Leaving out of account the refuse and the water, we may consider simply the nutriments. Speaking as chemists and physiologists, we may say that our food supplies, besides mineral substances and water, three principal classes of nutritive ingredients, viz. : Protein, carbohydrates, and fats ; and that these are transformed into the tissues and fluids of the body, muscle and fat, blood and bone, and are consumed to produce heat and force.

The principal nutrient of fish is protein. In chemical composition the protein of fish is essentially the same as that which makes up the bulk of the nutritive material of very lean meat. In both lean meat and in fish it is called myosin. It is very similar to the albumen (white) of egg, the casein (curd) of milk and the gluten of wheat. The protein compounds are sometimes called "flesh formers." They are the most important of the nutritive ingredients of food, because they are the only ones that contain nitrogen and they alone make muscle, tendon and other nitrogenous tissues of the body. Of the fats we have familiar examples in the fat of meat and fish, lard, butter, olive oil and other kinds of oil, including the oil of corn and wheat. Some kinds of fish, as salmon, shad and mackerel contain considerable fat, but the flesh of codfish, haddock, pike, perch, bass, bluefish and the most of our common food fishes contain very little fat, less, indeed, than is found in even the leanest meat. Of the carbohydrates, sugar and starch are the most important. The carbohydrates make the chief nutritive material of vegetable foods. Oysters and clams contain a certain amount of carbohydrates, as does milk. These different substances in food have different kinds of work to do in nourishing the body. The protein compounds, which are the only ones that contain nitrogen, make the muscle, tendon and other nitrogenous tissues. This, the carbohydrates and fats, which contain no nitrogen, cannot do. The carbohydrates and fats serve for fuel, yielding heat to keep the body warm and muscular strength for work. Protein compounds can also serve for fuel.

Since protein can do the work of the carbohydrates in furnishing heat and muscular power, and has a work of its own to do in building up the tissues of the body which the other nutrients cannot perform, the protein compounds are the most important of the food ingredients. And when we compare the quantities of the different nutrients in food with the market prices of foods, we find that protein is by far the most expensive. It costs, pound for pound, several times as much as fats and carbohydrates. The fats are more expensive than the carbohydrates and have a higher fuel value. In short, fish furnishes protein to form muscle and other nitrogenous parts of the body. Some kinds of fish contain considerable fat also. Since the protein is the most important and the most expensive of the food ingredients and fat is more costly and valuable than carbohydrates, it is evident that fish is an extremely valuable article of food. Indeed the importance of fish in domestic and in national economy has not yet come to be justly appreciated.

Our national diet is one-sided ; we eat too much of the fats and carbohydrates and relatively too little protein. This comes from our enormous consumption of highly fattened meats and of sweetmeats. As population becomes denser and economy becomes more necessary we shall have to devote relatively less of the productive power of our land to meat production. If we can replace part of the meat that we consume by fish, it will be greatly to our advantage as regards both health and purse. In the older and more densely populated countries of the world, as Europe and Asia, the food of the people is mainly vegetable, and is relatively deficient in protein. To produce meat to supply protein seems impossible. It thus appears, that, the world over, by fish-culture, the rivers and the sea are made to rightly supplement the land in the production of food for man. I hope in another place to enlarge upon these statements and to cite statistics to illustrate them, but must now go back to my subject, the digestibility of fish.

THE DIGESTIBILITY OF FISH.

There are two ways of studying experimentally the digestibility of fish as of other foods. One is by experiments in artificial digestion, in which the food material is exposed to the action of the digestive juices in the laboratory, in apparatus fitted for the purpose. The other is by direct experiments with man or other animals. A series of experiments upon the artificial digestion of fish in gastric juice have been made by Messrs. Chittenden and Cummins, and reported in Commissioner's Report of the Commission of Fish and Fisheries of the United States for 1884, page 1109. In the introduction to the account of their work these experimenters speak as follows:

"Few experiments appear to have been made on the digestibility of fish; this is the more strange when we consider what an important item of food fish constitutes, particularly along our seaboard. * * * * As Voit remarks, 'Nothing certain is known regarding the digestibility of different kinds of fish, although much is said concerning it. Probably digestibility is in part dependent upon the nature of the fat present and the manner of its distribution; thus the presence of a difficultly fusible fat with considerable stearin would tend to hinder digestibility (as in mutton); the same thing probably occurs when the contents of the sarcolemma are permeated with much fat (as in the lobster and eel).' This statement at once suggests the probability of great variation in the digestibility of the flesh of any one species, dependent on a large number of conditions, which, in the case of fish particularly, are somewhat difficult of control; thus age, sex, food, period of spawning, length of time they have been preserved, are a few of the many natural conditions which would tend to modify the digestibility of the flesh and render generalizations from even a large number of results somewhat uncertain."

The outcome of their work is expressed thus:

"The results of the analyses show plainly that the method adopted is as good as could be expected, for it must be remembered that the two results obtained from each sample of flesh are not merely from duplicated analyses, but from duplicated digestions as well, and in these, extending as they do over twenty-two hours, with slight variations in temperature and agitation, small differences are to be expected. The very great divergence noticed, however, in the results obtained from different samples of the same species of flesh show at once that there are other conditions, such as age, etc., which affect the digestibility of the flesh more or less, so that, in order to obtain results from which to draw strict generalizations, it would be necessary to experiment with fish of different species, of like age, sex, and reared under like conditions. As examples of this we have the very divergent results from two samples of veal, and also of two bluefish (88.69 and 73.44). As direct evidence that age, sex, etc., do exert a modifying influence on the digestibility of flesh, we have three experiments on the flesh of the lobster; one with a small young lobster, a second with a large female, and a third with a large male of the same species. The duplicate digestions gave fairly concordant results; the average relative digestibility being for the young specimen 87.81, for the large female 79.06, and for the male 69.13. This shows plainly some modifying influence in the flesh itself. In composition, so far as the solid matter is concerned, there was no appreciable difference in the three samples. Bearing in mind, however, these possible variations, it is very evident from our results that the average digestibility of fish-flesh is far below that of beef similarly cooked. In but two instances, in the case of shad and whitefish, does the digestibility of fish-flesh approach that of beef, although, from the average of our experiments, several are as easily digestible as mutton, lamb, and chicken.

"Pavy states that fish with white flesh, such as the whiting, etc., are less stimulating and lighter to the stomach, or more easy of digestion, than fish with more or less red flesh, as the salmon. Our experiments confirm this statement so far as digestibility is concerned. Thus the average digestibility of the salmon and trout is considerably below the average of the more digestible white fish. The difference between the digestibility of the light and the dark meat of the same flesh is somewhat striking, as in the case of the shad, where the digestibility of the former was found to be 97.25, as compared with beef, while the dark flesh was 87.32. A similar difference, though very much smaller, is to be noticed between the light and dark meat of the chicken.

"This difference in digestibility is in part due, without doubt, to the amount of fat present, for, as Pavy states, in the flesh of white fish there is but little fat, it being accumulated mainly in the liver of the animal, while in red fish there is more or less fatty matter incorporated with the muscular fibres. For a similar reason, eels, mackerei and herring are, according to Pavy, less suited to a delicate stomach than some of the white fish, and our experiments show that in digestibility two of them stand below the more digestible white fish; mackerel, however, from our single experiment with the white portion of the flesh, showed a comparatively high digestibility. In all of our experiments, however, with white fish, we rejected the outer layer of dark flesh, except in the case of the shad. The varying differences in digestibility are not to be considered as due wholly to differences in the amount of fat in the flesh; thus the flesh of fresh cod contains but little fat, and yet it is one of the most indigestible of the white fish experimented with. This agrees with Pavy's experience 'that it is a more trying article of food to the stomach than is generally credited.' Again Pavy makes the following statement, based on his experience in fish dietetics 'of all fish, the whiting may be regarded as the most delicate, tender, and easy of digestion.' 'The haddock is somewhat closely allied, but it is inferior in digestibility,' while 'the flounder is light and easy of digestion, but insipid.' With all these statements our results agree perfectly, assuming the whitefish of our experiments to be analogous to the English whiting."

It thus appears that Messrs. Chittenden and Cummins found considerable divergence in the digestibility of the flesh of fish of different kinds. These they attribute in part to the varying proportions of fat, the fatter fish being the less digestible, and in part to other characteristics of the flesh. My own impression is, that experiments on the actual digestion in the alimentary canal, in which other juices as well as the gastric come in play and other conditions are different, would show less difference in the digestibility of fish of different sorts than these investigators found in their experiments in artificial digestion with gastric juice alone, and also that there would be less variation in the actual quantities and nutritive material digested than the statements made by the authors quoted by Messrs. Chittenden and Cummins would imply. For we must not forget the distinction between the quantity digested and the ease of digestion. But, of course, this is a matter to be determined by actual experiment and observation.

The ways in which the experiments for testing the digestibility of foods by men and animals are made, are very ingenious and interesting. Physiologists use the salivary glands, or stomach or intestine of a living animal, much as chemists do their bottles and retorts and test-tubes. It is easy to get into the way of regarding an animal as simply an organism manifesting certain reactions under given conditions, and in not a few European laboratories a janitor is readily induced by the price of a few months' supply of beer, or a student by his scientific ardor to take this same altruistic view of his own physical organism. In the German laboratories, particularly, one finds not only the needed apparatus, but what is no less important, trained assistants and servants, so that one is relieved of much of the time-consuming and disagreeable detail of experimenting, which is so much of an obstacle with us.

THE QUANTITIES OF DIGESTIBLE SUBSTANCES IN FOOD.

The first question we have now to ask may be put in this way. What proportion of each of the nutrients in different food-materials is actually digestible? In a piece of meat, for instance, what percentage of the total protein and fats will be digested by a healthy person, and what proportion of each will escape digestion? The proportions of food-constituents digested by domestic animals has been a matter of active investigation in the European agricultural experiment stations during the past twenty years. Briefly expressed, the method consists in weighing and analyzing both the food consumed and the intestinal execretion, which latter represents the amount of food undigested. The difference is taken as the amount digested.

Such experiments upon human subjects, however, are rendered much more difficult by the fact that in order that the digestibility of each particular food-material may be determined with certainty, we must avoid mixing it with other materials. Hence the diet during the experiments must be so plain and simple as to make it extremely unpalatable. An ox will live contentedly on a diet of hay for an indefinite time, but for an ordinary man to subsist a week on meat or fish or potatoes or eggs is a very different matter. No matter how palatable such a simple food may be at first to a man used to the ordinary diet of a well-to-do community, it will almost certainly become repugnant to him after a few days. In consequence, the digestive functions are disturbed, and the accuracy of the trial is impaired, a fact, by the way, which strikingly illustrates the importance of varied diet in civilized life. For instance, in an experiment conducted in the physiological laboratory at Munich, by Dr. Rubner, the subject, a strong, healthy Bavarian laboring man, lived for three days upon bread and water, a diet, the monotony of which was much more endurable than one of meat or fish or most any other single food-material would have been. He was able to eat 1,185 grams (about 2 lbs. and 10 oz.) of bread per day. This contained 670 grams of carbohydrates, mainly starch, of which only about 5⅞ grams, or a little less than one per cent., escaped digestion. In this case, therefore, about 99 per cent. of the carbohydrates of the bread were digested. The bread contained 13 grams of protein, of which 13 per cent. were undigested, and 87 per cent., or seven-eighths of the whole protein, digested. The quantity of fatty matters in the bread was too small to permit an at all accurate test of their digestibility. In another experiment the digestibility of meat, beefsteak, was tested. The man consumed a little less than two pounds per day, but though it was cooked with butter, pepper, salt and onions so as to make it taste "extraordinarily well flavored," it was very difficult to swallow it the second day, and required great effort the third. The digestion, however, seemed to be normal, and all but about one per cent. of the protein was digested. Other trials with meat and with fish have brought similar results, and it is reasonably safe to say that when a healthy person with sound digestive organs eats ordinary meat in proper quantities, all or nearly all of the protein is digested. Some of the fats of meats, however, seem to fail of digestion. The number of accurate experiments of this kind is still very small. Some sixty or thereabouts have been reported. Nearly all have been made within ten years past, and the majority in one laboratory, that of the University of Munich. Most of the subjects have been men with healthy digestive organs, two or three laboratory servants, a soldier, several medical students and a few others. Several have been made, however, with children of a few families. All but a very small number conducted in Germany.

Some time since it was my fortune to pass a number of months in Munich, where, through the courtesy of Professor Voit, Director of the Physiological Institute of the University, I was enabled to make some experiments on the digestion of meat and fish by a man and by a dog. Each lived for three days upon haddock and then for three days upon lean meat, beefsteak. The dog was used to such experiments and got on very comfortably indeed. The meat and fish were each cooked with a little lard. He did not take to the fish at first, but after he got used to it seemed to like it. The first attempt with a man was with the same healthy, rather stolid Bavarian laborer, with whom Dr. Rubner's experiments with meat and bread, above referred to, were performed. He bore up very well through the trials with both the fish and the meat, but the assistant discovered at the end that he had surreptitiously eaten sourkrout, and the experiment was spoiled. Fortunately, a medical student, then working in the laboratory, became interested in the subject, and offered himself as a martyr to the cause. He had, for three days, flesh of haddock, fried with butter, flavored with salt, pepper, mustard, and Worcestershire sauce, and taken with beer and wine. Then came a period of rest, that is to say ordinary diet, and then a similar trial with beefsteak. I was with him at every meal and can bear warm testimony to his fortitude and determination. The menu was made as appetizing as possible under the circumstances. The first day of each trial went pretty well, the second day it was difficult, and the third day almost impossible to swallow the whole. I used all sorts of devices to make it easier, especially by distracting his thoughts from the food ; told stories of America, cracked jokes, made fun of him, at times almost angered him. And it is safe to say that all the effort was needed. As the result it appeared that he digested nearly the whole of both the meat and the fish. The results of the experiments are stated in tabular form herewith. The percentage of each ingredient, which escaped digestion, is given. In some cases a correction, for certain errors of experiment which need not be discussed here, is applied to the figures for amounts "apparently undigested," to show those estimated to be "actually" digested.

Summary of Results of Experiments on the Digestion of the Constituents of Meat and Fish by a Dog and by a Man. Percentages Undigested.

Experiments with Food.	Dog.		Man.	
	Meat and Lard.	Fish and Lard.	Meat, Butter, etc.	Fish, Butter, etc.
	Per cent.	Per cent.	Per cent.	Per ct.
Water-free substance, apparently undigested	3.4	3.2	4.3	4.9
Nitrogen (protein), from meat or fish, apparently undigested	2.2	1.6	2.5	2.0
Nitrogen (protein), from meat or fish, actually undigested	0.3	0.0	0.7	0.5
Fat, mostly from lard or butter, apparently undigested	2.8	3.0	5.2	9.0
Ash, apparently undigested	14.3	14.1	21.5	22.5

According to these experiments, therefore, practically all of the nitrogenous materials (protein) of both the fish (haddock) and the lean beef was digested by the dog, and all but one-half or three-fourths of one per cent. by the man. While more experiments are needed, the agreement of these results with what would be expected from the nature of the nitrogen compounds and what is known of the laws of digestion and absorption, leaves little ground to doubt that very nearly all, indeed we may say, practically all, of the protein of both will be digested by a healthy organism under normal conditions.

The conclusion that the flesh of the common kinds of fish agrees very closely in digestibility with that of the common kinds of meat, at least so far as the protein (the chief constituent of the "lean" of meat and fish) is concerned, seems equally well grounded. It would seem, however, from other considerations and especially from actual experiments with meats, in which the fat is imperfectly digested, that fish, having generally less fat than meat, is, on the average, more easily and completely digested. Perhaps it will be interesting to note how different food materials compare in digestibility as shown by experiments such as those just described.

Digestibility of Nutrients of Food-materials.

In the Food Materials Below.	Of the Total Amounts of Protein, Fats and Carbohydrates, the Following Percentages were Digested:		
	Protein.	Fats.	Carbohydrates.
Meat and fish	Practically all.	79 to 92 per cent.	....
Eggs	"	96 "	....
Milk................	41 to 100 per cent.	93 to 98 "	?
Wheat bread..........	81 to 100 "	?	99 per cent.
Corn (maize) Meal....	89 "	?	97 "
Rice	84 "	?	99 "
Pease	86 "	?	96 "
Potatoes..............	74 "	?	92 "
Beets	72 "	?	82 "

The amounts of fat in the vegetable foods are so small that the experiments do not tell exactly what proportions are digested. The meats and fish contain practically no carbohydrates. The digestibility of the carbohydrates (sugar) of milk was not determined, those of the vegetable foods except the beets, were almost completely digested. That the protein of cow's milk should be so much less completely digested than that of meal seems a little strange. Children have been found to digest a little more than adults, though the difference is not large. Thus Dr. Camerer, a German experimenter, found his boys and girls of from two to twelve years of age to digest from ninety-one to ninety-seven per cent. of the protein of cow's milk, while grown men in experiments by Dr. Rubner digested from eighty-eight to ninety-four per cent. But in experiments in which milk and cheese were eaten together by a man, the laboratory servant of Dr. Rubner's experiments, all or nearly all of the protein of both was digested. The percentages of fats of milk digested was practically the same with adults as with children. It is worth noting in these experiments, both children and adults digest only about half of the mineral salts of the milk. Why so much of the fats of the meat, from a twelfth to a fifth, should have failed to be digested it is not easy to say. Some of the food materials, as meat, bread and milk, have been tested each by several experiments with more than one person. With others, as eggs, corn meal, rice, pease and potatoes, only a single trial has been made. Doubtless extended series of tests would give averages differing more or less from these figures. Another thing that makes the results a little uncertain, is that some of the food materials may perhaps be more completely digested when taken in small quantities with others in the ordinary way than when so much of them is eaten and without any other food. These and other sources of slight error make more extended experiments very desirable. But enough has been done to show pretty clearly that:

1. The protein of our ordinary meats and fish is very readily and completely digestible.

2. The protein of vegetable foods is much less digestible

than that of animal foods. Of that of potatoes and beets, for instance, a third or more may escape digestion, and thus be useless for nourishment.

3. Much of the fat of animal food may at times fail of digestion.

4. The carbohydrates, which make up the larger part of vegetable foods, are very digestible.

5. The animal foods have, in general, the advantages of the vegetable foods, that they contain more protein, and that their protein is more digestible.

6. The comparative digestibility of fish and meats, and of the different kinds of fish, is not well enough decided by experiment to warrant as definite conclusions as are desirable. It seems probable, however, that the leaner meats are rather more easily digested than those which are more fat, and that, in like manner, the leaner kinds of fish, such as cod, haddock, perch, pike, bluefish, sole, flounder, etc., are more easily and completely digested than the fatter kinds, as salmon, shad and fat mackerel, and that for like reason fish, which is, in general, less fat than meat is, on the average, more digestible.

7. People differ in respect to the action of foods in the digestive apparatus, and fish, like other food materials, are subject to these influences of personal peculiarity.

One point more is worthy of remark before closing. The nutritive value of food is, of course, decided by other factors as well as by the proportion of digestible ingredients. In one respect fish is peculiarly adapted to the diet of that very large class of people whose occupation involves but little muscular exercise. As already explained, we consume excessive quantities of fat. This comes with our habit of eating highly-fattened meats, as well as butter and lard. Even when we attempt to reject the fat of the meat which comes upon our tables and is served on our plates, we consume a great deal of fat in the visible and invisible particles diffused throughout the lean. Statistics of dietaries in this country show the fat consumption to be enormous. Fat serves as fuel, and is useful for those who do hard muscular work, or are exposed to severe cold. For others it is not needed, and excess is a burden imposed on the system. The excessive eating of fat is contrary to good economy, and hygienists assure us it is a very serious damage to health.

Fish supplies the protein which meat furnishes, and which is needed to build the tissues of the body, without the large amounts of fat which are not needed by people of sedentary habits. For brain-workers it seems to be on this account a very useful food.

Wesleyan University, Middletown, Conn.

SOME OBSERVATIONS UPON THE GRAYLING.

BY J. C. PARKER, OF THE MICHIGAN FISH COMMISSION.

The question as to whether the grayling (*Thymallus tricolor*) could be successfully propagated artificially being practically undecided by this Commission, it was decided to prepare waters as nearly in accordance with natural conditions as possible and make as careful and systematic an attempt as we could to solve it. Accordingly ponds were made on the Buck Horn creek, of just sufficient depth to admit of screening and through which the whole creek flowed, with the hope that if placed here, they would in the spring—the spawning season—give us an opportunity to observe and handle them, under less difficult circumstances than in their native streams. We hoped that as the Buck Horn had originally been a good grayling stream, it would place at our disposal the most advantageous conditions. The ponds being in readiness, the several members of the Michigan Fish Commission proceeded on the 20th of August to the west branch of the Manistee, fifteen miles from the railroad station at Kalkaska, with boats, cans and camp equipage, prepared to make a week of it. The fish were to be captured with rod and line, it having been demonstrated that this was more certain, and the results more satisfactory, than any attempt to use nets of any description. The result was that at the end of the week we had caught and had in excellent condition about one hundred fine specimens. From five to six of these were put into a can, the temperature of the water—which was comparatively low—kept down by the addition of ice, and nine of these cans loaded into a lumber-wagon and the journey to the station over a bouncing corduroy road commenced. Only one opportunity to change the water *en route* was afforded, but, notwithstanding all this rough handling, they reached their destination with only the loss of some four or five specimens.

During the winter they were watched and cared for, but the loss was about twenty-five per cent. When the spawning season arrived a close watch was kept to see when any signs of spawn-laying should commence, but we watched in vain. So far as could be ascertained there was nothing to indicate that they had, would, or could, ever spawn, and to-day we are no nearer a practical solution of the vexed question than when we commenced. During this, and a subsequent visit to the same locality, I was enabled to make some observations upon their food and their habits in feeding, which may be of interest. Near the camp was a pool in which two small fish had their haunts, one about six inches in length, and the other half the size. The larger one when at rest was on a bit of clean sand in plain view; the other lay under some sunken drift wood, dark in color, and under which he concealed himself, only the tip of his nose being visible, and the contrast in color corresponded exactly with their resting places; the larger one was so nearly the color of the sand on which he lay as hardly to be distinguished from it; only when in motion as he arose to the surface for his food; the other was as dark as the sticks under which he lay, showing that the question of color is one of bottom locality and undoubtedly a circumstance of more or less light. I was somewhat surprised at the tenacity with which they adhered to a locality when once domiciled in it. Three or four times I drove them out of their haunts; one afternoon chasing the larger one several rods up the stream only to find him in the same spot the next day, and when I returned to the same locality, after an absence of four weeks, I found the same fish apparently in the same places. In rising for food I never saw either of them more than a yard from their haunts, and only rarely but a few inches. They would detect their prey at a considerable distance and slowly rise to meet it as it floated to them, and then a sudden flash, and they were back to their respective resting places. The deviation from the point where they lay was, from side to side across the stream, hardly ever but a few inches up or down. One day, when they were rising with more than usual frequency, I carefully crept out on a projecting log until I was nearly over them, and could watch their every movement, and, with watch in hand, counted the "rises" of the larger one for fifteen minutes. In this time he came to the surface and secured his prey fifty times. Sometimes he would rise nearly to the surface and then slowly settle down again, but whenever he actually seized anything he was back to his haunt again with a motion so quick the eye could scarcely follow him. After considerable observation I could detect the particular insect I was sure he would rise for, sometimes before he would show any motion in that direction. Watching his quick, unerring sight. and his ability to detect what was food, and what was not, led me into some generalizations on what their food really was, that were new to me.

In eviscerating fish for any purpose, I have always been in the habit of examining the contents of the stomach, and the stomach of the grayling had always puzzled me by the quantity of vegetable matter so often found in them; but the *a priori* conclusion was that he was necessarily a carnivorous, or insectivorous fish; the thought that he was a vegetarian as well, never occurred to me. I had observed that the fronds of the white cedar—*arbor vitæ*—were quite usually among the contents of the stomach, but I had always considered it as something adventitious, an accident, occurring in the procuring of his food, and not deliberately taken. But a somewhat singular circumstance that occurred upon this last expedition staggered me somewhat. On the afternoon of the day of my arrival, after the tent was pitched, and camp life organized, I proceeded to a pool below a flooding dam near camp, thinking I could secure enough grayling for the supper of myself and little daughter, who accompanied me. I succeeded in securing two nice ones, weighing probably about six or eight ounces each, and upon dressing them and examining the stomachs as usual, judge of my surprise upon finding one of them full of oats; there were eight kernels stored away in first-class style, and my first question was, where in the name of the Prophet could they have come from, for I knew that there wasn't a spear of grain growing within a dozen miles of this pool and the condition the grain was in showed that they could have been in the stomach but a short time. I finally solved the mystery by remembering that the man who brought us out—we arrived about noon—fed his horses some oats at a point just above the pool, and the grain was either blown into the water or carelessly thrown in by some one. I frequently found in their stomachs portions of the leaves and seeds of the water plants growing in the streams. Among the latter was in several instances a round seed about as large as a No. 4 shot, which I at first thought was a mollusk, a species of spherium, but on examining it with a glass what appeared to the naked eye to be the striations of the shell proved to be the veination of the seed. It may be urged against the vegetarian theory that many fish take that which in no way resembles their ordinary food, as the artificial fly and the different varieties of spoon and spinning baits, and that this particular fish could in no way have had any previous knowledge of oats as food, and consequently the taking of it must be in the nature of a freak rather than a habit, but I do not remember to have ever found in the stomachs of other fish any substance other than their food but which could be accounted for as accidental, while in the grayling the presence of vegetable matter in some forms is of so frequent an occurrence as to point strongly to the fact, that a part of their food at least is vegetable.

Another point in favor of this theory is the peculiar flavor of the fish and that which has given it its specific name. It is a well-known fact that the flesh of all animals is to a greater or less degree flavored by its food. Now, if this fish fed upon exactly the same materials as the brook trout, could there be a reasonable doubt but what its flesh would taste like that of the trout, while the fact is, that it is distinctly different.

You are probably aware of the difference between a liver-fed trout and one caught in its native wilds; a difference so patent, that a person relying upon the taste alone would pronounce them an entirely different fish. One thing is certain, whatever its food is, it must have existed in unlimited quantities to have supported such a large multitude of this fish as absolutely swarmed in the northern streams of this State at an early day. D. A. Blodget, now living at Grand Rapids (and one of the pioneers of the Muskegon at the Hersy-branch) told me that when he first built a dam at the mouth of this stream, that in the spring, during the spawning season, when the grayling were trying to find their way to the spawning grounds, that he has seen the inhabitants fill the box of a common lumber wagon *full* of this fish in a few hours and carry them out into the country, not only one such load, but half a dozen of each spring for several successive years, while as many more must have been taken away in smaller quantities, and he estimated the quantity taken by tons each year; that during the first winter he spent there, he supplied his table with this fish by taking a common nail-rod and sharpening it with his axe, and cutting a barb on it with the same tool, and going to any of the bends in the stream, and cutting a hole in the ice, he could in a little while get all he wanted by thrusting this primitive spear at random into the waters beneath; and as the number of fish that any stream can furnish is to a great extent limited only by the food supply, it seems that so great a number as was then found, not only in this particular stream, but in most all the streams in which they were found, must have had some food in much greater abundance than what is usually found in our ordinary trout streams.

Grand Rapids, Mich.

MR. MARKS stated that there were many grayling in Michigan yet, that the extermination had gone on in the Au Sable, made famous by the writings of Norris, Milner, Hallock, Mather and others who fished there in an early day, because of the driving of logs in that river. These logs are driven in the spring, when the fish are spawning, or after that event, and they plow up the gravel beds and destroy millions of eggs which are there developing. In his labors as Superintendent of the Michigan Fish Commission he could bear witness that while the grayling may be going from some streams on account of the operations of man, it was not true that the fish was in danger of immediate extinction, as has been the case with the buffalo and some land animals, but the destruction has been only on certain rivers, and has not been caused there by fishing but by logging.

MR. DUNNING asked why not plant the eggs of fishes in the waters instead of hatching them first?

DR. SWEENY replied that Dr. Sterling had recommended this plan, and that he had tried it and had produced better results than when the fish were left to impregnate their eggs, yet experience has taught that it is better to keep them until the fry are hatched, because in the troughs or jars the eggs and fry are not only placed under the very best conditions for hatching, but are protected from their enemies as well. A young fish that has been brought so far forward that it can hide from its enemies, certainly has a great advantage over an egg in the matter of self-protection, and to place the eggs directly in the waters would be a step backward in fish-culture.

DR. HUDSON said that the Connecticut Commission had some experience in the destruction of eggs and fry. In the early days of shad-hatching, before the invention of the McDonald jar, they used the floating-boxes, and used to put on rubber boots and wade out to examine them. Thousands of little fishes followed and devoured every egg that was taken out when the dead ones were removed. If we keep the fry and only turn them out when the sac is absorbed we will avoid a great destruction of both eggs and embryos.

MR. MATHER corroborated this by saying that years ago, when the floating-box was the best device known for hatching shad, he had observed in his work on the rivers, from Connecticut to Virginia, that underneath the boxes lay a host of small perch, sunfish and minnows, which were nibbling at the tails of such little shad as protruded through the netting, and the loss from this source was often considerable. By the use of the jars this no longer occurred, and although a young fish had to take its chances when turned out, it should be protected until it needs food ; besides this, fungus will destroy many eggs, as will also the sun and sediment.

MR. CLARK related an experiment made by the late George Clark, once one of the Board of Michigan Commissioners, when his (the speaker's) father was taking whitefish eggs at Mr. George Clark's fishery at Ecorse, on the Detroit river. The latter gentleman wished to test the planting of eggs, and made a box with screened sides and put gravel on the bottom, and placed the eggs on the gravel and sunk the box where there was a gentle flow of water. In February the box was taken up and there were no good eggs to be found in it, those which died first had developed fungus, and this had spread and killed every egg. Fungus is a deadly thing which is not allowed to appear in any hatchery which makes pretension to be well conducted.

DR. SWEENY explained that while the black bass and the sunfishes guard their eggs and keep off all intruders the trout and whitefish, in fact all members of the Salmonidæ, left them to their fate, and here is where man steps in as a guardian and prevents destruction at the most critical period.

CO-OPERATION IN FISH-CULTURE.

BY JOHN H. BISSELL, OF THE MICHIGAN FISH COMMISSION.

Within the limits properly allowed for a paper in a meeting like this, it is scarcely possible to do more than sketch or outline a subject such as I have chosen. I am consoled, however, with the reflection that the manner and style will be passed with indulgence if only there be some merit in the subjects presented for consideration, or at least good faith on the part of the reader.

I think it is generally agreed, that fish-culture has passed its purely experimental stage. It is in fact fast becoming recognized as a practical art, and an established department of civil government, its definitely ascertained results, which are now unquestioned, fully warranting the recognition it has received from the States and the United States. Having so attained to the period when it is capable of being made a useful factor in the economy of every civilized State, the persons charged with the public duty of administering its affairs and evoking useful results from its prosecution ought ever to be looking for reasonable and practical ways to secure it the highest degree of efficiency. The United States Commission with a new and broader organic law recently adopted and put in operation, with its departments of work newly recast and systematized, and under most zealous and competent guidance, is prepared now to apply in the solution of some economic problems, the many lessons of experiment and scientific observation, gathered and stored up in the past. The States which have been dealing practically with the fishery question in the last ten years have made good progress towards reliable and permanent methods of fish-culture, and now at length are able to bring forward some definite and tangible proof concerning its results.

Fish-culture, when appreciated and invoked in both its branches, artificial propagation and legal regulation, has demonstrated its ability to restore exhausted fisheries. Of that there is no need of citing evidence to this audience. The next forward movement toward the realization of the great promises of the practical Art of Fish-culture, in this country is, I believe, to be the working out of a just and comprehensive system of regulation of fishing as an industry, and as a recreation. A notable feature of this movement will be the attainment of more substantial co operation amongst the organized bodies existing for its prosecution under the State and Federal Government.

I have in mind two principal topics: 1. Co-operation between the United States Commission of Fish and Fisheries and the several State Fish Commissions; and, 2. The limited co-operation possible between the Commissions of neighboring States, or between States having similar fishery interests. I am not unaware of the fact that the United States Fish Commission has heretofore co-operated with the State Commissions. But I wish to call attention to the fact that such co-operation can be carried out on broader lines with advantage to all concerned.

You are all as familiar—perhaps many of you more so, than I--with the organizations employed in prosecuting fish-cultural work in this country, so that no detailed account of them is necessary. Here is the United States Fish Commission with men, with means, with appliances and with scientific knowledge, and while doing the same kinds of work that various State Commissions are doing, yet doing much more than any single State organization. Here are the State Commissions each prosecuting the particular kinds of work required by local conditions under which in the different States fish-culture is being carried on. At the points where these different organizations have work common to each, why may there not be cordial and effective co-operation? Not merely the negative, of not interfering with each other, but the positive working together to economize expenditures and effort, and thus increase general and permanent results.

Bordering the Great Lakes are six States having a population of about fourteen millions of people. The fisheries of these Great Lakes, as their product enters into the general commerce of the country, cannot be regarded as the concern of the six States—they are of national importance If the fish captured in these lakes were consumed along their shores I grant that the States would have no special claim upon the general Government for taking part in maintaining such fisheries, or helping in any way to their re-establishment. This was the condition of affairs once; but with the modern facilities of rapid communication and improved methods of transportation, their product is marketed all over the country, and for that reason the States bordering the Great Lakes have, in my judgment, as good a right to assistance from the General Government, in the directions I shall presently mention, as the fisheries of the Atlantic and Pacific Oceans. Our lake fisheries are not to be compared in extent and value to those of the seas, but it is a difference in degree not in kind. The United States is doing a most necessary work in the investigation and promotion of the Atlantic fisheries, is preparing to investigate more thoroughly, and help develop the fisheries of the Pacific; it has done the country an invaluable service in examining and illustrating the seal and other fisheries in connection with the last general census; for all of which it has earned the confidence and commendation of the country. Why should not a similar service be performed by it in co-operation with the States bordering the Great Lakes in making an exhaustive survey and examination of the fisheries from Duluth to the St. Lawrence river? "The reward of having wrought well is to have more work to do." If the Commission has not the equipment in steamers, the work already in hand probably requiring them all, why not borrow one or more of the revenue cutters that are lounging up and down the lakes? I may be doing that branch of the service an injustice, but I never have heard within ten years of those vessels doing anything more useful than cruise on a sort of dress-parade between Buffalo and Chicago.

If a revenue cutter could not be spared, then why not borrow from the Navy Department a despatch-boat, or some of the many steamers not suitable for modern naval warfare, and have her fitted out for this service. To do what? To be manned with the necessary crew, under command of an officer not above such service, placed under the direction of the United States Fish Commission, supplied by him with one or more naturalists, and one or more men competent to study and report upon the conditions, capacities and needs of the industrial fisheries, supplied with drags, sounding appliances, proper thermometers, duplicate charts of the lakes, and complete fishing apparatus. Upon the charts could be marked spawning-beds, seining grounds, the lines of inshore and outside fishing, abandoned fishing grounds, the lines where certain kinds of fish are most plentiful or scarce, the pound-net fishing stations and the like. With such an equipment it would be practicable to make a complete survey of the fishing, feeding and spawning grounds of the great lakes; exhaustive scientific observations and collections of the fauna; a census of the fishing industry, its methods, its product, its habits; in fact, a history that would, by its manifold and exact observations of the present condition and requirements of the industry and its possibilities, lead conclusively to a knowledge of the causes of its decadence, and what is necessary to be done for its restoration and permanent maintenance. Is it worth the expenditure? I think I can answer without hesitation for Michigan waters. I had occasion in 1886 to examine the history of Michigan fisheries, and was led to the conclusion, after careful examinations and comparisons of such statistics as are obtainable, that if our waters had been as productive in 1885 as they were in 1859, with the effectiveness of apparatus and extent of operations in the former year, the money value of the products of Michigan waters in 1885 would have been not less than fifteen millions of dollars, instead of about one and one-half millions. In 1887 I compared the product of the Michigan fisheries for the year 1885 with those of the Province of Ontario, and found that the money value of the former, if computed upon the same basis as that employed by the Canadian Department of Marine and Fisheries, exceeded that of the province by more than one hundred thousand dollars.

The States bordering the Great Lakes having an immediate interest to be subserved by such an examination, as the work is being prosecuted in their waters, should co-operate by furnishing a crew of three or four men to assist in gathering statistics and other information, which would be of great value to the State Fish Commissions in illustrating to the Legislatures the kinds of regulations required to restrain wasteful fishing, which has gone so far towards depleting the waters, as well as the kind and extent of operations to restore productiveness of the waters. They might also direct or assist in the fishing operations of the expedition. Such an examination would also demonstrate the exact extent to which artificial propagation of whitefish benefited the fisheries, and indicate what points along the lakes required attention in order to the more even distribution of future supplies. The information so gathered would help, by furnishing the required data, towards another and most important feature in the regulation of the fisheries of the Great Lakes, namely, the licensing of fishing as an industry. In alluding thus briefly to this subject there is not time to more than call attention to the fact that a fair system of licensing would in time defray all or the larger part of the expenses of keeping up the supplies of fish when the waters were once well stocked, as well as such part of the cost of enforcing the laws as the State would be called on to pay. There are several minor ways in which co-operation can be advantageously adopted, but not of sufficient importance to be enumerated here. They are being employed more or less, and are familiar to you all.

For many years the U. S. Commission has thus co-operated with two or three of the New England States in procuring salmon and Schoodic salmon eggs, on terms, I believe, equitable and satisfactory to all parties, and with most excellent results.

Another direction in which co-operation can, I believe, be advantageously employed is in a thorough examination of interior lakes. By interior, or inland, lakes the dwellers along the Great Lakes are wont to distinguish the smaller bodies of water wholly within the boundaries of the several States. In Michigan, the numbers, size, and natural conditions of the inland lakes make them a considerable part of the waters we are called upon to care for. In the earlier days of this work these lakes were planted with various kinds of fishes, not with any special reference to their adaptability to the fish planted, but because the Commission had fish for that purpose, and in a general way the people in the vicinity of the lakes wanted fish. I do not say this with the design of casting any reflection upon the authorities of those days. The promiscuous planting of fish was then perfectly natural; and our experience is based largely upon their mistakes as it is still more largely upon the notable success of so many of their experiments. As the years went by a very natural curiosity arose amongst citizens and fishery authorities to know what had been the result of those plants. Had all failed? If so, why? If the fish planted had not lived and prospered, would no others live in those waters? And, finally, the question formulated itself, are these waters suitable for any fish? If so, what kinds? There was but one way to answer these questions, and that was to go and find out. And so we went (by proxy). In 1885 in a desultory kind of a way the work of examining the lakes was begun. In 1886 a proper crew was organized, consisting of three men, one being in charge. They were provided with a gang of gill-nets having meshes of four different sizes, thermometers, a small drag or trawl, sounding lines, fishing tackle, blank reports with printed instructions, and a complete camping outfit. And so with fairly good and practical results the lakes of three counties on the southern border of the State were examined and reported on. For a short time towards the end of summer a second crew was sent out to examine some places where there were special reasons for knowing the contents and capabilities of several lakes. In 1887 further improvements were made in the outfit, and the crew increased to four. The addition of one man secured more expeditious work. The result of these examinations give the Michigan Commission in permanent and convenient form, not only the exact, but the essential, facts about the lakes in eight counties of this State. The size, depth, character of bottom, quality of water, temperature, inhabitants, kinds and quantities of food; in a word what fish are there and the knowledge what can and ought to be there in order to obtain the greatest productiveness of the given waters.

One characteristic these examinations have lacked. They afford an opportunity for scientific investigation, which would add materially to their practical utility, and which would certainly make them more complete from all points of view. We have not the means to supply that want. The United States Fish Commission has the means and the men. We are discussing with the Commissioner, and the head of the Department of Scientific Research of the United States Fish Commission, a practical method of co-operation in carrying on further examinations of Michigan lakes. Here is a field well worth cultivating. If fish-culturists are to do anything for the interior lakes they must know as well as possible the conditions under which their efforts must be tried. There are six or seven northern States besides Michigan, of which I have some knowledge, where such efforts ought to be made.

And while the lakes are being examined, why not the streams and rivers? Our experience has proved that there are hundreds of spring brooks in this State suitable for the growth of speckled trout where that fish was not native. A systematic examination of all streams would in this State within a few years secure the planting of trout only in waters entirely adapted in temperature and food supply to trout. It would in my judgment also result in our being able to establish black bass in miles of water suitable for this admirable game and food fish where now they are unknown. Definite and comprehensive knowledge of the rivers and streams of the State, put into the same permanent and accessible form as the reports Michigan is getting of the lakes, is of importance just as the work on the lakes is.

Secondly, what co-operation can there be between State Fish Commissions? The most obvious points for co-operation between States, are where they border the same waters, as on the Great Lakes, or have a common boundary on a river,—as the Ohio, Mississippi, or Missouri. And here we must touch upon the regulation of fisheries, a subject pregnant with difficulties. For the States bordering the Great Lakes, a uniform system for every mile of the great waters ought to be established. Not necessarily identical enactments; for the waters of a single State, like Michigan, require a diversity in regulations to make complete for all its waters the operation of a general system. The objects to be sought by each State are the same, the means to reach these objects will necessarily be somewhat modified by local conditions. From our own experience, I assume that it is a difficult thing to secure the passage of suitable laws by the State Legislatures for the preservation of industrial fisheries. We have no difficulty in obtaining fairly good laws for the protection of game fish; but we have tried in vain thus far to persuade the Legislature of this State to do for the fisheries of the Great Lakes what must be apparent to any man of common sense, who gives the subject any attention, is essential to preserve them.

I think the common judgment of men, who are entirely disinterested but careful observers of the past and present condition of our fisheries, accords with that which is always expressed by the most intelligent and candid of practical fishermen and fish dealers, to the effect that our laws should cover three vital points:

1st. To regulate the size of the meshes of nets, the times and places of fishing.

2d. The market size of the various valuable kinds of fish.

3d. The employment and authorization of competent State officers to enforce the regulations and inspect the products being marketed; and there should be confided to the chief officer discretionary power to suspend, within prescribed limits, the regulation respecting the apparatus, when such suspension will not result in the destruction of immature fish, and may be an advantage to the fishermen.

Regulations should be as general, as exact and as simple as is compatible with efficiency, in order that they may not be oppressive or obscure. Of course, each State must enact its own laws. Each State has exclusive jurisdiction of its waters to its boundary line; this on the Great Lakes is a matter of great importance. It has many times been suggested by persons who had not examined thoroughly the question of jurisdiction, that Congress could better provide for the regulation of the fisheries of the Great Lakes, because these waters bordered so many different States. This question has been settled once for all by the Supreme Court of the United States, so that whatever of advantage Federal legislation on this subject may seem to offer, it is a legal and constitutional impossibility, and must be dismissed. The States must do all there is to be done, and do it in their own several ways. Thus far it has been badly done,—or to speak more accurately, has not been done at all. Can there be any co-operation between the States to remedy this evil? There ought to be, is plain. And the fact of its recognized necessity ought to bring about, eventually, an affirmative answer. The force of a substantial and efficient example is the only constraint that can be brought to bear. When any one of the States bordering the Great Lakes will enact laws that are effective, its example will be followed.

Full and candid discussion between the fishery officers of the different States will be useful, and ought to be employed more frequently than in the past, for the purpose of harmonizing the views of all. By fishery officers I do not mean alone the Fish Commissioners, but include the wardens or officers employed to enforce the laws, by whatever names they may be known. And I believe that good results might be obtained from conferences between the Fishery Committees of the Legislatures of Michigan and Ohio, and Michigan and Wisconsin, and Ohio, Pennsylvania and New York. At least this is worth consideration.

A step in the right direction was taken by Michigan, in 1887, in the passage of an act for the appointment of a Game and Fish Warden. The act was not as broad nor the powers as extensive as the Commissioners urged upon the Legislature; but it was one point gained. The thorough, consistent and intelligent course pursued by the gentleman selected by the Governor as the State Warden will go far towards securing at another session of our Legislature the required improvements in the law, as it has already demonstrated the important advantages of the proper enforcement of such laws as we have. Wisconsin took the lead in this class of legislation, but from all I have learned of its operation, I judge that the statute needs amendments in some important points to make it effective. Ohio, too, has started in the right direction. This is all encouraging, because in each case it has been a movement in the right direction.

The fisheries, in my judgment, have reached a point where no half-measure will answer. What is needed is to look the necessities of the case squarely in the face and provide wholesome and sufficient remedies, that will put a stop to the destruction and marketing of immature fish of all valuable kinds; and while it gives nature a chance to help repair the mischief already done, will likewise help to secure to the States the benefits of the artificial propagation and planting.

A third suggestion in the line of coöperation that I think worthy of discussion is between the Fish Commissions and the educational institutions of the State—as for instance, with the instructors in Natural History in the State University, or the Agricultural College. There are many ways in which the two could aid each other. The University, or Agricultural College, or both, might furnish the naturalist to accompany a crew of Fish Commission men in examining interior lakes and streams. They might do a notable service by furnishing a naturalist, who is expert with the microscope, along with our crews employed in gathering ova of different fishes; and by a critical study of ova and milt during the spawning time, instruct the men as to the appearance of perfectly matured male and female properties, so as to bring such operations still nearer to perfection. At the same time, facts so acquired might be an actual and useful contribution to scientific knowledge. The Michigan Superintendent last fall proposed a very similar method for the purpose of improving the already good results in artificial fertilization.

Detroit, May 16, 1888.

DR. SWEENY was down on the programme for a paper on "Stocking Western Lakes and Streams," but he claimed that he was ignorant that such information had been required of him and he was not prepared to present it in a formal manner. He had no objection to talking on the subject, and said that the work of the Minnesota Fish Commission, of which he was a member, had been very successful, the failures, if there had been any, were small and of no account, but the successes were so much in excess of any failure that his memory refused to get down to so small a matter. There had been great success in the hatching and planting of brook trout, black bass, and wall-eyed pike; the returns from the fisheries showed that the continuous plantings had borne fruit and that these fishes have increased through artificial propagation. In Lake Superior the plantings of whitefish have borne fruit and the fishermen who opposed the work at first were now strongly in favor of it. The increased catches have convinced the fishermen that the work of hatching whitefish should be continued. Dr. Sweeny had a theory that it would be well to stock certain points with whitefish and then have no fishing done there for five years, next year take other points and stock them, and so on in a circle. It seemed to him that this would be worth a trial.

Mr. Clark asked how the fishermen could be managed. Would they abstain from fishing at certain points at the request of the Commission, or would laws have to be passed to regulate this? Again, would not the fishermen oppose such legislation and render it difficult, if not impossible to procure it? Take the pound-net men, for instance; at Bass Island there are four or five pounds and the owners would probably object to being deprived of their fishing grounds for a term of years, and in practice it will be found difficult to control the fishermen.

Dr. Sweeny thought that now, since the fishermen are convinced that fish-culture is of value to them, from a business point, they might be further educated so as to be sensible of their own interests.

Mr. Bissell inquired how large such reservations should be.

Dr. Sweeny suggested that reservations of three miles in length by a mile in width would be about the proper size.

Mr. Nevin called attention to the fact that whitefish do not always feed where they spawn, and that a good place to plant the young fish was not necessarily a good fishing place.

WORK OF THE WISCONSIN FISH COMMISSION.

BY JAS. NEVIN, SUPERINTENDENT.

The work of artificial propagation of fish in the State of Wisconsin is no longer an experiment in the minds of the people of our State. When the good work of restocking our streams and lakes with their native fish was first attempted we did not meet with much encouragement from many parts of the State. But with perseverance and successful operations the old feeling has vanished, and the cry from all over the State is "more fish," until now we are unable to supply the demand, even to that of German carp.

First in rank comes the pride of all waters, brook trout, and of these fish, most every county in the State has received a portion of the 2,255,000 fry that have been distributed this present season to 200 applicants, and the supply was insufficient to fill the demand, which at the first of the season was 4,720,000 fry, which were asked for by 286 applicants, and now we have nearly 100 orders on file for next season's distribution, and I dare say this number will swell to 350 orders before the shipping season begins next season.

Next comes California mountain, or rainbow, trout, which have done remarkably well in some parts of the State, and are prized even as high as its rival in beauty and delicacy, the brook trout, while in other parts they rank inferior. These rainbow trout seem to abandon the small streams and seek the larger ones, and the rivers, where they appear to thrive wonderfully. A gentleman of good authority, from St. Croix County, informed me that he caught a two-year-old that tipped the scales at just 4 pounds, and I could relate several instances where they have been taken at that age weighing from 1½ to 3½ pounds. We have just begun the distribution of these fish, and out of the 183 orders now on file I hope to be able to fill 150 of them with about 1,750,000 fry. All orders remaining unfilled, will be filled first, the following season.

Owing to the extreme high water in the Fox river this spring, where I collect my supply of wall-eyed pike eggs, I have been unable to procure a full quota, but have now in the hatching jars at Milwaukee enough to bring forth about 8,000,000 fry, which will be eagerly captured by the 220 applicants whose names are now on file. Since we have begun restocking our numerous lakes we have met with success, and now reap the harvest of our endeavors, by reading *confirmed* reports of success from different parts of the State, and still continue to sow.

The present season I placed in several inland lakes 800,000 Mackinaw, or lake trout, the eggs of which were collected in Lake Michigan, and were hatched at the Madison Hatchery. I do not approve of this method of stocking lakes with lake trout hatched in spring water, for I think it can be done with less labor and expense by collecting large quantities of eggs and carefully spreading them on the shoal reefs of the lakes intended to stock, and let them hatch and take care of themselves.

Our work on whitefish has not been as extensive the past season as formerly, for we were unsuccessful in getting a full amount of eggs, on account of the stormy weather on the lakes last fall, and a few of what we did get were touched by the frost, but have succeeded in hatching 16,000,000 fry, which have been deposited in the waters of Lake Michigan and Green Bay.

It is very gratifying to know that the Wisconsin Fish Commission has at last got the good will of the fishermen around the lakes, and that they are beginning to realize the benefit of the work done by the Commission. There has been more whitefish taken during the past winter and spring, than any season in the last ten years. I heard a fisherman remark the other day that fishing for whitefish was beginning to look like olden times. Ever since the pound net has been in existence, the fishermen have taken out the small whitefish faster than the several hatcheries could put them in. I have seen as high as 2,400 pounds of small fish taken out of one pot, and there were not ten fish in the lot that would weigh a pound each. It is now unlawful in Wisconsin for a man to have in his possession a whitefish of less than one pound, dressed, or one and one-half, undressed, and I am proud to say that the law has given entire satisfaction. The fishermen have always said that whitefish would not live after being caught in the meshes of a net, but last fall, while collecting spawn, I saw thousands caught that had the marks of the nets on them, where they had been previously caught, which proves that whitefish are not the delicate little fellows they have been represented to be.

The value of the lake fishing industry, as reported by the Fish Wardens to the President of the Board, for the year of 1887, are as follows:

Number of pounds caught	4,460,015
Value of fish	$271,269 78
Number of nets	12,750
Value of nets	$161,860 00
Persons employed	1,300
Number of boats	700
Value of boats	$177,285 00

Which shows that the fishing interests of the State of Wisconsin are worth protecting.

In conclusion, I will say a few words on carp and carp ponds. Of all fish I ever tried to catch by seining carp are the most difficult ; for when they find themselves surrounded by the net, if they can't get under it they will leap over it. As the temperature of the water at the hatchery was too low to successfully raise carp, the Commission leased a breeding pond, located about two miles from the hatchery, and covering about two acres. In the spring of 1887, I placed in this pond our large carp, and in May had a lot of willows cut and placed in the pond for the fish to spawn on. One day I went to the pond for some large fish for an aquarium, and as the pond could not be drawn down, I thought I could soon catch them by seining. But we seined two days and did not get a large fish. Another day, later in the season, we went to the pond for some fry to ship, and my two little boys, aged five and eight years, went along to pass the time away playing around the pond. Before beginning to fish, I had all the willows taken from the water and placed upon the bank, and, to amuse themselves, the boys rolled some of the willows back into the water. After some time we came to where the brush was to make a haul, and as we began removing it, were surprised to see numerous small fish dart from under the branches. Without taking out any more of the brush, we carefully surrounded it with the net and were very much surprised when we drew it in to take out of it 5,000 small, and fifty large carp. After taking care of the fish, we soon replaced the brush at about a dozen different places around the pond, and in this way we could catch all the fish—either large or small, we wanted, as they seemed to seek the brush for shelter and to hide.

I do not think there would be the large losses of carp in winter, if in the fall people would place a lot of brush in the centre, or deepest part, of their ponds, as the fish would naturally seek the brush and not the shoal water, and thus avoid being frozen in the mud. People who have carp ponds that cannot be drawn down, will find this experiment beneficial in catching their fish as well as serving as a protection.

Madison, Wis.

Mr. Bartlett, of the Illinois Commission, was on the programme for a paper on "Carp in Illinois." He had not prepared the paper, but in a few brief remarks said that the carp had increased and multiplied in his State, and it had produced tons of food from waters which had produced nothing of value heretofore, and the carp was a great boon to the people of Illinois and other States which had no ocean on their borders from which to draw food.

Mr. Fred Mather, a Superintendent of the New York Fish Commission, had been put down for a paper on "Work at Cold Spring Harbor," the station under his charge, but pleaded, with Dr. Sweeny, that he had not been notified that this was to be expected of him. He detailed the work with the different fishes, and said that he had hatched the tomcods in fresh water and had kept them there until the sac was absorbed, and then planted them in brackish water. The experiments with smelt had not brought out any new facts and the limited allowance for his station had not permitted further experiments with salt water fishes. The work of stocking the Hudson with salmon had been continued by the U. S. Commission, of which he was still one of the assistants, as well as one of the State Superintendents, and that the results had been satisfactory. He had built a new hatchery, which he would be pleased to have any of the members visit.

The question of the time and place of the next annual meeting then came up and after some discussion it was decided to accept the motion of Mr. Henry C. Ford to meet in Philadelphia, where he promised that the Anglers' Association of Eastern Pennsylvania would see that the necessary arrangements for entertaining the Society would be attended to. Mr. Bissell moved that the next annual meeting of the Society be held at Philadelphia on the third Wednesday and Thursday of May, 1889, and it was carried.

The election of officers for the following year then came up. Mr. Bissell moved that a nominating committee be appointed, as heretofore. Mr. Mather favored nominations in open meetings, because the committee system had not always worked well, as some of the older members knew. On a vote it was decided to appoint a committee and Mr. Bissell moved that Dr. Hudson, Mr. Butler, and Mr. Clark be that committee. President May accepted the committee, and they went into private session. The committee recommended the following gentlemen and they were unanimously elected: President, John H. Bissell, Michigan. Vice-President, S. G. Worth, North Carolina. Recording Secretary, Fred Mather, New York. Corresponding Secretary, Henry C. Ford, Pennsylvania. Treasurer, Eugene G. Blackford, New York. Executive Committee, Philo Dunning, Chairman, Wisconsin; S. P. Bartlett, Illinois; Dr. R. O. Sweeny, Minnesota; Dr. W. M. Hudson, Connecticut; C. V. Osborn, Ohio; Col. M. McDonald, Washington, D. C.; and James V. Long, Pennsylvania.

Thanks.

The Society then voted thanks as follows: To the Detroit Lodge of Elks, No. 34, for the use of their room. To the Michigan Fish Commission, for their efforts in making the meeting a success. To Professors Jordan, Forbes, Atwater, and others, not members of the Society, for valuable papers.

The meeting then adjourned until 2 P. M., on the boat which was to take them to the St. Clair Fishing and Shooting Club, by invitation through its President, Mr. W. A. Colburn, as before recorded. A pleasant trip of some twenty-five miles, on the steamer "Milton D. Ward," brought the party to the club house, which is on made ground on the St. Clair Flats, and a dinner which was noted for the excellence of its fish was in readiness. The members of the club showed their guests over the extensive house, and on the return trip it was voted that the club be an honorary member of the American Fisheries Society and receive its annual reports.

THE MEETING ON THE BOAT.

On the return from St. Clair Flats a meeting was organized to hear the report of the Treasurer, who, being unavoidably absent, had mailed his report, which came to the Recording Secretary before the boat left Detroit. This report, which appears elsewhere, was read and accepted.

Dr. Sweeny moved that the Treasurer be authorized to sell the reports, but it was argued that as this was all that absent members got for their dues, such a course would tend to decrease membership. The motion was lost.

Dr. Hudson complained that the last report had been delayed and had only appeared a month before this meeting. Mr. Mather explained that everything was in the printer's hands last August, but that there had been no money in the treasury to pay for it. In view of this fact he had asked Mr. Blackford if it would not be well to increase the annual dues from $3 to $5, but the Treasurer had said that the present sum was ample, if the members would pay their dues promptly.

A long argument was held on the propriety of allowing papers to be printed before they appear in the report, because some editors who never sent a reporter to the meetings, even when held in their own cities, had objected to their publication in *Forest and Stream*. Finally, on motion of Mr. Bissell, Messrs. Mather, Hudson and Ford were appointed a committee in custody of the papers, and to attend to the publication and to use their judgment about selecting a printer and getting the report out at as early a day as possible. They were also to allow such papers to be copied for simultaneous publication in other journals, if it be requested, the expense of copying to be borne by those wishing copies. This committee to meet at Mr. Blackford's, in Fulton Market, on Saturday, June 2, at 12 M.

It was also voted that the printing should be begun by June 1, and that those which are not then on hand shall be omitted, and the meeting adjourned until next year.

During the discussions and the after-dinner speeches on the boat, it cropped out that Mr. Fitzhugh had been quietly taking notes of the animated nature observable about the club house, and he was called on to give the results of his observations. Dr. Hudson, who had been working in a similar line on the St. Clair Flats, stated that the time for scientific observation at the Flats had been too short to make public the hastily-gleaned facts of a naturalist, and to eliminate the personal equation which is always consequent upon hastily prepared papers, or remarks. Mr. Fitzhugh assented to this, and promised to give the Society the benefit of whatever he may have learned, at some future time.

THE PUBLICATION COMMITTEE.

This Committee, consisting of Messrs. Mather, Ford and Hudson, met at the office of Treasurer E. G. Blackford, on Saturday, June 2, Mr. Blackford being present. A letter from the Michigan Fish Commission, in which the Society was asked to pay for the expense of procuring two papers, from scientific men, was read, the amount being $52.70. It was explained that the Michigan Commission had incurred this expense, in order to contribute to the success of the meeting, without the consent of the Executive Committee. Dr. Hudson moved that the Treasurer notify Mr. Bissell, President of the Michigan Commission, that it was the opinion of the Committee that there was no more money in the Treasury than would pay for the printing of the forthcoming report, and, that if there was a surplus, this Committee had no power to authorize the payment of this bill. Carried.

Dr. Hudson moved that as fast as the proof slips are printed, copies be sent to *Forest and Stream* and the *American Field*. Carried.

Dr. Hudson moved that the Recording Secretary prepare the papers and submit them, with the entire report, to two or more printers, for estimates of the cost of the work, which shall conform in general style of printing, paper and type, to the preceding reports, and that the report shall be ready for mailing by the first of August, 1888. The estimates to be made by the page. Carried, and the meeting adjourned.

The following letter was then sent to Mr. John M. Davis, who has printed the report for several years, Mr. Charles E. Schember, the printer of *Forest and Stream*, and Mr. Martin B. Brown, the Public Printer of New York City:

COLD SPRING HARBOR, N. Y., June 16, 1888.

DEAR SIR—The American Fisheries Society has ordered me to prepare the papers read at the last meeting and to submit them to two or more printers, for estimates of the cost of publishing. The report to be ready for mailing by August 1, 1888, and to conform in size, paper and type, to preceding reports, the estimates to be per page.

Four proof slips to be sent me, one of which will be returned, after correction, by either the author, or myself.

If you care to give an estimate on this work, I will submit the papers and a copy of the last report to you.

The new report will be larger than the last one, and only 300 copies will be printed.

Very truly yours,
FRED MATHER,
Recording Secretary.

Mr. Schember did not reply. Mr. Davis offered to do the work for $1.50 per page, with extra charge for tables. Mr. Brown agreed to do it for $1.45 per page, with no extra charge, and the printing was awarded to him.

TREASURER'S REPORT.

NEW YORK, May 10, 1888.

THE AMERICAN FISHERIES SOCIETY,

In account with EUGENE G. BLACKFORD, *Treasurer.*

Receipts.

1888. May	10.	Total receipts from Membership Dues		$267 00

Disbursements.

1887. May	28.	J. M. Davis, printing notices of meeting	$2 00	
1888. March	27.	" " postal cards	7 50	
April	6.	" " reports	112 00	
"	6.	175 stamped wrappers	3 68	
			$125 18	
		Balance due Treasurer at last meeting	80 17	
				205 35
		Balance in Treasurer's hands		$61 65

MEMBERS

OF THE

AMERICAN FISHERIES SOCIETY.

Honorary Members.

Frederick III., Emperor of Germany.

Behr, E. von, Schmoldow, Germany; President of the Deutschen Fischerei Verein, Berlin, Germany.

Borne, Max von dem, Berneuchen, Germany.

Huxley, Prof. Thomas H., London; President of the Royal Society.

Jones, John D., 51 Wall Street, New York.

St. Clair Flats Shooting and Fishing Club, Detroit, Mich.

Corresponding Members.

Apostolides, Prof. Nicoly Chr., Athens, Greece.

Buch, Dr. S. A., Christiana, Norway; Government Inspector of Fisheries.

Birkbeck, Edward, Esq., M. P., London, England.

Benecke, Prof. B., Königsberg, Germany; Commissioner of Fisheries.

Brady, Thomas F., Esq., Dublin Castle, Dublin, Ireland; Inspector of Fisheries for Ireland.

Chambers, Oldham W., Esq., Secretary of the National Fish-Culture Association, South Kensington, London.

Day, Dr. Francis, F. L. S., Kenilworth House, Cheltenham, England; late Inspector-General of Fisheries for India.

Feddersen, Arthur, Viborg, Denmark.

Giglioli, Prof. H. H., Florence, Italy.

Hubrecht, Prof. A. A. W., Utrecht, Holland; Member of the Dutch Fisheries Commission, and Director of the Netherlands Zoölogical Station.

K. Ito, Esq., Hokkaido, Cho., Sapporo, Japan; Member of the Fisheries Department of Hokkaido, and President of the Fisheries Society of Northern Japan.

Juel, Capt. N., R. N., Bergen, Norway; President of the Society for the Development of Norwegian Fisheries.

Landmark, S., Bergen, Norway; Inspector of Norwegian Fresh-water Fisheries

Lundberg, Dr. Rudolf, Stockholm, Sweden; Inspector of Fisheries.

Maitland, Sir J. Ramsay Gibson, Bart., Howietown, Stirling, Scotland.

Marston, R. B., Esq., London, England; Editor of the *Fishing Gazette.*

Macleay, William, Sydney, N. S. W.; President of the Fisheries Commission of New South Wales.

Sars, Prof. G. O., Christiana, Norway; Government Inspector of Fisheries.

Solsky, Baron N. de, St. Petersburg, Russia; Director of the Imperial Agricultural Museum.

Sola, Don Francisco, Garcia, Madrid, Spain; Secretary of the Spanish Fisheries Society.

Wattel, M. Raveret, Paris, France; Secretary of the Société d'Acclimation.

Young, Archibald, Esq., Edinburgh, Scotland; H. M. Inspector of Salmon Fisheries.

Walpole, Hon. Spencer, Governor of the Isle of Man.

Deceased Members.

Baird, Hon. Spencer F.
Carman, G.
Chappel, George.
Develin, John E.
Garlick, Dr. Theodatus.
Lawrence, Alfred N.
McGovern, H. D.
Parker, W. R.
Redding, B. B.
Redding, George H.
Rice, Prof. H. J.
Smith, Greene.
Shultz, Theodore.

Members.

Persons elected at last meeting and who did not pay their dues do not appear in this list.

Adams, Dr. S. C., Peoria, Ill.
Agnew, John T., 284 Front Street, New York.
Anderson, A. A., Bloomsbury, N. J.
Annin, James, Jr., Caledonia, N. Y.
Atkins, Charles G., Bucksport, Me.
Atwater, Prof. W. O., Middletown, Conn.

Barrett, Charles, Grafton, Vt.
Bartlett, S. P., Quincy, Ill.
Bean, Dr. Tarleton H., National Museum, Washington, D. C.
Belmont, Perry, 19 Nassau Street, New York.
Benjamin, Pulaski, Fulton Market, New York.
Benkard, James, Union Club, New York.
Bickmore, Prof. A. S., American Museum, New York.

Bissell, J. H., Detroit, Mich.
Blackford, E. G., Fulton Market, New York.
Booth, A., Chicago, Ill.
Bottemane, C. J., Bergen-op-Zoom, Holland.
Brown, J. E., U. S. Fish Commission, Washington, D. C.
Brown, S. C., National Museum, Washington, D. C.
Bryan, Edward H., Smithsonian Institution.
Bryson, Col. M. A., 903 Sixth Avenue, New York.
Butler, W. A., Jr., Detroit, Mich.
Butler, Frank A., 291 Broadway, New York.
Butler, W. H., 291 Broadway, New York.

Carey, Dr. H. H., Atlanta, Ga.
Cheney, A. Nelson, Glen Falls, N. Y.
Clapp, A. T., Sunbury, Pa.
Clark, Frank N., U. S. Fish Commission, Northville, Mich.
Clark, A. Howard, National Museum, Washington, D. C.
Comstock, Oscar, Fulton Market, New York.
Conklin, William A., Central Park, New York.
Cox, W. V., National Museum, Washington, D. C.
Crook, Abel, 99 Nassau Street, New York.
Crosby, Henry F., P. O. Box 3714, New York City.

Dewey, J. N., Toledo, O.
Dieckerman, George H., New Hampton, N. H.
Donaldson, Hon. Thomas, Philadelphia, Pa.
Dunning, Philo, Madison, Wis.

Earll, R. E., National Museum, Washington, D. C.
Ellis, J. F., U. S. Fish Commission, Washington, D. C.
Endicott, Francis, Tompkinsville, N. Y.
Evarts, Charles B., Windsor, Vt.

Fairbank, N. K., Chicago, Ill.
Ferguson, T. B., Washington, D. C
Fitzhugh, Daniel H., Bay City, Mich.
Foord, John, Brooklyn, N. Y.
Ford, Henry C., Philadelphia, Pa.
French, Asa B., South Baintree, Mass.

Garrett, W. E., P. O. Box 3006, New York.
Gilbert, W. L., Plymouth, Mass.
Goode, G. Brown, National Museum, Washington, D. C.

Habershaw, Frederick, 113 Maiden Lane, New York.
Haley, Albert, Fulton Market, New York.
Haley, Caleb, Fulton Market, New York.

Hall, G. W., Union Club, New York.
Harris, Gwynn, Washington, D. C.
Harris, W. C., 252 Broadway, New York.
Hayes, A. A., Washington, D. C.
Henshall, Dr. J. A., 362 Court Street, Cincinnati, O.
Hessel, Rudolf, U. S. Fish Commission, Washington, D. C.
Hicks, John D., Roslyn, Long Island, N. Y.
Hill, M. B., Clayton, N. Y.
Hinchman, C. C., Detroit, Mich.
Hofer, J. C., Bellaire, O.
Hudson, Dr. William M., Hartford, Conn.
Humphries, Dr. E. W., Salisbury, Md.
Hutchinson, E. S., Washington, D. C.

Isaacs, Montefiore, 42 Broad Street, New York.

Jessup, F. J., 88 Cortlandt Street, New York.
Johnston, S. M., Battery Wharf, Boston, Mass.

Kauffman, S. H., *Evening Star* Office, Washington, D. C.
Kelly, P., 346 Sixth Avenue, New York.
Kellogg, A. J., Detroit, Mich.
Kingsbury, Dr. C. A., 1119 Walnut Street, Philadelphia, Pa.

Lawrence, G. N., 45 East 21st Street, New York.
Lawrence, F. C., Union Club, New York.
Lee, Thomas, U. S. Fish Commission.
Long, James Vernor, Pittsburgh, Pa.
Loring, John A., 3 Pemberton Square (Room 8), Boston, Mass.
Lowrey, J. A., Union Club, New York.
Lydecker, Major G. I., U. S. Engineers.

Mallory, Charles, foot Burling Slip, New York.
Mansfield, Lieut. H. B., U. S. Navy, Washington, D. C.
Mather, Fred, Cold Spring Harbor, Suffolk Co., N. Y.
Marks, Walter D., Paris, Mich.
May, W. L., Fremont, Neb.
McDonald, Col. M., Fish Commissioner of the United States, Washington, D. C.
McGown, Hon. H. P., 76 Nassau Street, New York.
Middleton, W., Fulton Market, New York.
Milbank, S. W., Union Club, New York.
Miller, S. B., Fulton Market, New York.
Miller, Ernest, Fulton Market, New York.
Moore, George H. H., U. S. Fish Commission.

Nevin, James, Madison, Wis.

O'Brien, Martin E., South Bend, Neb.
O'Connor, J. J., U. S. Fish Commission, Washington, D. C.
Osborn, Hon. C. V., Dayton, O.

Page, George S., 49 Wall Street, New York.
Page, W. F., U. S. Fish Commission, Washington, D. C.
Parker, Dr. J. C., Grand Rapids, Mich.
Parker, Peter, Jr., U. S. Fish Commission.
Pease, Charles, East Rockport, Cuyahoga Co., O.
Pike, Hon. R. G., Middletown, Conn.
Post, W., Knickerbocker Club, New York.
Powell, W. L., Harrisburg, Pa.

Ray, Hon. Ossian, M. C., New Hampshire.
Redmond, R., 113 Franklin Street, New York.
Reinecke, Theodore, Box 1651, New York.
Reynal, J., 84 White Street, New York.
Reynolds, Charles B., 318 Broadway, New York.
Ricardo, George, Hackensack, N. J.
Robeson, Hon. Geo. M., Camden, N. J.
Ryer, F. R., Bellport, N. Y.

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