TRANSACTIONS

of the

American Fisheries Society

"To promote the cause of fish culture; to gather and diffuse information bearing upon its practical success and upon all matters relating to the fisheries; to unite and encourage all interests of fish culture and the fisheries; and to treat all questions of a scientific and economic character regarding fish."

FIFTIETH ANNUAL MEETING

OTTAWA, CANADA

SEPTEMBER 20, 21, 22, 1920

VOLUME L

1920 - 1921

Edited by Ward T. Bower

Published Annually by the Society
WASHINGTON, D. C.

The American Fisheries Society

Organized 1870 Incorporated 1910

Officers for 1920-1921

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Presidents, Terms of Service and Places of Meeting.

The first meeting of the Society occurred December 20, 1870. The organization then effected continued until February, 1872, when the second meeting was held. Since that time there has been a meeting each year, as shown below. The respective presidents were elected at the meeting, at the place, and for the period shown opposite their names, but they presided at the subsequent meeting.

1. William Clift..............1870–1872....New York, N. Y.
2. William Clift..............1872–1873....Albany, N. Y.
3. William Clift..............1873–1874....New York, N. Y.
4. Robert B. Roosevelt.........1874–1875....New York, N. Y.
5. Robert B. Roosevelt.........1875–1876....New York, N. Y.
6. Robert B. Roosevelt.........1876–1877*...New York, N. Y.
7. Robert B. Roosevelt.........1877–1878....New York, N. Y.
8. Robert B. Roosevelt.........1878–1879....New York, N. Y.
9. Robert B. Roosevelt.........1879–1880....New York, N. Y.
10. Robert B. Roosevelt.........1880–1881....New York, N. Y.
11. Robert B. Roosevelt.........1881–1882....New York, N. Y.
12. George Shepard Page........1882–1883....New York, N. Y.
13. James Benkard.............1883–1884....New York, N. Y.
14. Theodore Lyman............1884–1885....Washington, D. C.
15. Marshall McDonald........1885–1886....Washington, D. C.
16. W. M. Hudson..............1886–1887....Chicago, Ill.
17. William L. May............1887–1888....Washington, D. C.
18. John H. Bissell ....1888–1889....Detroit, Mich.
19. Eugene G. Blackford.......1889–1890....Philadelphia, Pa.
20. Eugene G. Blackford.......1890–1891....Put-in Bay, Ohio
21. James A. Henshall.........1891–1892....Washington, D. C.
22. Herschel Whitaker........1892–1893....New York, N. Y.
23. Henry C. Ford..............1893–1894....Chicago, Ill.
24. William L. May............1894–1895....Philadelphia, Pa.
25. L. D. Huntington..........1895–1896....New York, N. Y.
26. Herschel Whitaker........1896–1897....New York, N. Y.
27. William L. May............1897–1898....Detroit, Mich.
28. George F. Peabody..........1898–1899....Omaha, Neb.
29. John W. Titcomb..........1899–1900....Niagara Falls, N. Y.
30. F. B. Dickerson............1900–1901....Woods Hole, Mass.
31. E. E. Bryant ....1901–1902....Milwaukee, Wis.
32. George M. Bowers..........1902–1903....Put-in Bay, Ohio
33. Frank N. Clark............1903–1904....Woods Hole, Mass.
34. Henry T. Root..............1904–1905....Atlantic City, N. J.
35. C. D. Joslyn................1905–1906....White Sulphur Spgs, W. Va.
36. E. A. Birge.................1906–1907....Grand Rapids, Mich.
37. Hugh M. Smith.............1907–1908....Erie, Pa.
38. Tarleton H. Bean..........1908–1909....Washington, D. C.
39. Seymour Bower.............1909–1910....Toledo, Ohio
40. William E. Meehan........1910–1911....New York, N. Y.
41. S. F. Fullerton............1911–1912....St. Louis, Mo.
42. Charles H. Townsend......1912–1913....Denver, Colo.
43. Henry B. Ward.............1913–1914....Boston, Mass.
44. Daniel B. Fearing..........1914–1915....Washington, D. C.
45. Jacob Reighard.............1915–1916....San Francisco, Calif.
46. Geo. W. Field...............1916–1917....New Orleans, La.
47. Henry O'Malley............1917–1918....St. Paul, Minn.
48. M. L. Alexander............1918–1919....New York, N. Y.
49. Carlos Avery................1919–1920....Louisville, Ky.
50. Nathan R. Buller..........1920–1921....Ottawa, Canada.

*A special meeting was held at the Centennial Grounds, Philadelphia, Pa., October 6 and 7, 1876.

American Fisheries Society

ORGANIZED 1870

CERTIFICATE OF INCORPORATION.

We, the undersigned, persons of full age and citizenship of the United States, and a majority being citizens of the District of Columbia, pursuant to and in conformity with sections 599 to 603, inclusive, of the Code of Law for the District of Columbia, enacted March 3, 1901, as amended by the Acts approved January 31 and June 30, 1902, hereby associate ourselves together as a society or body corporate and certify in writing:

1. That the name of the Society is the AMERICAN FISHERIES SOCIETY.
2. That the term for which it is organized is nine hundred and ninety-nine years.
3. That its particular business and objects are to promote the cause of fish culture; to gather and diffuse information bearing upon its practical success, and upon all matters relating to the fisheries; to unite and encourage all interests of fish culture and the fisheries; and to treat all questions of a scientific and economic character regarding fish with power:

(*a*) To acquire, hold and convey real estate and other property, and to establish general and special funds.

(*b*) To hold meetings.

(*c*) To publish and distribute documents.

(*d*) To conduct lectures.

(*e*) To conduct, endow, or assist investigation in any department of fishery and fish-culture science.

(*f*) To acquire and maintain a library.

(*g*) And, in general, to transact any business pertinent to a learned society.

4. That the affairs, funds and property of the corporation shall be in general charge of a council, consisting of the officers and the executive committee, the number of whose members for the first year shall be seventeen, all of whom shall be chosen from among the members of the Society.

Witness our hands and seals this 16th day of December, 1910.

SEYMOUR BOWER (Seal)
THEODORE GILL (Seal)
WILLIAM E. MEEHAN (Seal)
THEODORE S. PALMER (Seal)
BERTRAND H. ROBERTS (Seal)
HUGH M. SMITH (Seal)
RICHARD SYLVESTER (Seal)

Recorded April 16, 1911.

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PART I

BUSINESS SESSIONS

PROCEEDINGS

of the

American Fisheries Society

FIFTIETH ANNUAL MEETING, OTTAWA, CANADA

September 20, 21, 22, 1920

The Fiftieth Annual Meeting of the American Fisheries Society was held in the Public Accounts Committee Room, House of Parliament, Ottawa, Canada, on September 20, 21, 22, 1920.

Opening Session, Monday Morning, September 20, 1920

The meeting was called to order by President Carlos Avery of St. Paul, at 11 a.m.

PRESIDENT AVERY: I am quite sure that you all feel very happy to have the opportunity of holding this, the fiftieth anniversary meeting of our Society, in the capital city of the Dominion of Canada. It is very fitting, it seems to me, that we should begin in this country the second half century of our organization. It is the first time that a meeting of the Society has ever been held in Canada, although the membership has been partially made up of Canadians and throughout the history of the Society much of its important work has been done by Canadian officials and citizens.

We are to have the pleasure this morning of listening to a few words of welcome from the Deputy Minister of Marine and Fisheries of the Dominion of Canada, Mr. A. Johnston. I have pleasure in introducing Mr. Johnston.

MR. A. JOHNSTON (Deputy Minister of Marine and Fisheries, Canada): Mr. President, the very few observations that I shall make this morning will be confined to a few words of welcome on behalf of the Department of Marine and Fisheries and on behalf of the Goverment of Canada; the larger and more formal welcome will be extended to you by Mayor Fisher, of this great capital city of Canada, who has been good enough to come here. But before that larger and more formal welcome is extended to you I want to extend a no less sincere welcome on behalf of the Government of Canada and of the Department of Marine and Fisheries. It was the hope of the Minister of Marine and Fisheries that his public engagements would enable him to be here to extend to you a welcome in person as a member of the Government and as Minister of Marine and Fisheries. But, as so frequently happens in the case of public men, public engagements have called him elsewhere and the pleasure of extending in person a welcome to you has been denied to him.

I merely desire to say that the Government of Canada and the Department of Marine and Fisheries are interested in the work that you are performing. We are delighted that on this fiftieth anniversary of your Society you have decided to hold your meeting in this country. We trust that subsequent meetings from time to time may be held here; we trust that your stay, short though it may be, will be such as to induce you to come again. We shall continue to watch the work of your Society with very great interest. If in the practical carrying out of your work you should stray into any of those great stretches of international waterways in which we are all commonly interested, and, perchance, come upon that invisible line which separates Canada from the United States and the United States from Canada, we trust that you will regard that particular line as a spot where cordial relations shall in no way cease; that you will regard it, as we shall endeavor in the future to regard it, as a place where new and more enduring friendships will begin.

I shall have an opportunity, I hope, during your meetings here, to come in more direct contact with the various members of your Society. I shall be anxious to make personal acquaintance with as many of your members as I can. I shall endeavor in every possible way to make your stay here pleasant and successful, and if there is anything that the Department over which I for the moment preside can do to make it such, we shall be only too glad to do it. I shall not detain you longer; again I extend to you on behalf of the Government and the Department a very sincere and cordial welcome to our capital city.

President Avery: Mr. James White of the Commission of Conservation was to have participated in extending a welcome to the members of this Society, but he is unable to be here. He wishes me to convey his apologies to the meeting and to express regret at his inability to attend on account of his presence at a session of the Chamber of Commerce of the Empire now meeting in Toronto.

We are enjoying the hospitality of this wonderful capital city of Canada, and it is particularly fitting that we should have a word of welcome from His Worship the Mayor. I take great pleasure in introducing to you Mayor Harold Fisher, of the city of Ottawa.

Mr. Harold Fisher (Mayor of Ottawa): Mr. President, ladies and gentlemen: Following the remarks which have been made by Mr. Johnston, there is really no necessity for my saying very much. Mr. Johnston has said nearly all that need be said. You noticed the position he took, close to the reporters; he is an old politician, you see. If there was anything he did not say this morning that he should have said, I have no doubt you will read it in the newspapers tomorrow morning.

I do not know exactly what you are here for, but I see something on the program about fish and fishing. That is enough to let me know that we all belong to one great fraternity. When I go to Heaven—and surely, Mr. President, I shall go to Heaven; I have been Mayor of this city for four years and there ought to be something coming to me—when I go to Heaven I am going to ask for a decent kind of boat, a fishing rod and a lake where there is a reasonable chance of catching a bass or a trout. I have never yet had sufficient time to tire of fishing. I do not know whether eternity would be too long, but I am willing to take a chance.

There is absolutely no need of my saying anything about this great city. Mr. Johnston has told you he is going to conduct you personally about the place, and I am quite sure you are in very good hands. I have found it my duty at times to warn these delegations about invisible lines, to which Mr. Johnston made reference. When he told you about the one that runs east and west across this continent he reminded me of the fact that when you get to that place you have to stand and pay duty on any little commodities that you want to carry across—not personal apparel. There are other invisible lines in this North American continent that are of equal importance; one of them is in the centre of the river which you see from the windows of this room. Mr. Johnston will explain to you why it is important that you should know something about that boundary—you can do things on one side of it that you cannot do on the other. Now, all I can say is that you are very welcome to Ottawa. I hope that your meetings will be profitable and that your stay will be very pleasant.

President Avery: I know of no gentleman who is more capable of making a fitting response to these cordial and eloquent addresses of welcome than one of our distinguished members, Mr. William C. Adams, Director, Division of Fisheries and Game, Boston, Massachusetts. I am pleased to introduce Mr. Adams at this time.

Mr. William C. Adams, Boston, Mass.: Mr. President, Mayor Fisher and the representatives of the Dominion Government: My impulse is to disregard all matters of dignity and to turn this into a sort of love feast. I am going to celebrate the occasion personally because it is my first trip across the invisible boundary line referred to by Mr. Johnston.

When I arrived at Montreal and walked through the Canadian Pacific station there, I was impressed by the exhibits I saw, in one of its outer halls or passageways, of the natural resources of Canada. This morning when reference was made to the invisible line that separates the United States from Canada I could not help trying to visualize the extent of the magnificent resources that touch upon that line at either side and at either end. You men who have travelled far and wide, ask yourselves whether there is any other place in the world where a line of the same length can be drawn and contiguous to which there will be as remarkable a group of natural resources as there is contiguous to the boundary line between Canada and the United States. I do not believe you will find it anywhere on earth, and that is the reason why we who live on either side of that line can sing the doxology, if you please, and thank God that we are neighbors and friends and that we have around us the most magnificent heritage that probably was ever given to any two nations in the world.

I am not going to turn this into a sermon at all. I am simply trying to point to one reason why we should make this meeting, the fiftieth in our history, the greatest event of rejoicing, the finest kind of love feast, that we have ever celebrated. Let us do that for a starter; then we will finish the job at a meeting of the International Association of Fish, Game and Conservation Commissioners.

We have heard this morning words of welcome that would hearten any crowd of red-blooded men. We are tremendously interested in what is, perhaps, the finest occupation in the world, that of making the great outdoors attractive to all classes of people in all walks of life. There is not any one activity that can result in more genuine, wholesome good to the human race than the very things that we are endeavoring to do, provided they are properly promoted and intelligently directed.

Some of the remarks that have been made here have taken a sort of turn that I desire to correct to some extent. The American Fisheries Society has been referred to as preeminently a United States organization, as a foreign body coming into Canada. Certainly the contributions to the work of the American Fisheries Society by the representatives of Canada in years gone by have been as valuable as those coming from any other source. We have never, I believe, regarded Canada as an outsider. I have always felt that the American Fisheries Society, true to its inclusive name, took in everything on the North American and South American continents, and I believe that before we get through the influence of the work that we are carrying on will be felt in all parts of this hemisphere, even the remotest. As we proceed with our work, the invisible line to which reference has been made will, I am sure, become of as little significance as the old Mason and Dixon line has become in the United States. The time is at hand when what is Canada's interest in relation to the commercial and the internal fisheries, fish and game, lumber, minerals or anything else, will likewise be the interest of the United States. As Shakespeare says:

> The friends thou hast, and their adoption tried,
> Grapple them to thy soul with hoops of steel.

So let us grapple ourselves to one another. There cannot be any longer a boundary line between the United States and Canada. When Mercier stood up in New York City a year ago last fall and spoke of the relationship between Canada and the United States, there was not a red-blooded man in the room who did not feel peculiar thrills running up and down his back.

We in the United States cannot read of the exploits of your Northwest Mounted Police without thinking of our Texas Rangers. We cannot think of the wind passing through the white pine and the hemlock in the north country here without thinking also of the birch and poplar on the hills of old New England. We cannot feel the sharpness of the air in Canada without realizing that we are hungering for just the same thing a little to the southward, and we know that when our boys arrive here from Kansas and Nebraska they are going to feel pretty much at home. So there is a great community of interests that draws us together, and it is irresistible. I want to say to you men of Canada that we are not coming here as interlopers; we are not coming here as representing a Society that is in any way foreign to you or to your interests. We are not going to refer to you during the whole of these deliberations as being other than brothers of ours. We are going to tackle this work believing that what we do is a community work, redounding for all time to the benefit of all of us.

President Avery: The next order of business provided for in our constitution is that of a roll call of members. We may dispense with this, however; the register which is being kept will answer that purpose.

REGISTERED ATTENDANCE

The registered attendance was 56, as follows:

Wm. C. Adams, Boston, Mass.
W. E. Albert, Des Moines, Iowa.
Carlos Avery, St. Paul, Minn.
Wm. F. Barber, LaCrosse, Wis.
A. C. Baxter, Columbus, Ohio.
J. A. Bellisle, Quebec, Canada.
George Berg, Indianapolis, Ind.
Seymour Bower, Lansing, Mich.
Ernest C. Brown, New York City.
Nathan R. Buller, Harrisburg, Pa.
E. T. D. Chambers, Quebec, Canada.
Alva Clapp, Pratt, Kan.
Eben W. Cobb, St. Paul, Min..
John N. Cobb, Seattle, Wash.
John M. Crampton, New Haven, Conn.
L. H. Darwin, Seattle, Wash.
George A. Dolan, Westerly, R. I.
Alex C. Finlayson, Ottawa, Canada.
Wm. A. Found, Ottawa, Canada.
S. B. Hawks, Bennington, Vt.
Charles O. Hayford, Hackettstown, N. J.
A. G. Huntsman, Toronto, Canada.
G. E. Jennings, New York City.
James C. Johnson, Riverside, R. I.
William C. Kendall, Washington, D. C
J. A. Knight, Halifax, N. S.
Geo. A. Lawyer, Washington, D. C.
E. Lee LeCompte, Baltimore, Md.
Dwight Lydell, Comstock Park, Mich.

Marshall McLean, Albany, N. Y.
D. A. MacKay, Ottawa, Canada.
Geo. N. Mannfeld, Indianapolis, Ind.
John C. Mattice, Bridgeport, Conn.
Honore Mercier, Quebec, Canada.
Arthur Merrill, Wilkinsonville, Mass.
Lee Miles, Little Rock, Ark.
Arthur L. Millett, Boston, Mass.
Wm. K. Mollan, Bridgeport, Conn.
James Nevin, Madison, Wis.
Raymond C. Osburn, Columbus, Ohio.
George E. Pomeroy, Toledo, Ohio.
George D. Pratt, Albany, N. Y.
Edward E. Prince, Ottawa, Canada.
Lewis Radcliffe, Washington, D. C.
J. A. Rodd, Ottawa, Canada.
Wm. H. Rowe, West Buxton, Me .
R. H. Siddoway, Salt Lake City, Utah.
Hugh M. Smith, Washington, D. C.
John W. Titcomb, Albany, N. Y.
John T. Travers, Columbus, Ohio.
R. C. Tuttle, Frankfort, Ky.
Harrison W. Vickers, Baltimore, Md.
S. J. Walker, Ottawa, Canada.
Wm. F. Wells, Albany, N. Y.
Solomon P. Whiteway, St. Johns, Newfoundland.
J. Asakiah Williams, Tallahassee, Fla.

NEW MEMBERS

In the year ensuing since the last annual meeting, the following have become members of the Society:

Barbour, F. K., 96 Franklin St., New York, N. Y.
Baxter, A. C., Chief, Ohio Fish and Game Division, Columbus, Ohio.
Crie, H. D., Director, Sea and Shore Fisheries Commission, Rockland, Me.
Dolan, George A., Fish Commissioner, Westerly, R. I.
Dryfoos, Leon, 508 State St., Erie, Pa.
Finlayson, Alex C., Dominion Inspector of Hatcheries, Ottawa, Canada.
Gould, Edwin W., State Sea Food Protective Commission, Portland, Me.
Greene, John V., Assistant, U. S. Bureau of Fisheries, Washington, D. C.
Kiplinger, Walter C., 2234 Park Ave., Indianapolis, Ind.
MacKay, D. A., Collegiate Institute, Ottawa, Canada.
Miles, Lee, Probate Judge, Little Rock, Ark.
Rich, Walter H., Bureau of Fisheries, 11 Exchange Bldg., Portland, Me.
Stuber, James W., Bureau of Fish and Game, Columbus, Ohio.
Travers, John T., Fish and Game Dept., Columbus, Ohio.

VICKERS, HARRISON W., Chairman, Conservation Commission, 512 Munsey Building, Baltimore, Md.

WALKER, S. J., District Inspector of Hatcheries, Ottawa, Canada.

WELLS, WM. F., Conservation Commission, Albany, N. Y.

WHITEWAY, SOLOMON P., St. Johns, Newfoundland.

WILBUR, HARRY C., Commissioner, Sea and Shore Fisheries, Portland, Me.

REPORT OF THE TREASURER

321 State House, Boston, Mass.,
September 14, 1920.

To the American Fisheries Society:

I herewith submit my annual report as Treasurer from the meeting in October, 1919, to September 14, 1920:

RECEIPTS

Balance in Treasury		$634.27	
Annual dues:			
For the year 1917	$ 6.00		
For the year 1918	132.00		
For the year 1919	760.00		
For the year 1920	50.00		
For the year 1921	2.00		
		950.00	
Club membership		5.00	
Life memberships (deposited temporarily for convenience in the general account, and later transferred to programs, etc.)		129.08	
Sales of Transactions and reprints		10.76	
Collection		.45	
Interest on deposits		2.58	
			$1,681.20

DISBURSEMENTS

Salary of Editor	$300.00	
Clerical services to Treasurer	100.00	
Expenses of meeting (stenographers, reporter, telegrams, programs, etc.)	129.08	
Printing transactions (1919)	696.61	
Deposits in Permanent Fund	75.00	
Postage (Treasurer)	26.78	
Letterheads, receipts, multigraphing	61.56	
Refund to adjust an account	3.14	
Collection	.20	
Expenses of officers of the Society (postage, stenographers, etc.)	24.32	$1,416.69
Balance, per cash book		$ 264.51

PERMANENT FUND

Balance as reported at 1919 meeting	$2,955.86
Interest (since added)	181.13
Deposits during 1920	75.00
	$3,211.99
Disbursement, Lewis Radcliffe for prize paper	100.00
Balance	$3,111.99

ARTHUR L. MILLETT,
Treasurer.

The report of the Treasurer was referred to the Auditing Committee.

MR. MILLETT: The sum of about $600 in dues is still unpaid, notwithstanding my best efforts to make collections. The dues outstanding are chiefly for 1918 and 1919; they do not run farther back than 1917, and they involve 108 individuals. The organization cannot continue on a paying basis unless we do something in regard to this matter. Last year I showed you a balance of over $600. This year it is $200; next year, if the same proportionate decrease continues, we shall be in debt. We cannot afford to do that; the name of the organization is worth too much. We must either raise the dues or find some way of collecting these arrears.

MR. J. W. TITCOMB, Albany, N. Y.: As I understand it, the Society cannot expect as large a revenue next year as it had last year, because last year the treasurer collected a lot of dues that had been a long time in arrears. So we have not the asset, if you call it an asset, that we had before. I do not think the members of the Society realize that when we publish the Transactions at considerable cost and send them out year after year to people who do not pay their dues, we are robbing ourselves; we are giving them something for which they make no return.

MR. ADAMS: May I ask whether there is anything in the by-laws that would prevent our passing a resolution providing that if the dues of a delinquent member are not paid within thirty days after receiving from the treasurer a notice by registered mail, his name shall be stricken from the membership of the Society?

Dr. Raymond C. Osburn: There is nothing, so far as I know, to prevent our adopting a resolution of that sort at this meeting. We have always hesitated to do that because a good many of our members are men of old standing in the Society; they are very busy, and perhaps some of them are a little negligent in regard to dues, or the matter does not touch them very seriously at the time. A great many of our members are not very well paid, as you all know, and sometimes they are pretty hard up. These notices are sent out frequently by the treasurer, so that everybody is not only warned but forewarned in time, and it seems to me that we must take some radical action against those men who persistently neglect to do their duty by the Society in this small matter. We can pass such a resolution at this meeting if we choose.

Dr. H. M. Smith: What is the by-law that bears on this particular point?

Dr. Osburn: It reads as follows:

> In case members do not pay their fees, which shall be $2 per year after first year, and are delinquent for two years, they shall be notified by the treasurer, and if the amount due is not paid within a month thereafter, they shall be, without further notice, dropped from the roll of membership.

It seems to me that we might very readily refuse to send the Transactions to anyone who was even three months behind in the payment of his dues, because if he gets the Transactions under such circumstances he is getting something that he is not paying for, and something which costs the Society a good deal to produce. So we might insist that we shall not send out our Transactions to any member who is at all behind in the payment of his dues.

Mr. Adams: It seems to me that we should interpret this by-law as mandatory, not simply as directive. If Treasurer Millett has sent out notices to these delinquents and thirty days have elapsed without payments being made, then as I read the by-law, those members must be dropped. If that is the case, this would seem to be the proper time to clean house in this matter. I realize, as Dr. Osburn has pointed out, the mental bent of some of our members, but no organization will prosper that is not predicated on clean-cut business principles. We should train these people in the way they ought to go rather than allow this vague, indeterminate asset to be carried on our books and perhaps sometime incur obligations against it, only to be disappointed.

Mr. Millett: Three or four years ago I had dues running back—well, almost to the dark ages,—but I have successfully cleaned them up to 1917 without hurting anybody's feelings. I realize that scientific men are the most thoughtless people in the world in regard to money matters, and that this organization is made up mostly of scientific men. I felt some satisfaction in getting all the dues in up to the last three years, but as Mr. Adams says, we must do something now. I do not like to be in the position of arbitrarily depriving any one of membership in this organization which means so much to scientific fisheries men; I do not know what to do.

President Avery: You will remember that last year provision was made for State memberships and membership of societies and other organizations; these have not been taken advantage of to any extent. If effect is given to that provision, there is an opportunity to finance this organization without worrying about the individual membership.

Vice-President Buller: I am a life member of this Society and I believe that I am not contributing to the extent that I should. Might it not be well for the secretary to communicate with the life members and ask them to become contributing members? I am willing to contribute $10 every year I am a life member of this Society.

President Avery: I do not suppose the treasurer will refuse your money, Mr. Buller, any time you wish to contribute it. That can be taken as a suggestion to other life members.

Mr. Pomeroy: To what extent have the various trout clubs and fish clubs been solicited for membership?

MR. MILLETT: We have not gone to the extent of soliciting any of these organizations. We have had one voluntary membership from a trout club during the last year, but none from any State organization.

MR. POMEROY: What we need is sustaining members, and we ought to interest these prospects for membership by communicating with them. When the Society held its meeting at Toledo, I recall that we went to the Castalia Trout Club and secured a number of members. In every club there are as earnest, active men as in the Castalia Club.

The report of the Executive Secretary, Dr. Raymond C. Osburn, was submitted orally and upon motion of Mr. Pomeroy, was approved.

President Avery announced the resignation of the Recording Secretary, Mr. John P. Woods, of Missouri, and called for nominations to fill the office pro tem. Accordingly Mr. S. B. Hawks, of Vermont, was nominated by Mr. Titcomb and elected as Recording Secretary, pro tem.

APPOINTMENT OF COMMITTEES

The following committees were named by President Avery:

Resolutions: Prof. E. E. Prince, Arthur L. Millett, Geo. E. Pomeroy, John N. Cobb, Raymond C. Osburn.

Time and Place of Meeting: W. E. Barber, John W. Titcomb, E. T. D. Chambers, John M. Crampton, W. C. Adams.

Program: Raymond C. Osburn, J. A. Rodd, Seymour Bower.

Nominations: James Nevin, W. E. Albert, W. H. Rowe, E. W. Cobb, Dr. H. M. Smith.

Auditing: W. H. Rowe, Dwight Lydell, S. B. Hawks.

President Avery further announced that two members of the Awards Committee, Mr. Glen C. Leach and Dr. Henry B. Ward, were unable to be present, and asked Prof. John N. Cobb and Mr. Charles O. Hayford to assist the chairman, Mr. John W. Titcomb, in finishing up the work of the awards.

An interesting letter from William Alanson Bryan, of Honolulu, was read.

The meeting adjourned for luncheon.

Afternoon Session, September 20, 1920

President Avery announced that in the absence of Vice-Presidents of Divisions and chairmen of committees the items "Reports of Vice-Presidents of Divisions" and "Reports of Standing Committees" would be postponed and papers taken up.

Prof. E. E. Prince, Dominion Commissioner of Fisheries, Ottawa, read a paper on "Fifty Years of Fishery Administration in Canada."

Dr. H. M. Smith, United States Commissioner of Fisheries, Washington, D. C., addressed the meeting on "The Alaska Fur Seal: An International Asset." Discussion was participated in by a number of members.

Mr. Lewis Radcliffe read a paper entitled "Notes on Functions and Activities of the Division of Fishery Industries of the U. S. Bureau of Fisheries." An extended discussion followed.

Dr. H. M. Smith gave an address on the subject "Some Recent Observations on the Freshwater Eel."

Upon motion of Dr. H. M. Smith it was resolved that the article by Dr. Henry B. Ward, entitled "Atlantic and Pacific Salmon," appearing in the issue of *Science* for September 17, 1920, be made a part of the record of this meeting.

The session adjourned.

Evening Session, September 20, 1920

The meeting was called to order by President Avery.

Several persons whose names are included on an earlier page in the list of new members were nominated and duly elected to the Society.

The Secretary read a telegram from former president M. L. Alexander, New Orleans, expressing regret at his inability to attend the convention, and extending congratulations to the Society on the occasion of its fiftieth anniversary meeting.

Dr. Raymond C. Osburn read a paper entitled "The Scientist and the Practical Man in Fisheries Work." An extended discussion followed.

Prof. John N. Cobb addressed the meeting on "Development of the College of Fisheries." Discussion was deferred until the next session.

Dr. Wm. C. Kendall read a paper on "Some Previously Unrecognized Anatomical Facts and Their Relation to Fish-Cultural Practices." This was illustrated by lantern slides. Discussion of this paper also was deferred until the next session.

The session adjourned.

Morning Session, September 21, 1920

The meeting was called to order by President Avery.

Proceeded with discussion of Professor Cobb's address made at the previous session.

Took up discussion of Dr. Kendall's paper presented at the previous session.

Dr. A. G. Huntsman, Atlantic Biological Station, St. Andrews, N. B., read a paper on "Climates of Our Atlantic Waters."

Prof. E. E. Prince presented a paper under the subject "Twenty-five Years of Biological Research in Canada."* Discussion followed.

Mr. William F. Wells read a paper entitled "Artificial Propagation of Oysters," following which discussion occurred.

Mr. John W. Titcomb addressed the meeting on "Some Fish-Cultural Notes." Discussion followed.

The session adjourned for luncheon.

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*This paper appears in this volume by title only, as Professor Prince advises that it cannot be made ready for printing at present.

Afternoon Session, September 21, 1920

The meeting was called to order by President Avery.

Mr. Dwight Lydell's paper on the subject "Progress in Practical Fish Culture," was read by Mr. Seymour Bower.

Vice-President Buller assumed the Chair, upon request of President Avery, and presided during the remainder of the afternoon session.

Discussion of Mr. Lydell's paper was participated in by several members.

Mr. James Nevin read a paper entitled "Fifty Years' Experience in Fish Culture." Discussion followed.

Mr. C. O. Hayford read a paper on "Trout Feeding Experiments" which was discussed.

Mr. John T. Travers read a paper on "Fighting Pollution in Ohio." Thereafter Mr. Travers gave a practical demonstration of the methods employed in combating pollution. Discussion followed.

The session adjourned.

Evening Session, September 21, 1920

President Avery called the meeting to order.

Two new members were elected. Their names occur in the list of members elected since the last meeting.

The paper by Dr. James W. Mavor on "Circulation of Water in Bay of Fundy and Gulf of Maine," was read by Dr. A. G. Huntsman. It was illustrated with lantern slides, and was followed by discussion.

Prof. E. E. Prince presented an interesting series of lantern slides illustrative of Canada's fish and game resources and various phases of fishery activities.

Preliminary to the reading of his paper entitled "A Survey of Game Fish Conditions in Ohio," Dr. Raymond C. Osburn read by title the three following papers which he said had to do with the work of the same survey: "Food of Young Small-Mouth Black Bass in Lake Erie," by E. L. Wickliff; "The Food of Young Large-Mouth Black Bass in Some Ohio

Waters," by C. L. Turner and W. C. Kraatz; and "The Gizzard Shad in Relation to Plants and Game Fishes," by L. H. Tiffany. Following the reading of his paper and discussion thereof Dr. Osburn gave a short resumé of Mr. Tiffany's paper.

Dr. Wm. C. Kendall presented a paper on "What Are Rainbow Trout and Steelhead Trout?" which was followed by discussion.

Dr. Kendall also read a paper on the subject "The Relationship of the So-called Blue Pike and Yellow Pike of Lake Erie and Lake Ontario." Discussion ensued.

The Secretary read a telegram from Mr. G. C. Leach, chairman of the Executive Committee, extending best wishes and expressing regret at his inability to attend the meeting.

The session adjourned.

Morning Session, September 22, 1920

The meeting was called to order by President Avery.

Mr. Hawks presented the report of the Auditing Committee, which was duly adopted.

President Avery: The Secretary has an announcement to make.

Secretary Osburn: There are one or two things to which I want to call attention. One is the advisability of members ordering back volumes of the Transactions of this Society for their various departments. Some of you, I know, have these; others have ordered them. For instance, I had a set ordered a couple of years ago—as many as could be secured—for the Ohio State University library. These transactions ought to be in the state libraries and in our university and college libraries to a greater extent than they are. They ought to be in the library of every fish and game department of the country; yet they are not, in many cases. In talking with a couple of the gentlemen here this morning I secured two orders for as many back volumes as can be furnished. I just leave that thought with you so that if you have any means of ordering these back volumes, you will do so. I may say that for the last twenty or twenty-two years you can get every number except those for the year 1903, which, I believe, is out of print. We have no copy of that year's issue for the files of the Society, and if anybody can furnish it, the Society would be glad to have it. The Transactions of this Society contain the whole history of the development of fisheries science and progress during the last fifty years. Very often a single paper in one of these volumes might be worth more to your department than the cost of the entire set. The cost is not very much; no increase in price has ever been made. The volumes sell now just for what they were sold when they were first issued, though some of them are beginning to grow scarce.

The only other announcement I have to make at this time is that I have turned in my resignation as Executive Secretary.

President Avery announced that at 11 o'clock a group photograph of members present would be taken at the front entrance to the Parliament Building.

Mr. A. C. Baxter presented motion pictures illustrative of fish and game work in Ohio.

At 11 a.m., by courtesy of the Ottawa Board of Trade, the members were taken on a motor trip through Ottawa. Following this at 1.15 p.m. a luncheon was given at the Chateau Laurier by the Department of Marine and Fisheries of the Government of Canada, to delegates, guests, and their ladies. After toasts had been proposed and drunk to the King and to the President of the United States, Mr. Alex. Johnston, Deputy Minister of Marine and Fisheries, who presided, called upon Hon. Honore Mercier, Minister of Lands and Forests, Province of Quebec, to address the gathering.*

Following the remarks of Hon. Mr. Mercier, Mr. Johnston called on Mr. Avery, President of the Society.

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*The Hon. Mr. Mercier's address on the subject "Forest Protection and its Effect on Fish and Game Life" appears in full along with other papers in this volume.

President Avery: Mr. Chairman, ladies and gentlemen: There seems to be an impression abroad that the American Fisheries Society is a national institution. It is an international institution; it knows no boundary line between the United States and Canada. The American Fisheries Society has been in existence for fifty years, and on account of its membership having been largely confined to the United States, as well as on the ground of convenience, its meetings have been invariably held within the borders of the United States. But in its membership are included also a number of distinguished citizens of Canada, men who have been engaged in conservation work, scientists of this great country; and much of the work of the Society has been done by Canadian members. Therefore we are not a foreign institution among you; we are meeting here as an international congress. It is fitting, it seems to me, that this Society should be of such a nature; by reason of the very condition of things its work belongs to the whole of North America. The problems with which the Society has to deal are very much the same in the United States as they are in Canada. The maritime fisheries of the Atlantic coast and of the Pacific coast are international; the fisheries of the Great Lakes and of the other international waters are of common interest to both countries; problems of fish culture and fish conservation which arise are common to both. Therefore, it is exceedingly fitting that this Society should be of an international character. It is very gratifying, I know, to the members of this Society who come from the United States, that we at last have the opportunity of holding one of our meetings in your great country. It is something that many of us have looked forward to with pleasant anticipation for many years, and now that we are experiencing the realization, we find that it is even more pleasant than was the anticipation.

The American Fisheries Society is not an organization for profit or gain of its members. It is an organization, strictly speaking, of a scientific nature. Its members are engaged in this work for the good of humanity, not for any profit for themselves or any exploitation of the great resources in connection with which they are working. The contributions of its members to the knowledge of the subject have added greatly to the increase of those resources and their perpetuation, and have made it possible for the fisheries to continue to exist in many parts of the United States and I assume also in some parts of Canada; and as time goes on the work of the Society in this respect will be more and more important in your country. As the more remote and newer portions of Canada are exploited by the commercial fisheries, there will be greater and greater need of replenishing the supply in order that the supply of food for the people may not be depleted.

It was about fifty years ago that the father of fish culture in the United States, Seth Green, began to sound a note of warning in the earlier proceedings of this Society, pointing out in addresses and papers submitted by him that the shad fisheries of the New England rivers and the sturgeon fisheries of the Hudson River were being depleted. The fact that sturgeon ever existed in the Hudson River has probably passed out of the memory of most people now living.

I was pleased indeed to hear the Honorable Mr. Mercier refer briefly to the question of international regulations for the preservation of game and fish. To my mind that is a great question which needs our careful thought and a solution of which it is not impossible to arrive at. Now I can speak more freely than he can, or than any Canadian can, because I come from a country which has been derelict in this respect. A treaty was agreed upon some twelve years ago for controlling and regulating international fisheries, but that treaty has never been put into effect owing to the negligence of my own country. It may be that the treaty should be revised; it may be that its terms are not what they should be; but the fact remains that it is not in effect; enabling acts have not been passed, and the question is still open and unsettled. To my mind, no question is ever settled until it is settled in the right way; therefore I hope that some movement may come out of this meeting which will in time bring about an enactment of laws under such a treaty which will effect harmonious relations with regard to international waters.

We should have closer cooperation, as Mr. Mercier suggests, in regard to the preservation of game as well. I know that it is entirely possible to bring this about. I know from experience that it is possible to bring about these things through international agreements, because it has been demonstrated in certain instances of which I know. Possibly you do not know very much about it, but we have lying between the State of Minnesota and the Province of Ontario one of the greatest wild life sanctuaries on the North American continent which came about through international agreement. We had no treaty; we had nothing to work with except common interest, but by getting together on the subject we secured government action in Ontario and also in the State of Minnesota, which brought this about. Therefore we have, lying side by side, a great game refuge in Minnesota and a similar reserve in Ontario, an indication of the results of international effort which points the way to what may be done on a much larger scale.

I realize that I should not make any extended remarks this afternoon, but I want to express what I know is in the minds of all the members of this Society from the United States, and that is our appreciation of the hospitality that has been extended to us during our stay in the capital of this Dominion. We have heard of the wonderful hospitality of the South. We have enjoyed and experienced that hospitality, but in no instance in my experience has it been warmer or more gracious than the hospitality that we have enjoyed here in Ottawa. We are under a special obligation to the Department of Marine and Fisheries of Canada, the Commission of Conservation, the Board of Trade, and of many individual members of these bodies whose names I need not mention, but whom we shall

all remember with a great deal of pleasure and gratitude after our return to our homes.

We in the United States are not so different from you Canadians. We are all of one blood. We are brothers; we come from the same race; we speak the same language; we have similar laws and similar institutions, similar ambitions and similar problems. We ought to live side by side as nations throughout the coming years in the utmost harmony and with the best of good feeling. There is no reason in the world why there should ever be any disagreement on any subject between the United States and Canada. In expressing these sentiments I wish also to express the same feeling as that expressed by Mr. Mercier—the hope that another opportunity may occur for our Society to meet within the borders of the Dominion, and under the Union Jack. I know of no place to which it would be more pleasant to go than the wonderful old city of Quebec, and I am for Quebec as soon as it is possible for the Society to meet there.

Mr. Johnston: The Commissioner of Fisheries for the Federal Government of the United States is with us today. Dr. Smith is well known to those at this luncheon who are citizens of the United States; to the general public of Canada I regret to say that it is quite possible Dr. Smith is not so well known. Officially, Dr. Smith is very well known in Ottawa, particularly in the Department of Marine and Fisheries. He has occupied his position with distinction to the nation which he serves, as well as with distinction to himself. Dr. Smith, while faithful to the interests of his own country, and very properly so, has always been a very good friend to the fisheries of Canada. I have, therefore, very much pleasure in introducing him to those who are present on this occasion, and asking him to say a few words.

Dr. H. M. Smith (United States Commissioner of Fisheries): Mr. Chairman, ladies and gentlemen: I thank you for this opportunity to say a few words upon this occasion. I have visited Ottawa on other occasions; I know something about the climate, and the scenery, and the hospitality of Ottawa; therefore, I knew what to expect when I and my colleagues from the other side of the line decided to meet here. We have not been disappointed. I want to endorse all that Mr. Avery has said about our feeling of appreciation for all that you have done to make our stay so pleasant and profitable. I am satisfied that there is no one from the other side of the boundary who does not feel very great satisfaction at the thought that the American Fisheries Society, after so many years, decided to meet in this beautiful capital city of Canada. Perhaps it will not be altogether inappropriate if I mention a little matter that I have not heard referred to at any of the meetings of the Society up to this time, namely, that the American Fisheries Society, now celebrating its fiftieth meeting, was in some respects the forebear of the United States Bureau of Fisheries, which is now also in its fiftieth year. It has been my very great pleasure and honor to have been associated with that bureau during thirty-five of the fifty years of its existence.

On the other side we view with no envy, but with genuine pride and pleasure, the superb fishery resources of Canada, and we heartily commend the most admirable manner in which you are administering those fisheries—in fish culture, fish protection, scientific study of the fisheries, and general administration. It has been said on at least one occasion, probably on numerous occasions, during these meetings—that for plentitude, variety, and excellence the aquatic resources of these two contiguous countries are unequalled. A very heavy responsibility rests on those in authority to see that proper use is made of these matchless food assets. Those in attendance at such meetings as these should return home with increased zeal and a renewed determination to labor for the public good. I have been attending meetings of the Fisheries Society for many years, and I am sure that I am glad I attended this meeting—and that is the sentiment of all of us. If we should at some time in the future be again invited to meet in Canada, preferably in Quebec, I am sure that there will be a very hearty response from the United States members of the Society. In the meanwhile, may we not hope for a very generous visitation from Canada at the meetings of the Society which are to be held in the United States? "Hands across the sea" is a very pleasing sentiment, but here in North America a more intimate association is desirable and physically possible. May not we who are interested in fisheries do our share to promote international comity and encourage the passage across the border, not figuratively of hands, but actually of feet and of the whole corporeal frame?

This concluded the proceedings of the luncheon.

Afternoon Session, September 22, 1920

The meeting was called to order by President Avery.

Mr. Arthur L. Millett read a paper entitled "Adequate Fish Inspection: A Means to Better Fish for the Consumer and to Increased Fish Food Consumption." Discussion followed.

REPORT OF COMMITTEE ON AWARDS

Preliminary to presenting the report of the Committee on Awards, Mr. John W. Titcomb, Chairman, said that as the conditions of award had not been published during the past year, the Committee reverted to the original conditions. Mr. Titcomb read these conditions as printed in the Transactions for June, 1918, pages 112 and 113.

A prize of $100 was awarded to Dr. William C. Kendall for his paper on "Some Previously Unrecognized Anatomical Facts and Their Relation to Fish-Cultural Practices."

The formal report of the Committee was as follows:

The paper by Dr. Marie V. Lebour has been eliminated from consideration. Her letter does not state that it is offered for competition; rather that it is sent as a contribution to the program of the jubilee meeting. Furthermore it does not comply in that it is an abstract or summary and not the full contribution. Still more significant is the fact that Miss Lebour is not a member of the Society and so under the terms of the competition not eligible. Rather than reject a paper from a well-known worker like Miss Lebour it is wiser to assume that it was not offered for competition.

The paper by Barney and Anson on the Relation of certain Aquatic Plants to Oxygen Supply, etc., is an interesting experimental study. It gives a reasonably clear demonstration of what is already well known as a general principle. It shows the application of the situation to the culture of the top-minnow Gambusia. It is of distinct significance for pond culture in the production of this fish which is exceedingly important in the campaign against malaria in our southern states. There are some serious defects in the general discussion and too many inferences to make it a scientific contribution of conspicuous merit. While commending the character and appreciating the value of the paper it does not seem to be of the type to warrant granting it a prize.

The paper entitled "Spawning Habits of the Spiny Lobster," by D. R. Crawford is a valuable record to supplement our scanty knowledge of this phenomenon. As a matter of fact it rests upon a single instance which, as clearly indicated in the text, was only partially observed. It is regarded as too incomplete to justify awarding it a prize.

The paper concerning Some Previously Unrecognized Anatomical Facts and their Relation to Fish-Cultural Practices, by Doctor Kendall, is of fundamental importance. It presents anatomical discoveries of great moment in a group where the amount of study previously given these fishes would have led one to think that it was impossible to add materially to a knowledge of their structure. The significance of the discoveries from the standpoint of comparative anatomy is very great and will command the attention of scientific circles over the entire world. It appears to us that in scope, in bearing upon scientific and practical fish culture, in newness, and in its fundamental character as well as in the completeness of the demonstration afforded, this contribution is well worthy of the prize.

In this connection we would also call attention to two other papers submitted and read by Dr. Kendall—one entitled "What Are Rainbow Trout and Steelhead Trout," and the other, "Relationship of the so-called Blue Pike and Yellow Pike." These papers present the results of long and exhaustive research on the part of the author, and will prove of incalculable value to our fish culturists and commercial fishermen. They have not been submitted in competition for the prize, but the committee cannot allow this opportunity to pass without indicating its appreciation of their excellence, and voicing the hope that more papers of this type will be submitted in future competitions.

The paper entitled "Coregonine Fishes of Lake Huron," by Walter Koelz, represents a large amount of work very carefully carried out. It shows long and careful study of the problem in its various aspects and a thorough handling of the subject that deserves high praise. It should be noted that much of the work given in this extensive paper is really taken from other authors and that if one were to sift out those original investigations upon which the giving of a prize depends, the contribution would be very much briefer. In the work of the author there is evidence of great thoroughness and care in handling data as well as in securing them in sufficient quantities to justify general conclusions. The results are not very striking in character or adequate to characterize the paper as in any conspicuous way exceptional. While ranking it as subordinate to the paper by Doctor Kendall, the Committee regard it as worthy to be given honorable mention in a competition.*

It is requested that the papers entitled "A Means to Better Fish for the Consumer and to Increased Fish Food Consumption," by Arthur L. Millett and "Principles Involved in the Preservation of Fish by Salt," by Harden F. Taylor, both competing in the third class, be left with the Committee for further consideration to be followed by a report to the Secretary.

John W. Titcomb,
John N. Cobb,
Chas. O. Hayford.

Upon motion of Mr. Buller it was decided that the papers submitted by Mr. H. F. Taylor and Mr. A. L. Millett be placed in the custody of the Committee for consideration and report to be filed with the Secretary.

The formal report of the Committee was adopted.

President Avery: I feel like suggesting that the thanks of the Society be extended for the painstaking work that the Committee has done. Its work involves real labor, a careful study of the papers, and an exercise of competent judgment. In these respects, therefore, we are indebted to the Committee.

On December 7, 1920, the following supplemental report was submitted by Mr. Titcomb, Chairman of the Committee on Awards:

SUPPLEMENTAL REPORT OF COMMITTEE ON AWARDS

At the recent meeting of the American Fisheries Society at Ottawa the committee on award of prizes for the best contribution on fish culture, biological investigations applied to fish cultural problems, and problems of the commercial fisheries, were voted more time on two papers which, through delay in the mails after having been sent to one member

*The paper by Dr. Koelz was returned to him by Dr. Osburn who regarded it as too bulky for publication. Dr. Koelz states that the character of the document is such that it cannot well be abstracted.

of the committee, failed to reach Ottawa in season for the committee as a whole to give them proper consideration. One of these papers is entitled "A Means to Better Fish for the Consumer, and Increased Fish Food Consumption," by Arthur L. Millett; the other is entitled "Principles Involved in the Preservation of Fish by Salt," by H. F. Taylor.

The original committee on awards consisted of John W. Titcomb, G. C. Leach, Charles O. Hayford and Henry B. Ward. Owing to the death of his mother Mr. Leach was unable to perform his duties as a committeeman at the time of the annual meeting and Mr. John N. Cobb was appointed in his place. The records of the Society show the vote of the committee as constituted and who were present at the annual meeting.

The same members of this committee have acted on the two papers above mentioned and it seemed no more than right, inasmuch as more time was granted, to give Mr. Leach also, an opportunity to pass upon the two papers. There are therefore five committeemen voting on these two papers.

The committee are unanimous in expressing a feeling that both papers are valuable contributions to the literature of the Society. While the conditions of award do not specifically state that the contributions should be based upon the result of original work on the part of the author, four members of the committee have expressed the feeling that judgment should be based upon original work.

The committee feels that Mr. Millett's paper does not represent the original work of the author but is of value as showing the direction legislation is taking in Massachusetts.

The committee is unanimous in the opinion that Mr. Taylor's paper represents much work in preparation and deals with a subject of great importance. Four members of the committee feel that the paper does not represent the results of original work on the part of the author to a sufficient degree to warrant awarding a prize.

In this view Mr. Leach dissents by stating that Mr. Taylor has copied from the writings of others, has profited by their experiments, and with his own research work has produced a paper that should be recognized as of great value to the public. He therefore favors awarding the prize to Mr. Taylor.

Under the conditions as interpreted by a majority of the committee, neither paper is regarded as worthy of the prize.

REPORT OF COMMITTEE ON TIME AND PLACE OF MEETING

Mr. W. E. Barber presented the report of the Committee on Time and Place of Next Meeting. It was recommended that the next annual meeting be held in the State of Pennsylvania, the time to be determined by the Executive Committee. The report was adopted.

Mr. Buller: Mr. Chairman, I am pleased that the Committee has decided that the next meeting of the Society will be held in Pennsylvania. I can assure you on the part of Pennsylvania that we will try to make your stay with us pleasant and instructive. It is intended to give you something that is quite unique. This Society has met for fifty years, usually in a hotel; our thought is to have you meet with us in the open, right in the midst of the buffalo and the elk and the hills and the streams, and to live during your week in tents and under army regulations. Provision will also be made for any ladies whom you wish to bring with you.

REPORT OF THE COMMITTEE ON RESOLUTIONS

Prof. E. E. Prince submitted the report of the Committee on Resolutions, as follows:

Whereas, The American Fisheries Society contains within its membership persons devoted to the preservation and increase of the fish life in the public waters of the United States, this being one of the purposes for which the Society was founded; and

Whereas, It is the duty, as it should be the pleasure, of persons in authority to do all within their power to maintain for the proper use and enjoyment of present and future generations the supplies of food and game fishes, especially those in national parks, and other parts of the public domain set aside for the benefit of all the people:

Therefore be it resolved by the United States members of the American Fisheries Society in fiftieth annual meeting assembled, That it is unjust and unwise, for the gain of a few, to permit the commercialization of public areas that have been formed for the recreation and use of all the people, and emphatic protest is specifically made against the proposition to convert into an irrigation reservoir a large and attractive section in the Yellowstone National Park that abounds with beautiful streams suitable for and containing trout, which waters would be forever destroyed by the contemplated irrigation project; and be it further

Resolved, That a copy of these resolutions be sent to the National Park Service of the United States and to the members of the appropriate committees of the United States Congress.

Resolved, That the thanks of the American Fisheries Society be extended to the Department of Marine and Fisheries, and the Department of Conservation of the Dominion of Canada; His Worship the Mayor of Ottawa, and the Board of Trade of Ottawa, for the splendid hospitality so freely extended to the members of this Society.

Resolved, That the thanks of the American Fisheries Society be extended to the press of the city of Ottawa for the excellent publicity given to the proceedings of our fiftieth anniversary meeting.

Resolved, That the thanks and appreciation of the Society be extended to President Carlos Avery, whose able administration during the year and dignified leadership during the meeting have been of great value to the Society.

Resolved, That the cordial thanks of the Society be extended to Dr. R. C. Osburn, who has served most assiduously and ably as Secretary for the past seven years, and whom pressure of other duties has compelled to resign as Secretary.

Mr. Millett suggested that every member write to his Senator or Representative in Congress and urge favorable consideration of the resolution regarding threatened commercialization of national parks, especially Yellowstone National Park.

The report of the committee was unanimously adopted.

REPORT OF THE COMMITTEE ON NOMINATIONS

Mr. Nevin submitted the report of the Committee on Nominations as follows:

President—Nathan R. Buller, Harrisburg, Pennsylvania.
Vice-President—E. E. Prince, Ottawa, Canada.
Executive Secretary—Ward T. Bower, Washington, D. C.
Recording Secretary—S. B. Hawks, Bennington, Vermont.
Treasurer—Arthur L. Millett, Boston, Massachusetts.
Vice-Presidents of Divisions:

Fish Culture—James Nevin, Madison, Wisconsin.
Aquatic Biology and Physics—E. A. Birge, Madison, Wisconsin.
Commercial Fishing—Seymour Bower, Lansing, Michigan.
Angling—John M. Crampton, New Haven, Connecticut.
Protection and Legislation—J. G. Needham, Ithaca, New York.

Executive Committee:

Glen C. Leach, Chairman, Washington, D. C.
W. A. Found, Ottawa, Canada.
W. E. Barber, LaCrosse, Wisconsin.

W. H. Killian, Baltimore, Maryland.
George H. Graham, Springfield, Massachusetts.
Dwight Lydell, Comstock Park, Michigan.
John W. Titcomb, Albany, New York.

Committee on Foreign Relations:

George Shiras, Chairman, Washington, D. C.
H. M. Smith, Washington, D. C.
William C. Adams, Boston, Massachusetts.
James White, Ottawa, Canada.
E. E. Prince, Ottawa, Canada.

Committee on Relations with National and State Governments:

E. W. Cobb, Chairman, St. Paul, Minnesota.
James Nevin, Madison, Wisconsin.
Jacob E. Reighard, Ann Arbor, Michigan.
E. T. D. Chambers, Quebec, Canada.
Charles O. Hayford, Hackettstown, New Jersey.

It was moved and seconded that the Secretary be instructed to cast one ballot for the Society. The motion was carried and the respective officers were duly declared elected for the year 1920-21.

Only the respective chairmen of the three above-stated committees were named in the formal report of the Committee on Nominations, but for convenience the other members of these committees designated subsequently by President Buller have been included.

President Avery: Before turning over the Society to my successor, I wish to express to you my own deep appreciation of the great assistance that has been rendered to me by every member with whom I have had anything to do during the past year. The office of President of this Society is largely an ornamental affair. The President is not supposed to have any work to do, and usually does not do anything except preside at the meetings; the actual work is done by the Executive Secretary and the Treasurer and other officers who are chosen for that purpose, and by the active members of the Society. Without the cooperation and the earnest work of these officers and the members, the Society would not be successful, and whatever measure of success we have had during the past year and during this meeting, I feel is entirely due to the work of those who have so ably cooperated in furthering the interests of the Society. I am impressed more than I ever have been with the importance of this organization and with the great work that it is accomplishing and that it has to do in the future. It is with a great deal of pleasure that I now invite my successor, Mr. Buller, to the Chair, so that I may turn over the duties of the presidential office to him. I feel that you have made a wise selection.

Mr. Buller here assumed the Chair, amid applause.

President Buller: Members of the American Fisheries Society: I hardly know how to express my appreciation of this great honor which you have conferred upon me. I assure you that during my term of office I shall do everything in my power to further the interests of the Society. I want you all to feel free at any time to communicate with me and advise me and help me in any way that will benefit this Society. I thank you.

Is there any matter that any member has to bring before this Society before we stand adjourned? If not, the Society will adjourn to meet at the call of the President in Pennsylvania. I may say that the exact place at which the Society will meet has not been decided upon, for the reason that it depends upon the kind of entertainment that we want to give you. You will receive ample notice of where and on what beautiful stream the encampment will be held. I trust that every one of you will be present and will bring as many new members as possible.

Adjourned sine die.

In Memoriam

S. P. BARTLETT

J. F. BROWER

SIR CHARLES FRYER

PHILIP NEIDLINGER

HIRAM PEOPLES

W. W. WELSH

PART II

PAPERS AND DISCUSSIONS

SOME PREVIOUSLY UNRECOGNIZED ANATOMICAL FACTS AND THEIR RELATION TO FISH-CULTURAL PRACTICES*

By Dr. William Converse Kendall
Scientific Assistant, U. S. Bureau of Fisheries
Washington, D. C.

The present discussion pertains to the peritoneal membranes of the abdominal cavity of salmonoid fishes, principally those membranes connected with or having relation to the ovaries and the deposition of ova.

Ninety-six years ago (1824), Rathke described the ovaries and oviducts of the various fishes, among which were certain salmonoids. Nearly 60 years later (1883), Huxley studied the European smelt (*Osmerus eperlanus*) and reviewed Rathke's work, confirming his statements in respect to the salmon, but in the case of the smelt correcting certain errors and amplifying the description by demonstrating the presence of oviducts, which all salmonoid fishes including the smelt were supposed not to possess. For nearly 100 years erroneous conclusions derived from Rathke's inaccurate interpretation of the structure and arrangement of the female reproductive organs have been perpetuated in every published account or reference to salmonoid genitalia. And fish-cultural practices pertaining to salmonoids, based as they were upon error, have resulted in apparently hitherto unexplainable conditions, such as a large percentage of unfertilized eggs, monstrosities among the fry, reduced egg production, sterility, and even mortality in the brood stock.

The fish-cultural error is embodied in the following quotation from Cambridge Natural History, p. 258, where the writer says of the Salmonidæ: "The large size of the eggs, their lack of adhesiveness, and the fact that *they fall into the abdominal cavity* (italics mine), out of which they may be easily squeezed,

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* This paper was awarded the prize of $100 in the annual competition by the American Fisheries Society for the best contribution covering original biological work.

renders artificial impregnation particularly easy, and the species of *Salmo* have always occupied the first place in the annals of fish culture." This statement, like every published statement pertaining to the subject, in anatomical, zoological, ichthyological and fish-cultural works, is simply the acceptance of the erroneous conclusions of earlier writers, particularly those to whom I have referred. Briefly stated, these conclusions were in effect that the salmonoid fishes were exceptions among teleosts in that they did not have closed ovaries and lacked oviducts, excepting certain stated vestigeal remains and the "funnels" in the smelt described by Huxley. The ovaries were stated to be platelike organs with perpendicularly arranged egg-bearing laminæ not covered by membrane on the outer surface facing the lateral abdominal wall. From these laminæ the ova, as they ripened, were deposited loose in the abdominal cavity and extruded through a genital pore behind the anal opening. Some members of this Society may recall that at the Washington meeting in 1914, I called attention to an apparantly closed ovary in an immature brook trout (*Salvelinus fontinalis*), and mentioned that I had seen in the Sunapee char what I regarded as possible oviducts. At that time I remarked that I had not had time for thoroughly investigating the subject, but hoped that I or someone might soon settle the question.

Six years have since elapsed, and I feel some satisfaction in being able to announce that I believe that I have settled the question. I have examined many individuals of salmonoid fishes, comprising four species of Pacific salmon, the Atlantic and landlocked salmon, rainbow, steelhead, redthroat, brown, Loch Leven and other trouts, various species of chars, whitefishes, ciscoes and the grayling; as well as hundreds of Atlantic smelts, both marine and fresh water. The salmons, trouts and chars are essentially alike in their visceral structure and arrangement. The abdominal cavity is separated from the anterior chamber containing the heart, gills, etc., by a diaphragm-like partition through which pass the esophagus and certain blood vessels. Continuing from the esophagus, the alimentary canal extends backward a certain distance as the cardiac limb of the stomach, makes a rather abrupt bend forward and extends as the pyloric limb forward to the liver, which is situated immediately behind the diaphragm. At its anterior end this pyloric limb makes a sharp bend and extends backward to the vent as the intestine. At the anterior end of the pyloric limb and on the anterior end of the intestine is a mass of cœcal appendages or pyloric cœcæ. Immediately behind the posterior curve of the stomach the spleen is situated, and the pancreas lies along the upper surface of the cardiac limb. The so-called "blood"along the dorsal surface of the cavity composes the kidney mass. Below this is the airbladder extending for the entire length of the abdominal cavity. The whole abdominal cavity is lined by a serous membrane called the peritoneum, which sends out folds forming covering, attachments, and supporting membranes to the visceral organs.

It is with two sets of folds of this membrane that this paper is particularly concerned. First, may be mentioned the mesenteries which are connected with the alimentary tract. All fishes possess a dorsal mesentery which in salmonoids is described as originating on the middle longitudinal line of the peritoneum covering the lower surface of the air bladder and extending to and supporting the intestine for nearly its entire length. However, in the salmon, at least, is another mesenteric fold which originates with the intestinal mesentery forward and connects with the cardiac limb of the stomach. This, to my knowledge, has not previously been described. The salmons, trouts and chars also possess an hitherto undescribed ventral mesentery which forms a longitudinal partition between the intestine and and ventral surface of the abdominal cavity, extending from just behind the pelvic region to the posterior end of the cavity. The dorsal intestinal membrane terminates a short but varying distance from the anal end of the intestine in the female but is complete in the male. So far as I have observed, the grayling, whitefishes, ciscoes, and smelts have no ventral mesentery, but the dorsal mesentery ends in the same way as in other salmonoid fishes.

The second set of membranes comprises those pertaining to the genital organs. From each side of the air bladder a peritoneal fold, termed the mesovarium or mesoarium, extends to each ovary, which contrary to the previously stated observations, almost completely enfolds the ovary. It forms the inner or axial surface of the ovary, and when the ovary is in normal position, extends downward and around and upward on the outer surface, so that the outer surface is completely covered and has no exposed laminæ. However, the position of the ovary is such that a comparatively narrow surface of the edges of egg-bearing laminæ, not covered by adherent membrane, is inclined inward in such a manner that the mesovarium lies on the free-egg surface forming a covering. The laminæ, instead of being situated vertically on the outer surface of the ovary, extend obliquely crosswise of the somewhat boat-shaped ovary, and when the ova ripen and burst from their inclosing follicles, instead of falling into the abdominal cavity they are deposited in the groove or angle between the upper edge of the laminæ, or free egg surface, and the mesovarium covering; the inner end of each laminæ is lower than the outer end.

If we follow the line of origin of the mesovarium on the surface of the air bladder, it is observed to gradually pass inward and fuse with the mesentery near its posterior termination. The two ovaries are seldom of equal length, the left usually being longer. In a ripe fish the left ovary generally extends tapering nearly to the posterior end of the abdominal cavity, while the right terminates some distance anteriorly to that point. In the case of the shorter ovary, or where both are short, the mesovarium continues from the posterior end of the ovary, uniting with that of the opposite side to form a trough on the upper surface of the intestine behind the posterior terminus of the mesentery. This trough near the genital pore widens and becomes attached to the abdominal wall on each side, thus forming a sort of shelf in front of the genital pore, or what might be likened to a funnel formed by the union of the expanded lateral edges of the trough and the peritoneum of the abdominal cavity above. Sometimes near the posterior terminus of the mesentery, particularly in the case of the longer left ovary, the lower edge of the pendent mesovarium extends to form the side of the trough on top of the intestine, while a membranous flap, which narrows to the posterior end of the tapering extended ovary, lies on or against the trough.

This trough serves as an oviduct, along which the ova pass from the ovaries to the genital pore. The outer walls of the ovary are supported in position partly by the shape of the ovary and the crosswise laminæ, tense with eggs, and by the abdominal wall. The sides of the trough are also supported by the abdominal wall.

Grayling, whitefishes, and others, excepting in the absence of the ventral mesentery, are essentially the same as the salmons, trouts and chars. So far as the structure and membranes of the ovaries are concerned, the smelt exhibits about the same arrangement as the fishes previously mentioned. The mesovariums continue also from the oviducts in a similar manner, but owing to the relative size and situation of the ovaries, the oviducal structure is somewhat different, as described by Huxley.

The left ovary is the larger and is anterior to the right or much smaller ovary, as stated by Huxley, but contrary to his statement, the ovaries are not semioval plates with vertical laminæ on the outside, but are somewhat as I have described in the case of the Salmonidæ, with the difference that each ovary might be regarded as a comparatively deep boat-shaped organ with the bottom bent upward so as to form a groove in which the alimentary tract lies. The anterior or left ovary bends up to the right and the posterior or right ovary to the left. The continuation of the mesovarium and ovarian covering of each ovary, near the end of the ovary, is deflected to the sides and attached to the left and right abdominal wall, respectively, to form the oviducts which are open above save for the peritoneal lining of the lower surface of the air bladder. At the posterior termination of the mesentery the two membranes unite to form a common passage. This arrangement makes a long left and a short right oviduct. The appearance of the ovaries turgid with eggs, when ventrally observed, is as of one continuous ovary or mass of eggs. But by careful manipulation, the two ovaries may be separated showing an oblique line of separation directed backward from right to left. When in this condition, the left oviducal membrane is pressed against the lateral abdominal wall by the gravid right ovary, and it is not until the right or posterior ovary is empty that this oviduct can be filled with eggs. Therefore, a partly spent fish may appear to have but one ovary, the right ovary with its immature eggs being collapsed and pressed between the turgid left oviduct and the right abdominal wall.

The previously mentioned inaccuracies regarding salmonoid ovaries were in consequence of observations upon spent fish in which the ovaries were collapsed and disarranged, perhaps by manipulation. Concerning the smelt, Huxley stated that he washed the eggs from the ovaries.

The significance of the foregoing as concerns fish-cultural practices is that the ripe eggs do not naturally fall into the abdominal cavity, and if by any means they are displaced into the cavity, they cannot be extruded or expressed. The prevalent method of stripping the fish not only is liable to displace the eggs, but to rupture the ovarian membrane, and thus render the fish partially or wholly sterile thereafter, if the fish does not die.

The difference in length of the ovaries suggests in the salmon and trout, and absolutely indicates in the case of the smelt, that the eggs do not ripen in both ovaries at exactly the same time, and it is an established fact that the eggs do not ripen all at once but rather gradually, those near the posterior end first. Sometimes it may take almost a week for a salmon or trout to deposit all of its eggs naturally. Therefore, the prevalent practice of firmly grasping a fish just back of the gill-opening and squeezing for nearly the whole length of the fish will result in expressing some immature eggs, incapable of more than defective fertilization, and is likely to injure the ovaries. If a second stripping movement is made, the collapsed conditions caused by the first pressure renders easy the displacement of eggs in the abdominal cavity and their consequent retention by the fish. If time and space permitted, I could cite many instances of such defects and injuries as I have mentioned. I will describe in detail only two examples observed by me, which will serve to illustrate what often happens, and possibly suggest what some particular trouble has been that has for a long time puzzled some persons.

Three landlocked salmon obtained at a state hatchery, which the superintendent told me had been stripped but once, showed displaced and retained eggs in each fish, and in two of the fish the ovaries were so severely injured it is difficult to believe that they could have ever functioned again. In one fish, nearly 18 inches long, the posterior part of the liver was mashed and broken, with 6 eggs embedded in it from behind and showing through on the outer side. Besides these, there were 21 displaced eggs embedded in various parts of the anterior viscera and 101 displaced eggs loose in the abdominal cavity. There were 63 eggs normally situated in the oviduct and upper surface of the ovaries. The ovaries of this individual were not injured, but the injury to the liver appeared serious. There were 191 eggs left in the fish.

A rainbow trout, a little over 18 inches long, from another hatchery, revealed the following conditions: A small portion, containing one egg of the anterior end of the right ovary had been broken off; the posterior end of the left ovary was also broken off, but still had a mesovarian attachment.

In this detached portion were 27 eggs adhering together. Thirteen displaced eggs were embedded in various parts of the anterior viscera and 113 loose in the abdominal cavity, while 15 remained in normal position in the ovary, 6 of which were still enclosed in follicles. This example suggests that attempt had been made to completely strip a fish not wholly ripe.

The foregoing indicates that if the artificial means of securing eggs of these fishes is continued, the structures and arrangements herein described must be considered, and some modification of the method be adopted. To this end, the Bureau of Fisheries purposes to conduct some experiments with rainbow trout. The situation, however, involves all Salmonidæ and related fishes.

Discussion

Mr. Eben W. Cobb, St. Paul, Minn.: I infer from the paper that it is the view of the writer that our method of stripping is wrong, and that it is very harmful to the fish. But men engaged in fish culture have been handling the same fish year after year and getting good results through the employment of this method, and that would seem to be a strong argument in favor of the assertion that stripping is not harmful. Some of these men can handle their fish very rapidly, at the rate of about one in five seconds, and most of them no not know very much about the structure of the fish. It seems to me that the suggestion made in the paper in this regard might be an encouragement to people to say that fish are killed in stripping. I believe there are various methods of stripping, if you could call them methods. Many men handle the fish in a certain way; others take hold of them in an entirely different way, using a different part of the hand. I myself contend that my method is right, but other men who claim that I am wrong seem to get just as good results as I do—perhaps some of them get better results. What I want to know, then, is how we can apply this information for the betterment of our work. I would like to know also how this information in regard to the structure of the fish could be applied practically by the fish culturist.

Dr. Kendall: I did not intend to convey the idea that injury would always result from stripping the fish, but it was my purpose to indicate the danger of injury from improper handling; that one consequence of stripping the fish was that there were a lot of eggs deposited in the abdominal cavity, which is not the natural place for them; and after they are there, it is with difficulty, if at all, that they can be removed. In fact, almost every fish that I have examined after stripping, has contained a variable percentage of eggs that were not obtained and, as a rule, were in the abdominal cavity. The eggs, as I stated, do not all ripen at the same time; of that I am quite positive; those in the posterior part of the ovary ripen first.

The methods of stripping, as Mr. Cobb suggested, vary with different strippers. My observation leads me to believe that the trouble has been due to rough handling; the caution I intended to express was that in stripping the fish, more attention should be given to its structure. This is based upon two or more years' observation of fish that had been stripped in various hatcheries. At some hatcheries there was a decline in the number of eggs obtained from the brood stock; at others the eggs were glassy and defective. The disclosure of these conditions brought about an investigation in connection with the anatomical work upon which I was engaged. It was found that while in many instances there was apparently no injury to the ovary or oviduct, many eggs were loose in the cavity, having fallen down and moved forward and become embedded in the viscera away up between the liver and the diaphragm and various parts of the visceral anatomy, which is an abnormal place for them to be.

As for the injuries, they are not always apparent. As Mr. Cobb says, some men have been breeding fish for many years, in some cases breeding them from the same brood stock for a long time, with apparently no damage to the fish. On the other hand there have been a great many losses through death of brood fish, poor eggs, and various other abnormal conditions. Many of these, it seems to me, may be ascribed to rough handling of the fish. The Bureau of Fisheries intends to conduct experiments this fall looking to an improvement in the methods of handling brood fish. It remains to be ascertained what is the best method in order to secure best results. It is possible that all of the eggs cannot be secured by stripping, or that even with careful stripping some may be left. Then the question arises as to whether the fish is harmed by having the eggs remain in it. Possibly there is no injury. It is possible that they are naturally expelled; there is some evidence to that effect.

It is my suggestion, then, that we must have regard to the anatomy of the fish in stripping, and that more care must be exercised in the operation. I would suggest that squeezing the fish several times until blood and fecal matter are extruded is often the cause of injury. I have seen that done at some of the hatcheries in order that the very last egg might be obtained; undoubtedly it injures the fish. Instead of beginning the pressure away up forward, as some do, and pressing down along the whole length of the abdominal cavity until the fish is collapsed and flabby, and then dumping it into a pond to recover, it would be better to begin at the back and very gently press out all the eggs possible; then put the fish back and let her ripen some more eggs and thereafter press them out too. Of course, it would be impracticable to continue this indefinitely if the fish takes a week or two in ripening her eggs; but it is possible that all fish do not take that long. Some ripen more quickly than others, but we know that fish will not deposit their eggs unless conditions are congenial and natural, until all the eggs that are going to ripen have done so.

Mr. J. W. Titcomb, Albany, N. Y.: Dr. Kendall has described certain methods of squeezing the fish and getting out all the blood and gurry in an effort to obtain the last egg. If I found a man at any of my hatcheries stripping fish in that way I would discharge him immediately; we do not call that spawn taking or stripping. We always caution our men as to the methods of stripping fish; our foremen in charge pick the best men and educate them for that particular work, and only those who will take all the necessary precautions are continued at that class of work. A good stripper should command more wages than does a man in any other branch of fish-cultural work, although we know that anyone who does practical work in connection with fish breeding and that sort of thing should have particular qualifications.

Mr. William H. Rowe, West Buxton, Me.: This paper is of great interest to me, as it is to anyone who is in charge of or exercises supervision over a hatchery. I have caught trout and salmon in the spring of the year in the wild state which still retained the spawn of the fall before. Dr. Kendall intimated that trout would not spawn if conditions were not right. Well, trout of that kind are not found in commercial hatcheries. I have thousands of trout that I do not make any attempt to strip, and it is my experience that they deposit their eggs in the tank with the other fish. Of course, the eggs are eaten by the fish; they are never fertilized.

Dr. Kendall spoke of the eggs being pressed into the liver of the fish. I do not know by what process that could be done; it surely would not be spawn-taking. I saw a trout one time which weighed over three pounds and which had been caught in the spring in a perfectly wild pond. It had two large ovaries with the eggs; each one was as large as my hand. I do not think that that trout would ever have got rid of those eggs; I think it would have died. If it had been the product of a hatchery, the result would have been attributed to handling. In this case, of course, the condition of the ovaries was not the result of any handling. I think that spawning is a very critical time in the life of the fish, and that in many cases they die either during the process or as the result of not spawning. In the spring many dead fish are found by men who drive logs in the rivers, fish not the product of any hatchery.

Mr. James Nevin, Madison, Wis.: A good man will not leave many eggs in the fish after he has handled it. If when the fish is taken up in the hand the eggs do not come freely, he should drop it and not handle it until the next day or perhaps not for four or five days. I have examined hundreds of fish after they have spawned, and have found very few eggs in them. There is a great knack in handling fish; the whole thing is to do it properly.

Mr. Titcomb: In the case of wild trout held in pens and stripped from day to day, I have found that if in stripping we leave one or two eggs, the trout will stay around the spawning bed until it gets rid of those eggs. We find that they are very persistent. We have penned fish two miles from the spawning beds and taken what we believed to be all their eggs, and within twenty-four hours we have found those same fish over on the spawning beds two miles away. I inferred that these fish were there to get rid of two or three eggs that we had left behind in the stripping process.

We have taken eggs from year to year from the same brood stock. I have in mind a thirty-five acre pond which yields 7,000 or 8,000 wild trout annually, all of which ascend the stream to spawn. That has always been the best trout pond for angling that I have ever known or have had the pleasure of fishing for ordinary sized trout; the fishing has been kept up by returning about ten or fifteen per cent of the progeny of the eggs taken. No mortality was ever noticed among the adult fish there, although they have been stripped annually for more than twenty years; the fish are all in fine condition.

I do not think any of us can say too much about proper handling. But I want to emphasize what Mr. E. W. Cobb said, namely, that we fish culturists cannot afford to have it go out from this Society that the method of spawning fish is injurious. I received a letter recently in New York City about the depletion of whitefish in a certain lake where the fish are caught on licensed lines. The complaint was made that five or six years ago the Conservation Commission operated a field station there for the collection of whitefish eggs during one season only, and that the depletion of the whitefish is attributable to that action on the part of the Commission. Of course, there was caught only a very small portion of the spawning fish in the lake which is fifteen miles in length. We run up against these things constantly, but certainly conditions as to public sentiment are not as bad as formerly. In the early days, if a fish culturist operated on lakes to get the spawn of wild fish, no matter what the species, it was claimed that he was injuring the fish, and if the fishing was poor the next year that condition was always attributed to the taking of spawn by the fish culturist. Of course, we know that is not the case.

Mr. Nevin: I may say that we handle in the neighborhood of 16,000 spawning fish every spring. We lose on the average from 25 to 125 fish a year. Some die three or four days after spawning, some a week afterwards, but we always make a point of picking up the dead fish and putting the fact on record. But we lose very few fish.

Dr. Kendall: Possibly the impression prevails that I was stating as a fact that inevitable injury results to the fish in the stripping process. Now, one fish culturist may have all the success in the world; he may not injure the fish in any way and he may get all the eggs that nature will provide. So far as he is concerned if he maintains that condition he has solved the problem. But my paper was directed to the improvement of conditions with a view to eliminating certain dangers in the stripping process which some other fish culturists, to my mind, have disregarded, the result being injury to the fish. I know of many such instances; I have specimens of fish from various state hatcheries as well as our own where undoubted injury has resulted to the ovaries or some other part of the fish. But I wanted to emphasize the fact that I do not say that artificial propagation or stripping of the fish is necessarily fatal to the fish; injury is the result of careless or improper manipulation of the fish. Many things should be considered in that connection besides merely the stripping process. I have seen a so-called spawn taker grab a fish around the neck, if it had a neck, put it down between his legs—he would be wearing a rough, oilskin suit—and squeeze out the eggs until he could not get any more; then he would fling the fish, with a collapsed abdomen, into the water. There the fish would remain until the abdomen inflated again, and after a while it would struggle up and swim off, feeling very sick. Take that fish afterwards and open it and you would find it full of water. It is such people that I want to caution. It was to help in that direction that the Bureau of Fisheries proposed to conduct some experiments at one of the stations with the rainbow trout. There have been set aside at that station a thousand or so fish, with controls, raceways and so on, so that experiments may be made in the taking of eggs by various processes and note made of the results.

With regard to the suggestion that fish sometimes retain the eggs, I myself know that to be a fact. It may be due to a natural or to an unnatural cause; it is not necessarily to be taken for granted that they have been stripped. Some other factor may have been a consideration in the matter. So I repeat that I do not seek to convey the impression that artificial taking of eggs is necessarily injurious, but that artificial taking of eggs in the wrong way may be injurious, as is shown by certain specimens in my possession.

Mr. Titcomb: The rainbow trout, of course, in eastern waters has always caused trouble. Since the early days there are references in the reports to glassy eggs obtained from rainbows. You will get them from rainbow trout the first year they are stripped; if any ill effects are shown as a result of stripping, the subject would be a very interesting one for study. I wanted to ask Dr. Kendall just how be obtained the specimens that he has to show. Were they taken at random?

Dr. Kendall: Some were sent to me from our hatcheries with a request for information as to what the trouble was. Other fish were sent pursuant to instructions to forward a certain number of females of a given age. Some had been stripped and some had not. Some of my fish I obtained at random in state hatcheries, fish that had been stripped once; some of our fish had been stripped twice. Others I obtained myself and had them sent in. I had no voice in the selection of the fish; I simply got the fish that were sent. The first intimation of trouble with the ovaries and eggs was before I recognized the exact anatomical arrangement of the fish. Several years ago some fish were turned in from one of our stations for examination to determine whether the trouble of subnormal egg production was not due to inbreeding.

Mr. Titcomb: Where the fish are in poor condition I find that they frequently hold their eggs over a year; this suggests that something other than the mere stripping may be responsible. Does not Dr. Kendall think that a diseased condition of the fish is as likely to be the cause of failure to spawn naturally as the handling of the fish in spawn taking?

Dr. Kendall: Well, so far as the retention of the eggs is concerned, that may be so. But ruptured ovaries, the presence of masses of clotted blood, and all that sort of thing, would hardly be due to any slight unnatural condition.

Mr. William F. Wells, Albany, N.Y.: There is one phase of this paper which has not been brought out very prominently, and before the discussion is closed I think it ought to be mentioned. I refer to that aspect of fish-cultural work which has to do with the relation of the scientist to the practical man. This discussion has been entirely along practical lines. There is no question that Dr. Kendall has done a wonderful piece of scientific work; he has disclosed facts which, if they do not succeed this year or next year in bringing about the production of one more fish from artificially stripped eggs, may in the long run have more effect on fish-cultural methods than can now be anticipated. Here is involved the question of the relation between the anatomist and the surgeon. The anatomical facts that have been determined during the last thousand years are the basis of our surgery today. The wonderful surgery of the present generation is due more to those great anatomists than to the wonderful surgeons who are alive today. In due respect to science, therefore, I think we should say that Dr. Kendall has done a wonderful piece of scientific work, and the fact that he can arouse so much interest on the part of the practical man shows that his work is one of those rare instances of scientific accomplishment which connects pure science—in itself worth while—with the work of the practical man, who, perhaps, is not always inclined to appreciate the ultimate results of scientific work.

DEVELOPMENT OF THE COLLEGE OF FISHERIES

By John N. Cobb

Director, College of Fisheries, University of Washington Seattle, Wash.

At the College of Fisheries, of the University of Washington, we are trying to do something new. We have the only representative educational institution outside the Empire of Japan which is giving full courses of instruction in matters connected with the oldest industry in the world. In the case of Japan, a beginning was made in the work about ten years ago.

The establishment of our College of Fisheries was largely due to the initiative of Dr. H. M. Smith, United States Commissioner of Fisheries, who in 1914 attended the first meeting of the Pacific Fisheries Society and was so enthusiastic on the subject that he got the university people started. But the university happened to be without a head at the time; and then the war came on and it was thought best to defer definite action. In 1919, Dr. Suzzallo, our President, and the Board of Regents, believing the time ripe, provided officially for the establishment of the college and then turned over to me the entire matter of working out details. We were entering upon a new line of work and had practically nothing to guide us, so we had to build from the bottom up. We made some mistakes, but we have not been afraid to acknowledge them at once and to change our methods when necessary.

During the war the U. S. Naval Reserve used a part of the campus of the University of Washington, and at the conclusion of hostilities there was left a group of buildings of which fortunately we were able to utilize three. One of them, Fisheries Hall No. 1, contains the administrative offices, and has a class room seating about 40 students, a net laboratory where the making and preservation of nets is taught, a testing laboratory, and a fisheries museum in which we probably have the finest collection of models of fishing apparatus to be found in this country. In the second building, Fisheries Hall No. 2, we have the hatchery and the ichthyological laboratory; also a lecture hall seating 150. Our hatchery is equipped with troughs, batteries and tidal box, and we can handle there about 7,000,000 eggs at a time. The arrangement of the hatchery is somewhat out of the ordinary. Each trough is seven feet in length, set crosswise, and has its own intake and outlet pipes. Each student is responsible for his particular trough, and that alone. Alongside this building there are a number of rearing ponds, and we are adding to them as fast as the need becomes apparent.

In the third building, Fisheries Hall No. 3, we have a complete cannery and saltery, mild-curing establishment, and barrel-making plant, and we intend to add to these a small smoke-house and freezer. In this cannery we are able to can any species of aquatic animal in any type of container. We can cook in water, steam, or oil. We have also a small dryer for partially drying the fish, and we have facilities outside for sun drying. We are trying to conduct the technological work along practical lines, in fact, as much as possible like the actual work in commercial plants.

We have three classes of students. First, there is the regular university student, the one who passes through the high school and comes to the university with all the necessary requirements. We enroll him for a four-year term, at the end of which time, if he passes the necessary examinations, he may attain the degree of bachelor of science in fisheries; he may remain an additional year, when, if he qualifies, he will obtain the degree of master of science in fisheries.

Second, there are scattered throughout the country a number of earnest men very much interested in fisheries and desirous of increasing their knowledge along these lines, but who lack the necessary educational requirements for admission to the university as regular students. So we devised a plan of taking these people in as special students. In other words, they come in and stay one year, two years, three, or four, or any length of time they please, conforming to the ordinary regulations at the university. They are not eligible for a degree, unless during the course of their studies they make up their deficiencies in the requirements for admission; if they do so, they automatically become regular students. But most of them never will be regular students; they are merely seeking, for instance, instruction in fish culture or fisheries technology. We let them take, out of the different courses offered, just what they want; they are not compelled to observe any set course. We have now four students who are specials. One who wanted fish culture came from New York, and we are planning that he will get through in about two years.

Third, in order to provide for men regularly employed in the industry, we established the short course. In the University of Washington we divide the year into four quarters. The student may take one quarter, then drop out one, two, or three quarters, if he wishes, and come back for another. But if he wants to take the four quarters in a year he can finish the regular work in three years instead of four. On the Pacific coast the fishing vessels usually come in about December and tie up for two and one-half or three months, and in March refit and go out again. As a result of this we selected the winter quarter, from January 1st to March 27th, for the short course. The only requirement of the student who desires to take advantage of the short course is that he shall be at least twenty-one years of age, though we are not particular to insist that he prove this, and be able to read and write English. We have been emphasizing frequently and insistently the fact that one does not have to be a high school graduate to take these courses; one does not even have to be a graduate of a grade school, provided he can read and write English, has fair intelligence, and a desire to increase his knowledge of the fisheries.

In these courses we eliminated all the higher mathematics, all the chemical formulas, and everything that would tend to confuse a student of this type. The lectures are written out in the plainest possible language. Some of these students may have acquired the habit of study when they were at school, but if so, most of them have been so long out of school that they have lost it, so we arrange the courses so that it is unnecessary for them to study at home unless they feel like it. Most of the work is done in the morning so that those who are employed in town, in canneries or offices, have a chance to work half a day there.

We started the first year with 40 students in the short course. We could have had 80, but we refused more because we had been carrying on the work for only about two months at that time, our equipment was rather scanty, and we did not think we could do justice to so many. We had 38 regular course students, making a total of 78 students taking both short and regular courses.

We offered courses in the history of the fisheries, classification of aquatic animals, canning of fish and of fishery products, the curing of fishery products, pickling, mild-curing, smoking, the curing of herring, etc. A great deal of stress has been laid upon the proper cure of herring; we teach both the Scotch and the Norwegian cures. This year, in addition, we are going to offer courses in pond culture, fish culture, and diseases and parasites of live fish. These are the diseases and parasites that the fish culturist is apt to meet with at some time or other during the course of his hatchery work. We also offer bacteriology of foods, which, next to canning, has been the most popular course. This is not surprising when you remember that the greater part of the fishery business on the Pacific coast is the preservation of fish by canning, salting, smoking or freezing.

Many of the fishermen also wanted to learn navigation, so we offered simplified courses in navigation to meet the needs of those operating not far from shore. On the Pacific coast there are approximately 1,000 power boats that are used as cannery tenders and in connection with the other fisheries. Each one must have a captain and an engineer, so we also offer courses in marine gas engineering. Also we offer a course in first aid to the injured. Most of our fishermen carry on their work far away from home; doctors are scarce, and consequently there is frequent need to treat injuries of various types.

We have a rule that regular students must, if possible, engage in some branch of the fisheries during their vacation, and we aid them in securing such positions. The student draws a regular salary while employed in this work; that is one thing that we have always insisted upon, as we think that the laborer is worthy of his hire. Every student we had last year, with the exception of two, participated in fishery work during the vacation period. Many of them took up work in connection with the inspection service of the National Canners' Association in Alaska; others were employed in different plants. Our rule is that if a student is employed this year in a salmon cannery, doing inside work, next year he must take up some other line of fishery work. He is expected to spend one summer of the four in a hatchery.

There are 36 salmon and trout hatcheries in the State of Washington owned and operated by the state, and seven owned and operated by the United States Bureau of Fisheries. In addition to these, a number of the counties have fish and game commissions, and a few of them operate small hatcheries; there are also five or six private hatcheries. With all of these we have a considerable demand for men, but we find our chief demand coming from outside our own country. We have had inquiries from a number of countries in Asia, and from South America.

Students who will enroll this quarter come from Siberia, Japan, China, Mexico and Canada, and from a number of

States in the Union. We are trying at present to cover the whole North American continent, but I see very plainly that our real work is to be carried on in connection with the fishery activities of the countries bordering on the Pacific Ocean. We have a wonderful field there,—probably the greatest undeveloped fishery resources in the world are in the countries abutting on the Pacific Ocean, and there is no doubt that this great section alone will keep us busy. We have been very willing, therefore, to welcome into the field any other college of the same type, particularly one established on the Atlantic.

I have just talked to the fishermen in Boston and Gloucester on this subject. They invited me to go down there and outline to them what we have done at the College of Fisheries in Washington. I did so, and I believe they are very enthusiastic in the matter. I found them laboring under a misapprehension, and possibly some of you people are in the same position. We are not turning out fishermen and we have not the slightest intention of doing so. Now, that is usually a shock to many people, but there are very few men who would care to devote four years of the best period of their lives to learning to be only a fisherman. What we are trying to do in our technological course is to turn out men of executive ability with a thorough understanding of the fisheries. A student with the broad training thus acquired may have a little more difficult time for the first four or five years, but at the end of that period he will go further and do better than one who has devoted his attention, we will say, to canning alone. In addition to that, we are trying to turn out fish culturists with good scientific training. All of our students have that, as we give them excellent training in chemistry, zoology, bacteriology, and botany before they begin with the fisheries work. Some men, of course, will develop along purely scientific fishery lines, and they will have plenty of opportunity for doing so.

We are devoting much attention in our courses to business administration; we are offering courses in elementary accounting, cost accounting, business management, employment management, marketing, etc., because the man who expects to attain to an executive position in a large company, not only in this country but elsewhere throughout the world, needs this particular training. Having it, he will be able to go into almost any plant and know at once whether or not the work is being properly done.

University life has many attractions. I never had very much of it in my time, but from the little I have had I know it to be exceedingly attractive. I have also discovered that it can be too attractive, and when I find myself growing a little bit detached from the commercial end of the industry, I put on my hat, tramp about a mile from the college, get on a street car, go down town and walk along the water front, dropping into different fish houses in order to get a little more of the commercial atmosphere. Our great trouble is that we have a tendency to grow away from the commercial fisheries, and if we begin to do this we are going in the wrong direction. We should keep closely in touch with the commercial end of the industry; its problems are our problems. As far as possible, therefore, we are confining our attention just now to practical problems. We do not have to go very far to find them, as they are numerous on the Pacific coast.

Every man at the university is engaged in some line of research that will benefit the fisheries in some way. Dr. G. C. Embody, who has recently joined our staff, is preparing to engage in research work bearing upon the question of the rearing and feeding of fish. In the preparations laboratory, Mr. C. L. Anderson and myself are carrying on canning and curing experiments. We are taking many species that are common there, but which have never been canned or cured in any way, and are preserving them in various ways. We are now preparing to take over from the State of Washington a considerable area of oyster ground, with a view to developing it and endeavoring, as best we can with the limited means at our disposal, to arrive at a solution of some of our many oyster problems. All of these things work for the benefit of the industry, and I am pleased to say that the industry appears to recognize it.

We have an advisory board in connection with the college, composed of a representative of the U. S. Bureau of Fisheries, the State Fish Commissioner, the publisher of the leading fisheries paper, one of the prominent fishery supply house men, one fresh fish dealer, and five cannery men, all selected from different parts of the state. We put many of our problems up to that advisory board with a view to obtaining their suggestions. Every member of the board is at the head of a large business; they are all men of ability and we get many valuable suggestions from them. In this way we keep closely in touch with the industry, and the industry keeps closely in touch with us.

We have a little fishery club in the college to which we invite persons passing through our city who have a fish story to tell, and this club is officered and managed solely by the students. They invite these people there and ask them to give talks, not lectures. The meetings are quite informal, and when a man is asked to speak to the students he may address them standing up if he wishes, or he may sit on a chair, or on a desk, whatever he finds most convenient. We have had people there talking on how tin cans are made, on cannery insurance, accident insurance, safety first, almost anything you could think of that has any possible relation to the industry.

During our short courses we bring in lecturers on all sorts of subjects. We have had two or three of the National Canners' Association inspectors, men from the sardine and salmon industries, men from the United States Bureau of Chemistry, and so on—any man who had a story to tell that would benefit the students or increase their knowledge. We find that all of these men are anxious to help us.

Many of you, of course, are interested in our financial affairs. I do not wonder at this, because when you come down to it, finances are at the bottom of about everything. We were fortunate in obtaining buildings that could be remodeled to suit our purposes. Of course, they are not of the most permanent construction but they will answer until we can get permanent ones, which we hope will be in three or four years.

We started shortly after the Legislature had adjourned, so we have never as yet asked for a special appropriation. The institution is a state university, the money necessary for its operation being obtained from a percentage of the taxes; we get a certain number of mills on each dollar of all state taxes. The percentage thus set aside is divided among the different colleges, and our share was $7,000. It did not look very large, and I did not think we would get very far with it, but they told me that if I could worry along with it until the Legislature met in January, 1921, they would see that something more was done for us then. So we have managed to get along thus far and still have some money left, though there will not be any by the time the Legislature meets. But here is where the commercial men came in. I put my problem up to the machinery men and they came through very handsomely. They asked what we wanted; I told them, and the next day the machinery came out with men to install it. Other men came forward with different things that we could use, and in that way we saved several thousand dollars. Our hatchery was installed through the courtesy of the U. S. Bureau of Fisheries. We have been very fortunate in obtaining assistance from so many different sources, and we are now trying in every possible way to justify their faith in us.

In our first quarter, the spring quarter of 1919, we were too late for the high school graduates of the first semester, but we had 13 students, all ex-soldiers. Most of these we trained so that they could go out the following summer as members of the National Canners' Association inspection service. Our real start, however, came in the autumn quarter, when we had 36 students. In the following winter quarter, we had 38 regular students and 40 short course students, a total of 78, a number which taxed our capacity to the limit. This last quarter (the spring quarter) we had 40 regular students, and in addition five or six vocational students from the army whom we are educating in fisheries. We have also a number of students from other colleges in the university who are taking certain courses with us—Pacific fisheries, history of the fisheries, the economic fishery resources of North America, and the like. We have been assured by the board of regents and the officials of the state that we have already practically justified our existence.

We get a great many inquiries from all over the world on various fishery subjects, methods of canning and otherwise preserving various species, fishing methods, etc. We devote a great deal of our time to answering these queries. We are also giving frequent demonstrations for the benefit of individuals who want to engage in fishing and canning. We take a person's product, run it through the laboratory for him, and tell him whether or not it will prove satisfactory. Of course we can only give snap judgment right then; the general rule in connection with our experiments in canning is to give out nothing favorable until the end of the year. Naturally there are certain products in connection with which we can render a verdict within a shorter time, and in such cases we do not hesitate to do so. Sometimes if there is a difficulty it is purely a question of finance—it may be impossible to pack the product and make the enterprise a commercial success at the price that would have to be charged; or it may be that bad qualities develop which make the product unfit or unsafe for marketing. We have taken cognizance of all these inquiries and have done our very best to answer them; any institution established will have to do the same thing.

Sometimes I think the whole world is seeking information. In one day we had a letter from Norway, one from Australia, two from Siberia, one from Japan, one from Canada, two from Mexico, and one from Chile, showing that undoubtedly by that time a knowledge of the College of Fisheries had managed to circulate throughout the whole world. You will notice that practically every part of the world is covered in this list except Africa, and I presume we shall hear from Africa in due time; probably the mails were a little bit delayed down there.

We have now reached the stage where we can really begin to do something. Of course, we are very much hampered by lack of money; all educational institutions are, for that matter—we, perhaps, more than some because we are in a rapidly growing country. In the fall of 1919 the registration at the University of Washington jumped from 3,500 to over 5,000, and it is probable that this fall (1920) it will go still higher. These great increases mean much from a financial standpoint, but we are managing to pull through. If we need assistance that we cannot get in any other way, undoubtedly the commercial men will help us, so that we are optimistic as to the future. If any of you feel that in your section you want to start a college of fisheries, we will tell you of all our mistakes, what caused them, and how we got around them, if we did get around them, so that you may profit by our experience.

Discussion

President Avery, St. Paul, Minn.: Does anyone wish to ask questions of Professor Cobb or to discuss his paper?

Mr. George N. Mannfeld, Indianapolis, Ind.; I desire to inquire as to the rates of tuition for the fishery courses which Professor Cobb has outlined.

Professor Cobb: The University of Washington is a state institution, and for a long time there were no tuition fees, but at the request of the student body a few years ago the tuition fee was fixed at $10 a quarter, the revenue derived from this source being devoted to a building fund. The cost of tuition, therefore, is $40 a year, if the student remains for four quarters. Usually he remains only three quarters, the summer quarter being omitted; that would make $30 a year. The laboratory fees run from $1 to $3 for each laboratory course, of which there would probably be two or three in each quarter. In addition to this, each student is assessed $10 a year by the student body, which manages all the activities of the students. This fee covers the daily newspaper issued by the student body, admission to all the student activities, such as football, baseball, basket-ball, etc., and medical and hospital attendance. These items would cover practically all expenses except board and lodging, so that the cost would run from $25 to $30 a quarter.

President Avery: Are the conditions the same for non-residents of the state as for residents?

Professor Cobb: Exactly the same. It does not make any difference where you come from, the same conditions prevail. Returned soldiers pay no tuition fees at all.

Dr. R. C. Osburn, Columbus, Ohio: May I ask Professor Cobb whether he is thoroughly satisfied that the arrangement of the long course and the very short course is a satisfactory one? I speak of that because in the agricultural colleges we have a somewhat similar situation —a four-year course for regular agricultural students, and various types of short courses. For instance, at the Ohio State University, in addition to the four-year course, we have a three-year course for students who begin work about the middle of November and continue until the first of April; which runs for eight weeks during the midwinter season. I was wondering whether Professor Cobb thinks that having the long course with the degree and the much shorter practical course is the most satisfactory arrangement that can be made in connection with the work.

Professor Cobb: We are not wedded to any one plan but are prepared to change the moment we find that the conditions require a change. I am thinking of establishing a short course in the summer time to meet the requirements of another class of students. These matters are still in the formative stage. I doubt very much, though, whether we would change the long course except in regard to the subjects offered; these we change quite frequently. It was most difficult, starting out as we did, to know what we ought to offer; we are finding out new things all the time and we are making the changes as we go along. We are making some changes now so as to increase the number of business courses offered; we find that the training involved in these courses has the effect of broadening the vision of the students. We are also increasing the number of elective hours. There are certain subjects which if taken in high school the student does not have to take in college and as a result the elective hours vary from 30 to 45 during the four years. In the short course we are hampered by the conditions that prevail in the industry; we have difficulty in getting these people except during the winter quarter. We would probably have better success if we started about the middle or early in December; but that would require quite an administrative change in the university, and we have not felt like asking for it.

Dr. Osburn: The winter period runs from January to March?

Professor Cobb: January to March 27th. We have a vacation period for Christmas. The short course students arrive home from the fisheries in December, and some of them leave again early in March, and if we could start early in December we could be through before any of them had to leave for their regular fishing activities. But we are in doubt about this because it would require special enrollment in one quarter and the finishing up of the course in another. You who are familiar with the internal workings of a university know how unfavorably a registrar would look upon a proposal of that kind.

THE SCIENTIST AND THE PRACTICAL MAN IN FISHERIES WORK

By Dr. Raymond C. Osburn

Ohio State University
Columbus, Ohio

In discussing the above topic it is not the purpose of the writer to elaborate upon the special merits of the members of either of these classes, nor to weigh the value of the efforts of either against the other, but rather, to indicate the value of cooperation and to show how the work of one class may be furthered by that of the other.

Before proceeding with this it may be well to define clearly what we understand by the terms "scientist" and "practical man." Briefly stated, the scientist is engaged in discovering new facts and general truths and in making them a part of organized knowledge, while the practical man accepts this knowledge and makes use of it in connection with his work. The one investigates and discovers, the other applies.

In the membership of this Society, both classes are represented and there are all gradations between them. The scientist is a practical man in so far as he works directly toward the application of his discoveries to useful ends, and the practical man is scientific to the extent that he works out ideas or lays open new truths in connection with his practice. Furthermore, many scientists are particularly interested in the organization of knowledge for practical purposes, and many practical men are keenly on the track of every advance in science, in order that they may put it to use in their work. We recognize these intermediate fields by the terms "practical science" and "scientific practice."

Now, after a good many years of membership in this Society, and of more or less close association with its members, the conclusion has been forced upon me that our science and practice are not pulling together as well as a good team should in order to achieve the best results. Science too often plunges ahead for a short distance, sometimes even without knowing where it is going, and without regard to practical ends. Practice, on the other hand, is too much of the time merely treading up and down in the same place, apparently working hard, but without making any advance; getting results, but no new ones. Science is a radical by nature and practice inclines to conservatism, and such a team is a most difficult one to make pull together. The truth is that they are both good, but it is equally certain that they are not sufficiently accustomed to each other to pull well together.

It would certainly be well if practice could advance a little faster on the heels of science, that we might make practical use of advances in knowledge as soon as they become available. Eventually, of course, our practice does follow science, but it may be a long way behind. For example, all of our modern fish-cultural practice is based on the fish-cultural science of past years, but some of it is rather antiquated in spots.

Now, I have no desire to place any high and mighty scientific control over the work of this Society. I do not belong to that so-called aristocratic set of scientific men who profess to think that science is a sufficient end in itself. Personally, I have always been a little dubious about those who pretend to think so, and am of the opinion that every one of them would be only too glad to extend his discoveries into the field of practical work if he only knew how to do it. Similarly, I am morally certain that the occasional practical man who professes to scorn scientific work and holds to the beaten track would be only too glad to make scientific applications to his own work if he only knew how.

To my mind, all scientific investigations are merely a means to the end that we may make greater knowledge applicable to our problems. Scientific investigation is futile if unapplied, and fish-cultural practice and commercial fishing, unaided by investigation, are bound to be wasteful and slow of progress. We must render science applicable and understandable, and make practice as scientific as it is possible to make it.

I know of no scientific men in this Society who "sit in the scorner's seat"; most of them have some knowledge of fisheries practice. On the other hand, there may be an occasional fish culturist, or commercial fisherman, though perhaps none such would be a member of this Society, who has not kept abreast of the times and who may have some doubts as to the value of scientific research in his work. That is, he is in the same class with the farmer who works like his father did before him and maintains that that is good enough for him. But the old-fashioned farmer need only observe the scientific farmer's greater results to realize the value of new methods, and the same will apply to fisheries work. Usually, however, such a man is given merely to cursing his luck for his failure instead of seeking the reason.

Now, we will agree, I think, that practice should follow scientific advances just as rapidly as possible, and the only question is as to how we are to achieve this result. Between the scientific man who is unskilled in practical work and the practical man who is unlearned in science, there is a wide gulf —they speak a different language—but, as I have said, there are at the same time all sorts of intermediates. The most practical of the scientists and the most scientific of the practical workers must be the interpreters between the extremes.

The scientist, in his ignorance of matters outside of his particular field, may not know the problems which confront the practical man, but, being shown them, he may be able to assist in their solution. The practical man, with his limitations of knowledge, may not know that the solution of his troubles has already been found, nor where to apply for assistance.

Our agricultural brethren, with their numerous experiment stations, colleges of agriculture, extension service, county agents, publicity work, etc., ramifying into every phase of rural life and work, are much ahead of us. It is true we have made some progress along the same lines, but how pitifully inadequate! Some experimental work has been carried on since the establishment of the United States Fish Commission, fifty years ago, but research has been comparatively limited for the reason that the Division of Scientific Inquiry has not had the appropriations necessary for its work. A few biological stations for fisheries work and one fisheries products laboratory have been established, but you can count them all off on the fingers of one hand. Without exception they are far behind the average agricultural experiment station in personnel, this being due to insufficient financial support. The deficiency has partly been made up by the cooperation of investigators, mostly college professors, for a couple of months during the summer, the Government bearing little more than the actual expense of the investigation, while the investigators work on problems that interest them and which bear on fishery matters. It has been productive of good results as far as it went, but it is altogether insufficient.

In the matter of education we are in still worse condition. Our first school of fisheries in America was established only a year ago, and a few universities are offering some courses which will give partial training to men entering fisheries work; but hitherto practically all of our research men have been recruited temporarily from among the biologists who were interested in aquatic life, and who have found an outlet for their extra energy along this line, while making a living by teaching. Our fish culturists, conservationists, and commercial fisheries men have been compelled to do without special training for their important work.

Extension work, properly speaking, does not exist, as far as I am aware, though information is spread to a slight extent by the occasional visits of superintendents and other officials to the men in the field or at the hatcheries. Many of our game protectors are doing good work in educating the people along the line of conservation, and in some states, at least, the sportsmen's associations afford excellent channels for the dissemination of information of certain kinds. Much more might be done in this way with proper organization.

Again, in the matter of publicity, we have the occasional reports and bulletins from government and state sources, while in the agricultural work, there are floods of such bulletins touching every phase of practical work and setting forth every new idea and every result of modern research. Through the agricultural extension service these touch every part of the country.

Now, it is perfectly evident that, in fisheries work, we cannot meet the agriculturists on any such program. Even if we had all the necessary funds for government, provincial, or state work, we should still be unable to carry out fully such a plan, because we lack the number of men trained to such duties. While for years the agricultural colleges have been turning out large numbers of men, and experiment station employees, county agents, etc., are all college men with special training for their work, our fisheries departments have of necessity been manned by men of practical experience only, most of whom have grown up in the work from the position of untrained assistant. Many of these are very able men, educated in the university of hard knocks, and the great body of our Society is made up of them. They probably know their limitations better than anyone else and whether a more liberal education would not have benefited them.

If we could begin right now and fill all vacancies with young men of scientific education, I am sure we would notice a great improvement, after these men had added experience to education. But we haven't the men nor, in most cases, sufficient funds to make positions attractive to them. Such being the case, the question arises as to whether there is anything else that can be done to bring science and practice closer together in fisheries work. I desire to offer a few suggestions that may be of use.

1st. To the scientific man not regularly engaged in fisheries work: Get in touch with your state or local fish men; cultivate their acquaintance and learn what are their problems and difficulties and interest yourself in their solution. Any problem is a good one for the scientist, and in its solution you will render a service to the state and to humanity. If you are a teacher, make your summers and other spare time count in such service.

2d. To the practical man: Get acquainted with the scientific men who can help you—zoologists, botanists, chemists, bacteriologists, etc.; tell them of your difficulties and enlist their services in your problems. They may know nothing of your particular difficulties, but, because they are trained in methods of research, they may be able, with study, to help you.

If possible to make such an arrangement, get at least one man with scientific training on your staff, either in an advisory capacity or, better still, as a regular employee. Most of our state fisheries bureaus and large commercial firms have no scientific men employed. If you can do no better, place a scientific staff in the field, or at the hatchery or station, during the summer. University men are often free at this time and can be interested in your problems.

Make every station and hatchery into a research laboratory as far as possible, by interesting the scientific men of your neighborhood, if there are any; universities and colleges are so numerous that you will probably find one not far distant. If you have water problems go and talk to the chemist. The chances are that he will be interested in finding out what is the matter. The botanist and zoologist will be glad to know what organisms are in your streams and ponds. Most of these men are peculiar in that they would rather work for nothing on some matter of interest to them than to draw a salary for doing something that does not interest them. But, of course, they are human and are none too well paid as a rule, so they will in all probability welcome some financial arrangement when it can be made. Sometimes, too, you may be able to offer them material of use to them in their teaching, and this is always acceptable. In the problems connected with commercial fisheries work, this will apply with equal force.

I am satisfied that there is a great deal of talent, the country over, that might be employed, even if only temporarily, in our fisheries work, if our superintendents and others in charge of such work were not too bashful to ask for it, and especially if a little money could be had for the temporary employment of scientific men, when not engaged upon their regular duties.

One thing more, you will create an interest in fisheries problems among the class of men where it will count for the most in future years; that is, among educated, scientific men; for the time will come when we will train our young men for this work just as we do now in entomology, plant pathology, and a host of other kindred practical sciences. You must help to create the demand for them which fisheries work requires.

Let us scientific investigators and practical fish men get better acquainted for the good of both of us, that we may make common issue against the difficulties which stand in the way of greatest production and utilization.

Discussion

Prof. J. N. Cobb, Seattle, Wash.: There is no doubt that for some time past there has been considerable complaint and dissatisfaction on the part of commercial men with regard to the apparent lack of interest manifested by the Society in their problems, and also in them individually. Now, I do not want you to look upon this as being said in any carping spirit, because I am up against the same problem in connection with the activities of the Pacific Fisheries Society, which I am trying to solve myself. Perhaps some of the men who are here may be able to offer suggestions that would help us and at the same time help out the American Fisheries Society.

There is no question that we do not get the commercial fishermen, the big dealers, and so on, men who could be of vast assistance to us in our work if we could only induce them to attend some of our meetings. There are times when the meetings are held at an inconvenient season of the year. We on the Pacific coast often find that to be the case; the only time we can arrange things so that we shall be able to meet the commercial fishermen is to hold our gatherings in October or November, because most of our people are in Alaska during the summer and early autumn. I strongly hope that the members of this Society will give this matter serious consideration; I think we should devise some scheme for reaching these people. In connection with the work of the Pacific Fisheries Society we have found these men always glad to help us out financially, but we want more than that—we would rather have the man than have his money. If the man wants to come in with his money, of course that is another matter. If the members of this Society have anything to offer now in this respect, I would like to hear it. I believe this is a matter to which we should give serious consideration, with a view to bringing it up at our next meeting. But the fact has to be faced that we are not reaching the great body of the fishermen who are really the backbone of the fishing industry in the United States and Canada.

Mr. W. F. Wells, Albany, N. Y.: At the meeting of the Fisheries Commissioners, at Atlantic City, and, more recently, the meeting of the Oyster Growers' Association, in New York, questions came up which bear directly upon this subject. The oyster industry is one of the biggest fishing industries. It is the one which is most susceptible to cultural methods, as you all know. Shell fish production is a farming proposition; those engaged in this work like to ally themselves with farmers, and in one state experiments have been conducted by the Department of Agriculture. Now, at the convention in Atlantic City, the Commissioners felt that they were losing their grip. It is a painful fact that the shell fish industries are declining to a point where the Commissioners feel that there will be not much more need of shell fish commissioners. Rhode Island is a good example; their receipts have dropped from $125,000 to $50,000. The marine district office in New York is faced with a similar decline; Connecticut is right on the ragged edge, and New Jersey is in the same position. I do not know about Maryland and Virginia; they were not represented at the meeting.

Every effort of the oyster growers to obtain "set" has failed and the Commissioners have done all in their power to meet the situation. The last hope is offered by the scientists who may be able to discover the causes for these failures. The period of life which the oyster passes before it "sets" is very little understood and, because the larval oyster is so small, requires special methods of study. The oystermen are not in a position to tell what changes have taken place, and all their old theories have been disproved many times during the last few years. Without being too confident in the instruments of science which have accomplished so much in other industries, and in the oyster industry of France, it may be reasonable to hope that technically equipped men may be able to do something for the oyster industry.

I would like to emphasize the point made by Mr. Radcliffe this afternoon with regard to the intermediary between the scientist and the practical man—the technologist. The motto of the Massachusetts Institute of Technology is *Mens et manus*, the head and the hand. In chemistry, in physics, in engineering, in fifteen or sixteen different courses they fill in the gap between practice and theory. Biology is included in the list; and one side of biology, of course, is this fishing industry.

Mr. Lewis Radcliffe, Washington, D. C.: My work takes me out among the commercial fishermen a great deal, and it would be a surprise to many of you to know how open-minded and interested the men in the commercial fisheries are with regard to the scientist's work. In some plants they are maintaining laboratories at considerable expense, and they have an open mind in regard to these matters. I am wondering how long this Society would last if there were no commercial fisheries in this country. It seems to me that we have a common interest and that we ought to work together.

Let me digress a little to point out that in connection with the work of the Bureau of Fisheries we carried out a technological investigation into matters affecting the salting of fish. The technologist was not a practical salter, and it would have taken him many months to learn the practical end of it. What we did in that case was to hire a practical salter, bring him to Washington and have the technologist teach him our method. While a few experiments of his own failed, the practical application of the method he was taught by the technologist was successful. Thus the technologist and the practical man come to have a higher regard for the work of each other.

Prof. E. E. Prince, Ottawa, Canada: I think the connection between the scientific man and the practical fisherman has already been accomplished to some extent, because, as I understand it, at the Pacific meeting in San Francisco the practical men did come forward and subscribe to the funds of the Society. They made donations of various kinds, and some of them become honorary members. The point is to get them to come to the meetings and take part in the work of the Society. I was delighted with Professor Osburn's paper. He has set forth in a clear and concise way the importance of that connection between the practical and the theoretical which can only bring the best results.

It may be said that there are three main divisions of the fishing industry. First there is the fisherman, then there is the merchant, the wholesaler and retailer, then there is the scientist. The interests of these three branches have appeared opposed to each other. The fisherman and the merchant do not pull together; there is no doubt about that. There has been founded in Canada an association called the

Canadian Fisheries Association, which started out with the idea of holding meetings in fishery centres and getting the merchants and the fisherman together. I do not think that they have brought about results in accordance with their expectations; it is the old story of oil and water not mixing very well. Later the United States Fisheries Association was started in the United States on the lines of the Canadian Fisheries Association, and both have invited scientific men to take part in their proceedings. I know that Canadian scientific men have several times taken part in meetings of the Canadian Association. We have given them some scientific material. I think that a committee ought to be formed with a view to holding a conjoint meeting of this Society, of the United States Fisheries Association, and the Canadian Fisheries Association.

It is important to get the men in the trade to take an interest in the work of the American Fisheries Society. Of course, we in this Society are all doing a great work among the people engaged in the fishing industry, the significance of which we may not fully realize. For instance, the fishermen and fish merchants read the papers that are published by this Society from year to year, and re-publish, for example, in the New York *Fishing Gazette*, and that is most valuable in spreading information. The *Canadian Fisherman* is another journal which is doing the same thing. But I do think that personal contact is the desirable thing, and I suggest that a committee be appointed to arrange for some kind of joint meetings. I say again that I have been delighted with Professor Osburn's paper; I am sure that it has been listened to with a great deal of interest by everyone present.

Mr. W. A. Found, Ottawa, Canada: Mr. President, I have very little to say, but I would not like this opportunity to pass without expressing a word of very real appreciation of the paper that Professor Osburn has read. It struck me that he would be an extremely good man to have as publicity agent for the universities. I am one of those who have been educated in the university to which he made some reference—the university of hard knocks—and I have some appreciation of what is needed from the universities. I have often felt that on this continent, certainly in this country, the university has been too largely regarded as a kind of something apart from practical, everyday life—rather a polishing institution for the sons, and latterly the daughters, of those who are blessed with sufficient of this world's wealth to meet the cost of a university education for their children. One of the principal things that the war has taught is that a very close relationship does intrinsically exist between the universities and the practice and business of the world's life. In this country where we have a comparatively small population and a very large area, and where there are so many opportunities from a financial standpoint, the people have possibly been prone to give little thought to the man who is content to study the problems of life. But the time is coming when industry will look to science for the answer to an ever-increasing number of questions; it is realizing more and more clearly as the days go by that to ensure success the knowledge and results of research of the scientific men must go hand in hand with that of the practical administrator. A number of our larger fishing concerns in this country are realizing this, and, as Mr. Radcliffe has said, are ready to give every encouragement to those who will take up questions that are bothering them.

One of the distinctions of the fisheries as contrasted with many other industries is that few have been engaged in it who are affluent enough to spend money on things that they feel they can get along without. But governments are realizing more and more the need for this kind of cooperation, and the people are realizing it more and more. The College of Fisheries that has been started in the State of Washington is an evidence of it; the activities of that educational institution have already lighted quite a flame and caused the eyes of the people of this country to be turned to the possibilities that exist along these lines. If we can do something to bring the universities into closer contact with the problems that we are trying to solve, a great deal will be done. With Professor Osburn's permission I shall seek to have as much publicity as possible given to a great many of the remarks that he has made, through the Publicity Division which we have recently established in our Department; because it does seem to me this doctrine of his is one that needs to be preached with fervor at this time.

I am not quite certain about the matter of amalgamation of associations; I do not quite understand the conditions existing in the United States. Here we have the association to which Professor Prince has referred, and which is paving the way to quite a successful career. That association is in charge of men who realize the necessity for scientific guidance. That is evidenced very largely by one incident which I will explain to you. It was learned by the Canadian Fisheries Association that representatives were not being sent from this country to the conference of scientific experts meeting this year at Honolulu, and appreciating the desirability of taking action in that regard the Association assumed the financial responsibility of sending a representative of the Biological Board to the conference. There clearly is hope for the future in the matter of bringing the university and the practical people into closer cooperation.

Dr. Osburn: I myself think that there is distinct hope for the future. The suggestions I made at the end of my paper were merely in connection with bridging the gap as best we can until we have our men trained for this work, as they undoubtedly will be in the future. In other lines of work such as I have mentioned—entomology, for instance—we have made this connection between the university and the state in practically all our states, and I know that the same is true of some of your provinces. The same may be said of plant pathology in connection with the botany department, and of bacteriology in connection with the water department, and so on. There is no reason in the world why we should not do it in the fisheries work, but it certainly has not been done to any great extent. In a few universities we have had this sort of contact, but only in a few of our states up to the present. We must, therefore, train a much larger body of men for fisheries work before we can begin to meet the demand, and in the meantime we should get in touch with the biologists, wherever we can find them, and get out of them all we can.

MR. CHARLES O. HAYFORD, Hackettstown, N. J.: Two years ago Professor Foster and I carried out some experiments in fish culture, he attending to the scientific side of it and I to the practical side. We decided that he was to be my student in the practical work and I was to be his in the scientific work. When Professor Foster would see any of the employees handling the fry roughly, he would take one of these little fish, put it under the microscope, and show the man just what he was doing. In a year's time we had a different crew of men as a result of pursuing this method, and there was a great difference in their work. We had one man there who spoke of the scientific man as the "long-haired fellow." We could not seem to get him started so far as the application of the scientific to the practical was concerned. One day Professor Foster came along and saw a toad sitting in a concrete pool. He called the fellow there and said to him: "I want to show you something in the way of protective coloration; that toad is of the same color as the concrete." Do you know that one thing got that fellow; it made him look at it in a new light. He commenced to notice that the dark fish frequented the dark, shaded parts of the pond and the fish of light color the lighter places, and so on. Well, today that man is the most careful we have in the hatchery, and he cannot sign his own name.

MR. S. P. WHITEWAY, St. John's Newfoundland: Mr. President, with your permission and that of the gentlemen present I should like to add a word on the subject of the practical as well as the scientific man.

The staple industry of Newfoundland is her fisheries, especially the cod fishery; but we have often found to our cost that a large catch is almost as much in the nature of a calamity as a small one, the cause of which is that we are virtually marketing our whole catch in the same way now as we did centuries ago. We are, therefore, now contemplating not only a better cure for fish marketed in the usual way, but also the marketing of a portion of the catch by some more scientific method of cold storage. Hence, Newfoundland is in search of some practical scientist along these and other lines; and as I am now in the presence of the greatest experts in connection with the fisheries of the United States and Canada, I should like to make that fact known, as it may lead to our securing the right man to become the general superintendent of the Newfoundland fisheries.

The practical man we have with us already. His opportunity came and was availed of in 1908, when we had one of the largest catches of cod on record; partly for this reason and partly because the capitalist having lost much money the previous year owing to a bad cure and a "slump" in the markets and must needs be reimbursed, the price fell from $5 per cwt. to $1.50. This was a fell blow to the fishermen.

And so in the autumn of 1908 at a small settlement called Herring Neck, in Notre Dame Bay, a Mr. William F. Coaker, a man of the people, organized some nineteen fishermen into a union with a view to protection, among other things, against such a recurrence in future. The Fishermen's Protective Union, of which the nineteen were the nucleus, and of which Mr. Coaker has ever been the president, now numbers some 20,000 fishermen directly, and indirectly some forty or fifty thousand. The policy of the Union is cooperation and its motto *Cuique suum* or "To each one his own." And to this end, halls and cooperative stores have been established in various settlements throughout the island where matters of local and general concern regarding economics, trade and commerce, and politics are discussed by the fishermen, while a supreme council is annually held at Port Union, Mr. Coaker's headquarters. Thus an opportunity is given to the fishermen for free self-expression and self-realization, which means in turn education.

Mr. Coaker advocates a better cure for codfish, fair and honest marketing by the capitalist, and a good price for a good article from the consumer. Owing to the lack of competition during the war and the great demand for foodstuffs, the price of cod became supernormal while the cure became subnormal. By reason of Mr. Coaker's cooperative stores, his borrowings from the fishermen, the concentration and mobilization of thought in the various local halls and at the annual Supreme Council, he has become a powerful factor in the trade, commerce, and politics of Newfoundland. In the autumn of 1920 he joined forces with R. Anderson Squires, a rising and able lawyer, in a political campaign which defeated the late government. Mr. Coaker thus became a very able lieutenant to Mr. Squires, who gave him a seat in his cabinet with the portfolio of Minister of Marine and Fisheries, a post which gives Mr. Coaker ample scope for his great energies to carry on his forward policy.

And so last year he visited the various countries of Europe to ascertain the quantity, quality, and grades of cure desired by each country; and on his return he introduced such legislation, on the assembling of Parliament, as would seem to meet the situation all around. This legislation has met with considerable opposition from certain local capitalists, the opposition press, and buyers in Italy; but the Minister is making substantial, if slow progress, maintaining good prices, obtaining a good cure, and keeping faith with the fishermen. What Mr. Coaker has accomplished in such a short time in his vast undertakings commercially, economically, and politically, is so extraordinary that it had better be expressed in the language of Lord Morris, ex-Prime Minister and predecessor of Mr. Squires, "Coaker is a mystery."

Such is our practical man, and should there be anyone among the present society who could help us in the securing of our scientific man, we should feel exceedingly obliged, as great results would accrue thereby —the scientific man with the practical—to Newfoundland.

Mr. J. W. Titcomb, Albany, N. Y.: I hope that the scientists of the country will all read Dr. Osburn's paper. If you go back twenty years you will find that the average scientist in the Bureau of Fisheries did not believe in practical scientific work; he did not believe in taking up any question in applied fish culture. Today look at the difference. Ten years ago there were hardly any scientists in this Society; today we are getting more scientists than fish culturists, and they are helping us. Twenty years ago the fishermen on the Great Lakes did not attach much value to fish culture. Last year I went to a meeting of the Great Lakes Fisheries Association, and I was astonished to find that all these fish producers of the Great Lakes are believers in fish culture. Now we are trying to produce more fish for the sportsman as well as for the commercial fisherman. In the United States, certainly in my state, it is the sportsman who makes most of the legislation; the commercial fisherman gets in only when he wants to protect his interests. The agitator who pushes for appropriations and legislation and all that sort of thing is the sportsman, the angler. Mr. Rowe, who is raising trout for the market, has come here at his own expense from the State of Maine. He is going to sit around here for three days and listen to all that is said, and possibly during the whole of the three days' session he will get an hour of practical information to carry back with him. Now, if we can all contribute something of value so that the representatives of the different interests can get something practical to apply to their work, others will be induced to come in with us. While I am very optimistic about this Society, whose efforts may have been responsible for the starting of these two colleges of fisheries and fish culture, I do not think we can expect to get all the commercial fishermen or all of the anglers with us as members, but we want to get all we can of them.

THE ALASKA FUR SEAL: AN INTERNATIONAL ASSET

By Hugh M. Smith

United States Commissioner of Fisheries
Washington, D. C.

Mr. President, ladies and gentlemen: You will realize what a far cry it is from what Professor Prince has just been talking about to what I am going to say. I have no formal paper to present, and I do not intend to inflict on you any general discussion of the Alaska fur seal; it is altogether too comprehensive a subject to be dealt with fully at this meeting.

My excuse for appearing before you is that the Alaska seal has emerged from a violent and, at times bitter, international controversy and has really come into its own. Its present condition is highly satisfactory, and in that condition the people of the United States and of Canada are especially interested. It is very appropriate that at this noteworthy international gathering there should be shown the results of international accord in handling a very troublesome fisheries question which, at one time—twenty-five or thirty years ago—looked as though it might precipitate belligerency between Canada and the United States. The difficulty was with regard to jurisdiction in Bering Sea and collateral questions, the circumstances connected with which some of you will recall.

The Alaskan seal herd is undoubtedly the most valuable herd of wild animals in the world. Its value will be appreciated when I say that if it belonged to a private concern it could probably be capitalized at $50,000,000 as it stands today, and could be depended upon to pay a very handsome return on that capitalization. I happen to be the official custodian of that herd; I am administering it to the best of my ability, in trust for the United States, Canada and one other power, which, by virtue of its citizens having been engaged in pelagic sealing many years ago, acquired an interest in and claim on the Alaska fur-seal herd.

The original size of the Alaskan seal herd cannot be stated with any degree of definiteness because of the difficulty in deciding from the early accounts whether there were two and one-half million or four million adults in the herd. But there is reason to believe that there may have been not less than two and a half million seals in the herd at the time the United States acquired Alaska from Russia, and in former times the number may have been considerably greater.

The decline of the Alaskan seal herd was a very pitiable event in the history of our fisheries. It was due, as we now believe, wholly to pelagic sealing—the indiscriminate slaughter of animals at sea by vessels under the United States, British and Japanese flags. As we look back on pelagic sealing, I think we are in accord in holding that it was a wholly indefensible practice. There was a most terrible waste of valuable life, because of the indiscriminate manner in which the killing had been done. The animals were shot at sea, and for every one recovered three or five or more were wounded or killed and not recovered. Then, too, there was a great waste due to the starvation of the pups on shore and the sacrifice of the unborn pups. So that in 1911 the Alaskan seal herd had dwindled from two and a half million animals to approximately 125,000.

This brings me to the Fur Seal Convention of 1911, which resulted in restoring or putting on the way to restoration this valuable herd of wild animals. This convention, participated in by the governments of the United States, Canada, Japan and Russia, decided that so far as those countries were concerned pelagic sealing should stop, and three of these countries at that time became pecuniarily interested in the Alaskan seal herd and have since been reaping rather satisfactory financial returns, in connection with which, however, only a beginning has been made.

The Congress of the United States, in the exercise of its power, in 1912 imposed a five-year close time on commercial sealing on the seal islands. I think I can say without indiscretion that it was an unfortunate act, based on insufficient information and representing an excited state of public opinion at the time the act was passed. The principal effect of the close time imposed by Congress upon commercial sealing was the accumulation of surplus male seals that could very properly and profitably have been taken for the benefit of the interested countries. Not a single fur seal was added to the fur-seal herd as a result of the five years' close time which Congress imposed.

Since 1911 the Alaskan seal herd has had a rather interesting growth. We have endeavored to take a census every year, but the taking of a census has become more and more difficult, and during the last two or three years an increased amount of approximation has been absolutely necessary. In the year following the suppression of pelagic sealing a census of the herd showed that it contained 215,000 animals. That was increased in the next year to 258,000 and in the subsequent years to 294,000 and 363,000. Last year, 1919, there were 524,000 animals in the herd, and this year's tentative figures indicate about 550,000, exclusive of about 28,000 that have been killed for their skins. Since the expiration of the close time, which prevented all commercial killing and simply permitted the taking of the inconsiderable number of seals required for food purposes by the natives on the seal islands, there have been taken about 90,000 seals.

One of the first problems which confronted us in 1917 when the close time expired was the handling of the old males that had been accumulating during the five years' period. I am happy to say that as a result of measures which we took the surplus male accumulation was gradually eliminated and at this time the herd is very well proportioned. These old males which have attained the age of about seven years are known as "wigs," probably because of the development of a mane which was suggestive of the woolsack worn by English judges. This name became known to the trade in the early days when that trade was first centered in London, and has continued up to the present time. In the days of regular commercial sealing there was very little market for "wigs." The skins are very large; the leather part is extremely thick; and when these seals were taken in the olden days and sent to London for sale, they were sold for the most part to Russia and used for the lining of the sod houses of the Russian peasants. Their value was from $3.50 to $7.50 each. It occurred to me that there ought to be a market for these large skins which had been accumulated during the enforced close time, and at our suggestion a St. Louis firm that dresses and dyes furs experimented with them. It seemed to me that they might be useful for automobile wraps or robes in an undyed condition. It developed, however, that under proper treatment these very heavy skins could be trimmed down, dressed, dyed and used for ladies' furs; and the most interesting development of the seal business in recent years has been the use that we have been able to make of these formerly discarded elements of the herd. They have, in fact, become the most valuable part of the seal herd today, their skins bringing higher prices than the best grade of skins from smaller seals. At one of the recent sales these "wigs," of which I am going to show you some samples, brought $169 apiece as against their former price of $3.50 to $7.50—when they could be sold at all.

Now, just a word about the financial results of the present arrangement. The United States has certainly profited by the stoppage of pelagic sealing. During the past ten years the net revenue from the seals taken in that time is about $6,000,000. Some of these skins have not yet been sold, and

I am estimating their value. Under the terms of the Fur Seal Convention of 1911 Canada is entitled to fifteen per cent of the proceeds; and Canada will be entitled to about $500,-000 as her share of the seals taken since 1917.

I believe that the Alaska fur-seal herd is bound to increase. There is nothing in sight to prevent its rapid increase, possibly to the extent of 8 to 10 per cent annually; and I would not be at all surprised if within a comparatively few years we would be taking 100,000 animals each year, made up wholly of surplus males selected with reference to their economic value, due regard being had, of course, for the needs of the herd.

Canada, it seems to me, may ultimately be expected to realize half a million dollars annually from the Alaskan seal herd. I may say that the convention to which I have referred runs until 1926, and may be terminated by any of the parties to it upon the giving of certain notice. I want to express the hope and belief that no nation will be willing to return to the carnival of waste and ruin that necessarily characterize pelagic sealing, and that the present arrangement, modified as circumstances may require, will be indefinitely continued, so that the Alaskan fur seal, under United States custody, may become a great permanent international asset.

Discussion

PROF. E. E. PRINCE, Ottawa, Canada: Are the trimmings ever utilized for leather?

DR. SMITH: Some experiments are being made with a view to utilizing the trimmings. I cannot say now that any very important use has been found for them.

PROFESSOR PRINCE: In the leather trade they very often slice up and split the hide.

DR. SMITH: That is not possible with fur-seal skin; you cannot split it as you would a porpoise hide. These skins have to be ground down, and in order that the skin may not be ground too thin in any one place the grinding is done by touch; the fingers are used to determine when the grinding shall stop. I may say that in the evolution of the seal-skin industry in this country, it has been necessary to devise special apparatus for handling the skins, and some very ingenious devices are resulting from the exigencies of the situation. Mr. Found visited the plant in St. Louis last year, and may be able to say something about it.

Mr. W. C. Adams, Boston, Mass.: Is this killing done by regularly authorized agents of the Government?

Dr. Smith: All the killing is done under direct Government supervision, with a Government agent present.

Mr. Adams: It it done by one government for the benefit of all?

Dr. Smith: All the killing is necessarily done by one government. We have a force of agents and their assistants on the seal islands, and we have 325 natives by whom most of the work of killing is done. These natives were taken there in the old Russian days, shortly after these islands were discovered. There may have been four million fur seals there at that time, but there were no people; there was no labor to utilize in obtaining the skins. These people have now become the wards of the Government; they have to be supported, fed, clothed, educated, given medical attendance—in fact, everything a community of 350 people needs has to be supplied by my Bureau.

Mr. W. H. Rowe, West Buxton, Me.: How are the seals captured?

Dr. Smith: The killing is done by means of clubs. The fur seal has a rather thin skull and is easily rendered unconscious by a rap over the head with a heavy hickory club. It is then immediately stuck and bled, and the skin is removed. I do not know of any form of trapping, or killing, or butchering that is more humane than this method of killing fur seals under Government supervision.

Mr. Rowe: Are these seals not afraid of man? My observation of the seals on the coast of Maine is that they would dive into the water if anyone attempted to approach them.

Dr. Smith: That is the hair seal, a very different creature from the fur seal. During summer, fur seals haul out on land in large numbers. Bodies of them can be cut off from the water and driven like cattle inland for longer or shorter distances, sometimes several miles. They are rounded up, selectons are made, the females and unsuitable males are discarded, and the others are killed on the spot.

President Avery: Is any use made of the carcasses?

Dr. Smith: During the long time that commercial sealing was carried on by Russia, and during the forty years when the seal islands were leased by the United States Government to the highest bidder, no use was made of the seal carcasses except for small quantities of the meat eaten by the natives and fed to the blue foxes on these islands. A reduction plant, however, has now been established, and although it has not been operated very successfully as yet, being only in its initial stages, we plan to utilize every bit of seal carcass. It makes an excellent fertilizer, and a splendid oil is obtained from it. I may say that this oil last year brought $1.50 a gallon for the best quality. It has been found to be the best oil known for automobile tops; it gives them an elasticity that no other treatment gives, so far as we know.

That oil can be sold at great profit for that particular purpose, and the demand for it exceeds the supply. We ought to get two gallons of oil from each seal carcass, so if we kill 30,000 animals in a year we will get 60,000 gallons of oil; that ought to be worth $75,000, anyway.

MR. S. P. WHITEWAY, St. John's, Newfoundland: When is your killing season, Dr. Smith?

DR. SMITH: The seals arrive on the islands in May and June. The killing begins at that time and continues until the 10th of August, when the skins begin to deteriorate. The fur is then not so valuable as it is earlier in the year; accordingly, the killing is suspended about that time.

MR. WHITEWAY: You speak of the seals gathering on the islands. Does that mean on the ice or on the rocks?

DR. SMITH: On the rocks. The shores are very rough and rocky, consisting of boulders, for the most part.

MR. WHITEWAY: What is the thickness of the fat between the carcass and the skin?

DR. SMITH: It depends on the condition and size of the animal. There is quite a thick layer of blubber fat which is very useful in the subsequent dressing of the hide and is in demand at the factory in St. Louis, where all these skins are now treated.

MR. WHITEWAY: The Canadian seal is similar to the seal of Newfoundland?

DR. SMITH: Yes.

MR. WHITEWAY: Of course, in the case of the Newfoundland seal, the oil is the most valuable feature.

DR. SMITH: The old males come to the islands in advance of the other elements of the herd. They arrive in May and stay on land without food or water for several months, usually until about the end of July. During that time they live on their stored fat; they have a vast accumulation of fat under the skin and throughout their tissues.

DR. R. C. OSBURN, Columbus, Ohio: Dr. Smith brought up a very interesting point in connection with practical conservation and the effects of study of biological conditions. Canada, since the beginning of the killing after the close season, has, I believe, received perhaps twice as much as the whole seal herd would have been worth at the beginning of the time when steps were taken to have the herd properly cared for. Dr. Smith has spoken of the much greater value of these larger skins taken from the six and seven year old males. I assume that it will be the policy to continue taking the three year skins, as formerly—that no change will be made in the killing age.

DR SMITH: The three, four and five year skins are those that will make up the bulk of the killing. There is a natural mortality which increases with the age of the seal. Although the value of the skin is greater with increased size, the mortality is also greater; so we are trying to arrive at the happy medium,—to take the skins when it will be most profitable to utilize the surplus males. That is probably when they are four years old, or thereabouts.

Dr. Osburn: The killing of two year olds has been stopped entirely, has it not?

Dr. Smith: It is not prohibited, but there is no reason for killing seals of that small size.

President Avery: Dr. Smith suggested that Mr. Found might have something to say with reference to the handling of seals at St. Louis. Have you anything to offer, Mr. Found?

Mr. W. A. Found, Ass't Deputy Minister of Fisheries, Ottawa, Canada: Mr. President, the Pelagic Sealing Treaty of 1911 seems to me to speak so loudly for itself that the only requisite to securing approval of it by the people is some degree of publicity with regard to what it is and what it has accomplished. I share the hope uttered by Dr. Smith that when the treaty expires in 1926 the good sense of the participating countries will cause them, while possibly eliminating some crudities that are in the treaty itself, to establish beyond peradventure this method of conserving to the participating countries an asset that was so rapidly reaching the vanishing point.

When Dr. Smith was speaking it occurred to me, as one from the north side of the line, that the impression might be given that pelagic sealing was an illegal operation. While I agree with all that has been said regarding undesirability of pelagic sealing, I would not want that impression to prevail, because pelagic sealing was a perfectly legal operation, established by the highest court of the world, that of international arbitration.

The treaty provides, for instance, that Canada shall receive fifteen per cent in number and in quality. One does not need to have had very much experience in dealing with the matter to realize what a difficult thing it would be to carry out the apportionment of fifteen per cent of the quality of the seal skins. The governments, therefore, made an arrangement—an eminently satisfactory one to Canada, and we have every reason to feel that in its handling of the matter the United States is treating us with every courtesy and consideration—by which the United States are carrying the whole load of killing the seals, and conveyed the skins to the St. Louis factory, where they are processed, letting us come in with a little more than taking over the money. Of course, we not only may, under the treaty, but are cordially invited from time to time to have representatives on the seal islands watch what is going on; but up to the moment it has not been found necessary to do much in this direction. All the skins are being handled in St. Louis, and you have before you an actual illustration of the work that is being done. I had the pleasure during the last winter of going through the plant of Funsten Brothers & Co., at St. Louis. That plant is certainly a very great credit to the owners; they have developed an article which is unusually attractive and which commands a very high price. For instance, if I remember correctly, $178 was the price of each of a number of skins of the type to which Dr. Smith has made reference. The plant is one which is well worth visiting, the skins being put through over one hundred different processes. The general results are certainly very satisfactory.

Dr. Smith: I do not want to prolong the discussion; I simply want to say that the only grievance we entertain with regard to the fur-seal business as it affects Canada is that Canada has persistently refused to send anybody up there to see what we are doing. We hope that this does not indicate any lack of interest. We want everybody to know what we are doing, and suggestions from Canada or from any other source are always in order. We have many problems to solve, and not the least important of them is the sending of supplies to the natives. It is impossible to do anything for them in winter; we have to make trips up there in open weather, and if for any reason the supply vessels do not get there, this community is in danger of starvation. It has been on the point of starvation several times. This year a large vessel which went up there loaded with supplies was unable to discharge its cargo owing to the tempestuous seas, and, in the absence of docks or harbors, was obliged to come back with three-fourths of its cargo on board. We hope that of the next trip, which may be on now for all I know, a different story will be told; if not, the condition will be a serious one for these natives, who are absolutely dependent on the outside world for everything they need except the seals that they eat in small quantities and the eggs of wild birds that nest in the rocks.

ATLANTIC AND PACIFIC SALMON*

By Henry B. Ward

University of Illinois, Urbana, Ill.

History repeats itself with monotonous regularity and the most patent facts of scientific knowledge apparently make no impression on the people at large even where their own interests are vitally concerned. They try over and over the same experiment and after the clearly foretold results have been secured they lament the unfortunate consequences. Not only that but an expenditure of money to improve the situation is often rendered useless by action which passes without adequate protest from those most immediately interested.

In former centuries the Atlantic salmon ran yearly in the rivers of the New England coast in such numbers as to excite the amazement of our forefathers. They thought the supply inexhaustible, but in 1798 a dam was erected on the Connecticut River and the results are thus described by Jordan and Evermann:

> The salmon was at one time very abundant in the Connecticut, and it probably occurred in the Housatonic and Hudson. * * * The circumstances of their extermination in the Connecticut are well known, and the same story, with names and dates changed, serves equally well for other rivers.
>
> In 1798 a corporation known as the Upper Locks and Canal Company built a dam 16 feet high at Millers River, 100 miles from the mouth of the Connecticut. For two or three years fish were seen in great abundance below the dam, and for perhaps ten years they continued to appear, vainly striving to reach their spawning grounds; but soon the work of extermination was complete. When, in 1872, a solitary salmon made its appearance, the Saybrook fishermen did not know what it was.

The experiment has been tried in many other places and each time the result has been the same. We have heard much in recent years about the dangers confront-

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ing the Pacific salmon which furnishes so important a part of the food supply of this country and of other parts of the world. Scientific men have called attention to the serious dangers which ill-considered promotion and careless destruction of spawning grounds have brought to bear on the supply of this splendid fish.

In response to these warnings President Roosevelt appointed a commission for the investigation of problems connected with the Pacific salmon and its fisheries, and Congress continued the work of studying the situation and of aiding the fish to maintain its position by the establishment and development of hatcheries. One of the oldest and most prominent is at Baird, Cal. It is accordingly with grave apprehension that I have read the following paragraph in a recent publication:

> Only a few spring-run fish have been seen in McCloud River at Baird, Cal., and the dam without a fishway in the Sacramento River is to a considerable extent responsible for the condition which threatens to render the Baird hatchery useless.

In California certain state officials have suggested that since the dam was constructed without a permit from the War Department, action to correct the evil should be taken by the United States authorities. But since the Sacramento River at the point in question has not been adjudged a navigable stream, no permit was required and the matter falls legally wholly under the control of the State of California. It is pertinent to ask whether that state is so lacking in foresight and its officers so devoid of responsibility for public interests that they will continue to permit conditions that menace thus directly the public welfare.

But the question has an even broader aspect. These fish are a national asset. They are born in the waters of an individual state but they soon pass into the ocean, glean from it without expense from any state or nation the supply of energy that brings them back at stated periods to contribute to individual enterprise and to national food supply a harvest that is of all which man gathers the most profitable because it demands least care and utilizes for its production otherwise unused sources of energy.

The nation is vitally concerned with the impending danger. It has contributed the means by which the hatchery is maintained and it has a moral if not a full legal right to see that no private agencies thus in irresponsible manner destroy the results of its efforts. Some way should be found and some agency invigorated to the point where it will insist upon the maintenance of proper fishways even though this involve expense upon the interests concerned.

This is, however, only one phase of a question which has many aspects. The run of Pacific salmon has entirely disappeared in some streams. In others it has been tremendously impaired. In districts like Puget Sound it has sunk to a fraction of its former size and during 1919 only one district in Alaska reported a catch that equalled 100 per cent of the number for the preceding ten years. Furthermore these results were obtained by the use of more boats, more men, more gear and other destructive appliances than had ever been in service before.

In his latest report the United States Commissioner of Fisheries calls attention to the situation in so far as it concerns Alaska waters and the salmon therein, in the following terms:

For about eight years legislation affecting the fisheries of Alaska has been pending in Congress. Protracted hearings have been held, and a large amount of testimony and data has been presented to the appropriate committees of the two houses. The necessity for a radical revision of the existing salmon law has been especially pointed out by various agencies and persons interested in the welfare of the fisheries of Alaska, and congressional committees have made favorable reports on bills embodying new legislation.

No new fishery laws have, however, been enacted; and the fisheries of Alaska, at the most critical period of their history, remain subject to laws which have been shown to be obsolete and inadequate. The

Bureau of Fisheries is thus placed at a great disadvantage in administering the salmon fisheries of Alaska and cannot justly be held accountable for conditions, practices and developments which, while having the full sanction of law, are not necessarily compatible with the perpetuation of the supply and in some respects are directly opposed thereto.

Concerning the magnitude of the problem the same report speaks in another place thus:

It is the salmon industry which gives to the fisheries of Alaska their great importance, and it was the salmon industry that contributed most notably to the increases that occurred in 1918. The value of all salmon products was $53,514,812, of which $51,041,949, represented canned fish to the number of 6,605,835 cases. Thus, 50 years after Alaska became a part of our national domain, the salmon resources alone yielded a product valued at over 7½ times the purchase price of the territory.

The public interest thus put in jeopardy is of the first magnitude and the danger both real and immediate. Biologists know how rapidly the progress of destruction proceeds and how soon the end comes when the diminution in numbers of any species has once become conspicuous. Increasing values always lead to redoubled efforts and multiplied appliances for securing a catch and the vicious cycle gains in velocity as it decreases in diameter.

The commercial interests are strangling the goose that has laid for them so many golden eggs and some are beginning to be apprehensive for the future. Unless public sentiment can be developed, unless the efforts of the Bureau of Fisheries can be supported by adequate appropriations, and unless the taking of salmon can be subjected to reasonable restrictions, that splendid fish will in a short time be as much of a luxury on the Pacific coast as its congener is today on the Atlantic.

FOREST PROTECTION AND ITS EFFECT ON FISH AND GAME LIFE

By Honore Mercier

Minister of Lands and Forests, Quebec, Canada

My first words must be those of gratitude. On my own behalf and on behalf of all your guests from the Province of Quebec I tender you sincere and hearty thanks for your warm welcome and generous entertainment of us on behalf of the Department of Marine and Fisheries of the Dominion of Canada. Coupled with this feeling of gratitude I am bound to admit that there rankles in my heart a certain amount of jealousy. To be frank, we in Quebec are envious of Ottawa for having secured the privilege which we feel that we should have had of welcoming you all in the *Old* instead of the *New* capital of Canada. I feel that we have a grudge against my good friend, Professor Prince, for stealing a march on us by going down last year to Louisville and securing for Ottawa the first Canadian visit of the American Fisheries Society and the International Association of Game, Fish and Conservation Commissioners. Had we in Quebec known that Canada could have had these conventions in September, 1920, and that my friend, Professor Prince, was going to Louisville to secure this privilege for Ottawa, I can assure you all that he would have had a hard fight indeed to prevent the delegation that we would have sent to Louisville from storming the convention there. There is only one way for Professor Prince to obtain absolution, and that is to undertake to work as hard for Quebec as the scene of these conventions as he did for Ottawa, just as soon as the two societies are willing to once more favor Canada with their most welcome visits. I understand that it is practically decided that the next meeting place is to be in either Wisconsin or Pennsylvania, but in order that there may be no misunderstanding as to future plans, I give notice that Quebec is in the field to receive and welcome both societies at the earliest possible occasion.

We may possibly be unable to do everything for you that Ottawa is doing, but we will do our best to give you the time of your lives, and you may perhaps not be unaware of the fact that Quebec is credited with certain attractions for which our friends and neighbors of Ontario have some cause to envy us.

I have been asked to say a few words to you on the importance of forest protection in connection with its effect on fish and game life.

It is a remarkable fact that man alone, of the animal creation, is responsible for any disturbance of the harmonies of nature. So exact was the balance of both vegetable and animal life as it left the hand of the Creator that so far as we are able to judge, it might have remained so to the end of time, subject only to the conditions of natural development, were it not for the changes produced by human action.

It is true that man, finding himself in the rudest stages of life dependent upon spontaneous animal and vegetable growth for food and clothing, has protected and propagated to advantage certain birds and quadrupeds, and has warred at the same time upon rival organisms which prey upon these objects of his care or obstruct the increase of their numbers. But what havoc has he not wrought with many of the useful wild things of our woods and waters!

Wise laws and many state, provincial, national and international fish and game protective organizations are at work to prevent further improper destruction of fish and game, and to repair as far as possible the damage caused in the past.

Amongst the most serious dangers now threatening the existence of fish and game in the inland portions of North America, I believe, we may count the rapid disappearance of the forests. The forest is the original guardian of both fish and game. It furnishes to the first mentioned, pure, fresh and well aerated water, protected from pollution by natural filtration and well capable of sustaining life and of favoring activity. Open everywhere to the air, full of freshness, and offering to wild game a succulent food of buds and berries and a variety of herbs and fruits, and protecting it from the heat of summer and the biting blasts of winter, the forest, with its flooring of soft moss affords it a hospitable shelter. The forest is so necessary to many species of game that they desert the locality when it is destroyed, but return when it reappears.

In Scotland the former deer forests have largely disappeared, and although certain moors are set apart for the propagation of this species of game, Sir William Shlich declares that the animals shot on these deer ranges are nothing like the fine beasts found in woodland areas, but that if a large part of the country was once more brought under forest we should no doubt improve the breed.

In the middle ages, as well as in earlier and later centuries, attempts were made to protect the woods by law, both because of their necessity for the breeding of deer, wild boars and other game, and for the purpose of furnishing building material and fuel for future generations. In feudal times the creation of so-called forests for the sole purpose of forming hunting grounds grew into an abuse of public and private rights. William the Conqueror is said to have destroyed sixty parishes and to have driven out their inhabitants in order to form a forest for his own hunting and that of his friends. It must be remembered, however, that the name forest was then given in hunting phraseology in England to any low growth of cover for game. The Conqueror punished with death the killing of a deer, a wild boar, or even a hare. The conquered English were hanged for the murder of a plover, death was inflicted on those who spread nets for pigeons, and those who had drawn a bow upon a stag were to be tied to the animal alive. In France up to the time of the Revolution the slightest trespasses on the forest domain were severely punished, and game animals were held strictly sacred, even when they ravaged the fields of the peasantry.

Many of the most valuable forests of both England and France, which proved so extremely important for the supply of timber during the late war, owe their preservation to their employment as hunting preserves. The enormous value of our forests today to many of our leading industries, and especially, as we all know, to that of pulp and paper, largely overshadows their importance from the fish and game point of view, and as protectors of these last mentioned we may rejoice that this is so, and that there are so many other weighty reasons for the preservation of the woods that are so essential to our fish and game life.

When last I addressed an association of those interested in fish and game protection in New York—I believe it was the American Game Protective and Propagation Society—I was at the head of the Department of Colonization, Mines and Fisheries of the Province of Quebec, and spoke upon the fish and game resources of the Province. It so happens that now, when I have had the honor of saying a few words upon the importance of forest protection to fish and game, I happen to be Minister of Lands and Forests of the same Province, and you may perhaps like to know what we are doing in my department for the protection of the natural nursery of fish and game.

An important provision of our law which operates against the unnecessary diminution of our forest area, provides for such classification of public lands as permits the sale for colonization purposes of only those which are really fit for cultivation.

One of the worst enemies of the forest is fire. Our system of fighting this evil is based upon a study of those adopted elsewhere, modified to meet local conditions and perfected according to certain ideas of our own based upon experience. Would I go too far in saying that one of the main causes of our forest fires has been the burning of slash by farmers on the border of the forest? This is now prohibited at any time except for clearing purposes, and then only from the 15th of November to the 31st of March of the following year, except by a permit from an officer of the department who must see that all necessary conditions are carefully complied with. Nobody is permitted to set fire to standing trees at any time except when they are at a distance of at least a mile from the forest. Any person who sets fire anywhere inside the forest or even at a distance of less than a mile from it is obliged first to clear the place where he is to make this fire, of all inflammable materials, and to totally extinguish the fire before leaving the place.

Locomotive engines used on any railway passing through any forest in our Province must be provided with necessary screens or other appliances to prevent the escape of fire or sparks. The engine driver in charge of a locomotive passing over such a railway must see that the above appliances are properly utilized. For contravention of this law, railway companies are liable to a penalty of not more than $1,000 and not less than $250. The railway companies, moreover, are obliged, under a penalty of $100, to clear away all combustible materials from the sides of their respective roadways by burning the same or otherwise.

The Lieutenant-Governor in Council may create, by proclamation, fire districts. During the construction and operation of its line through any fire district, every railway company and every license holder, whose license is located in any territory forming part of a fire district, shall place under the control and have at the disposal of the superintendent of forest fires, such number of men as may be required in case of fire. The salary and expenses of such employees are to be borne by the railway company, the licensee, and the Minister of Lands and Forests jointly. Penalty for refusing to comply with the above section ranges up to $500. Moreover, the Minister is authorized to employ in each fire district such number of men as he may deem necessary. All persons who drop burning substances, such as ashes from pipes or cigars, on the ground or elsewhere, whether in the forests, open fields or other places, are bound to extinguish such burning substances before leaving the spot. Contravention of this article is punishable by a penalty not exceeding $50 or by imprisonment for not more than three months in the common jail.

Last year a number of new and important modifications were made in the law for the protection of forests against fire, chief among which are the following:

Every holder of a license to cut timber on crown lands must, at all times between the 1st of May and the 1st of November in each year, have his timber limits patrolled by competent fire-rangers paid and selected by him, but appointed by the Minister of Lands and Forests, and the latter may prescribe the number of fire-rangers who must be so employed. Such fire-rangers must devote their whole time to such patrol.

The Minister may, however, require that the limits be patrolled also in the month of April, in certain parts of the Province where it is expedient to do so.

Every license holder must, between the first and the fifteenth of each month, during the period above mentioned, make a return to the Department showing the number of fire-rangers employed by him during the preceding month; the number of fires which started; the number of fires extinguished, and of those not extinguished; the extent of territory burned; and the amount of expense, if any, incurred by the license holder in extinguishing the fires.

If a license holder fails to make a return within the delay fixed or if he does not employ the number of fire-rangers fixed by the Minister, the latter may then have the patrolling done, with all necessary supervision and charge the whole cost thereof to the license holder, and the amount fixed by the Minister shall be final.

The return made by an association of holders of licenses to cut timber, for the protection of their limits against fire, shall be sufficient if it includes all the limits belonging to each member of such association.

The formation of district forestry associations on a business basis is encouraged by the Department, and all timber limit holders are required to join their district association or to patrol their limits themselves. Where there is water communication, patrol is made by canoe. Along the railways which traverse the forest, speeders are employed. There is also a hydroplane service and a tramping patrol through the woods, besides lookout stations on elevated points, telephone lines, pumps, etc. Lectures are given in various sections of the Province on forestry problems by members of the forestry service, illustrated by moving pictures and lantern slides.

You do not need me to tell you of the necessity of forest preservation for the maintenance of the regularity of the flow of water in our rivers and streams, for the prevention of inundations, or for assuring to our water powers the necessary capacity to produce all desired energy essential to the public welfare. As business men you realize the potential value of the forest to industries and to the capital and labor alike interested therein. As sportsmen you probably have not needed me to insist so much upon the necessity of the forest to fish and game life. All sportsmen are lovers of the woods, and surely it becomes us all to raise our voices whenever and wherever the opportunity occurs for their preservation. Settlers and others in this New World are too apt to regard a forest tree as an enemy. "Cut it down," is the battle cry; "why cumbereth it the ground?" I wish that all such men would bear in mind the quaint remark of an old writer on forest trees quoted by Evelyn:

> Trees and woods have twice saved the world, first by the Ark, then by the Cross, making full amends for the evil fruit borne by the Tree in Paradise by that which was borne on the Tree of Calvary.

That accomplished botanist and brilliant writer, Dr. Hugh Macmillan, speaking of the influences and functions of a pine forest, says:

> The pine is the earth's divining-rod that discovers water in the thirsty desert, the rod of Moses that smites the barren rock and causes the living fountain to gush forth. * * * We see the presence and hear the voice of the Creator among the pine trees as among the trees of the garden of Eden. Each tree is aflame with Him as truly as was the Burning Bush.

If I have said anything at all that may suggest additional precautions against forest fires, or that may tend to enlist your further sympathy and aid for the promotion of forest growth, I shall feel that I have spoken a good word for the fish and game life in which we are all so much interested.

I address an appeal to the members of the American Fisheries Society to work with us for the preservation of fish and game. May I be allowed, sir, to point to one special instance and to ask their help in securing the adoption of a uniform system between the different provinces of Canada, as well as between Canada and the United States?

A few years ago we in Quebec enacted a law by which we established a system of controlling the commerce in all fur-bearing animals trapped or hunted on our territory. Other provinces have passed a similar law. One of the clauses of that law is that if any of our game wardens learn that any wild animal has been killed outside of the close season established by law, no matter where it comes from, on instruction of the Minister he returns the animal, or the skin, to the country or province in which it was killed. This law has been productive of good results. We have been working in cooperation with the sister Provinces of Ontario and New Brunswick, and animals killed in these respective provinces out of season have been seized and returned to the province in which they were killed. The government of the province concerned may then take action against the party responsible for the infraction of the law. A year or two ago one of our citizens living in the Province of Quebec near the Vermont border killed a deer on American territory. Instructions were given to send that deer back to the State of Vermont. If this law were applied by all provinces and by all states, I am sure that poaching would be stopped. An international law as between the United States and Canada would, I am confident, bring about splendid results along these lines. If, for instance, the customs officers on both sides of the line were given authority to seize the skin of any wild animal killed out of season when an attempt was made to ship it across the border, and if they would seize also any skins not bearing the tags or stamps required by the laws of the province or state whence they came—if these skins could be seized and returned to the government of the state or province in which they were killed, we would go a long way towards preventing poachers from sending from one country to the other or from one province to the other, the skins of animals taken illegally.

Mr. Chairman, I wish to express my delight at meeting again some of the delegates from the United States whom I had the pleasure of meeting a few years ago in New York, and later in St. Paul, Minn. I do not know whether I am authorized to do so here at the federal capital, but I should like, sir, as a Canadian to say to our friends from the other side of the line that they are welcome to our country, and to express the hope that they will come back soon, so that we may again have the pleasure of working together, through a meeting held in this country, for the welfare of both countries in connection with the preservation and propagation of fish and game in North America.

NOTES ON FUNCTIONS AND ACTIVITIES OF THE DIVISION OF FISHERY INDUSTRIES OF THE U. S. BUREAU OF FISHERIES

By Lewis Radcliffe

Assistant in Charge of Fishery Industries, U. S. Bureau of Fisheries, Washington, D. C.

The taking of stock to determine the condition and trend of a business is a recognized practice. It is likewise important that those of us engaged in governmental activities should from time to time review our functions and take stock to determine in what degree we are fulfilling our duties for the benefit of our creditors, the taxpayers, and our own peace of mind. I hope that such a review of some of the functions and work of the Division of Fishery Industries (Statistics and Methods of the Fisheries) of the United States Bureau of Fisheries during the past eighteen months may be of interest and may perhaps give to some a wider acquaintance with the importance of its work to the industry and its relation to fish culture and biology.

DEVELOPMENT OF FISHERIES

Attributable in large measure to the Bureau's effort to secure a wider use of fishery by-products such as fish leather, oil, meal, scrap, etc., fisheries for sharks, porpoises and other unutilized aquatic animals have been established, not alone by fishermen in the United States, but by Canadian fishermen as well, and have attracted world-wide attention and consideration as evidenced by the volume of foreign inquiries for specific information. At the time of my visit to one such fishery last year, 44 porpoises were taken at one set and the daily catch of sharks ranged from 30 to 75. This afforded a hitherto unequalled opportunity for the biologist desirous of learning more about the habits, life history and diagnostic characters of these too little known forms. In the light of the predatory character of sharks capable of consuming upwards of 50 pounds of fish at a single meal and the fact that they have previously been neglected by the fishermen seeking marketable species, the value of the establishment of such fisheries is seen. Another fishery receiving attention is that for black drum, a little used fish of large size of the south Atlantic and Gulf section, for which specific information as to seasons and localities of abundance has been lacking.

IMPROVEMENTS IN FISHING OPERATIONS

In the spring of 1919 the Bureau suggested to menhaden companies the desirability of giving seaplanes a trial for spotting the schools of fish to increase production and eliminate unnecessary trips on the part of the fleet of vessels in seeking the fish. Later the Bureau was instrumental in having naval seaplanes detailed for the work to determine the commercial possibilities of their use in this fishery. One menhaden company has installed radio equipment on two of its vessels and at its station; vessels and planes are using charts in which the fishing areas are blocked off in lettered squares which are subdivided into numbered squares, and when a school is sighted its location is sent by wireless to the fishing boats. The work thus far has proved very successful and it is believed that the use of seaplanes may become a regular adjunct to the fishery.

The Bureau is also making preparations for the establishment in a limited way of a Fishery Intelligence Service, suitably located lightships and lighthouses along the New England coast sending daily reports of the presence of schooling fish to the Bureau's local agents at Boston and Gloucester, Mass., and Portland Me., for the benefit of local fishermen.

HANDLING, DISTRIBUTION AND MARKETING OF FISHERY PRODUCTS

For years the Bureau has been advocating the necessity of making certain improvements in the handling of fish from the time they are caught until offered for sale to the consumer, as, for example, the elimination of the practice of forking the fish. Not infrequently fish receive as high as 9 to 12 forkings, with the result that putrefactive bacteria may be introduced into the tissues and self-digestion of the cells promoted. The needless bruising of the fish resulting from this method of handling further promotes autolysis. This matter has recently been receiving the attention of fishery journals in the United States and Canada. The Bureau of Fisheries is endeavoring to learn what, if any, economical methods of handling may be substituted for the present practice, and is preparing to wage an active campaign to eliminate this practice. It is noteworthy that those in the industry are also appreciative of the necessity for the adoption of some other method of handling the fish, and express a willingness to aid in lessening the number of times the fish are forked.

TECHNOLOGICAL INVESTIGATIONS

An entire paper could well be devoted to the phase of the Bureau's work which deals with technological investigations of the underlying scientific principles governing the preservation of fishery products to determine the feasibility of their preservation by untried methods, and to discourage the use of unsatisfactory, wasteful, or uneconomical practices. Suffice it to say that the Bureau has developed improvements in the methods of fish salting, whereby it is possible to salt fish at higher temperatures and therefore in warmer climates, and this year gave practical demonstrations of the methods, resulting in the successful salting of 80,000 fish on the St. Johns River, Fla., where previous attempts failed. It has also developed satisfactory methods of canning the west coast mackerel and other local fishes. A packer on that coast recently received an order for 10,000 cases of mackerel preserved in a certain manner, and he came to the Bureau for the results of its experiments in canning fish by this method in order that he might undertake to fill the order. The Bureau imported the first plant for freezing fish in brine, made preliminary tests of brine freezing as compared with air freezing, and is initiating studies of certain of the basic principles of refrigeration for which there is need in the industry. Very properly in this field of technological investigation, it is doing work for the fisheries of like character to that done by the U. S. Bureaus of Plant Industry and Animal Industry in the field of agriculture. As specific examples, reference may be made to the work of the former in the technical investigation of the storage of vegetables, and of the latter in the determination of causes producing soft pork and the development of preventive or remedial measures.

INCREASING THE USE OF FISH FOR FOOD

In this exceedingly important field, the Bureau has conducted eminently successful practical demonstrations and lectures in fish cookery. Within a year its agents reached directly about 15,000 persons, mostly housewives, and many more indirectly. These demonstrations have been of great value in extending the use of the cheaper, more abundant species, and have served to introduce appetizing, inexpensive methods of cooking fish, to conserve labor, eliminate the use of expensive cooking fats and oils, and to encourage the use for food of parts of fish usually discarded. While fish compares favorably in protein content and digestibility with meats, our per capita consumption of fish to meat is approximately in the ratio of one to nine. In addition, experiments have been made to develop suitable recipes for preparing little used fishes for the table; and cook books, placards and posters recommending the use of fish have been freely distributed for the use of the trade.

At the present time when there is an over-production or an under-consumption of fish, or both, it will be evident that work of this character is of the highest importance. The Bureau regrets the limitations upon its operations in this field. As an example of the importance of such work, it is interesting to note that the catch in the Gulf States of black drum increased from 136,053 pounds in 1890 to 2,011,288 pounds in 1918, and of groupers from 427,781 pounds in 1890 to 5,935,825 pounds in 1918. Were it possible to continue such demonstrations, the use of these and other neglected fishes such as the haddock, sablefish, rockfish, whiting, etc., would be greatly extended and the number of markets handling such fish largely increased.

DEVELOPING USE OF BY-PRODUCTS AND UNUTILIZED PRODUCTS

Only the briefest mention can be made of the Bureau's varied activities in this field in increasing the production of fish leather, meal, oil, scrap, the saving of the scales of native fishes for the production of essence d'orient which is used in the manufacture of artificial pearls, the drying of shark fins, an oriental delicacy, the greatly extended use of oyster shells for poultry grit, the recovery of old salt and brine for reuse, and the like. It has recently been determined that tuna oil is superior to linseed oil as a drying oil, and a number of inquiries have been received from paint and varnish manufacturers desirous of obtaining supplies of this oil. Last year fish and shrimp meal in excess of 2,500 tons was produced in the south Atlantic and Gulf region for the first time and, if necessary equipment can be obtained, it is expected that about double that amount will be produced this year in these regions, or as much as was produced in the entire United States until recently. I believe the possibilities of using this material for feeding purposes by fish culturists merit serious consideration, particularly in view of the rising prices of feeds in use. As indicative of the increasing importance of this phase of the industry, it may be noted that while in 1890 the value of the by-products of the Gulf states fisheries was practically negligible, in 1918 the production amounted to 17,409,496 pounds, representing a value to the fishermen of $310,682.

INTRODUCTION OF USEFUL FOREIGN METHODS

Detailed scientific investigations as to the preservation of nets, the development of new methods, and improvements in old ones have largely been conducted by Norwegian technologists. The only preservative used to any great extent by our own fishermen is tar, and its use is confined largely to the coarser kinds of nets. The value of the fishing apparatus used by fishermen in the United States exceeds fifteen million dollars, a very considerable part of which consists of lines and nets. It is therefore evident that the introduction of useful foreign methods which will materially lengthen the life of nets, gives promise of effecting large economies in the expenditures for fishing gear.

One of the Bureau's technologists has recently translated all the important articles in Norwegian on the subject, and has in press a paper summarizing the important principles and methods of applying preservatives developed in Norway and other countries.

COLLECTION OF STATISTICS

One of the most important functions of the Division of Fishery Industries has to do with the making of statistical inventories and the dissemination of statistical information for the use of the trade. Such information is also of value as showing the trend of the fisheries, the need for and the results of fish-cultural practices, and the need for more adequate protection to properly safeguard the fishery harvests of the future. It shows the areas of greatest production and provides a permanent record for governmental use. Recent canvasses of the fisheries of the Pacific coast states, the Great Lakes, the south Atlantic states and the Gulf states have been made, in addition to the collection regularly of the statistics of the vessel fisheries centering at Boston and Gloucester, Mass., Portland, Me., and Seattle, Wash., and the completion of statistics regarding various minor fisheries. A canvass of the fisheries of the New England states is now in progress.

Of special interest to the conservationist and fish culturist are annual canvasses of the shad fishery of the Hudson River begun in 1914, and the shad and alewife fishery of the Potomac River initiated in 1919. In the former stream the rehabilitation of the fishery depends upon natural reproduction and local protective measures, and in the latter material aid is being given these agencies through extensive fish cultural operations. It is hoped that by conducting such canvasses annually over an extended period of years, informative data of considerable value may be secured.

CONCLUSION

In this brief statement mention has been made of some of the important functions of the Division of Fishery Industries and of some of its efforts in each field to render the commercial fisheries the aid they so richly merit. In conclusion I wish to emphasize the close interrelationship of its activities, which have been very properly correlated in one place, and the close relationship with the work of other divisions in this branch of the service. In the Bureau of Fisheries, there is working side by side with the Division of Fishery Industries, a division devoted to the biology of fishes—their habits, food, migrations and interrelations—which serves as an ever-present check on the increasing efficiency of exploitation. It tells us that the life in the waters is communal, and that interference not carefully restrained, may upset the balance in the waters; that sound biology and regard for the future forbid us to take unlimited advantage of everything we know about exploiting fisheries. There are, for example, known methods of taking fish more efficient than many of those in legitimate use, but sound policy requires that such methods be discouraged. Thus, the work of exploitation must be governed not only by the needs of the trade, but by the needs of the community of animals in the water. Species such as sharks, gars, and the bowfin, that appear injurious and destructive to the whole community of fishes, are receiving particular attention in preference to those already more or less sufficiently exploited. Mention has already been made of the relationship to fish culture. whereby the statistical canvasses may show the need for and the results of fish culture.

This brief reference to some of the Bureau's activities is given in the hope that we may have the pleasure of hearing of the excellent work Canada is doing in the upbuilding of her commercial fisheries, and that both may profit by an interchange of views.

[At the close of his paper Mr. Radcliffe exhibited samples of essence d'orient, fish meal, shrimp meal, shark and porpoise leather; also a pair of shoes, one made from cowhide and the other from shark leather.]

Discussion

Dr. R. C. Osburn, Columbus, Ohio: Shark hide will wear better, will it not?

Mr. Radcliffe: I do not know; that has not yet been determined. I wore a pair last winter and they were very satisfactory. As yet there are no shark hide shoes on the market.

Dr. Osburn: The porpoise leather is from the porpoise proper, I assume, not from the white whale?

Mr. Radcliffe: The porpoise, *Tursiops tursio.*

Mr. John W. Titcomb, Albany, N. Y.: The fish meal industry has been extended a great deal in the South. Is the fish meal now exhibited made strictly out of the by-products of fish?

Mr. Radcliffe: On the Atlantic coast it is made of menhaden in essentially the same way as fish scrap except that a little more care is exercised in using fresh fish and avoiding scorching in the drying. After drying it is put through a swing hammer grinder to break up the small needle-like bones. It is used for hog feed. It consists of the whole fish, flesh, bones and scales, with the oil extracted.

Mr. Titcomb: Is it being used as fish food?

Mr. Radcliffe: Prof. G. C. Embody might know. I am not acquainted with that feature of it.

Dr. H. M. Smith, Washington, D. C.: I think that Mr. Radcliffe has not brought out what I consider to be a very important feature of the manufacture of fish meal, as distinguished from fish scrap. Fish scrap, as made in the menhaden industry for many years, is used for growing crops, largely for stock feed. Now, this fish meal is given directly to the stock, so that you save a year's time and all the expense in connection with the harvesting and selling of the crop of grain.

Mr. Radcliffe: I may add that we are working hand in hand with the Bureau of Animal Industry, Department of Agriculture. That Bureau is recommending to the farmer that he give more protein feed to his hogs. The farmer, in turn, asks where he can get the protein feed, his principal source of supply now being the tankage from the meat-packing concerns. Officials of that Bureau tell us that a hog which has reached 225 pounds should have consumed 100 pounds of protein feed. Last year the farmers raised something like 70,000,000 hogs, which would require a large amount of protein feed if the advice of the Department of Agriculture were followed. We are helping out in this. We advise the fisherman to produce fish meal; the Bureau of Animal Industry advises the farmer to use fish meal, so our work dovetails in that way.

Mr. Titcomb: There is one point I would like to bring out, in case there may be some misunderstanding in regard to the use of fish meal. Mr. Radcliffe spoke of Professor Embody. Three or four years ago Professor Embody gave us a very interesting and valuable paper in which he referred to the use of fish meal. I do not think that the records of the Society have been properly corrected, but it turned out that the fish meal which he was using at that time was really a meat meal made in Chicago and sold as fish meal. Of course, fish culturists want to know the difference; we want to know that the fish meal which we are now talking about is really made from fish. Possibly, we have not experimented sufficiently along this line. We might be able to find some dry feed that we could keep in storage for the feeding of fish.

Mr. Radcliffe: I may say for Mr. Titcomb's benefit that we are assembling lists of actual producers of fish meal in this country. On the west coast about nine-tenths of the fish waste is now being converted into fish meal, only one-tenth into fish scrap. There is a production of something like ten thousand tons on that coast every year, but on the east coast they have been slow to recognize the value of fish meal. The best use we can make of fish is to eat it; the next best is to feed it to our stock, and then, as Dr. Smith pointed out, what you cannot use for these two purposes should be put on the land.

Mr. W. A. Found, Ottawa, Canada: We are discussing what seems to me to be a matter of extremely great importance to the fishing industry, as well as to the agricultural interests. The Pacific coast does not present the problems in this connection that the Atlantic coast does. On the Pacific coast, on both sides of the line, we have a large industry with centralized operations, the offal being produced in one place, or in connection with the salmon canning industry; and the rush of fish is great while the work is going on. On our Atlantic coast in Canada we have two essential fisheries, or, I should say, two essential parts of the fishery industry. The one may be regarded as the principal factor—the inshore fisherman who operates his own boat, sometimes with three men in a boat, and takes his fish to his own centre. This comprises by far the greatest portion of our industry. The wholesale end of it, the schooner and trawler fishing, where the fish are all brought to central ports, comprises as yet the smaller part of our industry. We are possibly wasting many hundred thousand tons of valuable material each year around our coasts; it has been estimated at 300,000 tons. If science can find a practical means of saving it from deterioration so that it can be brought to some center and there turned into commercial products, either fish scrap or fish meal, it would indeed be a step in advance. The value of fish meal as animal food is not a new thing; the manufacture of this material has been a big industry on the continent for many years. If we can do something along this line we shall solve a problem which is giving the Fisheries Branch of the Department of Marine and Fisheries in Canada a good deal of concern. We have the raw material, but it cannot be collected cheaply enough at any one centre to enable the carrying on of a paying business. If we can devise a method of collection or of economical operation on the spot, we shall accomplish something that will be of national benefit.

Mr. Radcliffe: We now have machines, adapted from the meat-packing plants, for converting small quantities of waste into scrap or feed. These machines have been successful in some places, but I fear that they will not work as well in others, particularly with material rich in glue. These are some of the problems with which we are faced. I may say that we have gone a step further and asked the Department of Agriculture, through its Bureau of Animal Industry, to carry on, as soon as it can, a series of feeding tests with material cooked at the fishing center, with a view to devising a method of enabling the little fellow, who has only a small amount of material, to produce a suitable feed for his hogs. If we could do this for our whole coast line, it would considerably increase the feed supply.

Prof. John N. Cobb, Seattle, Wash.: I was glad to hear Mr. Radcliffe say that somebody had devised a machine that would handle small quantities, because that has always been our problem on the Pacific coast. In a section where there are a number of salmon canneries within reach, it is easy enough to build a chute and a tank on the end of a dock and gather the material inside, but in the case of the single small plant located in an isolated section, it has been almost impossible to do anything with the fish waste. In order to make good fish meal, the scrap ought to be fresh; if it is not, it can be used only for fertilizer.

I have watched closely the fish-meal and fish-scrap industry of the Pacific coast, and I am sorry to say that I no not think any of the plants have made much money. During the war, oil was very high, fertilizer was high, and fish meal was high; so they had a chance then to make a little money. But the unfortunate thing has been the great initial cost of a plant and the fact that the plant could be operated only a very short period in the year; in other words, the plants must lie idle for eight to ten months of the year. It is thus very difficult to make a profit on an investment of something like $30,000. It would be well if some small plant could be established at each cannery, for instance, or at each fishing station, to handle this material, much along the line of the little plants formerly used in connection with the sardine canneries of Maine. These plants prepared what might almost be termed a paste which the farmers would take in this shape and put on their fields. These plants really did little more than extract the oil from the material, and did that very crudely. But I hope that this cheaper machine for the handling of small quantities of scrap will be found to be practical, because even out on the Pacific coast we have considerable glue in the scrap and most of the plants are experiencing trouble in handling it.

MR. WILLIAM F. WELLS, Albany, N. Y.: There is another aspect of this discussion which is of interest to those who are troubled with the question of preventing the pollution of streams and waters. Perhaps in the particular cases spoken of, disposal of waste material was more important than the question of pollution. It is true, however, with other waste products if not in the case of fish products, in which these same questions have been raised, that a solution of the problem of waste disposal will go a long way toward preventing conditions which have an important bearing upon the fishing industries. The pollution of waters, due to the discharge of organic wastes, which we have much difficulty in reducing with profit, is causing a great deal of damage and we must face the question of preventing negative profits or losses. In other words, looking at it from the point of view of pollution, we have to admit that even though we cannot reduce some of these materials with a profit, it may be necessary to ask certain industries to suffer a loss in order to obviate an even greater loss to the fishing industries.

MR. RADCLIFFE: I have in mind the case of a plant which was dumping from twenty to thirty tons of waste in one day. This plant is located in a city; they have only a short season, and they may be getting large quantities of waste one week and none the next. In another case, prior to taking up the question of manufacturing shrimp meal for the canneries, a plant was paying $15 a day for the services of men to dig holes in the ground to bury the waste. Today that manufacturer is producing from the waste a product for which he is asking about $85 a ton.

MR. WELLS: I would like to mention a law prohibiting the discharge of all wastes except the refuse from menhaden factories. When the fishing industries go to the legislature and ask for a law to prevent everybody else from putting waste into the waters and specifically omit the waste they themselves are producing, it does not seem very consistent, and, naturally, is not convincing.

MR. CHARLES O. HAYFORD, Hackettstown, N. J.: I would like to ask Mr. Radcliffe whether shrimp meal can be procured in other than comparatively small quantities. Recently, Professor Embody advocated the use of this shrimp meal. Now, in our hatchery we are using sheep's plucks, beef melts, pig melts, beef livers and butterfish. We find that if we mix these feeds somewhat as the age of the fish advances, giving them different combinations from time to time, we get a much hardier and more contented fish. Professor Embody advocates the use of this shrimp meal, even if mixed with the other foods, to supply vitamines. He tells me that in the experiments made at Cornell the fish took the shrimp meal very readily when it was sprinkled on the water. But the experiment has never been made on a large scale. At the station where I am in charge we use approximately 75 or 100 tons of fish food a year. It occurs to me that if we could obtain information as to the approximate quantity of this feed that is used by each state, as well as by governments and by private individuals, and if the relative values of these foods could be determined by tests carried on by the Bureau of Fisheries, there might be a greater demand for it than there is, particularly in view of the fact that the price of meat has so largely increased during the last few years. We formerly bought butterfish in 180-pound crates at two cents a pound; now they are charging us four or five, and do not care whether they sell to us or not. The fish culturist who gets a price of ten or twelve cents a pound on a certain kind of food will compare it with some other food the price of which is only three or four cents a pound. There is nothing to enable us to check up the relative values of the different foods that are being used.

Mr. Radcliffe: Shrimp meal will run between 43 and 47 per cent protein, and fish meal from 55 to 60 per cent. You would think, therefore, that fish meal would be the better feed, but the experiments carried on by the Bureau of Animal Industry in feeding hogs showed that when shrimp meal was fed the results were just as good as those obtained from the feeding of fish meal. The value of this feed lies in some of the other elements, such as vitamines.

Mr. Titcomb: This last phase of the discussion brings very forcibly to my mind the importance of having, in connection with the United States Bureau of Fisheries, an experiment station similar to agricultural experiment stations, where these problems concerning fish feed can be dealt with. The relative values of shrimp meal and fish meal and of the livers and plucks of various slaughtered animals—the relative values and the relative prices possibly, of some of these by-products—ought to be given publicity. We ought to be able to feed our fish intelligently, in order to get the best growth for the least money. That, to me, is a function of the Federal Government, because all the states are interested in the problem. The College of Agriculture at Cornell is doing a little of that work on a very small scale, and I assume that Professor Cobb's college on the Pacific coast will also do some work in that connection. I know that the present Commissioner of Fisheries has been very desirous of getting an appropriation from Congress for an experiment station. I think that the colleges which offer courses in fish culture and fishery industries should have federal as well as state support, and be operated on the same extensive plan as is the case with the agricultural college. I cannot let this opportunity pass without expressing my view that the Federal Government ought to support that branch of experimental work in fish culture and all that pertains to it, including the study of fish diseases. A resolution on the subject adopted by this Society at this time, if we have not had one in the past, might be a step in the right direction. I think that the subject is a very important one.

Mr. William H. Rowe, West Buxton, Me.: I am using in my hatchery some 75 tons of feed a year. On the strength of what Professor Embody said in his paper two years ago, I wrote to the firm that manufactures shrimp meal, but got no satisfactory reply and have never been able to get any of the meal.

Mr. Radcliffe: We have lists of producers of shrimp meal, and we are assured that they will take up actively its manufacture if they can be sure of a market for the product. I think that in the solution of these problems the services of trained technologists are necessary.

Professor Cobb: Professor Embody informs me that he intends to carry on extensive experiments in the feeding of fish. I may say that in one of our private hatcheries out west the fish are fed with ice cream cones broken up so as to float on the surface of the water. Of course, the diet is occasionally varied with liver, but this hatchery man said that they did very well on ice cream cones, one of the cheapest foods he found. Some of you might try that, along with fish meal or shrimp meal or anything of that kind; they ought to go well together.

Mr. Titcomb: I want to bring up one more point in this connection. Men cannot afford to buy ice cream cones or any other food that they know nothing about, feed their live stock on it for three or four months, and then have them all die on their hands. They are carrying on a live stock proposition and they know that they can pursue certain lines and carry their fish through to a marketable size; they do not know what may happen if they feed something else. We have heard a good many of these stories about cereals and all kinds of foods, but the commercial fish culturist cannot take chances on a live stock proposition in the carrying on of experimental work. Experimental work of general public importance should be done by the Federal Government. The very best fish culturists, scientists, and pathologists should be engaged in the work.

Mr. Rowe: I have been told that macaroni is good food for fish. Reference has just been made to ice cream cones along the same line. Now, Professor Embody told me that there was absolutely no food value in bran cereals for fish; that no growth could be secured from the use of these things. Mr. Chamberlain, who carried on the experiments for Professor Embody, worked with me during one summer season, and he also stated that cereals were of no use as food for fish; that all they were good for was simply to hold the other articles together.

Mr. Radcliffe: This fish meal need not necessarily be a finely ground material. Do not think that because you get it finely ground that it is the only way in which it can be produced. It can be manufactured to suit your particular needs.

Mr. J. A. Williams, Tallahassee, Fla.: I may say that if any fish culturist here is desirous of getting in touch with the shrimp-meal people, our department will be glad to put him in touch with those who will produce shrimp meal for him.

President Avery: To my mind this is a very excellent paper, dealing not only with an important branch of the Bureau of Fisheries, but indicating also a weakness in our own Society. While the discussion took a somewhat different tack, the paper dealt largely with matters of importance to the commercial fisheries, which are not represented in the Society to any great extent. I think it would strengthen the Society, and perhaps be beneficial to the trade as well, if we could arouse their interest in our activities. This is a suggestion to those who are working upon the problem of enlarging our membership, and strengthening the Society.

PRINCIPLES INVOLVED IN THE PRESERVATION OF FISH BY SALT

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The art of preserving fish by means of salt is of great antiquity. It was practiced by the Phœnicians and Greeks, and was brought to a high degree of perfection by the Romans. Mixed with spices, salt was used in the time of Christ on the shores of the Mediterranean and the outlying country, for the preservation of food, reference being made in the Sermon on the Mount to a salt which has lost its savor, meaning a salt in which the spices have lost their aroma by evaporation. In the centuries following, the art continued, both in the Occident and the Orient, to play an important part in world economy. Shakespeare puts in the mouth of his most wonderful character, Falstaff, the words: "If I be not ashamed of my soldiers I am a soused gurnet"*—a pickled gurnard, the gurnard being held in such light esteem that it was a term of contempt; whether "sousing" or pickling made the fish doubly contemptible had better be left to the philologists to determine. Less than twenty-five years after Shakespeare wrote that play, the Plymouth Colony landed in America and brought with them the arts of sousing and pickling fish. The descendants of the pilgrims are still pickling fish around Cape Cod, and particularly at Gloucester.

To a great many people it may seem that science has contributed little or nothing to the improvement of methods of preserving fish by salt, perhaps this view is shared by a considerable number of people who are engaged in the business of salting fish. To them it may appear that salting fish is

*King Henry IV, Part I, Act IV, Scene II.

just salting fish, and "that's all there is to it." It may be admitted readily that science has not so pervaded and dominated the fish pickling industry as it has other ancient arts, but it has contributed something, and is capable of contributing a great deal more, and here lies the purpose of this paper. That purpose is to present the rationale of salting and pickling fish so that the reasons for the various steps and modifications will be readily understood and appreciated, to the end that the art may be practiced more intelligently and successfully. It is a further purpose of this paper by showing what the few attempts made by science have done for the art, to convince and persuade those on whom the industry depends for its existence and progress, that science can be expected to do a great deal more than it ever has done if it is energetically studied and applied.

HOW SALT PRESERVES

Salt preserves by extracting water. Spoiling is a series of chemical activities for which water is necessary; remove the water and spoiling is arrested. The removal of water by means of salt is in some senses a truer dehydration than actual drying in air, for changes of an undesirable sort take place in air drying that are never corrected, while salting may be done in such a way that few changes other than removal of water are brought about. The statement that salt preserves by extracting water is to be taken strictly and literally, for salt has no peculiar preserving or antiseptic quality, as many people seem to think. Things live, die and putrefy in the sea, which is one-fifth saturated with salt. But by sufficient concentration, salt, an otherwise almost inert, harmless substance becomes a powerful preservative, merely because, if concentrated sufficiently it extracts water. The process of transferring water from one place to another, as from the inside of a fish to the outside, under the influence of concentrated solutions, is known to physicists and chemists as osmosis. This principle of osmosis is of almost universal application in nature, and is used by men in the arts, but a good understanding of it is not common. By osmosis our food is taken from the intestines to the blood without any communicating opening; by osmosis, oxygen is taken from the air into the blood, without any leakage of blood; by the same principle the kidney tubules remove undesirable substances from the body while holding back all desirable substances; by osmosis the roots of plants select the necessary minerals from the soil; a weak sugar solution will readily ferment, but if made concentrated it destroys yeast and bacteria by osmosis, and is therefore an excellent preservative of fruits. Salt is also a preservative by virtue of its concentration. Any other neutral mineral substance equally soluble would preserve in the same way that salt does, but salt happens to be the only one that the human palate and stomach will tolerate.

HOW SALT EXTRACTS WATER

At the risk of appearing verbose, the writer undertakes to elucidate the principles that govern osmosis because osmosis is nearly the whole principle of salting fish. Without a knowledge of osmosis people may salt fish successfully by rule, but without such a knowledge it is quite impossible to understand the process.

If a thin animal skin or membrane separates two liquids, and if the liquids are alike, nothing happens. But if they are unlike, one or the other, or both, of the liquids will pass through the skin to the other side; this passage through the skin or membrance is called osmosis. Just what components pass through the membrane, and in what direction, and how much, depends on many circumstances. For the purposes of salting fish, water is always the liquid, plus whatever is dissolved in the water, and the skin and cell-membranes are the dividing membrane. We thus have water and salt outside, cell-membrane between, and fish juice or protoplasm inside, and we desire to know what will happen, and how we can influence the process to suit our needs. The quantity and direction of flow through the skin or cell-membrane will depend on (1) the nature of the dividing membrane; and (2) the nature and quantity of the substances dissolved in the water on each side.

The nature of the dividing membrane will be considered first. Almost any substance can be made into a thin film or membrane. Such things as glass, tinfoil and mica may be exceedingly thin, but are totally impermeable and therefore uninteresting in the present connection. But other membranes or films, such as parchment paper, gelatin films, animal bladders, and gold beaters' skins, are permeable to a greater or smaller degree. Suppose pure water were on one side of a membrane and water containing dissolved salt on the other. If the membrane is perfectly permeable to all constituents, water will pass through to the salt solution, and salt will pass through to the water, and these movements will continue until the two sides are alike, and then stop. It is always the tendency for the two liquids to come to equilibrium, and they would do so if the membrane were perfectly permeable. Nearly all membranes, however, permit a freer flow of the solvent, in this case water, than they do of the solute, that which is dissolved, in this case, salt. If the membrane permits the water to flow, but absolutely prevents passage of a dissolved substance, the membrane is said to be semi-permeable. In the example taken above, of pure water on one side, and salt solution on the other, if the membrane were semi-permeable, then the water would pass through to the salt solution, but the salt could not get through to the water. The level of the pure water would fall and that of the salt would rise; the difference in liquid level would exert a pressure called osmotic pressure. Ideally semi-permeable membranes are not realized in nature, though some of the membranes in plants and animals approach ideal semi-permeability while they are living. Ideal semi-permeability with respect to particular dissolved substances has been achieved, and is found in living organisms.

It is to be remembered that in case of semi-permeable membranes, the solvent will flow from the less concentrated to the more concentrated side of the membrane, so that if we wish to extract water we need only to make the outside more concentrated than the inside, if we wish to add water we make the outside less concentrated than the inside, i. e., we use pure fish, and that permeability increases at temperatures near the freezing point of water.

It is also to be remembered that membranes do not necessarily hold their degree of semi-permeability unalterable; the permeability of the membrane can very readily be changed, as will be seen later. There is reason for believing, for example, that the permeability of fish to salt increases after death, for stale fish strike through more quickly than fresh fish, and that permeability increases at temperatures near the freezing point of water.

The tissues of fish consist of cells; each cell is a bag of semi-liquid, like the white of egg. The surface of every cell either is, or acts like, a semi-permeable membrane. If we surround the cell with water, the inside will be more concentrated than the outside, and water will go in; if we surround the cell with strong salt solution, water will pass out to the salt. Some salt will also pass into the cell, which fact shows that the cell wall is not ideally semi-permeable.

But what of the protein within the cell? Why does it not come out while the salt is going in? The answer to these questions makes it necessary to pass from a consideration of the nature of the membrane in osmosis to a consideration of the nature of the dissolved substance.

By a great many experiments it has been found that some dissolved substances never pass through membranes under any circumstances, while others will pass through some membranes.

It is found that those which never pass through are also those which on drying out do not crystallize, but shrink to a tough mass. They are called colloids; examples of them are glue, albumen, gelatin, and soap. The smallest possible particle of these substances is comparatively large, too large, we may imagine, to go through the texture of the membrane. They are not only large of molecule but complex in structure. The bulk of animal bodies consists of colloids called proteins, dissolved in water. The other class of substances, those that may pass through membranes, are the crystalloids — substances which, on drying out, crystallize in regular geometrical shapes. Examples of this class are salt, sugar and like substances. It is not to be supposed, however, that all crystalloids will pass with equal facility through any given membrane. Nearly all membranes are in some measure selective of particular crystalloids. The ideal semi-permeable membrane permits none to pass, but as membranes degenerate from ideal semi-permeability to complete permeability, they permit more and more of these dissolved things to pass through.

The phenomena of osmosis having been briefly reviewed, one may readily perceive the importance of applying the principles to the salting of fish. Salt is brought in contact with the exterior of the cell, it dissolves in some of the moisture, forming a saturated solution. This solution is separated from the contents of the cell by a cell membrane, which is more or less semi-permeable. Water passes out of the cell to the salt and the processes of decay are stopped because of insufficiency of water. The membrane, not being absolutely semi-permeable, permits some salt to enter, and the fish remains salty. The contents left in the cell are proteins or the valuable food elements of the fish which, being colloids, are not permitted by the cell-membrane to pass out. Thus, the fish is preserved.

When the time comes to eat the fish the process is exactly reversed. The fish is bathed in pure water. The cell contents are more concentrated than the exterior, so water passes in. The cell-membrane is to some extent semi-permeable, so the protein does not escape, but the salt does. This exchange is carried to a point where the meat is again plump and the desirable quantity of salt left in.

Thus, we have, by exposing the meat of fish to salt, removed the water and caused some salt to enter the meat; we have stored the fish; we have then by exposing the fish to water, put water back in the cells and taken out the excess salt. The actual food material of the fish, the cell protein, is still where it was, for practical purposes, unchanged. If every step has been scientifically correct we have at the end very nearly the fresh fish we had to start with. But there is the rub. At every turn it is possible to depart from the scientifically correct.

The principles of osmosis here very briefly stated are the fundamentals of the art of salting fish. They are the starting point for the investigations for which the writer has been responsible. In all that follows there will be frequent occasion to refer to osmosis.

FACTORS AFFECTING PERMEABILITY OF FISH CELLS

The preservation of fish by salt is practiced extensively in the cooler parts of the United States, but very little has been done south of Chesapeake Bay. The reason fish have not been salted in the warmer part of the country is that the process has not been satisfactory. Repeated efforts to salt alewives on the St. Johns river in Florida previous to 1920 uniformly resulted in failure. In 1918 research on this problem was undertaken under the immediate direction of the writer. The results of a part of this program were published this year,* but continuation of the program planned is held up for lack of funds.

The hypotheses which guided this work were somewhat as follows: During the course of "striking through" the fish, two things are happening, (1) the flesh is breaking down by autolysis (a process to be explained later) and (2) the salt is penetrating the flesh. Salt arrests autolysis when it arrives, but con-

*Tressler, D. K. Some Considerations Concerning the Salting of Fish. Report of the U. S. Commissioner of Fisheries for 1919, Appendix IV, 54 pp., 1920, Washington.

siderable damage may be done before the salt has reached the innermost parts of the fish. Now, these two processes, salt penetration and autolysis, are runing a race, so to say; if the salt penetrates to the innermost parts before autolysis has destroyed them, the salt wins the race, and the fish is saved; if, before the salt can get to the innermost parts, they have been decomposed by autolysis to an intolerable degree, then autolysis wins and the fish spoils. High temperatures accelerate both processes but while accurate measurements have not been made, we know by practical experience that at high temperatures spoilage is increased much more than penetration of salt, so that at a sufficiently elevated temperature the fish will invariably spoil. Now, to make certain that the race mentioned shall always be won by the salt, we may do one of two things, viz., retard the rate of decomposition or accelerate the penetration of salt. Working at a lower temperature is the only practicable means of retarding decomposition, but since we desire a method suitable for warm climates it is necessary to accelerate penetration of salt. How can the salt be caused to penetrate fish more rapidly?

The physiologists have shown that in living animals salts of calcium, barium and magnesium have a marked effect in retarding or arresting penetration of membranes. By examination of numerous analyses of commercial brands of salt it was found that the salts of calcium and magnesium are those nearly always present as impurities. A few of these analyses are given herewith, as reported by Tressler and others.

Analysis of Various Salts for Curing Fish

Determinations	Turks Island salt	Trapani Italian salt	Iviza Spanish salt	Diamond Flake Domestic salt
	Per cent	*Per cent*	*Per cent*	*Per cent*
Sodium chloride (salt)	96.52	95.82	98.05	99.78
Calcium chloride . . .	....	.32	.49	....
Calcium sulphate . . .	1.53	....	....	.37
Magnesium chloride. .	1.20	1.19	....	.00
Magnesium sulphate. .	.80	1.75	.80	.00
Sand, etc.	.13	.15	.06	.00

By appropriate methods of measuring the rate of penetration of salt into fish it was found that if absolutely pure salt is used, a very rapid penetration is obtained but even small additions of from ½ to 5 per cent of these salts of calcium and magnesium cause a very pronounced retardation of penetration. In order to bring about a much more rapid penetration of the tissues, then, we have but to obtain a salt free from these impurities. The time gained by the use of pure salt enables fish to be salted at a much higher temperature and yet not spoil. Fish were salted in an incubator room in Washington last January at a temperature of 90° F. at first, rising to 100° F.—the hottest summer weather. No unpleasant odor developed, and the fish, upon being cooked and eaten, were pronounced excellent.

There was a further and somewhat unexpected difference between the effects of pure and impure salts. The flesh of the fish salted by impure salt is white, opaque, or chalky in appearance, and much harder or firmer in consistency; that of fish salted with pure salt is translucent and somewhat yellowish and much softer. While the former white, firm, fish is the customary quality demanded in commerce, there are strong reasons for believing the softer and yellowish fish produced in pure salt to be superior. There is reason for believing that the whitening of the fish in impure salt is explained by the fact that the calcium coagulates the protein, just as heat, by coagulating egg white, causes it to be white and firm. But where there is no calcium in the salt, the protein retains its natural translucency and yellowish color. The calcium in impure salt is retained by the fish, a matter that will be discussed later under the subdivision on flavor of salted fish.

At this point, mention should be made of another effect of salt upon the protein constituents of fish. Strong solutions of salt precipitate certain protein substances, different substances falling out successively from a mixture of dissolved proteins as the concentration of salt is increased. The nature of the proteins is not altered by this precipitation, for upon replacement of the salt solution with fresh water the proteins redissolve and appear to be restored to their original condition. Salt thus causes a temporary precipitation or fixation of proteins in fish, to a certain extent hardening the tissues, and reducing the likelihood of changing.

Not only does quite pure salt penetrate the fish more rapidly, but when the time comes to cook the fish it is found to soak out more rapidly also. Practical experiments in the experimental kitchen of the Bureau of Fisheries indicates that fish preserved in very pure salt soak out in from a third to a half the time required by fish preserved in crude salt.

What is the practical lesson of this work? It shows that by the judicious selections of salt, not on the basis of its cheapness, but on the basis of composition, one can produce a salt fish of almost any desired quality. If salting is to be done in very warm weather, it will be necessary to use the purest grade of salt to secure very rapid penetration. In this way a soft yellowish fish of excellent quality is obtained. Where weather is cool enough to permit, a salt containing more calcium and magnesium may be used, in which case a whiter and firmer fish will be produced.

Can these very pure salts be obtained commercially? Several brands of salt of the highest degree of purity are available both on the east and west coasts and at a cost not much above the price of cruder salt. In many cases the single item of fish saved, that might otherwise spoil, will repay the extra cost of pure salt, to say nothing of the improvement in quality of the salt fish.

FLAVORS OF SALT FISH

The calcium and magnesium are taken up by the protein in the cells and held, not coming out when the fish is soaked. Now these impurities, particularly calcium, have an acrid taste, and greatly accentuate the "saltiness" of salt. Pure salt is not as "salty" as crude salt. If the calcium is held by the tissues at the time of soaking out, while the salt is removed, then after soaking there is a much greater amount of calcium present in proportion to the amount of sodium than there was in the original salt, and a correspondingly more acrid "salty" taste. It is therefore necessary to soak out fish much longer, or until they are "flat" if they have been cured with crude salt, while with pure salt they may be soaked out until they suit the taste, after which they retain their original flavor.

Certain improvements in the flavor of fish have been noted after they have been salted by improved methods. The fish variously known as mud shad or gizzard shad (*Dorosoma cepedianum*) is plentiful in certain parts of the country, but held in very low esteem because of its muddy, unpleasant flavor. After being washed free from blood and salted in pure salt, this unpleasant flavor disappeared, and the fish compared very favorably with fish commonly more esteemed. The muddy taste of the carp and other fish from muddy ponds and streams is believed by some to be caused by species of Oscillatoria, a blue-green alga growing in the slime of the fish; by others it is believed to be humic acid derived from the mud. Perhaps the two views could be entirely reconciled; but the actual chemical compound or compounds responsible for the unpleasant flavor seems to be removed by the brine.

If this lead were followed in detail it is quite possible that salting would turn out to be the best method of utilizing fishes that are of a rather poor edible quality when in the fresh condition. This aspect of the matter deserves particular attention of the canners. Many species of fish of great abundance could be profitably packed if the flavor were inviting. With highly improved technique in salting, the undesirable flavors might be removed by curing and soaking out before canning. This process would be unthinkable on the basis of the customary salting methods where there is in the end an excessive saltiness or flatness of flavor, but the mild, sweet fish prepared by improved technique and pure salt is a much more promising possibility for canning.

DRY SALTING AND BRINE SALTING COMPARED

The next question taken up in the investigations referred to was that of the relative merits of the application of the salt to fish in the dry state and as a concentrated brine. In the Chesapeake Bay region the herring are usually pickled in brine. By a strict comparison of the two methods it was found that there is developed a smaller quantity of the products of decomposition, the amino acids, when the salt is applied dry. Not only this, but it was also found that salt applied in the dry condition penetrates the fish more rapidly.

Among the products of protein decomposition are amino acids. A determination of amino acid nitrogen was taken as a measure of decomposition—the more the amino acids the greater the amount of decomposition. This being true, the following table, summarized from Tressler's results, will show the superiority of dry salt over strong brine for preserving fish.

AMOUNTS OF AMINO ACID NITROGEN FORMED PER KILOGRAM OF FISH AT DIFFERENT TEMPERATURES

Method of salting	Temperature ° F.	Amount of amino acid per kilogram of fish after—					Condition at end of salting period
		19 hrs.	67 hrs.	5 days	7 days	9 days	
		Grams	*Grams*	*Grams*	*Grams*	*Grams*	
Dry salted .	63	0.078	0.083	0.085	0.085	0.119	Good
Brine salted	63	.089	.129	.135	.183	.234	"
Dry salted .	70	.084	.086	.098	.097	.126	"
Brine salted..	70	.100	.165	.158	.190	.292	"
Dry salted .	75.5	.077	.092	.099	.104	.134	Fair
Brine salted..	75.5	.102	.186	.179	.228	.316	"
Dry salted .	80	.074	.086	.119	.141	.158	"
Brine salted..	80	.086	.189	.210	.300	.383	Spoiled
Dry salted .	87	.076	.089	.159	.195	.208	"
Brine salted..	87	.097	.244	.266	.377	.510	"
Dry salted .	93	.065	.105	.151	.193	.236	"
Brine salted..	93	.080	.238	.320	.465	.666	"

It is seen that the brine salted fish consistently undergo a greater decomposition than those salted with dry salt, as shown by the abundance of decomposition products, amino acid nitrogen. The average excess of amino acid nitrogen in the six lots pickled in brine over the six lots in dry salt is 51 per cent, a very material difference. It will be noticed in the last column of the table that spoiling of fish pickled in brine takes place at a lower temperature than it does in dry salt. Fish were satisfactorily salted in dry salt at 80° F., but at this temperature fish pickled in brine spoiled.

To complete the evidence in favor of using dry salt the following table in substance from the same paper shows the rate of penetration of salt into squeteague when applied dry in comparison with brine:

PENETRATION OF SALT

Method of salting	Section of fish	Percentage chlorine in dry sample after—			
		1 day	4 days	7 days	10 days
Dry salted....	Outer layer, from surface to a depth of ½ cm. . . .	9.8	16.2	19.6	19.5
Dry salted....	Inner layer, from ½ to 1 cm. below surface.	2.6	11.0	16.0	18.7
Brine salted..	Outer layer, as above	1.8	15.3	17.3	17.8
Brine salted..	Inner layer, as above	8.4	8.3	12.2	15.7

What is the reason for the superiority of dry salt over strong brine or pickle, especially since the dry salt very shortly forms its own pickle? In answer to this question it is necessary to refer to the principles of osmosis. It was shown that the flow of water is from the less concentrated to the more concentrated. The relative concentrations govern the direction of flow and also the rate or quantity of flow. Salt is going into the cell and water coming out. If brine is used, it is losing some of its salt which penetrates the cells, and is being diluted with water which is coming out. This process rapidly brings the contents of the cells into equilibrium with the brine, that is, with the film of brine immediately in contact with the fish. Stirring, as usually done, may cause a momentary increase of penetration by removing the film of dilute brine adjacent to the fish, but we may imagine that a new dilute film forms again very rapidly. If, instead of brine, dry salt is placed in contact with the fish, very material differences are at once apparent. Part of the salt, dissolving in the free moisture, forms strong brine which begins its extraction of water from the cell. The water coming from the cell is not able to dilute the adjacent brine, because some of the excess of dry salt present immediately dissolves and thus assures saturated brine at all times. It should also be obvious that since the very purpose of using salt on fish is to extract water, the addition of water to begin with simply supplies just so much water to the salt and satisfies the affinity of salt for water to that extent. The water should come from the fish and not elsewhere.

To put the conclusions from this section of the paper into words, when salt is applied dry to the fish, there is a more rapid penetration of salt, less decomposition of fish, and it is possible to preserve fish at a higher temperature; the superiority of dry salt over brine resides in the fact that the brine in contact with the fish is not permitted to be diluted when salt is present in crystalline condition.

OTHER FACTORS THAT AFFECT PERMEABILITY

While no investigations appear to have been made on the influence of temperature on the permeability of fish flesh, investigations have been made on a great variety of other living things, so that it is probably safe to generalize cautiously regarding such influences on fish. Osmotic pressure varies, approximately, as absolute temperature.* That is, if we double absolute temperature, osmotic pressure is doubled, other factors being held constant. The range from freezing to 100° F. within which fish salting is usually done is, on the absolute scale, rather narrow (491.4° to 559.4° A.), so the maximum variation due to this cause would be about 14 per cent. It is, however, a common experience in pickling fish that the warmer the tem-

*Absolute temperature is based on absolute zero, the point of no heat, or absolute cold, which is — 273° C. or — 459.4° F. If we use degrees the same size as Fahrenheit's degrees, then 0° F. is 459.4 absolute; 50° F. is 459.4 + 50 = 509.4 absolute, etc.

perature, the more rapid the striking through, a difference too great to be accounted for by temperature variations of osmotic pressure. The cell-membrane itself must change. Whether any more free permeability caused by warm temperature is permanent after the fish is chilled again is not known, but the question would be well worth investigating. Cold, when in the neighborhood of freezing, also promotes permeability, as has been proved by various experiments. It is quite possible that fish chilled to a point near freezing would strike through much more quickly than fish at the customary warmer temperature. This matter also should be investigated.

Stale fish, i. e., fish whose cell-membranes have died, are more permeable than fresh fish. The past spring some fish were held in the laboratory all day at a temperature of about 75° F., and toward night were salted in pure salt and put in an incubator at 100° F. By the next day they were struck through. The combination of stale fish, high temperature, and pure salt brought about extraordinarily rapid penetration.

LOSS BY FISH OF NUTRIENTS IN BRINE

The liquid that comes from fish during the salting process is not pure water, as every fisherman knows, but contains a quantity of material derived from the fish. Most of the nitrogenous matter found in brine represents just so much good food gone to waste, and just so many pounds of fish that might fetch a good price gone overboard. The quantity of protein that escapes into the brine is highly variable, for reasons that will appear later. That some idea may be had of the magnitude of the loss of fish substance in brine, the following figures are given; these figures were obtained in the course of investigation on the recovery of valuable materials from old brine.

Loss by Fish of Nutrient Materials in Brine

Brine	Grams dry protein per liter of brine	Avoirdupois ounces per gallon
Rockfish brine from Alaska.......	29.30	3.9
Herring brine from Gloucester...	34.80	9.8
Cod brine from Gloucester........	73.30	4.6

Since all the nitrogen in the brine was calculated as protein, these figures are undoubtedly too high, but the bulk of the nitrogen is certainly of protein origin, so the figures may be taken to illustrate the point made. If we assume fresh fish to be 75 per cent water and 25 per cent dry protein, the figures show the equivalent amount of food fish flesh dissolved in brine to be 15.6, 39.2 and 18.4 ounces, respectively, or from 1 to 2½ pounds to the gallon of brine. Bitting* calculated the losses in the curing of codfish as follows: Loss of weight in dressing, 40 per cent; loss in salting, 40 per cent of what remained after dressing; drying on flakes, 9 per cent of the salted fish. The 40 per cent of the dressed fish contains much protein or valuable nitrogenous food. It would certainly seem to be worth our while to examine into the causes of this loss and to prevent or salvage it if possible.

How does this protein get out of the fish? It was said above that protein is a colloid, and that colloids do not diffuse through membranes. A small amount must come from the blood, and from the cut surfaces on the fish, but most of it will probably be found to come from the interior cells by a process not yet investigated. We do know something directly about autolysis, however, the great enemy of the fish dealer, which liquifies the contents of fish flesh, and we have every reason to believe that if autolysis were stopped the losses of protein into brine would be reduced to a minimum. What is autolysis, and how does it do its damage?

Protein, the colloid, cannot pass through an osmotic membrane. But proteins can be decomposed into simpler substances which readily dissolve and pass through. The agency which breaks protein down into these simpler substances is called an enzyme, and protein must always be so liquified or digested by enzymes before it can be absorbed through membranes. Hence the necessity of digestion in the stomach of animals preparatory to absorption through the intestines. Now animals, includ-

*Bitting, A. W. Preparation of Cod and Other Salt Fish for Market. U. S. Department of Agriculture, Bureau of Chemistry, Bulletin No. 133, 63 pp., 1911, Washington.

ing fish, require a certain amount of new protein to support body activities which failing, the animal would immediately perish. But the hazards in the existence of any animal often make it obligatory to do without food for a shorter or longer period. If the stomach became empty because of temporary shortage of food or an injured mouth, the animal would die unless special provision were made to supply protein from some other source. But nature has kindly provided a means whereby the proteins in the less important parts of the body can be used, for the time being, to support the activities of the absolutely necessary vital parts. The stored protein is within cells, and could not possibly be carried by the blood stream to the point of need unless it could get out. So there is in each cell stored along with the protein some enzyme ready in case of threatened starvation to break the protein down into simpler substances which penetrate outward into the blood for transportation to the point of need. The writer, in certain experimental work, kept some pigfish (*Orthopristis chrysopterus*) for three months absolutely without food. They lived at the expense of their own bodies, the proteins apparently being digested by autolytic enzymes.

These enzymes, present in every part of the fish, while almost an absolute necessity to the living fish, become the greatest enemy of the dead fish, for they soften and liquefy the cell contents, cause unpleasant tastes and odors, and permit the contents to escape from the cell into brine. The proteins could not escape as long as they were proteins, but when they are broken down by autolysis into simpler substances the latter rapidly diffuse into the brine and are lost. This, at least, is the hypothesis supported by some facts.

What factors promote autolysis, and what factors oppose it? Warm temperatures promote it directly. A temperature sufficiently high to destroy the enzyme stops it. Low temperatures retard it directly.

If cells are ruptured as they often are by rough handling of the fish, autolysis rapidly decomposes the protein; and for this reason every bruise received by the fish during capture and subsequent handling results in the loss of so much protein during salting. A bruise on a fish has about the same effect as does a bruise on an apple, promoting rapid decomposition. The writer is of the opinion that if the bruised fish turned brown as the bruised apple does, the fisherman and packer would be more careful in the handling of their fish.

Factors that increase permeability of membranes seem to promote autolysis; low temperatures seem to increase the permeability of the cells so that fish that have been chilled decompose more rapidly on being warmed than fish that have never been chilled, though as long as the fish remains on ice the low temperature may prevent the enzymes from doing their work. It is as if increased permeability increases the escape of the enzymes, and that once escaped they play havoc if temperature conditions are allowed to become favorable. The optimum temperature for autolytic activity is about human body temperature, 98° F. The autolytic enzymes act under a slightly acid condition; in neutral or alkaline medium they act very little, if at all. It has been noticed by various investigators that autolysis does not begin until 2 to 4 hours after death. During rigor mortis there is a decided development of acid that may very materially promote autolysis. It may therefore be that salting fish imediately after capture would strike through the fish before autolysis gains any headway. It may be possible, also, to take advantage of the removal of soluble products by brine in the salvaging of fish on the point of spoiling. Fish that have been held a long time are soft and of a disagreeable odor, because autolysis and possibly some bacteria, have decomposed the tissues to some extent.

One might reasonably expect research to show that if rapid penetration is secured by means of pure salt, the amino acids and other sour or disagreeable substances in stale fish resulting from autolysis would be removed by changing brine a few times, leaving the fish in a condition quite wholesome and fit for food. It is, of course, not intended here to encourage the practice of holding fish until they are bad, and then salting them, but it is recognized that it is in the public interest neither to destroy food that can be used, nor to market fish unfit for food, and it is recognized as legitimate and desirable to develop a means of saving fish wherever they have, through the unavoidable exigencies of the fishing business, come near to spoiling.

It would not be profitable to present this complicated subject any further here. Enough has been said to show that the loss in salting fish, by solution of protein in brine, is very great; some discussion has been presented which will serve to show that losses of this kind are preventable, and the probable direction in which the remedy for this great loss will be found, and also, let us hope, to assist in convincing the skeptics that scientific work on this aspect of the salting process would be worth while. It is of the greatest importance that research work be undertaken for the purpose of discovering the conditions under which the cell proteins are digested and pass out, and for ascertaining the conditions under which these processes may be arrested. Specifically, such questions as follow should be answered: Once the permeability of cells has been increased by abnormally high or low temperature, does this increased permeability persist after a normal temperature has been restored? When autolysis is set in action by a bruise, do autolytic enzymes affect only the part bruised, or do they escape and attack the uninjured cells, destroying them also? To what extent does the acid of rigor mortis accelerate autolysis and can this acceleration be prevented by early application of salt? To what extent is loss of soluble material in brine due to rough handling, and to what extent to other factors? Can advantage safely be taken of the removal of products of protein decomposition by brine to salvage fish that are on the point of spoiling?

INFLUENCE OF METHOD OF CLEANING FISH ON SALTING

In the various processes of salting or pickling fish, the fish receive no preliminary treatment, or may be gibbed, beheaded, split through belly, split through back, or cleaned perfectly by being cut open, scraped and washed before the salt is applied. By what criteria can we judge the merits of these various methods? The best way to answer this question is: Other conditions being held constant, which method or methods of cleaning result in least decomposition during the salting process?

A series of trials was made by cleaning the fish by the various methods and salting them by the same process and determining the amounts of amino acid nitrogen developed. Two sets complete were tried, one consisting of one sample each cleaned by the various methods and held at a temperature of 79° F. during the salting process; another set similar to the preceding but held at 80° F. during the salting process. Both temperatures are high for salting fish, and the test is correspondingly severe. The results are shown in the following table which is abbreviated from the paper by Tressler:

Development of Amino Acid Nitrogen in Fish Cleaned in Various Ways

[Fish salted 4 hours after capture, with Diamond Flake Salt, containing 99.78 per cent sodium chloride; salting period 9 days]

Method of cleaning	Average temperature of salting	Amino acid nitrogen formed during salting period per kilo of fresh fish	Condition of fish at end of period
	°F	*Grams*	
No cleaning, salted round	79	0.77	Badly spoiled, bloated
Pipped	79	.63	Spoiled
Head cut off, abdominal cavity split open, viscera, except milt and roe, removed	79	.68	Spoiled
Cleaned perfectly, milt and roe removed, kidney and and membranes scraped and all blood washed out	79	.37	Excellent condition
No cleaning, salted round	88	1.12	Badly spoiled, bloated
Pipped	88	.76	Badly spoiled
Head cut off, abdominal cavity split open, viscera, except milt and roe, removed	88	.82	Badly spoiled
Cleaned perfectly, milt and roe removed, kidney and and membranes scraped and all blood washed out	88	.47	Excellent condition

Since amino acid nitrogen indicates decomposition, the conclusions from this table are entirely obvious: Only those fish were successfully salted at temperatures of 79° and 88° which had been thoroughly cleaned and from which all blood had been removed. While these high temperatures were chosen for the test because severe tests bring out differences in a more striking way, the differences will still exist even at lower temperatures and manifest themselves in the poorer or better quality of product. Now it may be either the blood or flesh or both in which the decomposition takes place. Since the perfectly clean fish decompose only slightly in may be that only the blood decomposed in such cases as those given in the table, and the decomposed blood pervading the otherwise sound tissue gives the appearance and odor of decomposition to the whole fish. On the other hand, it is possible that the enzymes in the blood when present, operate to decompose not only the blood proteins, but the tissue proteins also. However this may be, the indisputable fact remains that if fish are to be salted in very warm weather, it is absolutely obligatory that the blood be removed. The blood cannot be removed by mere eviscerating and rinsing in water. The kidney, a very bloody organ inclosed by a membrane against the backbone, must be scraped out before the fish is washed. If fish are cleaned in this manner, and salt of a very pure quality be applied in the dry condition, it is astonishing not only what severe temperatures it will stand, but also how excellent it is when cooked.

IMPROVED METHOD OF SALTING FISH ESPECIALLY FOR WARM WEATHER

Several factors have now been shown to have a marked influence on the quality of fish pickled in salt, namely, care in handling before salting to prevent bruises, use of salt free from calcium and magnesium (less than one per cent total impurity), packing in dry salt, and thorough cleaning and removal of kidney and blood. By combining all these factors into one method, highly satisfactory results under the most adverse conditions have been obtained.

A trial of the method was made in the herring season of 1920 (March, April and May), on the St. Johns River, Florida. This region was selected because it offered a combination of the conditions sought. The climate is excessively warm and there is an abundance of fish (alewives) adapted to preservation by pickling in a region where an industry might well be built up and where repeated efforts to salt fish in the past had failed. Accordingly, local fishermen and dealers were interested to cooperate in the undertaking and an experienced fish packer from the Chesapeake Bay region was sent to Florida, after he had been thoroughly instructed in the technology of salting, to try the method on a small commercial scale.

The details as conveyed to the fishermen for handling the fish were: (1) Avoid (a) bruising in removal from gill nets, (b) walking on, and (c) piling deep in boats; (2) salt as soon as possible; (3) wash and scale in cold water; (4) behead and eviscerate and (a) scrape out kidney or (b) split nearly through to the back and lay open; (5) wash in weak brine to remove all traces of blood; (6) rub with fine salt of a high degree of purity and pack backs down in a barrel, leaving fish lightly covered to form their own brine; (7) after struck through pack down and add other fish of the same lot to fill barrel; and (8) in conclusion (a) head up barrel and pour saturated brine into bunghole to cover fish for storage, or (b) if to be sold for consumption at once, "corn" them by taking out of the brine and rubbing in fine dry salt, then pack in sugar barrels or other light containers and ship immediately.

The results fully justified expectations in every way. The fish were preserved successfully and none that had been handled in the prescribed way spoiled. They were pronounced in eating qualities as good as or better than the best commercial salt herring from the Chesapeake Bay region. In order to test the absolute necessity of the prescribed methods, other small batches were put up in different ways, by using cheaper salt, leaving roes in, and such modifications. These trials were failures without exception. The Bureau of Fisheries has been advised that plans are being made by those who received the instructions to pack fish in carload lots by this method next season.

The successes and failures under these extremely adverse conditions tell us much about what could be expected under more favorable conditions. What succeeds under severe conditions will be a finer product under more favorable conditions, and what spoils under severe conditions will be an inferior product under conditions in which it does not actually spoil.

It should be noted that the product prepared by this method is mild and sweet, approaching very closely fresh fish in eating qualities, if it has been properly soaked out.

SCOTCH CURED HERRING

The discussion in this paper so far presupposes the desirability of preserving, as far as possible, the flavor and eating qualities of fresh fish. The Scotch cure does not involve this supposition, but aims directly at giving the cured fish a new and distinct flavor from partly decomposed or fermented blood, the purpose being the same as that governing the flavoring of cheese by ripening. The blood is not removed, the fish rather being allowed to cure in its own blood pickle, a distinctive flavor thereby being imparted. They are gibbed, rubbed with dry, fine salt and packed, more fish being added to make up for shrinkage, and shipped or stored in the original blood pickle. The method is suitable for cold but not for warm climates. Since, however, Scotch cured herring come in a special class of fermented products where different motives and processes are concerned, the method will not be further discussed here.

BEHAVIOR OF FAT DURING SALTING PROCESS

So far in this paper discussion has been limited to the behavior of the protein or meat constituents of fish. It will be found that fat is also of the greatest importance, and requires very careful consideration and study. All fishes have some fat, but the quantity is variable from species to species, between individuals of the same species, and within a single individual from season to season. The distribution of fat is also different in different species of fish. Some fishes, such as herring, salmon and alewives, contain fat well distributed throughout the body tissues. In others, such as cod and haddock, the fat is localized in some particular part of the body, as, in the species mentioned, the oil is contained in the liver, the flesh being almost entirely destitute of oil. For reasons that will be set forth later, fat fish must not be exposed to the air because of untoward changes that air causes in the fat; but no harm is done to the protein constituents. Therefore fish which do not contain fat may be dried in air after they are salted.

In practice these differences are well recognized. In the case of cod and haddock, in which the muscle tissue is free from fat, the greater part of free water is extracted in the usual way by salt, later assisted by the pressure of piles or kenches in which the lower layers are pressed by the weight of the upper layers in the kench, and finally by drying out-of-doors or in artificial drying tunnels. Fish prepared by this method are packed and shipped in the dry state, with advantages in saving of freight and simpler handling in general. In the case of mackerel and herring, and such other fishes as have fat muscle tissue, the fish must at all times be carefully excluded from contact with air. If the fish are directly exposed to air for a time, the fish "rust," i. e., the fat becomes reddened and rancid, and the value of the fish for food is very greatly impaired. This rusting, especially of salt mackerel, is of immediate and pressing practical importance, for there is a regular waste of a large percentage of mackerel on our northeastern coast for no other cause than rustiness and rancidity. This aspect of the subject has not been investigated to any great extent, but there is just as much reason to expect valuable results to accrue from work on this problem as have accrued from the work already described.

Fats consist of a combination of glycerin with fatty acids. In the absolutely pure state, which is scarcely attainable in fact, they would be colorless, odorless and tasteless. They usually contain a greater or smaller quantity of coloring matter dissolved; under certain conditions the combination, glycerin-fatty acid may be broken down, free glycerin and free fatty acid resulting. Free fatty acid has both taste and odor, in fact, our choicest fishes such as salmon, shad and mackerel, owe much of their peculiarly palatable flavor to the small amount of free fatty acid present. But free fatty acid, on exposure to air and light, readily oxidizes, developing during the process a darker color and an unpleasant odor and taste which we call rancidity. Once fats have become rancid they can never be restored to their original sweetness.

What conditions promote rancidity? First, the fat must be decomposed or "split" into glycerin and free fatty acid. Next it must oxidize. Just as fish contain autolytic enzymes that decompose protein, so they also contain fat-splitting enzymes. These enzymes require moisture and warmth for their activities. Fat that has been removed from the tissue that produced it may be kept, under proper conditions, for a long time, because only a small amount of fat-splitting enzyme goes with the oil, but when the fat is not removed from the original source, all the enzyme is present and available to produce decomposition. So in salt fish the fat is in the presence of moisture and an abundance of enzyme, and the necessary warmth is usually present also, ideal conditions for decomposition. The fat having been split to fatty acid, there are two factors, so far as known, namely, air and light, which promote oxidation.

Some little study has been devoted to the effect of salts, such as sodium chloride and calcium chloride on the splitting of fats, but not enough is known about the effect of these substances in concentration to be of any assistance. Whether or not bruises have the effect in promoting decomposition of fat that they have in promoting decomposition of protein is not known, but would be well worth knowing, and here further investigation is certain to be of value. It is known that much of the fat in living fish is contained within enclosed cells, and that even the fattest fish is not greasy when fresh. But whenever the cells are ruptured by rough handling, decomposition, or whatever cause, the oil escapes and is exposed to all the unfavorable influences of enzymes, moisture, air and light, and the fish has become greasy. Eventually it will become rancid. And further, oil escaped from the fish, being lighter than brine, at once rises to the top of the barrel and is lost as food.

All sorts of possible preventives of rust are practiced or suggested for practice; such things as impermeable barrels, air-proof covering over the liquid, a reducing substance in the brine to absorb the oxygen, cool, dark storage, and the like. There is, of course, much dissolved oxygen in the juice of the fish and in the brine and also considerable amounts of free oxygen occluded in the cavities of the fish to effect considerable rancidity even if all outside air is excluded. This dissolved and occluded air can be removed by a vacuum pump, but has never been tried commercially, so far as the writer is aware. Very little improvement can be expected until the problem has been thoroughly investigated by scientific methods. In the improved technique recommended by the Bureau of Fisheries in Florida, complete covering of the salt fish by brine in tight barrels was specified.

REDDENING OF COD AND HADDOCK

If cod and haddock escape rusting because of lack of fat, they are subject to another enemy perhaps as bad, namely, reddening, by which large quantities of cod and haddock are lost every year. For the past three years work has been conducted by Dr. W. W. Browne under the Division of Scientific Inquiry of the Bureau of Fisheries on the causes of reddening and significant results have been obtained. The cause, in general, has been known for many years to be bacteria; but otherwise little has been known of their origin, or of their peculiarities.

Briefly stated, the results of the work cited are as follows: The bacteria that cause reddening are of two distinct kinds, a spirochæte which in colonies is pale pink, and a bacillus whose colonies are deep red. The two organisms grow in such close harmony that mixed colonies occur which vary in color from pale pink to deep crimson as the proportions of the two organisms present vary. The evidence points to the solar sea salts from the tropical and subtropical seas as the source of the infection. Solar sea salts, both American and foreign, are infected. Mined salts seem to be free from the infection.

Every species of bacteria is acclimated to some particular set of conditions, some of them almost incredible for living things. These red bacteria are accustomed to live and grow either on moist salt or very strong salt solutions. If bacteria are particularly resistant to some condition, as to strong salt in this case, it does not follow that they are likewise resistant to all severe conditions; it is the bacteriologist's business, by studying all the habits and peculiarities of the organism, to discover its weakest point where attack will destroy it. The strongest resistance of these bacteria, that against salt, is also the weakest, for it has been found that water less than 15 per cent saturated destroys them. Thus, the best and simplest remedy for the trouble is clean, fresh water, and plenty of it. Of course, it would be futile to try to stop the reddening of cod as long as every shipment of salt brings new infection, and the butts, floors, buildings and the surroundings at packing plants are heavily infected. The remedy is to clean up the places completely with cold water and live steam, and to abandon imported solar salts. Facts already given indicate also that for other reasons salt free from impurity is better. The results on reddened cod only emphasize this advice.

The research on reddening should not, however, end here. We are, again, dealing with questions of permeability. The bacteria are adjusted to strong salt solutions, that is, the body fluid is of such concentration and their covering membrane is of such partial permeability that when surrounded by strong salt solution they live normally, but when water or weak brine surrounds them, these relations are disturbed and they die. Probably water enters the cell in excessive quantity. It is known that the reddening does not attack fat fish. Perhaps the fat acts directly on the membrane, or indirectly by acting on the calcium and magnesium in the salt, to effect the disturbance.

RECOVERY OF BRINE

Even crude salt now costs considerably more than coal. Yet the fish packers who are usually very careful to economize coal are prodigal in the use of salt. Every hundred pounds of brine that goes overboard contains about twenty-five pounds of salt, to say nothing of the valuable nitrogenous matter that the brine extracted from the fish. Considerable work has been done by the writer and his associates on the development of a process to recover salt and other substances of value from old pickle. A trial plant has been in use and under observation at an important fish packing establishment for over a year, but has not reached a satisfactory stage for publication of details. Brine pure enough for use is recovered, while a substance very rich in nitrogen is yielded as a by-product. This substance in the dry condition is nearly white and friable and contains enough nitrogen to command a handsome price as fertilizer, if suitable for that purpose; but there are other uses of it under consideration for which it may be more valuable. The method being tried recovers brine; for this reason some other method that would produce dry salt may be better. In any event, this promising subject is commended to the chemists and engineers for study; we cannot doubt that a few years will bring forth a complete solution of the problem of recovering things of value from brine that will make us wonder why we ever threw it away.

ACCESSORY AGENTS IN SALTING

Various other chemicals are sometimes used in salt, or along with it for various purposes. Some of these will be briefly discussed.

Saltpeter performs two functions in brine for the preservation of meat, namely, it combines with the red substance of blood, hemoglobin, which is unstable, to form a permanently stable red derivative, nitroso-hemoglobin. By virtue of its oxidizing power it may also oxidize hydrogen sulphide into sulphur dioxide and water, i. e., a very foully odoriferous stuff to a substance which both bleaches and sterilizes. Saltpeter is, however, little used in curing fish, for the red color is undesirable, and hydrogen sulphide is rarely troublesome.

Boric or boracic acid is added to the final application of salt to dried salt cod. This is to prevent reddening. Undoubtedly it does do so, and undoubtedly most of it is removed from the fish when the latter is soaked up before cooking. Nevertheless, the writer is of the opinion that the end of this practice is not distant. Boric acid has long ago been condemned as a food preservative. With the comparatively small amount of scientific investigation that has already been done, we have reason to hope that not only can reddening be prevented, but that by the general refinement and improvement of methods it will become unnecessary to use artificial preservatives to prevent reddening. Of course, it devolves upon the scientists to make good these claims and expectations, but it devolves upon the fish industry to provide the scientists and provide them with means to make good.

A method of promoting the preservation of fish by salt by the aid of sodium hypochlorite along with the salt has been patented. The original idea, it is understood, was to decompose the salt in sea water by electrolysis, sodium hypochlorite being formed. It was claimed that the sodium hypochlorite penetrates faster than ordinary salt. This substance contains some oxygen that may be given off to act as a sterilizing agent; after the oxygen is given off, ordinary salt or sodium chloride remains. What advantages the process possessed are not altogether apparent, for nothing appears to have come of it. It may be said, however, that sodium hypochlorite readily destroys urea, so that this substance might be advantageous in the preservation of grayfish and sharks, but is unstable and must be used as soon as it is made.

OTHER FACTORS

The size and shape of the fish obviously has much to do with the time required for salt to penetrate through. Salt effects no preservation of parts until it reaches them. A thick fish may spoil while a thin fish may be saved; hence the splitting of fish. Other methods of applying the salt to the inner parts of fish may be used, such as a needle syringe whereby the brine is forced into the tissues, and compressed air which is used to force brine into fish after the excess air has been removed from them in vacuo. It should also be possible to insert a needle in the gill arch and with pressure completely irrigate the whole system of arteries and veins of a fish, removing absolutely all the blood at one stroke without cutting the fish.

CONCLUSIONS

The preservation of fish by means of salt is an excellent method, even in the crude inexact manner in which the art has hitherto been practiced. The comparatively small amount of scientific research that has been done on the problems and principles involved has not only justified itself in practice, but furnishes abundant grounds for the expectation that a great deal more of valuable results would follow further work.

It is not mere guessing to say that when advantage is taken of all that is known of improved salting methods, a fish equal in edible qualities to fresh fish for nearly all palates is obtained, for fish so prepared have been cooked and eaten in this laboratory.

There is every reason to expect a good future for the salt fish industry, but progress must be made. Preservation by this method is eminently practicable, simple and reliable for holding and transporting our sea fishes to the inland population.

Scientific research should be encouraged more than ever; it does not do itself, but must be done. Governmental institutions can do something, but unless the industry concerned really uses its influence to see that adequate attention is paid to the problems of the fisheries like this, we may be certain that no one else will do so.

SUMMARY

1. A discussion of the principles involved in the preservation of fish by salt has been presented.

2. Salt possesses no inherently peculiar preserving qualities, but preserves foods by extracting water.

3. The principle by which salt (and other soluble substances) in concentrated solution extracts water is called osmosis. Osmosis is the passage or interchange of liquids and solutions through membranes more or less permeable. The permeability of cell-membranes in fishes is affected by high and low temperatures; the presence in or absence from the salt of certain impurities, notably calcium and magnesium compounds; by the treatment of the fish; and by the staleness of the fish.

4. Calcium and magnesium, in addition to retarding penetration, cause a whitening and hardening of the fish.

5. The flavor of fish is often altered by the salting process. Calcium salts retained in the tissue increase the salty

taste and make necessary a prolonged soaking out. Undesirable flavors of fishes from muddy waters may be removed by salting them.

6. Salt applied dry penetrates the fish more rapidly and effects a quicker cure, with less danger of spoilage in warm weather.

7. There is a very material loss of protein material from fish during the salting process. This material is probably decomposition products ordinarily unable to pass out of the cells, but which are digested by autolysis, an internal destructive process.

8. Autolysis is increased by crushing, bruising, rough handling, pewing, elevated temperatures, low temperatures followed by a rise, and, in general by factors that increase cell permeability. It is retarded or arrested by continued low temperatures, sufficiently high temperatures, and salt.

9. The damage done by autolysis appears to be in large part preventable.

10. Fish containing blood, or otherwise not well cleaned, spoil at a lower temperature than those thoroughly cleaned and freed from blood. Thoroughly cleaned fish may be salted at from 90° to 100° F. if pure salt is used.

11. A method of curing fish embodying the improvements cited was tried in Florida on a small commercial scale with gratifying success. Plans are being made to pack fish next year on a large scale by this method.

12. Scotch cured herring develop a peculiar flavor which is derived from the fermented or otherwise altered blood. This method has for its aim an alteration to suit particular tastes, while other methods of salting discussed aim at the preservation of the fresh qualities of fish.

13. Fats undergo certain changes after the fish is salted, resulting in a condition known as "rusting." Rusting consists of oxidation of fat after the latter has been split into free fatty acids. This splitting is caused by tissue enzymes in

the presence of warmth and moisture. Oxidation is brought about through the agency of light in the presence of water. While rusting causes large losses of fish, the means of preventing it, such as tight barrels, air tight covering, and cool dark storage, are not very satisfactory. The problem demands further investigation.

14. Fishes whose flesh is not fat, and therefore not prone to rust, are subject to damage by reddening. Reddening is caused by two organisms, a spirochæte and a bacillus. They may be destroyed by fresh water or live steam. They originate probably in solar sea salt, and are apparently not found in mined salt, or other purified American salt.

15. Work has been done toward the development of a process for recovery of salt and other valuable materials from brine. There are a number of promising possibilities which should make this an attractive field for chemists and engineers.

16. Certain substances are sometimes used as adjuncts in salting fish. Saltpeter preserves a pink color and neutralizes hydrogen sulphide. Boric acid is used for preserving cod against reddening. Sodium hypochlorite has been proposed as advantageous in conjunction with salt. It may be produced electrolytically from sea water.

17. The size and shape of the fish influences the rate of penetration of salt into it. Certain mechanical methods of forcing brine into large fish may be advantageous.

ADEQUATE FISH INSPECTION: A MEANS TO BETTER FISH FOR THE CONSUMER AND TO INCREASED FISH FOOD CONSUMPTION

By Arthur L. Millett

State Inspector of Fish, Boston, Mass.

It is elemental that good food preserves and protects the health of a nation.

It is fundamental that the better the condition of a food staple the more of that staple will be consumed.

It is a lamentable fact that the consumption of fish in the United States and Canada is pitiably low as compared with England and several other European nations, and this in spite of the fact that the fishing resources of the first two named countries are unrivaled in the world.

Several reasons have been presented for this state of affairs. Inadequate and slow transportation and poor handling of catch are two most frequently brought forward, but the main reason has been generally overlooked —the supplying of only good fish to the consumer.

If the same care were taken with the marketing of fish food as with beef and canned products, the yield of our farms of the sea, lake and river would now be vying for supremacy with land food commodities. Beef and canned vegetable products are subjected to stringent inspection, and the results from the standpoints of health and increased and increasing consumption are apparent to all. If inspection has done this for beef and canned goods, why cannot a proportionate measure of good results be thus obtained for fresh and salt fish foods? It is the contention of this paper that it can.

CANNOT WORK MIRACLES

Fish cannot come out of cold storage in any better condition than it is put in. The sudden cold blast and freezing of fish can work no miracle. Fish in the retail store cannot be expected to be strictly fresh if it is second or third grade when shipped by the wholesaler. Salted fish which was in poor condition when split, salted and boxed will not be "Prime Georges" or "Selected Bank" when it reaches the table for the Friday fish dinner, even though plentifully treated with boracic acid and every bone pulled.

FISH INSPECTION—THE SOLUTION

Inspection which will trace the fish from the time of landing on the wharf until it is wrapped up by the market man is the solution of these "poor fish" troubles. Fish inspection that actually inspects, as is the case with beef and canned goods, will mean that the public will have the opportunity of buying only good fish. With this accomplished, then, and only then, may we look for the per capita consumption of fish here and in Canada to increase and not before. Not until the consumer can secure better fish will fish food consumption increase.

WHAT MASSACHUSETTS IS DOING

The Commonwealth of Massachusetts, the largest fresh and salt-fish producing state in the country, after an investigation of her fisheries business, decided that something must be done if the fresh and frozen-fish industries were to endure; and in 1919 passed a Fish Inspection Law designed to secure better fish to the public and thus increase fish consumption, and to deal severely with those who refuse to live up to the "good fish" requirements of the law.

This new law, which combines health, economic, and anti-profiteering features, has to do basically with furnishing the public with the opportunity of buying only good fish and with knowing exactly what they are buying, and on this is based the assumption that, with this achieved, public confidence in the use of fish as a food staple will be greatly increased, thereby bringing about an increased demand for, and consumption of, Massachusetts-caught fish, to the end that the time-honored one-fish-day-a-week will be relegated to the discard, and that two and even three Fridays may become the rule and not the exception in the food week program of every family.

WILL BRING CONFIDENCE TO FISH-BUYING PUBLIC

If the public can be educated to the fact that in buying its fish dinner it is buying only good fresh or frozen fish and that the dealer is, under the law, not allowed to expose for sale fish unfit for food (as has too often been the case); also that the dealer is obliged by law to indicate to the purchaser just what grade and what species of fish he is buying, all in truthful terms, either by printed signs or word of mouth, it is contended, and it would seem reasonably so, that a state of confidence will be set up in the minds of the buying public with the inevitable result that this same public will buy more fish, and will eat more fish, that the average home will have more fish days, and that fish as a food staple will come into its own.

This is the groundwork of the act to regulate the sale and cold storage of fresh food fish, passed by the Legislature of 1919.

The immediate cause back of this new law was the investigation of the fish industry which was conducted by a special committee of the Legislature. That committee in its report to the Legislature made many recommendations and the outcome of these recommendations is the present act, under which the state inspector of fish operates.

PROTECTS PUBLIC AND HONEST DEALER

It should be emphasized that this new law imposes no hardship. It does, however, protect the public and the honest dealer. Since it will lead to increased consumption of fish, it will be a direct financial benefit to the dealer; and by reason of some of the provisions it cannot fail, it would seem, to make several lines of fish cheaper to the consumer than at the present.

Briefly, the law, which affects both wholesale and retail dealers in fresh and frozen fish and also, in a less degree, dealers in salt fish, provides the following salient points:

All fresh food fish must be divided into three grades before being offered for sale or placed in cold storage. Naturally the first is to be known as "new fish," while the term "offshore fish" will designate the second grade fish. Under the law "fish of the third grade shall include all fish which are suitable for splitting or salting, but are not suitable for sale as fresh fish;" and also, fish of the third grade cannot be sold at retail for food.

Under the law only fish of the first two grades may be placed in cold storage, or offered or exposed for sale at retail for food.

MUST SELL UNDER TRUTHFUL NAMES

The law provides for the designations of fish of the various grades, and also, that only truthful terms shall be used in the designation of the fish offered to the consumer. For the purpose of enforcing the law, regulations have been decided upon whereby with the assistance of a system of invoices and receipts the exact grade and quality of the fish can be truthfully represented and traced way down the list from wholesaler and commission men through the retailer to the buying public. This is one of the prominent features of the regulations under which the act will be enforced.

The dealer has the choice of marking his fish by signs or by truthfully describing it by word of mouth. He must do either one or both of these things. The sections referring to the cold storage of fish are quite stringent, but seem to meet with little or no objection from the cold storage operators. Every concern carrying cold storage fish must have a sign to that effect, and fish which have been in cold storage may not, under the law, in any manner be represented or sold or advertised as fresh fish. The seller must also inform the purchaser, either by sign or word of mouth, whether the fish purchased is fresh or has been frozen. There are other regulations limiting the time cold storage fish may be held by the retailers, and a similar system of checks and invoices is arranged for, as in the case of fresh fish dealers. The regulations, it may be said, are mostly the translation into plain, everyday English of the more technical phrases of the law and also naturally provide ways and means for the enforcement of the law. This, in brief, covers the act and regulations.

During the past four months in a tour of various parts of the state, observing many fish markets and methods of sale, the need of such a law as has been briefly explained here has been strongly evidenced.

HOW FISH ARE MASQUERADED

Considerable quantities of fish which appeared to be below standard have been observed with little or no attempt to distinguish between the grades both as to price and quality. This is more noticeable in markets of the cheaper class than in others. In many types of markets, however, has been seen what at least can be termed evasion of truthful terms; for instance, lowly pollock masqueraded as "Boston Bay Blues," and, in some cases, was baldly and boldly labelled "Bluefish."

Catfish, because of its close affinity to the name of despised dogfish, and its own none too pleasant personal appearance, appears, nicely skinned and steaked, on clean white platters, temptingly marked "Whitefish." Naturally the buyers think it is the whitefish of the Great Lakes. It can be truthfully stated, however, that the catfish is one of the most delicious of all our salt water groundfish.

In some markets Pacific halibut masqueraded as eastern halibut, and Pacific salmon as eastern salmon. There is no question here, in these two cases, as to the quality or fitness for food, but the economic value of the new law is emphasized in that the unlawful substitution means from 5 to 10 cents a pound to the purchaser, the Pacific fish costing the dealer less in both instances.

These few cases are cited merely to show what this law, properly enforced, can do away with, to the benefit, financial and otherwise, of the consumer, and this also without detriment in any way to the honest dealer.

PROGRESS ALREADY MADE

It can be asserted here with assurance that already the new law is proving its worth. A campaign of education throughout the state, acquainting dealers and public with the scope and intent of the new law, has aroused much interest and has been strongly taken up by the press. Many of the leading dealers, particularly among the wholesalers, have shown a splendid readiness to cooperate.

Masquerade titles for fish are being eliminated from the weekly price lists of many large concerns. A smaller amount of number three grade fish is being handled by the splitters and also as a result of this law the great salt fish concerns are already planning to handle little or no third grade fish next season. The importance of this is far reaching.

Pollock, properly labelled, are appearing in the markets and a few days ago there was observed in the show window of a large retail market, where generally the platter of "Whitefish" was wont to appear, a large catfish, head, skin, tail and all, calmly reposing on a cake of ice and actually tagged "Catfish."

It is not claimed that a fish millenium has been reached through this new law, but a good start has been made and conditions are certainly improving. Every state that enacts a similar law is bringing the "better fish—more fish" era nearer to hand.

THE ANSWER TO AN UNSOLVED PROBLEM

This paper does not attempt to discuss whether inspection by national or state agents is preferable or likely to be more effective. An effort has simply been made to show that thorough fish inspection, from the moment of landing down through the various trade and cold storage channels, until the fish reach the hands of the consumer, will accomplish the desired results—a better quality of fish food for the public and increased consumption.

How to supply the consumer with a better grade of fish has been for years and is today one of the greatest unsolved problems of the commercial fisheries world. It has been demonstrated that an overplus can be produced under present conditions, but the goal most necessary to gain is to determine how fish in better eating condition can be offered to the public.

Adequate fish inspection is the solution. With this achieved, will come increased confidence on the part of the buying public and an increased catch will thus not only be taken care of but will be necessary to meet the demand.

Discussion

President Avery: Is there any discussion on this very important paper?

Mr. Millett: This paper was not prepared with any idea of particular merit in itself, but simply to bring to your attention the fact that in the State of Massachusetts, the greatest fresh and salt-fish producing state of our country, steps are being taken in the direction of having all the food fish that goes to the consumer so prepared that it shall be fit for food. On many occasions in the past the consumer has found fish absolutely unfit for food, and that has been the cause of many people not liking fish and not eating fish.

Mr. Marshall McLean, New York, N. Y.: May I ask Mr. Millett if any provision is made for the utilization of third-grade fish? Fish is a commodity which spoils rapidly. Could third-grade fish be manufactured into fertilizers or anything of that kind?

Mr. Millett: Concerns like the Russia Cement Company would take all the third-grade fish they could get for glue and fertilizer. I mention this company because it operates in the vicinity of our city.

Mr. McLean: Is that permissible under the law?

Mr. Millett: Yes, as long as the fish do not get into the markets.

President Avery: Are third-grade fish unfit for consumption?

Mr. Millett: No, they are not; that is the point. The law is very misleading. Third-grade fish are fit for food, but not, of course, as good as the first two grades. I may explain that during the summer, vessels carrying twenty tons of ice, when they should carry sixty, go to the Banks, fill up with fish, and bring them home. These fish are not all fit for the Boston market, though they may be all right if salted, because salt is a preservative. The firms in Gloucester are now making efforts to bring about an arrangement under which they will not accept even third-grade fish for their salting. In other words, they are going to use for their salting the same grades of fish, No. 1 and No. 2, that you buy in the market to eat fresh.

Mr. Geo. D. Pratt, Albany, N. Y.: What is to become of your third-grade fish?

Mr. Millett: When a boat is out three weeks or more, the first two weeks' catch can be salted on the vessel; then the last weeks' catch can be brought home in fresh condition. This would revolutionize the methods of fishing during the hot summer months.

Mr. W. E. Barber, La Crosse, Wis.: Are your fish houses licensed in Massachusetts?

Mr. Millett: No, except to the extent that they were licensed under the Food Administration.

Mr. Barber: The licensing of these institutions is important. It seems to us in Wisconsin that a law licensing these fish-packing intitutions would be most effective in bringing about observance of the law. If they know they will lose their license if they violate the law, they simply will not violate it.

Mr. Geo. A. Lawyer, Washington, D. C.: What classes of fish are denominated "third-grade"?

Mr. Millett: Third-grade fish are simply those that are a little too old to appear on the table. I do not know exactly how to explain it, but they are fish that are not suitable for sale in retail markets. When we catch fish for the markets our vessels go very heavily iced and the fish should arrive in splendid condition. They are really in the pink of condition.

Mr. Lawyer: What percentage of the catch is third-grade?

Mr. Millett: I should say about one-fourth.

Mr. Lawyer: This law will tend to eliminate third-grade fish?

Mr. Millett: Yes, for the table.

Mr. Lawyer: And is that going to help increase the supply of fish?

Mr. Millett: Surely; it is going to make the fisherman take better care of his fish and make shorter trips. More salted fish will also be brought in.

Mr. Lawyer: What I was coming at was this: you will not continue to have third-grade fish. It is going to be made into fertilizers and its value, whatever that may be, as a food product destroyed.

Mr. Millett: When the fishing operation is properly carried on you would not find more than a few thousand pounds of third-grade fish in a 150,000 pound trip. These would naturally go to the fertilizer people.

Professor Prince: I would like to say one word from the Canadian standpoint. I consider this one of the most practical and valuable papers that we have. We have had much extremely valuable material presented, but when it comes down to bed rock it is really, after all, the consuming public that is the ultimate goal in the exploitation of commercial fisheries. A prominent Canadian fish merchant said to me: "I like fish, but if I get a poor fish I do not want to see fish on my table again for another week." Now it is possible to put fish in our markets in the very best condition. I think Mr. Millett's paper really implies that. Of course, you cannot make good fish out of bad; if the fish are not cared for in the first instance they cannot be improved afterwards. Salting may save them but it does not make them better. In many cases the inferiority of fish is due to the fact that when salted they were not in good condition. There is no reason why we in the United States and Canada should not have the very best quality of fish, whether smoked or fresh. Mr. Millett puts everything in a nutshell, and what he has given us will be of great value. In Canada we are taking steps towards improvement in these matters, through our Canned Fish Act, Preserved Fish Act, and so on, and we are trying to bring about more efficient inspection. But of course it will be difficult to achieve the results desired until the fishermen realize the part they must play. In that rests the secret of this whole business.

Mr. Millett: We in Massachusetts feel that we are making a start in this matter. We hope that other states and countries will go ahead and help us out.

Mr. Lawyer: Is it profitable for the fisherman to catch fish for fertilizer?

Mr. Millett: No, we do not catch fish for fertilizer; that is furthest from the mind of any person who is engaged in the fishing business. We catch third-grade fish for splitting and salting.

Mr. Barber: I was amused at the statement in the paper that when catfish were sold as whitefish they had a ready sale. The catfish may be just as edible and just as palatable as whitefish, yet to most people its name is repulsive. Would it not be possible for this Society to change the names of some of our fish? For instance, in our state what is known as the "sheepshead" finds a ready market when sold under the name of "gray bass," whereas if offered for sale under the name of catfish, it could not be sold at all. We have also what we call "dog-fish," a name which has somewhat the same implication as catfish.

Mr. Millett: One of the few occasions on which I differed with my friend Dr. Smith was when he took steps, in connection with his work in the Bureau of Fisheries, to masquerade "dogfish" under the name of "grayfish." I never liked the idea of it.

Mr. Barber: It should not be "dogfish."

Mr. Millett: In the Missouri River, in the Upper Platte and around there, the catch of catfish is something like 27,000,000 pounds a year. What is the need of changing the name from catfish, when 27,000,000 pounds a year are sold under that name?

Mr. Barber: Because it tastes better.

Professor Prince: There is in progress at this very time a conference in Ottawa dealing with the trade names of fishes, and a list is in course of preparation, which may be the subject of consideration by this Society at some future meeting. Many fish which at present bear a grotesque name will appear under some different name. I have in my hand a pamphlet which deals with a fish to be known as "mutton fish." It is the rock-eel, or marine eel-pout and though many people object to it, it is the best fish for table use that I know of. Along our Canadian shores it occurs in quantities, but here and along the shores of the United States it is not yet much used for food. "Mutton fish" is a good name.

FIFTY YEARS OF FISHERY ADMINISTRATION IN CANADA

By Prof. Edward E. Prince

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The Dominion fisheries have been for over fifty years administered by a department, or bureau, of the federal service under a minister, who is an elected Member of Parliament, a member of the cabinet, and holds the portfolio of marine and fisheries.

Federal administration was established by virtue of an act passed by the Imperial Parliament in London, and dated March 29, 1867, and naming "Sea-Coast and Inland Fisheries," as among the subjects within the exclusive legislative authority of the Parliament of Canada, along with twenty-eight other matters coming under that authority. The four Provinces, Nova Scotia, New Brunswick, Ontario and Quebec, had been separate colonies before coming into confederation, and had their separate jurisdictions. As other Provinces, like Prince Edward Island, and British Columbia, came in (until there were at least eleven divisions, nine Provinces and two Territories included in the Dominion) it is easy to understand that rights of property, and of jurisdiction, which had not been fully defined, readily became subjects of legal dispute. From time to time test cases have been tried, and the highest Imperial Court, the Privy Council Judicial Committee in London, has been appealed to and has given many important decisions.

Fisheries Department Created.—The first Minister of Marine and Fisheries was the Hon. Peter Mitchell, a native of New Brunswick, and long a prominent figure in Canadian politics. In his first report, addressed to His Excellency the Right Hon. Sir John Young, Baronet, Governor General of Canada, he says: "No such department had previously existed in any of the Provinces which now form the Dominion, but when the extensive and varied interests, connected with these branches of the public service, were duly considered, it was deemed advisable to create a separate department for their administration, with a member of the Government at its head; but the Canadian act, specifying its organization and scope, passed during the first session of the new Federal Parliament, did not receive His Excellency's assent until May 22nd, and the department did not begin its legal existence until July 1, 1868."

Successive Heads of the Department.—During the period, over fifty years, which has elapsed since that date no less than a dozen distinguished Canadian statesmen have held the fisheries portfolio. Including the present minister, these are and have been: Hon. Peter Mitchell, Hon. Sir Albert Smith, Hon. A. W. MacLelan, Hon. J. C. Pope, Right Hon. Sir George E. Foster, Hon. Sir Charles Hibbert Tupper, Hon. John Costigan, Hon. Sir Louis H. Davies, Hon. J. Sutherland, Hon. Raymond Prefontaine, Hon. L. P. Brodeur, Hon. Rodolphe Lemieux, Hon. J. D. Hazen and Hon. C. C. Ballantyne, the last-named being the present head of the department. Five of these received from the hands of the Sovereign the high honor of knighthood, and in every case it was in recognition of services rendered in connection with the Canadian fisheries. The fisheries have been recognized by the King, as the fathers of confederation recognized them, to be of supreme importance and involving interests of the greatest national and international moment.

Early Conservation Efforts in Nova Scotia and New Brunswick.—Prior to confederation in 1867 the supervision of the fisheries, in the respective areas named, had been in the hands of the United Provinces of Upper and Lower Canada, and administered by the Crown Lands Department, but in Nova Scotia and New Brunswick, a fisheries committee existed which relied much upon advice from outside bodies such as the Provincial Association for the Protection of Inland Fisheries and Game in Nova Scotia (founded in Halifax in 1853), and largely owing its efficiency to officers in the Imperial Forces (army and navy) stationed in Canada, among whom Captain William Chearnley was most prominent and for some years acted as supervisor of fisheries. He had a number of wardens under him, who received 25 pounds per annum under authority of chapter 17 of the Nova Scotia act of 1853. The scheme to frame a complete set of regulations, based on Captain Chearnley's report after an inspection tour in 1853, fell through. The Nova Scotia fisheries act, passed in 1853, providing close seasons, rigorous penalties for violations, appointment of wardens in every county, etc., had proved a failure, and the fisheries committee in 1855 decided to vote no more grants from the public treasury for fishery protection. New Brunswick, as early as 1845, authorized stringent salmon laws in Restigouche County by an act of assembly (8 Victoria, cap. 65), but Dr. M. H. Perley, in a report on the New Brunswick Fisheries (1852), remarked that "these very stringent and salutary provisions * * * are not enforced. In practice the act seems almost a dead letter," he said "and a close time, prohibition of taking and sale of grilse and immature salmon, prevention of the use of the fish spear, and the enforcement of uniform laws in the Province generally are necessary." It is interesting to note that, while salmon and trout claimed first attention, the protection of oysters was also included in early fishery legislation in Prince Edward Island and New Brunswick.

It was realized in New Brunswick that, unless backed up by public opinion, the enforcement of fish and game laws is almost impossible, and in 1851 a series of local fishery societies was started with the aid of a vote of five hundred pounds ($2,500) from the Legislature in Fredericton. Three of these proved most successful in Charlotte County, opposite the coast of Maine, and an annual fishery fair held on Campobello

Island—one of which I attended a few years ago—is the survival of the old fishery society of southern New Brunswick, founded seventy years ago.

Early Fishery Protection in Quebec Province.—In the Province of Quebec, or Lower Canada as it was called, a bill for protecting salmon fisheries was introduced by the Hon. David Price, member for Chicoutimi, and passed by the lower house in Quebec, in 1855 or 1856, but after being approved by the upper house it never proceeded further. Probably the clauses requiring owners of dams to provide fish-passes proved fatal, lumbering being the leading industry in Canada at that time.

Fine salmon waters were very ruthlessly treated by the lumberers, and Mr. Richard Nettle, a venerable and strenuous advocate of fishery protection, whom I remember in the Dominion service twenty years ago in his old age, recorded in 1857 that Mr. Boswell, of Quebec, bought the Seigniory of Jacques Cartier, with the old French rights in order to restore the Jacques Cartier River by salmon culture; but as no protection could be guaranteed by the Government he abandoned the project.

Richard Nettle First Hatches Salmon.—It was the first scheme to hatch salmon artificially in Canada, but Mr. Nettle did not drop the idea of fish culture, and later he procured eggs and hatched salmon in a small hatchery devised by him in Quebec City, after his appointment as Superintendent of Fisheries for Lower Canada, under the Crown Lands Department. Mr. Nettle, who was thus the first man to hatch fish in Canada, had a staff of ten overseers, stationed on the Saguenay, the Godbout, and some Gaspe rivers, and many reports were published by him, the last in 1859, which are still of very great interest. His little work on the salmon fisheries of the St. Lawrence and its tributaries, published in Montreal in 1857, is an interesting but pathetic record, for it shows the barbarous treatment of salmon and trout waters generally, in early days.

Almost every river and stream from Niagara to Labrador abounded with salmon in 1825, he tells us, and while he criticises the Hudson Bay Company for not appreciating the salmon resources, he candidly admits that a "prohibition by the company affords the only present safeguard for the existence of the salmon; * * * were that protection withdrawn," he says, "for one season, without effective means substituted, salmon would be exterminated from our country." Mr. Nettle was himself an energetic and fearless officer, and inflicted fines, under the act of 1855, for violations detected by him during his lengthy tours.

First Fishery Cruiser in Canada.—A vessel was found to be necessary for proper patrol, and as early as the period with which I am dealing a fishery protection schooner, *La Canadienne,* in command of Dr. Pierre Fortin, made inspection trips down the St. Lawrence shores, and even visited the Magdalen Islands, and the waters from the Bay of Chaleurs to New Brunswick and Nova Scotia. Dr. Fortin's reports, and his description of the condition of the salmon, cod, herring, mackerel, seal, and whale fisheries are extremely interesting. In his 1859 reports he tells of ten whaling vessels fitted out at Gaspe, and operating with 200 local whaling men for black whale, i. e., the great Arctic right whale, which has long been extinct, excepting in remote polar waters. He speaks of humpback, sulphur-bottom, and finner whales as plentiful. He was succeeded by Inspector Theophile Tetu in September, 1867.

In the old and rather rare printed reports, issued at this time, the name of Mr. W. F. Whitcher appears as an officer of the Quebec Crown Lands Department, who early paid attention to the fisheries, and was afterwards appointed the first Commissioner of Fisheries at Ottawa. Mr. Whitcher did great service for the fisheries, and was regarded as an able authority and a courageous administrator.

Ontario Laws and Administration 60 Years Ago.—The Ontario waters or Great Lakes fisheries were also the object of attention in these early times, 70 years ago. The first Superintendent of Fisheries in Upper Canada was Mr. John McCuaig, and he seemed to have only one officer under him, Mr. William Gibbard, of Collingwood, who looked after the more westerly waters, Lakes Huron and Superior; they found great difficulty in enforcing what is called in the printed reports the "New fisheries act of 1859."

A system of leases for fishing locations along the Great Lakes was introduced, but in carrying it out much trouble was experienced. Some fishermen occupied the locations without making the required payments, in the hope, the officer reported, that after twenty-one years' possession they would have a title even against the Crown; but many claimed that they had already paid rents to alleged owners, who were supposed to be lessees of the Crown Lands Department, Toronto. Ten families, for example, at Point Pelee, Lake Erie, paid rent for seven years (from 1852) to James Paxton, Amherstburg, who himself rented land at $50 per annum, with the alleged fishing rights. The officer reported that Paxton had not paid the rent and owed the Crown Lands Department $350, or seven years' dues. The officer favored fishery leases to responsible men, because it would have the effect, he thought, "of ridding certain localities of a reckless and lawless class of men who are doing their best to depopulate our waters." Reckless overfishing seemed to have already begun, even when the country was still sparsely settled and virgin forests extended everywhere. We see how lacking in uniformity, and how incomplete was the fishery administration in eastern Canada, now formed of the five Provinces from Ontario to the Atlantic coast.

Federal Fisheries Act, 1868.—A new era commenced at confederation, and on the same day upon which the act received the Vice-Regal signature (May 22, 1868) whereby the Department of Marine and Fisheries was created, the fisheries act also received the necessary assent of the Governor General. The Federal act is entitled "An Act for the Regulation of Fishing and the Protection of Fisheries." Section 24, the last section of chapter 60 in the 31st year of the reign of Her Majesty Queen Victoria, declared that it should be known and cited as the fisheries act. With it was associated chapter 61, 31 Victoria, "An Act respecting Fishing by Foreign Vessels."

Federal Act Incorporated Existing Laws.—The various Provinces had anticipated that federal fishery legislation would probably be based upon much of the existing legislation in Upper and Lower Canada, and in New Brunswick and Nova Scotia. One Nova Scotia authority, Mr. T. F. Knight, in a report on the fisheries approved by the provincial government, said that "Under the act of confederation, the Canadas, New Brunswick and Nova Scotia, the fisheries are consigned to a special bureau, and * * * the assimilation of the laws relating to them will be one of the most delicate tasks the Government will undertake." As a matter of fact, the first federal fisheries act was largely such an assimilation of existing laws, and whole clauses were bodily transferred, and remained there unchanged for nearly twenty years. Many of these local provisions, no doubt suitable enough in early days of colonial settlement, seemed too petty and detailed to stand in a federal act; but most of them still remained in the well-known act of 1886, known as chapter 95, though modified in part by Orders in Council, passed from time to time down to 1906, when chapter 45, revised statutes, supplanted chapter 95 (1886). The statutes of 1910, 1911 and 1912, referring to fisheries need not be dwelt upon, but further changes were embodied in chapter 8, 4-5 King George V (act of 1914), and amending acts of 1917 (chapter 16) and 1918 (chapter 22).

Some Features in First Act.—The twenty-two clauses of the first fishery act contained much that was unwieldy, of an unnecessarily detailed character, and, as already stated, mainly transferred from the early provincial acts. But some parts of the act are so important that a brief reference seems necessary to certain of them: (1) A staff of federal fishery officers, invested with magistrate's powers for the purposes of the fishery act; (2) Federal fishery licenses and leases; (3) close seasons for salmon, whitefish, lake trout, and other important species; (4) provisions for requiring fish-passes, and clear passage for any fish named in the act; (5) prohibition of the capture of the young of any fish named in the act; (6) free passage of fish on Sundays, and prohibition of Sunday fishing; (7) prohibition of pollutions in waters frequented by fish; (8) provision of fish-sanctuaries or fish-reserves; (9) oyster and shellfish fisheries embraced in the act; and (10) Orders in Council amending the act to have the same force as the act itself.

There were some anomalies, such as the provisions which repealed ten existing provincial acts, viz., 29 Victoria cap. 11 (1866), which amended chap. 62 (1859) of Upper and Lower Canada acts; 23 Victoria, cap. 52 (1860), and 26 Victoria, cap. 6 (1863); and Victoria 30 cap. 14 (1867), of the Province of New Brunswick acts, while other provincial acts were to continue in force, viz., 16 Victoria cap. 69 (1853) New Brunswick, and chapters 94 and 95 of the Nova Scotia acts, 28 Vict. cap. 35 (1865), 29 Vict. cap. 35, and cap. 36 (1866), and it was also provided that commissioners or overseers of river fisheries in Nova Scotia, under chapter 103 of the provincial statutes, should continue to exercise authority. One curious clause in the first federal fishery act is rather a conundrum, viz., sub-sec. 3 of Sec. 14 which forbids any one between June 1 and September 30 making a fire in or near any forest or bush, or on any uncultivated land, on the north shore of the St. Lawrence or Gulf from the Saguenay River to Red Island, within the said gulf, whereby the fire spreads to a distance of one arpent. The fine should not exceed $50, and included the responsibility for all damages occasioned by such fire, but licensees or proprietors might burn or cut wood, if not doing any injury to their neighbors. Such a forestry enactment seems out of place in a fishery act. But if incongruous clauses and superfluous and cumbersome sections appear, there are also notable omissions.

Lobster Industry and Other Omissions.—No mention of the lobster is made at all, no prohibition of the use of edible fish for fertilizer purposes, and only a bare reference to whale fishing, in which industry explosives were forbidden; and there is no reference to the great salmon and lobster canning enterprises, which have formed the subject of much necessary later regulation. After I became Commissioner of Fisheries in 1893, the necessity of establishing licenses for lobster fishing and salmon canning seemed to me urgent in order to protect and regulate them; but I found that most of the older departmental officers opposed my suggestions, because canning was not a fishing operation, and lobstering was not "a fishery in law." My reply was: "Make lobstering a fishery in law, demand a lobster fishing permit or license, and bring salmon canning under the act." Many years later, it is hardly necessary for me to say, both these early proposals of mine were embodied in the Canadian fishery laws. During the last twenty-five or thirty years the oyster, lobster, Pacific salmon, and other fisheries, have been the subject of innumerable regulations, chiefly in the form of Orders in Council.

Advantage and Danger of Orders in Council.—An Order in Council is a law passed by the Canadian cabinet without recourse to Parliament, and having the force of an act of Parliament as already pointed out. It is a ready and speedy method of accomplishing legislation, and the fishery act provides that Orders in Council amending parts of the act shall have the force of the statute or act itself. There is a danger perhaps in this procedure, for hasty legislation is not always good legislation, and a statute of Parliament has greater weight and importance in popular estimation, but legislation sanctioned by "The Governor General in Council," to use the correct phrase, saves the time of Parliament and on the whole is a great advantage to the country.

Lobster Regulation Started 1873.—Lobster legislation has been prominent during the last 40 years, the first lobster regulations being enacted by Order in Council in 1873, when three provisions were authorized: viz., (1) Prohibition of spawn lobsters; (2) lobsters under 1½ lbs. weight forbidden; and (3) soft-shell lobsters illegal. The following year (1874) a close time, July and August, was specified, and a nine-inch size limit introduced.

SPECIAL DOMINION REGULATIONS FOR PROVINCES.—Subsequently special codes of fishery regulations for the several Provinces were framed modifying the general provisions of the act to meet local and special conditions, and these have been found more handy and convenient in each Province in the work of enforcing fishery regulations. The first clause (with the exception of the Nova Scotia regulations) always required that a license shall be obtained by any person desiring to fish in such Province.

TOO MANY REGULATIONS.—It must be admitted that this accumulation of legislative enactments, fishery acts, provincial codes of laws, authorized by Dominion special Orders in Council, to meet conditions arising from time to time, forms a rather confusing body of legal provisions; but on the whole these Canadian laws have worked beneficially, and accomplished great things for the fishery resources of the Dominion.

DISPUTED FISHERY RIGHTS, FEDERAL AND PROVINCIAL.—After confederation was accomplished, and especially after British Columbia in 1871, and Prince Edward Island in 1873, and Alberta and Saskatchewan in 1905, were admitted to confederation*, it was felt that the exact limits of fishery rights and prerogatives remained in many respects ill-defined. Some friction was caused, and important cases, such as that of "The Queen *versus* Robertson" on the famous salmon river Miramichi demonstrated the desirability of some authoritative decision on these disputed rights.† In 1892 the

* Manitoba was a Territory incorporated in 1870 in the Dominion.

† According to this decision of the Supreme Court of Canada (in 1882) the Dominion can legislate in regard to all fisheries, but has no power to interfere with or control or grant exclusive fishery leases in any non-navigable river whether the bed or soil be vested in the Crown in right of a Province, or in a private owner holding a title from the Crown.

Quebec Government questioned Dominion rights in respect to inland fisheries, and denied the validity of an eel-fishing lease on the Richelieu River which had been issued from Ottawa. The Dominion Government invited the Quebec Government to agree to a reference to the highest legal tribunal in the British Empire, the Privy Council in London, and to allow the Dominion to issue leases and licenses pending a final decision; but Quebec refused. Various other cases arose, and in 1894 Ontario passed a code of fishery regulations, followed by similar action in British Columbia in 1897, so that the authority of the Dominion was being directly impugned. A reference was made to the Imperial Privy Council in the form of an appeal against the judgment of the Supreme Court of Canada on seventeen points in controversy, which judgment was not acceptable either to the several Provinces, or to the Federal Government, and was not indeed a unanimous decision of the Bench.

IMPORTANT FISHERIES DECISION, 1898.—Setting aside a number of minor points the Imperial Fisheries Judgment, dated July 18, 1898, decided these four important questions:

1. That fisheries jurisdiction, the making of fishery laws in Canada, is vested in the federal government.
2. That property rights in fisheries, and in consequence the issue of leases and licenses, is vested in the several Provinces.
3. That the federal government can impose a tax for revenue purposes on every license fishery issued by the Provinces. (This power might be so exercised as to make provincial licensing a practical impossibility.)
4. That all public harbors, and the fisheries therein, are vested in the Dominion.

DOMINION RETAINS GREAT PROPERTY RIGHTS.—It was admitted, before the Imperial Tribunal, that in such a Province as Nova Scotia all the existing harbors are public harbors,* and as all the mouths of salmon rivers, and probably

*Hon. Mr. Longley declared "Every harbor in Nova Scotia is a public harbor." p. 227; Official Report of Imperial Privy Council Appeal, London, 1899.

every important oyster bed, is in a public harbor, the Dominion possesses vast property rights in the fisheries, and the day may come when wise counsels will prevail, and the present state of uncertainty be removed by the entire fisheries jurisdiction and property rights being finally vested in one authority, viz., the Federal Government. This will do away with all conflict and uncertainty, and be a benefit to the fisheries in every way. The single aim of protection, conservation, and wise regulation (in the interest not of Provinces, or sections of the country, but of the whole Dominion) could then be carried out. The Provinces held the opinion that they could get considerable revenue out of their fisheries, but this is an error, though in British Columbia the license fees did amount to a large sum annually, and as the valuable salmon fisheries were mainly carried on within the limits of rivers rather than in the open sea, the situation was somewhat complicated. A *modus vivendi* was for a time adopted, until a further legal decision was obtained.

Full Dominion Control Desirable in Fisheries.—Whatever uncertainty may exist as to Provincial and Dominion rights, the most desirable consummation is the Federal assumption of all such rights. All friction, and injurious conflict and misunderstanding would disappear, and the sole effort of the Dominion would be to exert every effort to make the fisheries everywhere productive and prosperous. No fair-minded critic, looking dispassionately at the history of fisheries administration in Canada, will deny that the Federal Government did great things for the fisheries for a long period of years. What would have been the fate of the resources of our waters in Canada had no protective efforts been made, is unquestionable. Their extent and value today are due to the federal measures, but they are capable of vast extension, and even decaying fisheries like the oyster industry can be restored if a proper Dominion conservation policy be adopted.

The Services of Prominent Officials Referred to.—Who are the men to whom the preservation of Canada's fisheries are mainly due? I have mentioned the names of the cabinet ministers at the head of the department in successive Governments, most of them deeply interested in the welfare of the fisheries; but the deputy ministers must not be forgotten, though in most instances they were chiefly concerned with marine and shipping matters. William Smith, the first Deputy Minister, was a sturdy and assiduous Scotsman, born in Leith, Scotland, and an imperial customs officer at St. John, N. B., but for nearly thirty years known as "Fishery Smith," or more irreverently as "Fishery Bill," during which long period he was the official head of the Department. Honest John Hardie, who was connected by marriage with the first appointed Minister, Hon. Peter Mitchell, acted for a time on Mr. Smith's retirement. Col. F. F. Gourdeau, Mr. Alexander Johnston, and Mr. G. J. Desbarats, also performed the duties of deputy or executive head, but I must not omit Col. John Tilton, who was Deputy Minister of Fisheries from 1884 to 1892, when the marine branch had its own deputy, and fisheries had a separate deputy, a condition changed when the title of Commissioner of Fisheries was revived, and when I was given the position in October, 1892. Deputy Minister Smith on resuming the title of Deputy Minister of Marine and Fisheries, shared with me much of the administrative work in the Department.

The First Commissioner of Fisheries: W. F. Whitcher.—It is simply mere justice to refer to the great services rendered by such men as Mr. W. F. Whitcher, who held high office for nine years (from 1869 to 1877), and who signed the annual fisheries reports, which also bore the signature of the Minister himself. Mr. Whitcher did an enormous amount of work, and was most untiring in the task of inspecting the fisheries, so that his published reports are of great interest; but his conspectus of the fishery articles in fishery treaties between Britain and the United States concerning Canadian fisheries, printed in 1870, is one of the best summaries available, and is a masterly synopsis of the points in international law involved, and the bearings thereof, and it only covers thirty-one pages. For several years the annual fisheries report was called the "Report of the Commissioner of Fisheries," and signed by him, but there has always appeared an ineradicable tendency for the marine branch to assume precedence over the fisheries in departmental routine, not always to the advantage of the fisheries of the country.

SAMUEL WILMOT—HATCHERY PIONEER.—One prominent Canadian fishery officer merits in this connection very special reference, viz., Mr. Samuel Wilmot, a pioneer fish culturist and fish conservator. He was full of courage and enthusiasm, and even when he was wrong would still fight for his opinions. He had no technical training, but had erected a fish hatchery on his farm near Newcastle, Ontario, and in a report dated December 31, 1878, he speaks of his first hatching efforts as begun in 1865. In 1866 he was appointed an Upper Canada fishery officer, and in 1868, the year after confederation, became an official of the Federal Government. For his earyl serviecs to fis hcutlure he wa sapid $2,000. I n1876, eight years after his first federal appointment, he became the first superintendent of fish breeding in Ottawa, but numerous other fishery duties were given him, and he attended to departmental correspondence, inspected fisheries in various parts of Canada, drafted fishery laws, and was chairman of several fishery commissions, the principal ones being the British Columbia Commission (1892), and the Great Lakes Commission (1893), each of which embodied its evidence and conclusions in bulky blue books, prepared and edited by Mr. Wilmot himself. He represented Canada on important public occasions, such as the Great Fisheries Exhibition in London, 1883, and the Chicago World's Fair in 1893. Many of Mr. Wilmot's reports are of very great interest, such as his Lake Winnipeg and Fraser River (British Columbia) reports, made after his visits of inspection in 1890. The original Lake Ontario hatchery, which was transferred from Mr. Wilmot to the Dominion Government, was followed by others, so that there were in 1875, a series of five equipped and in operation, viz., the Restigouche, Miramichi (in New Brunswick), and the Tadousac (on the Saguenay), and the York (Gaspe) hatcheries in Quebec Province. These had increased, thirty years later to twenty-eight, with eleven subsidiary establishments, which were turning out 1,000,000,000 fry (in 1905), more than half being whitefish and yellow pickerel or wall-eyed pike.

W. H. Venning—An Able Pioneer Inspector.—Of equal importance among these early fishery officials was Mr. W. H. Venning, acting at first as inspector for all the maritime provinces, but later limited to New Brunswick. It is impossible to overestimate the services of Mr. Venning, whose official reports, the first dated October 10, 1867, are full of wise recommendations and reliable information. His son, R. N. Venning was long chief clerk, and later Superintendent of Fisheries, a position he held when he retired some years ago. His services in the Bering Sea negotiations were notable, and he did a variety of work during his forty years in the Government employment.

J. C. Kirkwood and S. P. Bauset.—When the officials of the Crown Lands Department, Quebec and Toronto, moved to Ottawa at confederation, there were included two men who deserve honorable mention, one Mr. J. C. Kirkwood, and the other Mr. Samuel Pierre Bauset. The former was transferred back to Toronto on accepting a provincial government post, but Mr. Bauset remained for a long period as chief clerk of fisheries in Ottawa. He was a perfect encyclopedia of information on fisheries administration and regulation in Canada, was infallible on official precedent and procedure, and possessed of the characteristic vigor and zeal of the typical French Canadian.

Dr. William Wakeham.—It is impossible to mention many who deserve to be recalled in any review of fisheries administration in Canada, but Dr. William Wakeham, the successor of Pierre Fortin and Napoleon Lavoie, ranks among the most efficient and well-informed officers in the service.

and he may be said to have given its deserved repute to the old outside fisheries service. He entered on his official work in 1879, and for 35 years had charge of the most difficult inspector's district in the Dominion, namely, the Gulf of St. Lawrence and Labrador area. He combined patrol duty with a Government physician's work, and the remote fishing communities of Laborador, north Gaspe, and the Magdalen Islands, looked upon the gulf inspector as a benefactor, as much as an arm of the law. He was one of the ablest and most esteemed officers the Canadian Government Service ever possessed. With Dr. Richard Rathbun, of Washington, Dr. Wakeham made a complete survey of the fisheries of the boundary waters from the Bay of Fundy to Puget Sound during the years 1893-1896, under the International Fisheries Convention, and the results were a code of joint regulations. and an exceedingly valuable detailed report. I had the honor of acting as expert adviser with Dr. Wakeham on this international survey, and Dr. Hugh M. Smith, U. S. Commissioner of Fisheries, also joined the Commissioners for a time as expert adviser for the United States. It is worthy of mention that Dr. Wakeham had command of the *Diana* on the well-known Hudson Bay cruise in 1897, and presented a most valuable report on the fisheries, etc., in peri-Arctic waters.

Recent Official Work—Codes of Regulations.—Of my own twenty-eight years' work, as Commissioner of Fisheries for Canada, and of the work of more recently appointed officers I cannot speak, but it fell to me to frame the early drafts of the fishery regulations for British Columbia, to draw up a more complete set of lobster fishery regulations, as well as oyster regulations, and new codes of Manitoba, and Northwest Territory laws, all of which were in the main, embodied in regulations passed by the Government at Ottawa, and most of which were carried out for a long period, until amended in recent years by new codes. The lobster regulations framed by me remained in force with little activities, and I have omitted all reference to a most important

Ministers of the Department to revise the fisheries act, and as International Fisheries Commissioner, appointed under the Fishery Treaty of April 11, 1908, I framed conjointly with my United States colleague, Dr. David Starr Jordan, a system of international regulations, sixty-two in number, which received the sanction of the Parliament of Canada, pending similar action by the United States Congress as called for by the Treaty. The regulations were never conjointly promulgated, and a new international commission has been authorized, which it may be hoped will succeed in securing concurrent action in the fisheries administration of contiguous waters along the international boundary between the United States and Canada.

The Work of Outside Inspectors and Others.—Inspectors Chapman, Hockin, Gilchrist, McNab, etc.—If the inside fisheries staff are responsible largely for the conservation and development of the fishing industries by a wise central administration system, it remained with the outside service, the inspectors, fishery overseers, and others, as their essential duty, to enforce the laws and encourage expansion and conservation. Mention should be made of men like Inspector R. A. Chapman, of Moncton, N. B., for over twenty years a zealous and conscientious officer in New Brunswick; also Inspector Robert Hockin, of Pictou, N. S., an officer of rare knowledge and courage, with a combined scientific instinct and legal acumen which made him a valuable aid to the service for nearly thirty years. He invented the Hockin Fish-Pass which twenty-five years ago was approved by the Government, and many have been constructed on various rivers. Inspector F. C. Gilchrist, Qu'Appelle, had the gigantic task of supervising the vast western area between Manitoba and the Rocky Mountains, and did it marvelously well. In my possession I have a mass of letters and communications of much scientific merit, for he not only enforced the observance by Indians and white men alike, but during his tours made scientific observations and tests in remote lakes and rivers of the west that are of incalculable value. He sacrificed his life when making tests with a new form of net, suitable he thought for the requirements of the Indians, and less wasteful than the devices they used. Exposure in inclement weather, during this work, brought about his death, but from 1885 to 1896 he did splendid service. I should like to mention Inspector Bertram, the able officer who had charge of the Cape Breton fisheries from 1884 until his death in 1909; and I cannot omit Inspector John McNab, New Westminister, British Columbia, under whom in the early "nineties" the vast fisheries of the Pacific Province progressed from small beginnings. He was the only officer who knew the northern waters. I had the privilege of visiting with him in 1894 the Nass River and its tributaries, Work Canal, Prince Rupert, then called Tux Inlet, Metlakahtla, Rivers Inlet, and some of the upper Fraser waters, where I saw vast schools of salmon spawning. John McNab was the only fisheries official (excepting Officer William Roxburgh, a native of Glasgow, Scotland, who knew the Skeena and interior waters), to whom the whole coast, and most of the headwaters, were familiar. McNab was born in Nova Scotia, and was one of the "Forty-Niners" who prospected for gold in the wild northern regions, where his knowledge proved of inestimable value later to the fisheries service. It is impossible to estimate too highly the great work such officers did in the early days of fishery development.

CAPTAIN J. T. WALBRAN.—In much of this valuable work Capt. J. T. Walbran, of the cruiser *Quadra,* gave his skilled aid for many years. Never was there an abler, more scholarly, and enthusiastic departmental official than Walbran. I made several cruises with him along little-visited parts of the Pacific coast, making plankton and bottom catches with naturalist's nets and accumulating much valuable biological and fishery material, and in all my work Captain Walbran was assiduous in his help and advice. He had a distinguished brother, Canon Walbran, of Ripon Cathedral, England. Both brothers had antiquarian and historical tastes of uncommon character, for one wrote on the antiquities of the ancient city of Ripon, and Captain Walbran himself wrote the very best work on Pacific place-names in existence. Dr. G. M. Dawson had done some B. C. plankton work before mine, and that famous scientist generously placed his collection in my hands to describe with my own large collection, but all perished in a fire which devastated the west parliamentary building in 1897.

INSPECTOR LATOUCHE TUPPER.—Inspector R. LaTouche Tupper deserves mention for his splendid work as inspector on Lake Winnipeg and Manitoba waters. In his hospitable home on the Red River, at Selkirk, he had a fine library of works on fish and fisheries, and had remarkable scientific and literary tastes. Captain Dunn, who for many years cruised the Great Lakes, also did courageous and effective work in fisheries conservation. All the officers I have just referred to are now dead; but the Department has on its staff some men of special ability, one of whom I must mention, viz., Mr. John J. Cowie, recognized by all who have any knowledge of Canadian fisheries, as an eminent expert with unrivalled experience and knowledge of fish-curing methods and products. The oyster fisheries owe much to the skill and labor, for nearly thirty years, of Mr. Ernest Kemp, a member of a family prominent in English oyster culture on the famed Whitstable beds for two hundred years. No government service ever possessed abler and more indefatigable men than the officers I have referred to. The fisheries owe more than can be estimated to the valuable work they did in the special lines to which they devoted their lives.

GENERAL SUMMARY OF FEDERAL FISHERY ADMINISTRATION.—Of various branches of activity, such as publicity work, improvement of cured and pickled fish, better government-assisted fish transportation and other efforts, many now in progress, I cannot speak. It must suffice to quote a summarized statement of such activities from a lengthy article of mine, recently published by the London *Times*, in the "Times Book of Canada," which is an expansion of the article

Messrs. Appleton, of New York, asked me to prepare a few years ago for the *Encyclopedia Americana.* This summary gives a slight idea of the varied work, administrative and otherwise, performed by the Fisheries Department, now part of the Marine and Fisheries Department, Ottawa, of which Mr. W. A. Found is Assistant Fisheries Deputy. The more salient features are:

1. The maintenance of a system of leases and licenses, which until the fisheries decision of 1898 the federal government claimed to have the sole right to issue. Certain Provinces now issue licenses, and much doubt exists as to the limits of Dominion and Provincial rights regarding certain licensing and leasing powers, which the judgments of 1898 did not remove.

2. Enforcement of conditions concerning fishing, amount, mesh, etc., of nets and gear, close seasons, dams and other obstructions, pollutions, etc.

3. Fish culture by means of hatcheries, and propagation of fish of commercial importance chiefly, though salmon and game fish are not excluded.

4. Fisheries intelligence bureau, established in 1889, and reporting movements of fish schools off the coast, supplies of bait, etc.

5. Bounties to fishermen derived from an annual Parliamentary vote of $160,000, representing the interest on $4,500,000 paid to Canada by the United States, under the Halifax Award of November 23, 1877.

6. Publicity operations, really a development of the old system of issuing special reports, which afforded information upon leading fishery topics, and the spreading of information among the fishermen and public by lectures and addresses. I have myself in twenty-five years delivered over three hundred addresses and illustrated lectures to Canadian clubs, Empire clubs, boards of trade, fishery conventions, and other public gatherings, in every part of the Dominion from Halifax to Vancouver, and have published numberless articles in vari-

ous journals, including the Canadian Fisherman, New York Fishing Gazette, Pacific Fisherman, Montreal Star, Toronto Globe, American Fisheries Society Transactions, etc. Further development of this propaganda is in progress, and must bring important results. A special publicity branch is now at work.

7. Technical fishery education scheme. This has embraced lectures to fishermen, and practical instruction, the first step being taken at Little River, N. S., in 1913, and the last being courses in 1919-20 under Professor A. P. Knight on "Lobster Life and Conservation," and by Professor A. G. Huntsman and myself in the Maritime Provinces in the spring and fall of 1920 on "Habits and Life-History of Fishes."

8. Fishery exhibits at expositions in Canada and abroad, including Government fish-dinners, as at the Toronto annual exhibition, the issue of fish cook books, circulation of Biological Board fish bulletins on new food fish and other topics of great public interest.

9. Fish-curing and packing instruction by qualified officers, including improvement of methods, barrels, and packages, and general standardization of the packed products.*

10. Commissions of fishery inquiry which, during the last quarter of a century, have numbered more than twenty. The commissioners, usually men prominent in the industry, or well-informed locally, visited the fishing centres, took evidence, and published reports and recommendations for the guidance of the Government. A fishery committee of the House of Commons, and an advisory fishery council, have from time to time aided in a similar way. The published reports of commissions and various committees are a mine of valuable information on the fishing industries.

11. Bait freezers have been established under Government auspices, and fish refrigerators have been subsidized, while a fish-drying house was for a time operated, as an ob-

* Legal authorization of standards, and official inspection, etc., are provided under the recent fish inspection act (1914) and canneries act.

ject lesson, at Souris, Prince Edward Island, and it was demonstrated that curers might be made independent of foggy and damp weather in the dried fish industry.

12. Fish offal and dogfish reduction works have also been operated, but the cost of collecting material over wide areas proved serious, though the grinding and preparation of fertilizers, and the extraction of oil yielded satisfactory products. Loss however resulted each season and the scheme was abandoned.

13. Oyster culture, the restoration of destroyed beds, and the planting of barren areas, have been carried on under an expert, while scientific experiments by the Biological Board have been continued for some years under such recognized authorities as Prof. R. Ramsey Wright, Dr. J. Stafford, Prof. E. W. MacBride, and Prof. A. D. Robertson, London, Ontario. Lobster culture has also been vigorously pursued by Professor Knight with a view of rearing young lobsters on natural resorts, or recently discovered nurseries, rather than by artificial methods in hatcheries.

14. A service of fishery cruisers and patrol boats, enforcing the fishery regulations, has always formed an important part of the work of administration in Canada.

15. A system of state-aided transportation services was inaugurated in 1907. From Canso and Halifax, N. S., a fish car ran to Montreal and Toronto, the earnings for the shippers being guaranteed up to 2,000 lbs., and also the cost of icing. Three cars also were run weekly on which the Government paid one-third express charges for fish. A corresponding service has also been tried from the Pacific coast to the prairies.

16. Last but not least the Federal Government has encouraged scientific fishery research in various ways, notably by establishing, in 1898, the Biological Board of Canada, which has charge of laboratories or research stations, one being at St. Andrews, on the Bay of Fundy, and another, the Pacific station at Departure Bay near Nanaimo, British Columbia. A station on the Great Lakes ceased operations after

some years of useful work. The Board, of which for twenty-one years I have acted in the capacity of chairman, consists of representatives from the principal universities of the Dominion, with some departmental nominees of the Minister, and it has fortunately such independence and freedom that technical researches can be conducted, unhampered by the red-tape of officialdom which is fatal to all enthusiastic and fruitful scientific work.

Arctic and Biological Expeditions.—Other scientific investigations have from time to time been authorized, from the date of the celebrated researches in the Gulf of St. Lawrence by the late Dr. J. F. Whiteaves, within four or five years after confederation. During the years 1914-15 a remarkable series of fishery investigations was carried out under the direction of Dr. Johan Hjort, formerly Director of Fisheries for Norway. With the aid of two fishery cruisers, *Princess* and *Acadia,* and some subsidiary vessels, and with the help of a fine staff of scientists, Dr. Hjort was able to present a volume of reports at the close of his two years' work on the fish-life, plankton, hydrographic, physical, and dynamical features of the Gulf of St. Lawrence waters, of the highest scientific value. There have been various expeditions to Hudson Bay, the first under Capt. A. R. Gordon, R. N., in 1884, and later expeditions such as Commander Low's in the *Neptune* in 1884 and 1886, and Dr. Wakeham's expedition and Captain Bernier's in 1906 and 1908-09; all have had most interesting results to report. A Canadian Arctic expedition 1913-18, planned by Mr. Vilhjalmur Stefansson, an Icelandic Canadian born in Manitoba, has been very successful and between sixty and seventy reports on the biology, hydrography, geology, ethnology, etc., of the regions north of the Mackenzie River and Coronation Gulf are in course of publication at the present time.

Conclusion.—Looking over this elaborate program of activities, and I have omitted all reference to a most important branch, viz., statistics of the fisheries, because this work, carried on for fifty-two years by the department, has been recently transferred to the Census Bureau of the Dominion, it is impossible to question the incalculable benefit to the Canadian fisheries which this far-reaching system of protection and conservation has accomplished during more than half a century. Professor G. Brown Goode did simple justice to the wonderful organization inaugurated by the fathers of confederation, when he said at the Great Fisheries Exhibition in London, in 1883, of the Fisheries Department in Ottawa, that "there was nothing elsewhere to be compared to it."

Discussion

President Avery: We are certainly very much indebted to Professor Prince for this very valuable historical paper. I feel that we do not realize the importance of the fisheries of Canada in their relation to the United States. We obtain a great portion of our fish supply from Canada; we are, therefore, directly interested in the development of Canada's fish resources.

Professor Prince: Mr. President and gentlemen, I cannot rise on this occasion without expressing extreme gratification—and I am sure that in this sentiment I am joined by all other Canadians present—at the fact that the American Fisheries Society at last meets in Ottawa. The occasion is all the more interesting because this is the jubilee meeting of the Society, which is now celebrating in the Canadian capital fifty years of valuable and useful existence. I think that this is a unique historic event and one which calls for special reference, particularly on the part of Canadians. I thought that it might interest you to hear something of the succession of events which has led up to the federal system of fisheries administration in Canada,—a system much in contrast with that obtaining in the United States.

WHAT ARE RAINBOW TROUT AND STEELHEAD TROUT?

By Dr. William Converse Kendall

Scientific Assistant, U. S. Bureau of Fisheries

Washington, D. C.

Whenever the trouts of certain localities are studied, difficulties are encountered in an effort to make the specimens conform to the classification. Gilbert refers to the trout and whitefish as "two forms which seem to be superior to any discoverable law of distribution." Gilbert and Evermann again say (1894) that with every additional collection of black spotted trout, it became increasingly difficult to recognize any of the distinctions, specific or subspecific, which had been set up; that their collections added not a little to the difficulty and they were convinced that the greater number of the subspecies of *S. mykiss,* which the common redthroat trout was then called, had no sufficient foundation. On the other hand, in 1896, a comparison of many specimens of *"Salmo mykiss clarkii"* indicated to Evermann and Meek that it would be necessary to recognize more species or varieties of Salmo in the northwestern portion of the United States than have hitherto been admitted.

The specific identity or distinctness of the rainbow and steelhead trouts has been the subject of long discussion and of varied and varying opinions. In 1919 Jordan wrote that on this question he had at different times held different opinions. His final judgment was that the coastwise trout of California are the young of the species which in the sea and large rivers is called steelhead, *Salmo rivularis,* and the original rainbow was therefore the young of *Salmo rivularis,* or as it used to be called, wrongly he believed, *Salmo gairdneri.* "As *irideus* (misspelled *iridia*) is the oldest name," he said, "it must stand."

According to Jordan, then, the technical name of the steelhead trout should be *Salmo irideus.*

It is not my purpose, at the present time, to attempt to straighten out the tangles of taxonomy, but I offer for consideration a theory which appears to be supported by a number of facts and which seems to me to indicate a consistent law of distribution. Also, if usage is reversed and an effort made to make taxonomy conform to the law, the present confusion may be shaped into at least a semblance of orderly arrangement. If the trout originated in fjords and mossy brooks on the flanks of European glacial mountains, as Jordan once wrote, what was the incentive for wandering to remote seas? It seems to me that the present distribution into fresh waters far inland must have been due to some cause other than aimless wandering from one stream to another and that it must have been in conformity to some natural law.

There is no known European or Asiatic trout closely related to the small scaled forms of the Pacific coast of North America. There are trout on the other side of the ocean from Kamchatka to Formosa which are more nearly related to the coarser scaled forms. *Salmo mykiss,* of Kamchatka, has 138 scales and the *Salmo* of Formosa 130, according to Jordan. As Jordan now says, *Salmo mykiss* is more like the American steelhead. It would therefore seem that the trouts of America were native Americans.

Again Jordan writes (1919) "Most primitive of the American species, no doubt, is the one named for William Clark, *Salmo clarkii.* It was born in Alaska and has worked its way southward as far as Eel River in California." The idea is implied, perhaps, but not expressed in the foregoing, that the smaller scaled species was originally associated with cold water, which idea the present distribution of small scaled forms supports. I do not quite understand what is meant by "primitive" in this instance. It would apparently signify that all the other forms originated in this alleged Alaskan native. I cannot reconcile this idea with a development of a small scaled form from a coarse scaled form of Europe or Asia, which moved successively southward and inland in very irregular and diverse routes, producing offshoots with both large and small scales. To me, the Salmonidæ afford a striking example of an anciently established "zone system" which is now applicable to the whole salmonid world. We know that on the Pacific coast the genus Salmo occurs as a more or less marine fish from the neighborhood of 57° to approximately 34°, north latitude. The most southern inland trout occurs in Durango, Mexico, probably in the headwaters of the Yaqui River or some neighboring stream, the mouth of which is in about 27° north latitude, near Guaymas. In lower California, a trout is found in the San Matir Mountains in about 33° north latitude.

It would appear that authorities would have us to suppose that the trout have reached the cold waters of these high altitudes by slowly traveling from cold waters of Alaska into warmer waters of Mexico, thence into cold waters again. Surely there is no discoverable law for distribution of this kind. Where streams contain trout in their upper waters and sea-run forms do not occur, we must assume, it seems to me, that the coastal region is beyond the limit of suitable conditions. We therefore appear to have a marine zone or coastal area of more or less favorable conditions comprised between the degrees of latitude mentioned (57° and 34°, approximately), and an inland and altitude zone comprising irregular areas of distribution, extending to at least 30° north latitude, and if the mouth of the river is considered, even to 27° north latitude. Assuming that 75° north latitude now represents conditions similar to those of latitude 57° north, which is stated to be the southern limit of a general ice cap on the Pacific coast in the last glacial period, and taking the latitude of Arroyo Grande, or Santa Maria River, California, as the present corresponding southern limit of marine trout, the southern limit of marine forms in the glacial period would have pushed down to about 27° north latitude, or almost exactly to the mouth of the Yaqui River in Mexico—a striking coincidence.

It is a well-known fact that, as a rule, northern fishes are characterized by smaller scales and more numerous vertebræ than those of the south. At least, so far as the scales are concerned this is true of the Salmonidæ, comprising the salmons and trouts, with perhaps some exceptions which, after all is known, may prove the rule. In our hypothetical trout marine zone, it is only in the north that small scaled forms are found in the sea or near the coast. In inland waters small scaled forms are found in high altitudes far to the southward. But, coastwise, in intermediate localities, trout with intermediate sizes of scales occur, and in the sea and accessible fresh water, large scaled forms occur far north. These facts suggest that the routes which have been scheduled by Jordan were not strictly correct.

It does not seem possible that a large scaled fish entering the Colorado, could ever become the small scaled species of the Kern, or a small scaled form from any source could ever directly change into a large scaled fish of another locality; and Jordan's statement that "It is not the preservation of the most useful features but of those which actually existed in the ancestral individuals, which distinguished such species," is an argument against the derivation of Durango trout from the Missouri or Snake Rivers. Our zone theory hangs upon one essential point, namely, that the conditions at present necessary to the existence of the trouts indicate that the trouts were evolved in and synchronously with the changes of environmental conditions culminating in those of the present time. In this zone of marine trout, having an extent of some 30 degrees, we may suppose were intermediate zones, occupied by forms intermediate between those with a tendency to small scales, associated with the northern limit, and those with a tendency to large scales, associated with the southern limit. Probably owing to lack of uniformity in the intermediate conditions, the intergradation from those with a tendency to small scales to those of large may not have been perfect.

Partial segregations may occur within large aggregations, caused by local thinning out of interbreeding individuals. Such partial interruptions to complete interbreeding may be due to indirect barriers. An indirect barrier may be some condition or influence tending to concentrate the individuals of any section in a certain locality, while there is no actual obstruction to their passage from one section to another.

It goes without saying that it could not have been until the final recession of glacial conditions that marine trout were able to enter and permanently occupy fresh waters in the regions of glaciation. While perhaps some rivers of the most southern limit of this zone were accessible, they later became unfavorable to the existence of the trout. In some of the more southern and therefore earlier accessible waters where conditions remained more favorable, the fish have survived. In such instances we should expect the larger scaled fish. As successively more northern waters became accessible, they were occupied by trout. Some at first accessible became later inaccessible, thus entrapping the first trout to enter them.

As the habitat zone with, of course, its subordinate zones moved northward with the recession of the glacial conditions, the occupants of the respective zones would enter the accessible fresh water encountered. They might be few or many. But inasmuch as all regions were not provided with accessible fresh waters, the present faunas would represent only those which were derived from the respective zone reaching it at the time of accessibility. Some which were cut off from the sea by impassable barriers to the ascent of fish would contain first arrivals, while the lower part of the water course would be frequented by later arrivals. And so on, until theoretically there should be some sort of an intergradation of the marine forms from their southern to their northern limit. Owing, doubtless, to modifications of the environmental conditions of the coastal forms other than those directly pertaining to the glacial retreat, such as warm oceanic currents for instance, the marine trout would be able to move farther north than they otherwise would.

So while there is demonstrable evidence of the zone system in the interior, it is not so plainly evident along the coast. Consequently among them there appears to be a medley of forms in some localities, which may be due to predominantly fresh water forms sometimes mingling with predominantly marine forms. Or it may possibly be partly attributable to hasty examination, to attention being directed to the wrong structures or characters. The usual characters emphasized in descriptions are often those which are never diagnostic, or they may be structures or dimensions which vary with the size, age, sex, and breeding condition.

As concerns the steelhead-rainbow question, it is probably true that the marine forms from one end of the habitat zone to the other, taxonomically at least, must be regarded as the same species. Many of the trout occurring in waters accessible to this species are regarded locally, at least, as rainbow trout and the anadromous forms as steelhead. Occasionally some other species may make its way into salt water and when reascending the stream, perhaps with the common steelhead, it is called steelhead.

Now the fact appears to be that the form bearing the name *Salmo irideus* is an anadromous form. But the form from the McCloud River which has been propagated artificially under the name of "rainbow trout (*Salmo irideus*)" is a distinct species which Jordan has named *Salmo shasta.* Some time ago Jordan stated that the name *rivularis,* formerly regarded as a synonym of *irideus,* should be used as the designation of the steelhead, on the ground that Richardson had applied the name to a young blueback salmon (*Oncorhynchus nerka*). The blueback salmon seldom attains a length of over 30 inches. Richardson's *Salmo gairdnerii* was stated by him to be 31 inches long, and there are other differences from the blueback mentioned in the description.

From about 1880 to about 1895 the only rainbow trout propagated and distributed in the east were raised from eggs of trout from the McCloud River, which is one of the headwater tributaries of the Sacramento River. They possessed much smaller scales and were otherwise different from the coastwise so-called rainbow trout. They were inhabitants of cold water which fact indicates that they originated in a more northern section of our previously mentioned zone system than did the coastwise so-called rainbow and steelhead. With the disappearance of the congenial cold coast waters they were left behind, isolated in upper Sacramento waters, and their differential characters became fixed, so to speak.

By the scale count and by coloration, to say nothing of certain other characters, there was and is absolutely no difficulty in distinguishing a pure bred McCloud River type of rainbow from marine steelhead forms wherever found, whether in San Francisco Bay, Klamath, Rogue, Columbia River and Alaska, or the Great Lakes or anywhere in eastern waters.

All of the steelheads which have been introduced into eastern waters, so far as records indicate, came from Washington and Oregon. Their introduction into certain northern waters of the east has been fairly successful as far as acclimatization is concerned. Attention should be called here to the fact that practically all steelhead trout introduced into eastern waters were derived from eggs obtained from wild fish, and practically all rainbow eggs and young fish distributed for many years, with few exceptions, have been derived from domesticated fish in comparatively limited brood-stocks at hatcheries.

For a number of years the propagation of the rainbow met with varying success according to the conditions obtaining where its propagation was carried on. It was found that they did better at some hatcheries than at others. But finally, difficulties and puzzling conditions arose at even the previously most successful hatcheries. The average yield of eggs decreased; a large percentage of eggs could not be fertilized; there were so-called glassy eggs, and other defective eggs, also masses of collapsed egg-shells, etc. By some, these conditions were attributed to inbreeding. So, after a while an effort was made to improve the brood stocks by securing eggs from wild trout.

At first these wild trout eggs came from California, and as the records show, not from the McCloud River, but from the Klamath River basin where at one time Gilbert, and later Snyder, found all sorts of trout excepting *Salmo shasta* forms. The Klamath River trout, from which these eggs were obtained, possess larger scales and are otherwise different from the McCloud trout. Later, wild rainbow trout eggs were taken in Nevada and Colorado. In both places the rainbow trout were originally introduced, and consisted partly of McCloud trout and partly of Klamath trout. So the rainbow trout of the eastern hatcheries finally became the product of McCloud trout with a considerable admixture of other varieties or species. I have examined trout from several of the stations of the Bureau of Fisheries, and there appear to be some typical McCloud fish, some which seem to be a pure breed of another form, or other forms, and others which appear to be crosses.

It is not my purpose to discuss the fish-cultural effects of this adulteration. As an illustration of the effect of the confused ideas resulting from the long discussion of names regarding fish, an esteemed member and former officer of this Society and a state commissioner, in a meeting of the Society, said that he regarded the rainbow trout and steelhead trout as identical and handled them accordingly. The eggs of both had been derived directly or indirectly from McCloud River rainbow trout and Oregon steelheads, and it cannot be known how many hybrids of these two forms he produced and planted in the waters of his state.

If there was inbreeding of the brood of original McCloud stocks at different stations, it seems to me that the exchange of eggs of these several stations to be reared as breeders would have relieved the situation. The new California material should have been kept separate and alleged inbreeding prevented in the same way. However, we didn't know. In fact it is quite possible that all of the troubles, if any, were not attributable to inbreeding. Indeed, the majority of difficulties not due to other causes, elsewhere referred to, were probably produced by the remedy applied, i. e., admixture of a new stock of wild trout of other species.

I have recently received specimens of supposed rainbow trout from the Madison River, Montana. Two of four specimens are unmistakably straight steelhead trout. Two are of some other form but not typical McCloud River trout; probably they are Klamath "rainbows," whatever they are taxonomically considered to be. To repeat, as far as now known the oldest name for the fine scaled trout of the McCloud and upper Sacramento type is *Salmo shasta* Jordan. The streams of Mount Whitney, Kern River, and other waters in that region are inhabited by trout of this character. In fact, it is hard to distinguish, even by color, *Salmo gilberti* of the Kern River from *Salmo shasta.*

The steelhead, as previously stated, must continue to bear the name *Salmo gairdnerii,* with which *Salmo irideus* and *Salmo rivularis* become synonymous. Although it will not aid in distinguishing *Salmo shasta* from *Salmo gairdnerii* by external observation, it should be mentioned that the rainbow has 63 vertebræ and the steelhead 60, invariably in the specimens which I have so far examined, counting all segments.

Discussion

Mr. J. W. Titcomb, Albany, N. Y.: What is the effect of inbreeding these different forms?

Dr. Kendall: A difficulty attributed to inbreeding is a gradual reduction in the egg yield of brood fish. Now, whether that is attributable to this mixture or not, we do not know; that is one of the problems we shall try to solve. But it is quite possible that the descendants of these hybrids would have a reduced egg yield, and that complete sterility of the fish might finally result.

Mr. Titcomb: We have some stock in New York where we have mixed the two kinds of trout; in fact, we are planting them regardless of whether they are rainbow or steelhead.

Dr. Kendall: So far as classification is concerned, the books are wrong. The steelhead trout is the one that has the coarser scales. I have counted the scales of various steelheads from the different rivers, including types from the coast; the scales run about 130, a few more or less according to the locality. The McCloud River rainbow was introduced early into Europe and elsewhere. It has scales numbering about 160 in the lateral line.

Mr. Titcomb: Am I correct in understanding that the so-called rainbow trout was introduced into New Zealand where some of these fish have been known to weigh 25 pounds? I understand that after they had been called rainbow trout for a great many years there, it was decided that they should be called steelhead.

Dr. Kendall: I remember the time when it was decided that the New Zealand rainbows were steelheads. Two mounted specimens were sent to the Bureau of Fisheries, at Washington, and for a long time they hung on a wall in the laboratory. One day Dr. Evermann looked at them and said that they were not rainbows, that they were steelheads; and henceforth the New Zealand rainbows were steelheads. Possibly it may be significant that this decision was made at a time when the steelhead was supposed to have the finer scales, and the conclusion may have been based upon that character. If so, the fish were probably rainbows. But to determine the matter definitely it would be necessary either to count the scales or to know the locality from which the fish were originally obtained. A leopard cannot change its spots; the rainbow trout of 160 scales cannot change its scales to 130 or 120.

Mr. Titcomb: When you cross the rainbow and steelhead, are you going to produce a hybrid that will not breed?

Dr. Kendall: Some hybrids do breed. It has been determined that they will breed, with a reduced egg yield and inferior fry. I have had no experience in that line, but other fish culturists have, in Europe, England and other places. Francis Day relates a number of instances of crossing trout of different species, but in no instance did he get perfectly satisfactory progeny that were continuously fertile.

Mr. Titcomb: You do not know anything then, about the results of mixing the steelhead and rainbow trout?

Dr. Kendall: No, I do not know that they have been mixed except in cases of which I have read.

Mr. Titcomb: I have mixed them a number of times; in fact, I have entertained the idea, from what I have read, that the steelhead and the rainbow were merely variations of the same fish.

Dr. Kendall: That has been a common impression right along.

Mr. Titcomb: Something like 30 years ago I was talking with United States Commissioner McDonald, and I asked him what results he had obtained with rainbow trout in the east. I remember he stated that they had sent great numbers of them into the waters of New York state, and that they had all disappeared. I have not had much experience personally with New York waters, but it is particularly interesting to me to study the results of planting rainbow or steelhead trout. We do not know absolutely what waters are suitable for rainbow trout. It is a curious thing, but we have streams in New York and a few in Vermont where the planting of rainbow trout has been followed with very good results, and where they have reproduced and maintained themselves afterwards. But in the majority of these streams in New York state where the rainbows have been planted, the fish have absolutely disappeared; and yet there are streams which we annually plant with fish and which afford good fishing for the rainbow trout so-called. It is corroborated by anglers that these are good rainbow trout streams. Now we choose for the rainbow, as we do for the brown trout, the lower waters of the streams where the tendency is for the water to become considerably warmer and is not congenial for the native brook trout. We do not consider the rainbow so destructive to the brook trout as the brown trout. The rainbow trout, if planted in the headwaters, naturally works down into the larger, deeper pools of the lower part of the stream, where the temperature is higher. They are certainly a fine fish to catch on the fly, too.

Mr. W. H. Rowe, West Buxton, Me.: I have fish at my place that I have raised that came from the Wytheville, Va., hatchery. They are called rainbows and they spawn in November or December. I have fish that came from the Pacific coast, called rainbows or steelheads, that spawn in April. Can you explain why this should be?

Dr. Kendall: The spawning of Salmonidæ, as well as of other migratory fishes—and most of them them are more or less migratory—is in conformity with a certain temperature range. They must have a certain temperature in which to spawn, and that spawning period is determined by the temperature prevailing in the rivers at a particular time. For instance, the migratory fish start from the sea; they ascend the rivers and reach the spawning waters at a certain time, but if the temperature is not right they wait for it to get right before they spawn. So we have temperature and other river conditions to which these fish are adapted and which they cannot transcend. It has been a matter of considerable wonder for a number of years that we have fish from the Pacific coast which appear to have changed their habits when they have been sent east, and that fish raised from eggs from the McCloud River in California, instead of spawning in January, February, March, and April, or even May, as they do in the McCloud, have approached the spawning time of the common brook trout, namely, the latter part of October, November, December, January, and so on. But the truth is, as it seems to me, that they have not changed their habits; they are simply trying to conform to the temperature that prevails at the new location. The fish mentioned by Mr. Rowe were probably adapted to a certain temperature that prevailed at that time of spawning.

Of course, there are many other factors that may affect the time of spawning, but temperature is one of them and a very important one. As a matter of fact, steelhead trout derived from northern fish on the Pacific coast spawn in the spring in northern waters in the east, and they do pretty well. But we have more or less difficulty with the rainbow trout. In the McCloud River the temperature of the water is more uniform throughout the year. The fish there spawn not on a rising temperature but on a falling temperature of the water, because the spring water is colder than the water in winter and the rainbow and steelhead trout spawn at the season, wherever they happen to be, on a falling temperature. It was stated in an old report of the Bozeman, Mont., hatchery that the temperature was very uniform throughout the winter, and that in the spring it was one or two degrees or more colder, because of the melting snows. So the water in the spring is probably colder than it is when there is no melting snow or ice. It was at this time the rainbows were said to spawn at Bozeman.

Mr. Rowe: I was wondering whether that would prove that one was rainbow and the other steelhead.

Mr. Titcomb: It was at the Wytheville hatchery that the rainbow trout was originally domesticated in the east to any extent, so far as I know. As I understand it, the fish originally spawned rather late in the spring. The water is all spring water, and there is very little variation throughout the season. As the fish became domesticated and accustomed to that even temperature, they gradually began to spawn earlier and earlier. When I was in charge of fish-cultural work at Washington I recall that we looked upon it as unusual when eggs were obtained by the first of December. Since that time, the fish have been spawning even earlier than that. It seems to me that the change may be due to the unnatural conditions of water temperature there, and the lack of any unusual changes which we get in the wild streams. The steelheads in the wild waters, so far as we know, all spawn late in the spring, because we have cold winters there, and the fish do not spawn until the water gets warm enough for them in the spring. It is unfortunate that our rainbow trout spawn just after the open season begins. The anglers go out and often find a lot of steelheads or rainbows congregated in the headwaters for the purpose of spawning, and it is a great temptation to them to hook these fish.

MR. LEWIS RADCLIFFE, Washington, D. C.: If there is any tendency to sterility in these trout, it seems to me that it would be well for the fish culturist to go back to the native waters, get pure trout stock, and try it in comparison with the others.

SOME FISH-CULTURAL NOTES

By John W. Titcomb

Fish Culturist, Conservation Commission, Albany, N. Y.

It is the purpose of the present offering to simply treat of certain different fish-cultural subjects with the idea of promoting or stimulating further inquiry or investigation.

WATER TEMPERATURE AT WHICH FISH SPAWN

I was rather surprised to find that after the long period of work in fish culture we have no records stating definitely the water temperatures at which the various species spawn. Now, we know the temperature at which many of the species spawn, but it may be said of a great many fish artificially propagated that the range of temperature at which they spawn is not known. We all recognize that the fish are guided as to the time of spawning by water temperature. Some spawn on a falling temperature, in autumn; others spawn on a rising temperature in the spring of the year. I merely call attention to this in the hope that those engaged in fish culture who read these notes will pay more attention to this phase of the subject, so that we can together get data for a table which will be available to all interested persons.

A VARIATION IN TABLE MANNERS AMONG CANNIBALS

This spring I discovered for the first time a fish which eats one of its mates by taking it tail first. I think you will agree with me that ordinarily when a fish takes another fish it seizes it across the body, sometimes by the tail, but that in any case it turns it around and swallows it head first. In one of our hatcheries where pike perch are propagated, some of the little fry were kept for twelve days, at which time it was found that they were swallowing each other tail first. I have a number of specimens of these little fry about half an inch long with the head of one sticking out of the mouth of the next one. In one instance there are three specimens where one had swallowed his mate tail first up to the head, when a third one came along and swallowed the second one by the tail; so we have three heads and three pairs of shining golden eyes in a line, and one tail.

VARIATION IN GROWTH OF TROUT UNDER DIFFERENT QUALITIES AND TEMPERATURES OF WATER

Years ago the American Fisheries Society adopted the plan of describing the fingerlings as No. 1, No. 2, No. 3, etc., according to size of the fish, a one-inch fish being called "No. 1 fingerling," a two-inch fish "No. 2 fingerling," and so on. That method of nomenclature gives opportunity for considerable range, but it does not tell the story as accurately as can ocular demonstration. In connection with the bottle specimens of trout which are exhibited, I may say that each foreman who distributed trout was requested to preserve specimens periodically in connection with shipments. Special labels were furnished calling for data to be filled out with pencil and placed inside of each bottle before mailing it; upon receipt, the labels are affixed on the outside of the bottles. The labels call for the weight per thousand fish, date, number of fish carried to a ten-gallon can, and the number of months the fish have been fed.

A table has been prepared based upon the information obtained from available bottled specimens. Had the specimens been secured for the purposes of compiling the table, an effort would have been made to have the dates of collection correspond at all hatcheries, a practice which will hereafter be adopted. The four different conditions of water supply are as follows:

A. Supply derived partly from driven wells at a uniform temperature of 52° F., supplemented from surface springs more or less exposed to the air and therefore varying slightly in temperature. No complete record of temperatures has been kept at the hatchery, but the foreman reports that it will average about 51° F., which has been entered in the tables to enable comparison with other entries.

B. Supply is from a spring covering about one-eighth of an acre in area, with the resultant variation in temperature from that of the source, which latter is uniformly 48° F. During the winter months the temperature is somewhat lower than during the summer.

C. Supply of spring brook water, temperature ranging from 38° to 46° F.

D. Supply from a trout stream of which the temperature ranges from 34° to 42° in the winter months, and from 38° to 58° in April and May.

Development of Trout Under Different Conditions of Water Supply

Date.	Length. *Inches.*	Weight per thousand.* *Ounces*	Temperature. *°F.*	Days fed. *Number.*	Fish to can. *Number.*
		Water Supply A.			
Brook trout:					
April 1	2¾ to 2-7/16	53	51	126	500
May 1	2½ to 3¼	80	51	156	400
August 31	3¼ to 3-⅞	333	51	212	100
September 30	5½	1,250	51	242	100
October 31	6⅝ †	2,750	51	273	50
Brown trout:					
April 1	2¼ to 2½	48	51	126	500
August 31	2¾ to 3½	250	51	217	150
September 30	3¼ to 3¾	375	51	247	100
October 31	5½	1,255	51	278	100
Rainbow trout:					
April 1	2½ to 2¾	42	51	74	500
July 2	2½ to 3	80	51	150	200
September 30	4 to 4¼	500	51	216	150
October 31	4¼ to 4½	625	51	246	100
		Water Supply B.			
Brook trout:					
April 13	1-3/16 to 1-5/16	10	47 to 51	55	1,000
May 5	1-9/16 to 1¾	15	48 to 51	73	500
May 31	2 to 2⅛	48	49 to 53	100	400
June 30	2-5/16 to 2-9/16	64	48 to 54	130	300
August 2	3⅛ to 4⅛	488	48 to 53	162	125
September 17	4½	900	49 to 52	210	80
October 27	5	1,120	48 to 51	250	50
		Water Supply C.			
Brook trout:					
April 12	13/16 to ⅞	5	40 to 46	21	2,000
April 28	1 to 1⅜	8	45 to 50	37	1,000
		Water Supply D.			
Brook trout:					
April 12	15/16 to 1	5	54 to 58	31	1,000
July 19	1⅝ to 1-13/16	15	54 to 60	80	500
August 24	2¼ to 2-7/16	36	54 to 60	116	500

* Determined from weight of a few average size specimens.
†One trout; much fatter and heavier than a wild trout of same length.

Reference to section A of the foregoing table shows that on April 1st there were fingerling trout of three species ranging in length from 2¼ to 3¼ inches, in contrast with the fish at another hatchery shown in section B which on April 13th, nearly two weeks later, range from 1 3-16 to 1 5-16 inches in length. The smaller fish cost more than the larger ones, the eggs at both hatcheries having been laid down about the same date. A comparison of the sizes of fish on different dates in section A with sections C and D, shows that the same situation exists.

In some water supplies there is a rapid growth late in the summer, which compensates for slow growth earlier in the season, this, of course, being possible only in instances where the fish are not distributed until late in the season. The weight of fish of a given length differs under varying conditions. This may be due to feeding methods or to the kind of food used. The specimens and data herein referred to may suggest further inquiry on this subject with a view to determining whether the difference is due to water supply, or to feeding methods which can be remedied.

It is recognized that most fish culturists must accept conditions as they find them, and that each hatchery has its individual problems as to water supply and other matters, but it is strongly recommended to those who have charge of a number of hatcheries that they collect specimens and compile data along the line shown in the foregoing table. This will enable the study of certain economic problems from a new point of view.

If called upon to locate a new hatchery, the specimens and resultant data may serve to forcefully show, merely by comparison of water temperatures, the suitability or unsuitability of some site under consideration. Although generally recognized by fish culturists, it seems desirable to add here that no considerable investment should be made in hatchery construction until the water has been thoroughly tested with eggs and fish and until a year's record of water temperature is available.

POND CULTURE IN ABANDONED SECTIONS OF CANALS

Some of you have heard about the efforts of the New York State Conservation Commission to utilize abandoned portions of the Erie and Champlain Canals, state property otherwise unproductive and having little or no promise of future value.

When we attempted to drain these sections we were surprised to find that what apparently had been nothing but an accumulation of slime had many depressions below the normal canal bottom, and that complete drainage was difficult. The canal contained innumerable fish, carp, suckers, sunfish, rock bass and several species of minnows. This work was undertaken just at the beginning of the war, but aside from some parts has not been completed on account of labor conditions and the high cost of material. In some places we have been obliged to construct side outlets in order to effect complete drainage. In the meantime we have been breeding large and small mouth black bass and bullheads in the sections worked. We have seined out as much of the foreign materials as possible, and the results have been favorable, though not as good as we expect when it has all been cleaned up.

I have been rather surprised to find that bass held as brood fish do not find nearly enough to eat; in other words, they do not catch and feed upon the numerous minnows. The suckers breed there. The young bass come on all right but the parent bass are thin and it appears necessary to resort to feeding, just as we do in the artificial breeding ponds at the hatcheries. The same is true of the parent bullheads. We have stocked a canal section with bullheads from Chautauqua Lake ranging from one to three pounds in weight. They reproduce and the young develop into fine, healthy fish; but the adults are very emaciated and it is evident that they must be fed. Strange to say, some bullheads native to the canal are able to thrive and develop into nice plump adult fish. They are not as large as the Chautauqua bullheads; this suggests that we may have to acclimatize these fish of larger growth imported from other places, before we can get satisfactory results without artificial feeding. The canal sections range from a mile to a mile and a half in length, so that everything looks favorable for the fish to thrive there, just as in natural ponds.

One main section of the canal ponds was drained and cleared of all natural enemies, and then stocked with 50,000 small mouth bass fry. Owing to the fact that construction and drainage features were not completed until a short time before it was necessary to ship the fry, the pond was not filled until two or three days before the fry were introduced. Observations of the fry after the first week indicated that there might have been a lack of the normal amount of food; but after two weeks they recovered from their rather emaciated condition and grew rapidly. The total result of the harvest from those 50,000 fry was 14,100 fingerlings ranging in length from 2 to 3¾ inches, a yield of approximately 28 per cent. The fish were harvested when from six to eight weeks old. This gives rather interesting data upon the planting of small mouth bass fry in a pond a mile in length with an average width of between 60 and 70 feet; but it is hoped, another season, with the pond flooded several weeks in advance of planting time, that a larger percentage of fingerlings may be produced. A pond of this character offers many opportunities for experiments of an economic character. For example, the determination of how many fry can be planted in such a place to procure the best results in fingerlings; the question as to whether it is possible that 30,000 fry will yield as many fingerlings as 50,000; whether we are moving the fry from the nests too soon while they are very delicate; and whether better results will be realized if they are held a week longer in the water where hatched. These are economic questions having a bearing upon all bass fry distributions to public waters.

THE COMMON BULLHEAD (*Ameiurus nebulosus*)

The bullhead has not had a very high social standing among fishes, and not much protection, but it seems to be coming into its own. There is a great demand for bullheads in the State of New York, and I find that in other states the bullhead is being propagated more largely. There is not much literature on their habits, so I am submitting a few notes as to observations made during the past summer.

Spawning at Chautauqua Lake is at water temperatures of from 68 to 72 degrees F., and the period of incubation is from 10 to 14 days. The nests are constructed in from one to three feet of water and vary in size and depth, the average nest being from 8 to 12 inches across and from 6 to 10 inches deep. The construction of those at Chautauqua Lake varies according to the soil; some of the nests are without much depression, but such are usually in a root or log or bog. Three bullheads were seen in one hole at the same time, but the sex was not ascertained.

There is a great variation in the spawning season of bullheads; as late as July 17th we found a nest of eggs from a pair of bullheads native to that particular section of the canal. We secured a sample of 2,188 eggs from a female estimated to weigh one pound.

Dr. Emmeline Moore, whom some of you heard at the meeting of this Society last year at Louisville, Ky., on the Foods Which Feed the Little Bass, has made some notes on the bullhead as follows:

> Bullhead nests were under observation in ponds Nos. 1, 2, and 3, from June 9th to June 23d. The typical nests were neatly rounded holes dug into the mud near the edge of the pond with about 8 to 14 inches of water covering them. The diameter of the holes was about 11 inches. The shape of the holes was that of a hollow cone extending into the mud at an angle of about 30 degrees, and at a depth of 14 inches to 2 feet. There were variations from the type nest. One pair of bullheads used a deserted muskrat hole. Another nest had a curious outlet extending upward vertically from the middle of a cone shaped nest. This outlet presented the appearance of a crayfish hole in diameter and workmanship and its function may have been that of a runway for enemy crayfish to steal fry from the nest.
>
> The two parent fish were occupied on the nest during the incubation period, one relieving the other or both remaining on the nest together for a short space of time. Their chief activities were concerned with the protection of the nest from intruders and in keeping the water in circulation, a process accomplished by a movement of the fins while with head forward they hovered over the nest.
>
> The parent fish were not observed bringing off their brood, but judging from the size of the fry seen thereafter, the incubation period must be from 10 to 14 days, and that soon after hatching the fry are led forth to suitable forage grounds.

A large school was seen feeding in the shallow water over a mud bank in pond No. 1 on July 8th. The fry were probably ten days old at this time. They were moving together in a compact mass under the rigid discipline of the two parents who encircled the school and closed in if there was a tendency to stray away. Straying away seemed to be accidental, for with remarkable instinct they kept together. Occasionally one of the parents moved into the midst of the school allowing the fry to swim over and around her. The movements of the school when foraging were very slow, spreading over the mud like a gigantic black amœba. Their food at this stage consisted of water-fleas, small crustacea, caddice worms, mayflies, etc. This school was shipped a day or two thereafter and observations confined to scattered individuals taken from the seine in other ponds.

At Chautauqua Lake it was observed by the foreman that after the young bullheads leave the nest one of the parents takes the school to very shallow waters, about four inches in depth, where they hover under the protection of the parent until the yolk sac is absorbed. It is not definitely known whether it is the male or female which guards the young. He adds the rather interesting statement that when disturbed, the parent fish will scatter the young, at the same time swirling the water and roiling it for protection.

Discussion

Mr. John M. Crampton, New Haven, Conn.: I understand Mr. Titcomb to say that he developed a two and a half inch trout from the 1st of January to the 1st of April. What was the temperature of the water—cold?

Mr. Titcomb: Spring water.

Mr. E. T. D. Chambers, Quebec, Canada: Were these fish fed anything besides liver?

Mr. Titcomb: Yes, we feed them beef livers and beef melts and pork livers and pork melts, principally. I do not compel the foreman to take the cheapest kind of food, because if he has any trouble with his fish he will put the responsibility on me. But I think it is a fact that in some waters we can use melts entirely in the raising of fish, while on the other hand there are some waters which will not admit of the use of melts. The Chautauqua hatchery trout are raised on beef liver; the foreman there has had trouble when he has attempted to use melts; he also objects to pork liver. After the fish are two inches in length he also uses carp.

Mr. S. B. Hawks, Bennington, Vt.: Mr. Titcomb referred to the placing of 250 fish in a can. What is the size of the can?

Mr. Titcomb: It is a regulation ten-gallon can; in other words a milk can of the standard type. Of the larger fish we are shipping about 75 to the can.

Mr. James Nevin, Madison, Wis.: We are shipping now from 100 to 125; they are about the same size as yours.

Mr. Titcomb: We are shipping some of ours 125 to the can, but the largest size runs 75 to the can. We would not be able to supply our applicants with fish if we shipped them all when they attain the two inch size. We make our allotments to applicants by cans instead of by the number of fish. We give one or two cans to a mile of stream, regardless of the time when the fish are distributed. We begin to distribute when they are small fingerlings, and thus avoid congestion in the hatcheries. The applicant can have the largest fingerlings if he makes request for them, in which case his application is held over until the fish run about 75 to a can. Another applicant may get 1,000 in a can of these small fingerlings, or even more. By alloting by cans instead of by number of fish I do not have apprehensions at the end of the season about failing to fill all applications. We usually have several carloads of these larger fish to sweeten up people with and make encores to clubs, and so on. If you send them some of these fish that run 75 to the can, they would rather have them than 5,000 fry.

Mr. Lewis Radcliffe, Washington, D. C.: Mr. Titcomb is to be congratulated on his efforts to get more specific information as to the time when certain of these fishes spawn, and the temperature of the water at that time, and also to get more definite data as to the productivity of these various ponds. The fishermen in some localities recognize in a general way when to expect the fish; they say, for example, that when the dogwood is in blossom, shad may be expected. I believe that in many cases they do not realize that the conditions which bring the dogwood into blossom also bring the shad into their waters.

Mr. W. C. Adams, Boston, Mass.: It seems to me that this is the proper place, in the course of a discussion of trout culture, to describe the plan which Massachusetts put into operation last winter. It consists in planting eyed trout eggs that will hatch in anywhere from five to ten days after they are planted in the spring holes picked out for them. Our scheme has been to take a certain number of these eggs and the ordinary wire that we use in the hatching troughs, turn the wire up at the side so as to make a tray of it, about two feet long, the width being that of the wire ordinarily used for the purpose. We anchor this tray in a spring hole which is tributary to one of our trout brooks, in such a way as to have it, say, a couple of inches off the bottom of the spring hole or section of brook, in order that there will be plenty of ventilation all around the eggs. Then, having anchored the tray, we put the eggs on it, limited in number to avoid any possibility of overcrowding. This done, we thatch over the top of the tray with very heavy brush, and put finer stuff on top of that to conceal it from predatory animals and birds. Our observation has been that after these eggs hatch the young fish drop into the silt in the bottom of the spring hole or brook and stay there until the egg sac is consumed; then they start on their natural life course. Last year, if my memory serves me correctly, we planted 500,000 of these eyed eggs, principally in the eastern part of Massachusetts, although we put a liberal stock in the west branch of the Swift River, for example, which is up in the more rugged part of our state.

One of the great problems in fish culture, as I conceive it, is the utilization of all those things which you may describe as by-products,—that is to say, any fish hatchery can produce more eggs ordinarily than it can hatch; certainly it can hatch more fry than it has the facilities for rearing to reasonably sized fingerlings. Now, in our state we are going to try to utilize our hatcheries to their maximum development, and that means that we are going to eye more eggs than it would be of value to us to hatch, for the reason that we would not be able to rear the fry. We are going to put our wardens on snowshoes and send them, with these eggs, into inaccessible parts of our state—inaccessible at that time of year in any other way than on snowshoes, on account of the presence of anywhere from two to five feet of snow on the level in certain sections. These spring holes and many of the brooks are open the whole year round, and we believe that if we can plant fry in the small tributary streams, we shall be utilizing a product which otherwise we could not take care of to advantage; and we shall be doing exactly what nature herself would do if given full opportunity, that is to say, filling every spring hole and every small stream tributary to a good trout brook, full of fry.

Mr. Eben W. Cobb, St. Paul, Minn.: Our experience has taught us that the temperature at which fish spawn varies in different geographic locations. We have also learned that we can bring eggs from certain sections to our hatcheries with very little loss, whereas, when we bring them from other sections the loss is much greater. At our Bemidji hatchery, which I believe is somewhat farther north than Ottawa, pike perch have spawned in water at a temperature of 46 degrees. If the water turns cold after they begin to spawn we still gather some spawn but the take is much decreased, and if a snowstorm comes hard enough to turn them back the run of fish is of very little benefit to us. If eggs are shipped out from Bemidji to the southern part of the state, the utmost care being exercised in transferring them, the loss will be 25 per cent greater than with eggs that have been hatched up there where the conditions are the same as those to which the fish have become acclimated. The question of the temperature of the water is a very large one. It would take a great deal of time to get anywhere with it, because you run into all kinds of unlooked for conditions. Fish seem to be acclimated to their own particular section, and each section has its own problem. The results obtained in one section cannot safely be depended upon elsewhere without careful investigation.

Mr. Titcomb: What is the temperature of the water at the Bemidji hatchery?

Mr. Eben W. Cobb: The fish spawn there at 46°. We cannot transport from Bemidji to the St. Paul hatchery where the spring water supply runs at 50°, and get the good results obtained in transporting from Whitefish Lake, which is farther south and where the temperature variation is not great as compared with St. Paul.

Mr. Titcomb: This matter of temperature is a very interesting subject. We gathered a lot of yellow perch eggs in one of our northern lakes, and took them to a hatchery on Lake Erie which is furnished with water from the municipal supply, obtained from the deep waters of the lake. The water is all right for herring and whitefish but in the spring of the year it is very cold, and our attempt to hatch yellow perch in it was a failure. An attempt to hatch pike perch would be a failure too, because the water does not warm up to the temperature that the eggs require.

It seems to be easier to carry eggs from a given temperature to a slightly higher temperature than to carry them to a temperature in a hatchery which is lower than the normal spawning temperature. For example, I think it would be very difficult to take white perch eggs from the Susquehanna River and hatch them in a New England hatchery, even if it was supplied with water corresponding to the same conditions. My impression is that the Bureau of Fisheries has transported quantities of white perch fry from the Susquehanna River to northern waters for the purpose of stocking northern ponds. But the waters of the Susquehanna River being warmer than the northern waters at that season of the year, the fry when planted in the colder northern waters could not survive the sudden change in temperature.

Mr. C. O. Hayford, Hackettstown, N. J.: During the past three years, Professor Foster, of Lafayette College, has directed a biological survey of about 2,000 miles of spring runs and trout streams, and it has been found that there is an enormous difference between the fish in these streams both in quantity and in size. You may have two streams coming down a mountain under almost exactly the same conditions not over a mile apart and one will be teeming with food while the other has practically none. Some streams contain the most minute organisms; others contain organisms of the larger types. After three years' experience we find best results are obtained by planting fish according to size and quantity of insect food, starting with No. 1 in spring runs and headwaters, and using No. 2 and No. 3 as the streams grow larger. The most interesting thing to us was the vast difference in size and quantity of the various kinds of insects. We are trying, with Dr. Embody's assistance, to work out a system of stocking according to the amount of food per mile, for the different sizes of fish.

Mr. Titcomb: That is what I would call, in common phraseology, "great stuff." The work which Mr. Hayford has outlined as being done in New Jersey is certainly ahead of that done in any other state. I want to get to the point where all planting of fish will be done under the supervision of somebody who knows something about it. If we can get a survey of the waters similar to that which is made in New

Jersey, we can do very much more intelligent work and save a great many fish now wasted. People are spawning and raising fish many of which are thrown away when distributed.

PRESIDENT AVERY: Mr. Hayford is certainly taking advanced ground in this matter. The information which he gives us is very welcome.

MR. HAYFORD: I wish to state further that a great deal of the credit for this work is due to Dr. Embody and Professor Foster.

MR. DWIGHT LYDELL, Comstock Park, Mich.: Reference has been made to the bullhead. I may say that we have been propagating bullheads for a couple of seasons and it is our observation that they spawn in practically the same temperature of water stated by Mr. Titcomb. Their nests are about the same as those mentioned, and the bottom is very rough. They spawn under the stumps, of which there are a number.

FIFTY YEARS' EXPERIENCE IN FISH CULTURE

By James Nevin

Conservation Commission, Madison, Wis.

Upon the basis of my experience of the past fifty years of fish-cultural work, in Canada as well as in the United States, I desire to present some views that may be of general interest. On the 1st of September, 1869, I began the work under Samuel Wilmot, of New Castle, Ontario, who was the father of fish culture in Canada. I served thirteen years under Mr. Wilmot with the fisheries department of Canada before taking up my work in Wisconsin on September 1, 1882. I remember well when the first meeting of the American Fisheries Society was held. It was in New York City, and I secured copies of the newspaper accounts brought home by Mr. Wilmot, who was in attendance.

The memory of my boyhood days while I was engaged in the business in Canada is still as fresh as though the events happened but yesterday. The methods in vogue at that time were very crude by comparison with those of today, and it is with great pleasure that I note the progress made in fish culture during the past half century. Fifty years ago there was only one hatchery in Canada, that at New Castle, Ontario. Today there are upwards of fifty or more hatcheries, producing hundreds of millions of fish for the public waters of Canada, and cooperating with us across the border in keeping international waters stocked.

The success in fish-cultural work and the stocking of waters with suitable fish has been worth millions of dollars more than the cost. It has become a great asset to the people of the North American continent. Note should be made, however, that many fish have in the past been deposited in waters not adapted to them. Thus there has been at times great waste of good seed sown in barren waters adapted only to other forms of fish life. Fortunately this is practically a thing of the past, as most of our states before planting occurs are now having, or have had, their public waters examined to ascertain which kinds of fish are best suited to their needs.

We have had considerable loss in transferring fingerling and yearling brook trout from one hatchery to another. We have endeavored at all times to get them accustomed to the water before placing them in ponds, but often after twenty-four hours the fish would act as though they were going into spasms, and turn up and die. When fish begin to act in this manner they need a strong solution of salt in the water. It is the best remedy we have for fish at this time and has saved many that would otherwise have died. I have often wondered whether fish when first liberated in public lakes and streams die in the proportion they sometimes do at our hatcheries, where we have made every effort to prevent such loss.

On several occasions in the past I have sent out men to observe fingerling trout that had been planted. In two instances quite a loss was noted, although it is generally difficult to learn the exact loss when fish planted in streams are carried away by the current and disappear from view. Judging by the numbers of fish that are taken from some of the waters which have been stocked, one would think that they must all have lived and thrived. Again, from other waters that have been stocked at the same time, very few fish, if any, have been taken to tell of their existence there. We are reassured, however, upon finding some of these fish in nets when we are fishing for carp and other rough fish.

I have always been a firm believer in the planting of brook trout fry before the sac is absorbed and before they begin to take food. We have the largest losses of fry at our hatcheries before they begin to feed; this is when we attempt to hold them in the troughs until after the cold weather and spring freshets have passed. Brook trout did not exist in two-thirds of the streams in Wisconsin until stocked with fry during the winter months. Our instructions to applicants are to be sure to plant the little fellows in the headwaters of the streams, and I feel sure that no state or country has had any better results in the stocking of streams than we have.

On the other hand we do not like to send out fish in the winter season on account of weather conditions and the difficulty in getting them to the streams. Many of the waters are frozen over, and often we have deep snow with which to contend. The people are beginning to ask more for fingerlings, but heretofore we have not had the quality of water at our hatcheries to grow large numbers of fry to the fingerling size. We now think we have the water at our new hatchery at St. Croix Falls, in the northwestern part of the state, in which with care we can grow fish with very small loss. We intend to raise more brook trout fry to the fingerling size, and not plant until all danger of spring freshets has passed. Whether we shall get any better results is a question in my mind. One thing we do know, however, is that we shall be pleasing a great many more people; also that we shall be able to make annual allotments to all the streams we think adapted to brook trout, though, of course, not giving each stream as large numbers as if we sent out fry.

For many years I have been studying the quality of waters we use for the raising of brook trout, and have learned which are suitable, simply by comparing the number of fish planted in various streams with the number taken from them in after years. Streams that we formerly thought were excellent for trout often did not show the results we had expected. This applies also to certain varieties of fish planted in the lakes.

The spring water at our new St. Croix Falls hatchery is a regular cure-all and sanitarium for fish. Trout that are hatched from weak eggs seem to receive such invigoration that we have practically no losses. The water is much superior to any I have ever had to do with for the raising of trout fry. We have given it a thorough test during the past two hatching seasons, so we feel at this time that we can go ahead and spend money in making this hatchery one of the best and most useful of any. There may be many more fish-cultural stations in this country that possess water as invigorating to brook trout fry, but I know of only one, namely, that privately owned by Mr. G. Hansen, at Osceola, Wis., about five miles south of St. Croix Falls. It is a commercial trout hatchery where Mr. Hansen has raised and sold many tons of brook trout annually for the past thirty years. His fish have been clean and free from disease during all that time. I claim that this is due to the quality of the water.

The inbreeding of fish is something that has never been brought to the attention of this Society, to my knowledge, and it is a matter which I think is very important. I would be pleased to hear regarding it from those engaged in the propagation of brook trout. For the past twenty-five years we have been exchanging and buying eggs from different places, each year endeavoring to get new blood into our stock, but have never had the success desired with the fry hatched from the purchased eggs. In fact, we did not have as good results as we did from our own stock.

For the past few years we have been getting more soft eggs at spawning and more weak fry with blue sacs at hatching than formerly. We have attributed this to the inbreeding of fish. At every possible opportunity we now secure eggs from wild trout. Last season we got one hundred wild male fish and impregnated 125,000 eggs at our Bayfield hatchery, and the result has been marvellous in the production of strong, healthy fry, there being no weak fish or fry with blue sacs among them. Every fish culturist knows that fry with blue sacs are doomed to die. We have kept separate the one hundred male fish obtained last year, and will watch the results this season. We are in hopes of getting a much larger number of wild male trout for use at spawning time this fall. Should anyone in the business having a number of soft eggs when taken, let them remain in the milt in the vessel in which taken, and set it in cold running spring water for an hour or more, or until the eggs get hard before putting them on the trays, results will be very beneficial.

At one of our hatcheries it is difficult to carry a large percentage of brook trout fry until they begin to feed, consequently for a number of years we have been sending the eggs to other stations to hatch and distribute. The resulting fry were always stronger and there were fewer losses than among those of the home product. After the fry from the eggs thus transferred began to feed when about six weeks old, some were returned to the parent hatchery without serious loss thereafter. This shows that there is something in the water that affects the fry from the time they are hatched until the sac is absorbed and feeding begins. If the eggs had remained at their home station we would not have raised twenty per cent of the fry to the age of two months.

As to rainbow trout, I think we keep a larger stock of breeders and take more eggs than any of the middle or eastern states. We do not have the trouble in raising them that we do with brook trout in the same waters where we hatch and distribute millions of fry. These fish have been bred from the same stock for the past forty years, and the eggs and fry from our stock of breeders last season were as strong and vigorous as any we had ever taken. One might naturally think that if there is anything to the inbreeding of fish, results would be the same with rainbow as with brook trout.

We intend to increase our capacity and keep a much larger stock of brown trout in the future than we have in the past, as the fry planted in our streams have done exceptionally well. I do not find from observation that the brown trout are any more destructive in the way of cannibalism, of which they are accused, than any other variety of game fish. Their food qualities are almost equal to those of brook trout and their ability to fight will always give the angler a thrill. If the fish is of any size, the fisherman will have a tale to tell of a hard-fought battle and the time it took to land the catch safely.

Diseases of fish are many, and an ounce of prevention is worth a pound of cure. Salt has been the cure-all for most of our trouble with fish in the past. We have found another remedy, however, which we think is an improvement over salt, if properly used, for the removal of fungus or the killing of copepods on the gills of the fish, or in fact any germs that attack fish. If taken in time the use of potassium permanganate, one-half grain to a gallon of water, varying slightly according to the age of the fish, will bring results. A bath of a couple of minutes at a time in this solution about twice a day for several days if necessary, will kill most of the germs and keep the fish free from disease. Hereafter in the spring and fall we shall give all of our brook trout a bath at sorting time, hoping to thus keep them free from all germs.

To be successful in brook trout work, one must be alert and wideawake at all times in watching over the stock on hand. Close attention must be given to the feeding and care of the fish, or trouble is bound to result. A careless man has no business with the raising of fish in any manner.

Fish culture today is recognized by some as a big business proposition, although but few people truly realize the importance of it. Millions of pounds of food products are taken annually from our waters in a commercial way. This goes on from year to year. In addition, there is the recreation and sport for the angler as well as food he thus obtains from our waters each season. The many varieties and great numbers of game fish are worth untold millions to our country each year.

The only way that this vast wealth can be kept with us, so that future generations shall be able to realize the importance and reap the benefits of the industry is by the propagation and planting in our waters each year of more millions of fish. This together with regulations governing the size, daily catch and the season when they may be taken, will make it possible to maintain the fish supply for all time to come.

If it had not been for the propagation of whitefish on the Great Lakes, there would be practically none in those waters today. More whitefish have been taken from the waters of Wisconsin, Lake Michigan and Green Bay during the past two seasons than were taken in the previous decade. The fishermen say there are more lake trout in the waters of Lake Michigan now than there were forty years ago. This speaks well for the many plantings of fry which have been made.

It is remarkable to consider the large numbers of fish taken from year to year from our Great Lakes system, and then remember that the numbers caught annually have not diminished. When we recall the great waste resulting from the capture of immature and practically valueless No. 2 whitefish and trout, we are prompted to call attention to what they would have been worth to the fishermen at present prices if left for another two years to have reached a satisfactory size and weight. The resulting big addition to the food product would not have cost anyone a cent.

Something more should be done by the several states immediately concerned and by Canada to replenish Lake Superior with whitefish. It is almost fished out as far as this species is concerned, and some united action should be taken at once. The international waters should be governed by uniform legislation by the two countries, so that it will be possible to prevent waste of small trout and whitefish. The taking of these valuable fish before they have reached proper size should be strictly prohibited by both countries.

Discussion

Mr. E. T. D. Chambers, Quebec, Canada: May I be allowed to ask if the author of the paper can give us the date at which the gentleman whom he styles the "Father of Fish Culture" in Canada began his operations?

Mr. Nevin: He began about 1866.

Mr. Chambers: As a matter of historical accuracy, if the statement made in this paper is correct, I wish to correct a statement I made in the "History of the Canadian Fisheries," published about eight or ten years ago, in which I stated that the father of fish culture in Canada was Richard Nettle, who commenced operations in the city of Quebec—only in an experimental way, of course, at his own place of residence in the city. He succeeded in hatching in the late fifties, and the result of his operations has been published in his book entitled "Salmon Fishing in Canada," published by Lovell, of Montreal, in the year 1859 or 1860. The facts which I mention in the work to which I refer are also recorded by Mr. Rodd, of this city, in a paper which he read before the Canadian Fisheries Association—I do not remember the date—at its meeting last year at a point on Lake Erie. The facts can be very easily ascertained because Mr. Nettle's book is in print; and there is also in existence a report made to Sir Edmund Head, who was then Governor General of Canada. I am enabled to fix the date approximately because of the fact that Sir Edmund Head's only son was drowned while bathing in the St. Maurice River at the Falls of Shawinigan, and Sir Edmund was so heartbroken that he returned to England. That was before 1860 and Sir Edmund Head was a great patronizer of Richard Nettle in connection with his first hatchery and the operations which he carried on at his residence in the city of Quebec. His work may not have been upon a large scale but he certainly started the idea and in quite a practical manner. He took salmon eggs from the St. Charles river and hatched them at his place in Quebec; he also hatched trout eggs taken from waters in the province of Quebec. [Mr. Chambers later said that he had ascertained the exact year in which Nettle hatched trout at Quebec and planted them in Lake Beauport, and that it was in 1857.]

Mr. Wm. C. Adams, Boston, Mass.: Mr. Nevin spoke about the question of transporting fry.

Mr. Nevin: Those were fingerlings from six months to one year old, from three to five inches in length.

Mr. Adams: We have had difficulty in transporting small fingerling fish from a hatchery over a distance of about eighty miles to a rearing plant. When in forty gallon cans we lost our shipments, but when in ten gallon cans we had no trouble.

Mr. Nevin: This last fall we transferred a carload of about 10,000 fingerlings to the Wild Rose hatchery. These fish were placed in troughs in the hatchery building. I watched them for two hours and there was no sign of any fish dying; they were in perfect condition, and I went to supper. I had not been gone fifteen minutes when the foreman of the hatchery came rushing up to the hotel, telling me the fish were acting badly, a lot of them turning on their sides as if they had spasms, and beginning to die. I went to the hatchery with him, ordered several pails of salt placed in the troughs, and left the fish in this solution for some five minutes and they all revived. In fact, we lost only about 75 fish out of the 10,000 transferred. In my opinion, if I had not been on hand and used the salt as we did, we would have lost from one-half to two-thirds of the fish, judging by their looks when I reached the hatching house.

Mr. Adams: Would that be practical treatment for fingerlings as small as an inch and a half in length?

Mr. Nevin: Yes. That has been happening to us for years. In transporting fish we have better results in November than in any other month.

PROGRESS IN PRACTICAL FISH CULTURE

By Dwight Lydell

Michigan Fish Commission, Comstock Park, Mich.

Perhaps the animal kingdom affords no more striking example of waste and loss than occurs in the reproduction of young fish in a wild or natural state. When a parent fish must be provided with reproductive germs in such lavish numbers—often a thousand or more in order to produce a single adult—or, in other words, when nature must gamble at odds of a thousand to one in order to insure a posterity, it is timely to inquire into the extent to which this remarkable waste may be conserved and utilized. It is therefore the mission of the practical fish culturist to rescue from peril, to salvage natural waste and so shape its destiny as to add enormously to our food resources. It is obvious that he will succeed only to the extent that he is able to determine what are the real constructive forces of nature, then provide ways and means of utilizing, in proper balance, such of these forces as are in harmony with the special work at hand; and at the same time to constantly safeguard against all adverse conditions and natural forces that blight and destroy.

It is my purpose merely to refer briefly to improved practical methods that have stabilized and increased production to an extent that many additional millions of young fish have been added to our output in recent years.

Advancement in practical fish-cultural work depends to a great extent upon the fish culturist himself. He must thoroughly investigate natural conditions in his locality, and must devise means to control or modify any features inimical to satisfactory results. Certain kinds of pond fish will, with ideal weather conditions, reproduce themselves to some extent, but the fish culturist, if he is observing, may develop such other conditions as to insure a good output every season. Of course, the locality, kind and temperature of water, quantity of flowage and many other essential matters must be taken into consideration. The output of different kinds of pond-hatched and reared fish also depends a great deal upon the manner in which the pond is prepared for this particular work.

PREPARATION OF PONDS

The first requisite is that the ponds be in proper condition. If in a locality where freshets prevail and the bottom is covered with silt, the ponds should be drawn down the previous fall, cleaned, and allowed to remain dry until they become thoroughly frozen. This is to destroy undesirable forms of plant and animal life. To permit thorough cleaning, each pond should be provided with a concrete runway or gutter around the inlet, through the bottom, and connecting with the outlet. When the pond is being drawn down the mud is gradually forced with scrapers toward this gutter; when the pond is finally down, the mud is practically all in the center. Then a heavy flow of water is turned on and the mud is gradually washed out through the gutter. In the spring the ponds are again drawn down, and if they are to be used for the propagation of bass, the beds are placed where the fish culturist deems fit and according to the number of breeders he wishes to put in each pond.

If the ponds are located where but little richness comes from the flood water, they are fertilized, especially around the shallow margins, with some good kind of pond fertilizer. If too much vegetation has been growing in any pond, crayfish and adult goldfish are introduced to keep it down where it will not interfere with the subsequent collection of young fish. If not enough vegetation grows, it should be planted. Chara, which is very desirable in pond culture, can be transplanted in the fall, late in September or early in October, by drawing a pond that has an abundance, letting it dry, and then scattering a goodly supply over the bottom of the ponds that lack vegetation. The reason for the introduction of goldfish and crayfish is that they do not prey to any extent upon the insect life that furnishes food for other kinds of young fish. As the goldfish breed about a month later than the other varieties of pond fish, their young furnish an abundance of food later on. A pond with plenty of shallow margin will yield a greater number of fingerling fish; this is because more food is produced in the shoal margin areas.

INTRODUCTION OF BREEDING FISH

The breeding fish are carefully sorted, both with respect to their size and condition, and none but strong, healthy specimens of about the same size are placed in each breeding pond. The number put in each depends a great deal on its water area and the amount of natural food available for their young. Before the fish are transferred from the storage to the breeding ponds, the temperature is taken, and it is determined with absolute certainty that the temperature of the water meets the requirements of natural spawning conditions. If the hatchery water supply is from a spring brook, it is shut off from the breeding ponds, and the temperature of the latter allowed to rise to a point where breeding will take place quickly after the brood fish have been introduced. The breeding stock is held in one or two of the deeper ponds with an abundant supply of running water, and thus spawning may be retarded several days. The fish are constantly kept under close observation to see that breeding does not proceed too far before they are transferred to the warmer breeding ponds. It is far better to lose a few eggs in the retaining ponds than to lose them all in the breeding ponds, which latter will occur if the fish are sorted too early. After the fish have been sorted and transferred, close watch is kept of weather conditions and temperatures every moment until the hatching season is over. Only enough water is introduced into the breeding ponds to keep them at normal level, as this is better than having too large a flow. If the temperature starts downward, the water is shut off immediately.

If the fish culturist has studied different varieties of fish during the breeding season, he will probably recall that some streams in his vicinity failed to produce any fry during certain seasons. If he will study this matter closely he will find that proper conditions did not prevail. There may have been a few warm days and the fish came on the spawning ground and actually laid their eggs. Later on there was a cold spell, one or two cold nights when the temperature of the water dropped, thus causing the fish to desert their nests and practically the whole season's output was a total loss. The farther north the fish culturist is located, the more trouble he has with temperature conditions; but there is nothing to hinder him, if he keeps in close touch with the situation, in bringing about almost whatever he desires in this respect.

REARING YOUNG BASS IN PONDS

When the young bass are about to rise from the nest, they are screened, if for no other reason than to determine how many should be left in a certain pond to be reared to fingerlings. If there are too many, the surplus is transferred to other ponds or planted in public waters. Too many fry in one pond will result in their destroying the food supply, and then they would naturally all starve. The practical fish culturist after looking over his ponds carefully and estimating the amount of food therein, should be able to determine about how many thousand fry ought to be released. Scattering finely ground clam meal around the borders of the ponds increases the natural food supply. This was tried in 1920 at the Mill Creek Hatchery in Michigan, with results which confirmed our former experiments. No doubt fish scrap meal or any other form of meat or fish meal would serve equally well.

After several years of experimental work it has been found that better results have been obtained in raising bass in ponds with the adult fish than otherwise, provided the adults are well fed every day. The reason is the impossibility of keeping out of the ponds during the breeding and rearing season beetles, tadpoles and other forms of aquatic life which naturally prey upon the food that the fish culturist has provided for the young fry. Adult fish in the pond eat these larger aquatic forms, and therefore the minute crustacea are saved for the little fish. If it happens that too many fry have been released in a pond, close watch is kept of the young fish and food conditions, and before the food supply has become exhausted a number of the fish are removed to insure the remainder a food supply sufficient to last until they reach the fingerling stage. This is done from time to time, in fact, it is often necessary to resort to this thinning-down operation four or five times before the final cleanup of number one, two and three fingerlings.

REARING YOUNG BLUEGILLS IN PONDS

The propagation of bluegills is as yet in its infancy, especially in Michigan. Other states may have progressed further, but we find that the adult bluegills do not live any too well in small or medium ponds, and for some reason about two-thirds of the breeding stock is lost each season. Good results have been obtained, although it has been necessary to provide new stock each year, which in a way is a drawback. We have been very successful in the last two seasons in securing fingerling stock of this variety without any breeders. We simply went in the breeding season to some of our inland waters where bluegills were quite plentiful and obtained an abundance of fry. We noted that a large percentage of the fry were destroyed if left in the lake. Close observation disclosed that the young bluegills, when old enough, would rise from the nest and then toward evening settle back again. This happens four or five times before the fry are strong enough to swim away. During the operation many thousands are destroyed every time they attempt to rise. It was found that by taking a glass tube three or four feet long, and putting it down in the nest with the thumb over the upper end, thousands of the young fish could be obtained at one operation. They were then placed in cans and taken to the hatchery. The young fish, just before they rise from the nest, have something of a golden appearance.

When approaching the bluegill nesting ground the operator can select the more desirable nests occupied by the large fish. Two men in a boat will have no trouble in securing several hundred thousand young bluegills in a couple of hours if taken at the right time. As the breeding season of this species covers quite an extended period, we have no trouble in getting the number desired. Upon arrival at the hatchery the fish are put into ponds that have been recently prepared.

At first results were not absolutely satisfactory, as the fry settled to the bottom of the pond in the mud and silt and many of them were smothered before they were strong enough to rise. This trouble has been overcome by making small screen-like devices of cheese cloth stretched over a frame of any convenient size and submerged around the shallow margin of the pond. The sides of the screen frames should be about three inches high, so the fry cannot wriggle off into the muddy bottom of the pond.

Less care is necessary in estimating the number of bluegills placed in a pond, provided there is food enough to get them started, as they can be readily fed upon prepared food. We have been successful in feeding fresh liver or clam meal, very finely ground. In one pond, three hundred feet long and two hundred feet wide, we have about sixty thousand fingerling fish. You will find that this experiment merits your consideration and trial, provided you are in a locality where bluegill fry can be obtained from outlying waters.

COLLECTING AND HATCHING PERCH

The best results so far in rearing perch have been obtained by preparing the ponds as above described, turning on the water about the second week in April, in our locality, and then introducing several pairs of goldfish, according to the area of the pond. The young perch fry are introduced immediately after hatching. Nothing further is done until the perch show up around the shores, at which time they are about three-quarters of an inch in length. Then feeding is begun and continued until the latter part of August, when the fish are about three inches long. Several perch upon being examined have been found to contain small goldfish. The pond devoted to this work in 1920 yielded about 18,000 three-inch perch and several thousand young goldfish, the latter being removed during seining operations for perch. After exhausting or taking what they wanted of the natural food supply, the perch began to feed upon the young goldfish, and in addition took prepared food introduced three times a day.

In former years it was customary to collect the adult perch for breeding purposes, and results were considered very successful. But it was found by holding them over and feeding until the next season, we did not get as many eggs or as high a percentage of good eggs as we got from the wild stock brought to the hatchery. In order to improve this situation, we set about to find a way whereby the spawn might be obtained from wild waters. At first we studied spawning conditions in our inland lakes. We found that invariably the perch spawn during the night, coming to the shallower parts of the lake and hanging their ribbons of eggs on brush or rushes or any fairly suitable place. We also found that nearly all of this spawn was destroyed by turtles and other enemies in the lake. Even the perch themselves fed upon it the next day.

Early one morning we made a tour of a lake known to contain many adult perch and found that quantities of the spawn could be collected and shipped to the hatcheries. We also found that nearly one hundred per cent of the spawn was fertile and in some instances far better than that obtained from the station ponds. But this only supplied us with a limited quantity; therefore, observations were made on waters of the Great Lakes. At Wildfowl Bay, in the Saginaw district, where adult perch were quite abundant we found that during the spawning season hundreds of millions of perch eggs were destroyed by being washed ashore in great windrows along the beach. It is safe to say that two hundred million were lost in this one locality. Collecting operations have since been carried on there two seasons and the supply has been unlimited. There seems to be no reason why nearly all of these eggs could not be rescued and sent to our hatcheries, provided equipment for handling them were available. As most of them are in the eyed stage when they are washed ashore and are a total loss to the waters from which they come, I see no reason why other states should not profit by securing some of these eggs.

Experiments heretofore in hatching the eyed spawn have always been carried on with the old Chase hatching jar, but this season we found that about ten million of the eggs placed in a fry tank twelve feet long, four feet wide and two feet deep, hatched out very nicely and yielded good results. This tank was supplied with water through a pipe running the length of one side above the surface and pierced with a small hole every two inches which produced a nice spray and caused good aeration.

The eggs are in semi-buoyant ribbons and are very easily moved; the least circulation will tend to stir them up from the bottom. When left alone they will settle to the bottom of the tank, and if left three or four hours the young fry will smother wherever they come in contact with any object. This can be obviated by taking a hand-net about ten inches square of fine wire cloth stretched tightly over a frame, and moving it through the water until the resulting currents cause the whole mass of eggs to move up from the bottom. This should be done at least once an hour until the fry are hatched, which, if the eggs are eyed when secured, will be only a few days.

Discussion

Mr. J. W. Titcomb, Albany, N. Y.: I would like to ask Mr. Lydell what temperature he finds most favorable to the hatching of fresh water mussels; also the nature of the fertilizer used.

Mr. Lydell: The temperature is about sixty. For fertilizer we are using nothing but clam meal; we can get tons of it in our locality.

Mr. W. C. Adams, Boston, Mass.: I would like to ask Mr. Lydell whether an excess of tadpoles is injurious to the pond for small-mouth black bass culture?

Mr. Lydell: We have found them very injurious during the spawning season. We have boys patrolling our ponds in the evening and picking up these toads. We pay them so much a toad and we get barrels of them. We find that one young tadpole will eat more natural food than seven or eight young bass.

Mr. Adams: Even if the adult bass were to feed on the tadpole when the tadpole was two years old, it would still be disadvantageous to have these tadpoles in a bass pond, in your opinion?

Mr. Lydell: When a tadpole is two years old it would be a frog. We have very few of them; they are collected and put into our lakes.

Mr. Adams: Would the tadpole from the frog be any different from the tadpole from the toad?

Mr. Lydell: I do not think so.

Mr. Adams: So far as the principle is concerned the two would be similar?

Mr. Lydell: Yes. I would clean them out of any pond in which I wanted to rear young bass.

Mr. Titcomb: Do you ever use the tadpole for feeding bass?

Mr. Lydell: Often in the fall; we are feeding some now, collected from outside waters.

Dr. R. C. Osburn, Columbus, Ohio: The principle, of course, is that the tadpole is a vegetable feeder and will clean up the algæ upon which these small crustacea and insect larvæ feed; therefore you will reduce the natural food of the bass by having the tadpoles in the pond at a time when the bass are too small to feed on the tadpoles. On the other hand, at a later stage the tadpoles will be gone before the bass are big enough to handle them. If, therefore, you want to grow tadpoles for bass culture, the thing to do is to have an entirely separate pond for them and put them into your bass pond at the proper time.

Mr. Lydell: We have one pond more exclusively for bullheads, and into that pond we put all the large tadpoles. When we began to feed our young bullheads the clam meal, I noticed that it took more to feed the tadpoles than the bullheads. Wherever the bullheads congregated to take food, there you would see the tadpoles also; in fact, they were growing just as fast as the bullheads. But we were perfectly satisfied to feed them, because we are using them now to feed our bass.

Mr. Adams: Do you attempt to keep a stock of the adult bass throughout the year, or do you collect your breeders each spring?

Mr. Lydell: We keep a stock the year round. We have possibly six hundred now, but if our stock gets low we introduce some each season from different localities. We prefer to collect stock fish in the late fall.

Mr. Adams: What do you feed your adult bass throughout the year?

Mr. Lydell: Clam meal, minnows and crayfish. We start feeding the clam meal right after the spawning season and continue until the fish are put into the wintering ponds. From then on we feed them minnows and crayfish.

Mr. Adams: Do you see any objection to having a regular pond for minnows to breed your own supply?

Mr. Lydell: I think it would be an advantage to have a pond of that kind. We have a great many crayfish in our ponds and they are fed alive. Every pond is prepared for bass in the spring, and the large crayfish are put in.

Mr. Titcomb: Do the crayfish ever catch the young bass?

Mr. Lydell: Hardly ever. Occasionally, when seining them up we get too many crayfish in the net; then they will catch the bass.

Mr. Adams: Adult fish of what size are generally collected for breeding stock?

Mr. Lydell: About three pounds. We have a great many of the large size. If you put a lot of the small size in with them, you do not get very good results. True, we like to use as large fish as we can, because a large pair of bass does not take up any more room than a small pair, and they produce about four times as many fry.

Mr. Titcomb: How many years do you keep your breeding stock of bass?

Mr. Lydell: Until they die of old age; some may be ten years old. In the spring of the year, when we are sorting, if the fish look thin and not in the pink of condition, we throw them into the creek.

Mr. Adams: Would you say that a pond fifty or sixty feet in diameter, a round pond, is too small for bass culture?

Mr. Lydell: No. When we started our work we had some ponds of that size, holding only about six or seven pairs of breeders. We had one pond that was only twenty feet across. We had one pair of bass in there and got just as good results from that one pair as if they had been in a larger pond; but we could not raise in that one pond the fry that came from the pair. I may say that our ponds, this year, are about 350 feet long by 130 to 140 feet wide. There is a kettle about 5½ feet deep in all of our ponds.

Mr. Adams: Do you have any trouble getting the fingerlings out of these kettles in the fall?

Mr. Lydell: No. We find, however, that in the summer the large bass will collect in the kettle as long as they are well fed. If you see them going to the shore very much you can depend upon it that they are looking for something to eat. The small bass usually stay in the shallow part of the ponds, whereas the larger fish hardly ever go there.

CANADA AND THE UNITED STATES CAN RESTORE THE GREAT FRASER RIVER FISHERY

By JOHN PEASE BABCOCK

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Notwithstanding that the salmon fisheries of the Fraser River system have elsewhere been ably and adequately dealt with by the fishery authorities of Canada and the United States, it is so desirable that the transactions of the American Fisheries Society should contain a digest of the facts in this great international case that this paper is submitted.

The sockeye salmon fishery of the Fraser River system was formerly the world's greatest salmon fishery. The run of salmon in those waters was greater every fourth year than in any other waters. This fishery is no longer great. A discriminating study of the significant facts in the development and decline of this fishery demonstrates the necessity of dealing with them at once in an international way. These facts have been fully established, are no longer questioned, and should be more generally understood. The restoration of the sockeye salmon fishery of the Fraser River system is the greatest, and at the same time the least expensive, reclamation project in which Canada and the United States can jointly engage, and if adequate measures are adopted its success is certain.

The prominent facts in the history of the sockeye fishery may be stated as follows:

The waters of the Fraser River system as defined in the proposed treaty between Great Britain and the United States include all the fishing waters in the Province of British Columbia and in the State of Washington which are frequented by sockeye salmon in their migration from the Pacific Ocean to the spawning beds of the Fraser River basin. They include

Juan de Fuca, Rosario, and Haro Straits, and the other American estuary waters leading into the Gulf of Georgia, and the waters of that gulf as well as the channels of the Fraser River up to Mission Bridge, in British Columbia.

Fishing for sockeyes began commercially in the channels of the Fraser in British Columbia in 1876. It was extended to the waters of the Gulf of Georgia immediately outside the mouths of the river in 1890. Fishing for sockeyes began in Washington waters in 1891 with the installation of traps in the vicinity of Point Roberts. Traps became an important factor in 1897. Purse-nets came into use in American waters in 1901 and in recent years have greatly increased in number. During the period from 1900 to 1918, when the industry was at its height, the catch of sockeyes in Canadian waters produced a pack of 5,030,730 cases. During the same period the catch in American waters gave a pack of 7,382,343 cases. This represents a combined total pack of 12,413,073 cases, of which the Canadians produced 40 per cent and the Americans 60 per cent.

Dr. C. H. Gilbert, of Stanford University, in his "Contributions to the Life-history of the Sockeye Salmon,"* has demonstrated by scale-reading that the sockeyes that run in the Fraser River system are hatched in the watershed of that river in British Columbia, live for the first year or more of their lives in its lake waters, then migrate to the sea, where they remain and grow until the summer of their fourth year, and then seek to return to the Fraser River basin in order to spawn, and after spawning die.†

The Fraser River basin formerly produced more sockeye salmon every fourth year, known as the "big year," than any other known river-basin, and in the following years, known as the "small years," produced runs of commercial importance.

* See British Columbia Fisheries Reports, 1913 to 1918.

† There are however, exceptional cases in which fish proceed to sea immediately on hatching; and there are certain proportions which return in their third and fifth years.

The following statement gives the entire pack of sockeyes in American and Canadian waters of the Fraser River system for the years 1891 to 1919, inclusive:

SOCKEYE SALMON PACK OF FRASER RIVER SYSTEM, 1891 TO 1919 INCLUSIVE

Year.	Canadian waters.	American waters.	Total.
	Cases.	*Cases.*	*Cases.*
1891	176,954	5,538	182,492
1892	79,715	2,954	82,669
1893	457,797	47,852	505,649
1894	363,967	41,791	405,758
1895	395,984	65,143	461,127
1896	356,984	72,979	429,963
1897	860,459	312,048	1,172,507
1898	256,101	252,000	508,101
1899	480,485	499,646	980,131
1900	229,800	228,704	458,504
1901	928,669	1,105,096	2,033,765
1902	293,477	339,556	633,033
1903	204,809	167,211	372,020
1904	72,688	123,419	196,107
1905	837,489	847,122	1,684,611
1906	183,007	182,241	365,248
1907	62,617	96,974	159,591
1908	74,574	155,218	229,792
1909	585,435	1,005,120	1,590,555
1910	150,432	234,437	384,869
1911	62,817	126,950	189,767
1912	123,879	183,896	307,775
1913	736,661	1,664,827	2,401,488
1914	198,183	336,251	534,434
1915	91,130	64,584	155,714
1916	27,394	78,476	105,870
1917	148,164	411,538	559,702
1918	19,697	50,723	70,420
1919	34,068	64,346	98,414
Totals	8,493,436	8,766,640	17,260,076

The foregoing table gives a complete record for six four-year cycles and for the first two years of the present cycle. The outstanding features therein shown are: (1) The great packs made every fourth year; (2) the comparatively small packs made in the three intervening years; (3) the gradual but pronounced decline in the runs in the small years; and (4) the startling decline in the pack in the last big year, 1917.

As far back as written records exist, a phenomenally big run of sockeyes to the Fraser is shown every fourth year. All the early explorers record it and quote the Indians as saying it had always existed. It has been a characteristic peculiar to the Fraser and unknown in any other river. Up to 1917 the Fraser River district produced more sockeyes every fourth year than the combined catches made in Alaskan waters during all but one of those years, as the following statement shows:

Sockeye Salmon Pack of the Fraser River System and in Alaska

Year	Alaska.	Fraser River System.
	Cases.	*Cases.*
1901	1,319,335	2,033,765
1905	1,574,428	1,684,611
1909	1,705,302	1,590,555
1913	1,965,237	2,401,488
1917	2,488,381	559,702

The sockeye salmon runs to the Fraser River system in the big years have been alarmingly depleted, and the runs in the small years are no longer of commercial importance. Both are threatened with extinction.

Complete records exist of conditions on both the fishing and the spawning grounds of the Fraser system since 1900. The record of the pack shows the catch, because the entire catch is marketed in cans. The number of fishermen employed and the amount of gear used are also recorded. There are adequate data also for a comparison of conditions on the spawning beds since 1900. Dr. Gilbert, in "The Sockeye Run on the Fraser River,"* says:

> No other sockeye stream has received such close and discriminating study. Annual inspection has been made of the spawning beds of the entire water-shed, and predictions of the run four years hence have been fearlessly made. It is a matter of record how consistently these prophecies have been fulfilled.

The observations of conditions on the spawning beds have been made by the same observer since 1900.

* British Columbia Fisheries Report, 1917.

The records for the fishing grounds show that the runs of sockeyes to the Fraser River system in the big years 1901, 1905, 1909, and 1913 produced an average pack of 1,927,602 cases, and that in 1917, the last year in the cycle of big years, it produced a pack of but 559,732 cases, or 70 per cent less than the average of the four preceding big years. The startling decrease in 1917 is due to the fact that the great runs of 1913 did not reach the spawning beds of the upper section of the Fraser basin, for the reason that the river's channel at Hell's Gate was blocked by a great slide of rock following the construction of the Canadian Northern Pacific Railway through the canyon of the Fraser. A tunnel was driven through the rock cliff that overhangs the narrow channel immediately above Hell's Gate. During the spring of 1913 the action of frost caused a section of that cliff, including a portion of the tunnel, to slide into the river's channel, which formed an obstruction that the main portion of the run of fish could not get over. After frantic and continued efforts to surmount the obstruction the fish became exhausted and were swept downstream by the rapid current, where they died in the channels below without having spawned.

The British Columbia Fisheries Report for 1913 states that the number of sockeyes that escaped capture on the fishing grounds, and that later reached Hell's Gate that year, was fully as great, if not greater, than in the four preceding big years. The condition at the principal spawning beds of the Fraser created by the obstruction is described in the following excerpt from an article by the author, in the British Columbia Fisheries Report for 1913:

I feel fully justified from my investigations in concluding that the number of sockeyes which passed above the fishing limits was as great this year as any preceding big year of which we have a record, and I think even greater. The sockeyes made their appearance in the canyon above Yale in June, and during the high waters of that month and July large numbers passed through to Quesnel and Chilko lakes. The greater proportion of the run of sockeyes in late July, and in August and September, was blockaded in the canyon by rock obstructions placed in the channel, incident to the construction of the Canadian Northern Pacific Railroad, so that few were able to pass through during that time. No humpbacks succeeded in passing through the canyon. The blasting of temporary passage-ways enabled a large proportion of the sockeye run of October and November to pass through the canyon. In August, sockeyes were seen drifting down-stream between Hell's Gate and Yale; the movement was very pronounced in September, and continued until the middle of October. The streams which enter the Fraser between Hell's Gate and Agassiz were filled with sockeyes from the middle of August until the end of October, while they had not been observed in those streams in previous years. Very few sockeyes spawned in any of those streams and most of them died without spawning. Great numbers of dead sockeyes which had died without spawning, were found on the bars and banks of the Fraser between Yale and Agassiz in September and October. The number which reached Quesnel Lake was little more than an eighth of the number which entered that lake in 1909. The run to Chilko Lake was equally small. The sockeye run to Seton Lake was 30,000, as against 1,000,000 in 1909. The August and September run of sockeyes to Shuswap and Adams Lakes was much less than in any former big year, and the October and November run was also less. The sockeye eggs collected there this year totalled but 9,000,000, as against 27,500,000 four years ago, and 18,000,000 in 1905. The run to Lillooet Lake was less than in any recent year. Finally the run to Harrison Lake was slightly better than in 1909.

These facts, in my opinion, warrant the conclusion that the number of sockeyes which spawned in the Fraser River watershed this year was not sufficient to make the run four years hence (1917) even approximate the runs of either 1905, 1909, or 1913.

The disastrous effect of the 1913 blockade was manifested on both the fishing and spawning grounds in 1917, since the run in the latter year was the product of the 1913 spawning. The catch of 1917 produced a pack of but 559,732 cases as against 2,401,488 cases, or 76 per cent less than in 1913, notwithstanding the fact that more gear and more fishermen were employed than in 1913 and the price paid for fish was higher.

Small as was the catch of 1917, too great a proportion of the run of that year was captured; that is, a sufficient number of fish was not permitted to reach the spawning area. In place of the millions of sockeyes that reached Hell's Gate in 1913, only hundreds of thousands reached there in 1917. The obstruction having been removed, the fish had no difficulty in passing through to the spawning beds above. The numbers that passed through in 1917 were far less than in 1913, notwithstanding the blockade of the latter year. In place of the 4,000,000 that entered Quesnel Lake in 1909 and the 552,000 that entered its waters in 1913, less than 27,000 passed into that great spawning area in 1917, and the numbers that reached all the other great lake sections were proportionally less than in 1913*. The number of sockeyes that reached the Fraser basin in 1917 was not, in most sections, greater than in some recent small years. The result of the spawning in 1917 will not produce in 1921 a run even approximately as great as that of 1917. In other words, it may be expected to be very much less. The great run of the big years was destroyed by the 1913 blockade. The remnant of that run cannot withstand the drain made upon it in 1917. It is already so small that it must hereafter be classed with the runs in the small years. And like the runs in the small years it will be completely wiped out if present conditions continue.

The runs of sockeyes to the Fraser system in the small years are no longer of commercial importance. Dr. Gilbert, in his article entitled "The Sockeye Run on the Fraser River"† says:

> The history of the Fraser River sockeye runs shows unmistakably that the three small years of each four-year cycle were over-fished early in the history of the industry. During the early years, when fishing was confined to the region about the mouth of the river, and drift-nets alone were employed, no evidence exists of overfishing. The last cycle in which these conditions obtained was 1894-96. During each of the small years of that cycle (1894, 1895, and 1896) there were packed approximately 350,000 cases on the Fraser River and about 60,000 cases in Puget Sound. During each of those years, therefore, about 5,000,000 sockeyes were taken from the spawning run and used for commercial purposes. It should have been considered at that time an open question whether enough salmon to keep the run going had been permitted to escape to the spawning grounds. Apparently, however, a third of a million cases a year could be safely spared, for the following cycle shows no decrease. If from the beginning the pack had been limited to a third

* British Columbia Fisheries Report, 1917, p. 21.
†Ibid., pp. 113-114.

of a million cases for each small year, apparently the runs would still have continued in their primitive abundance.

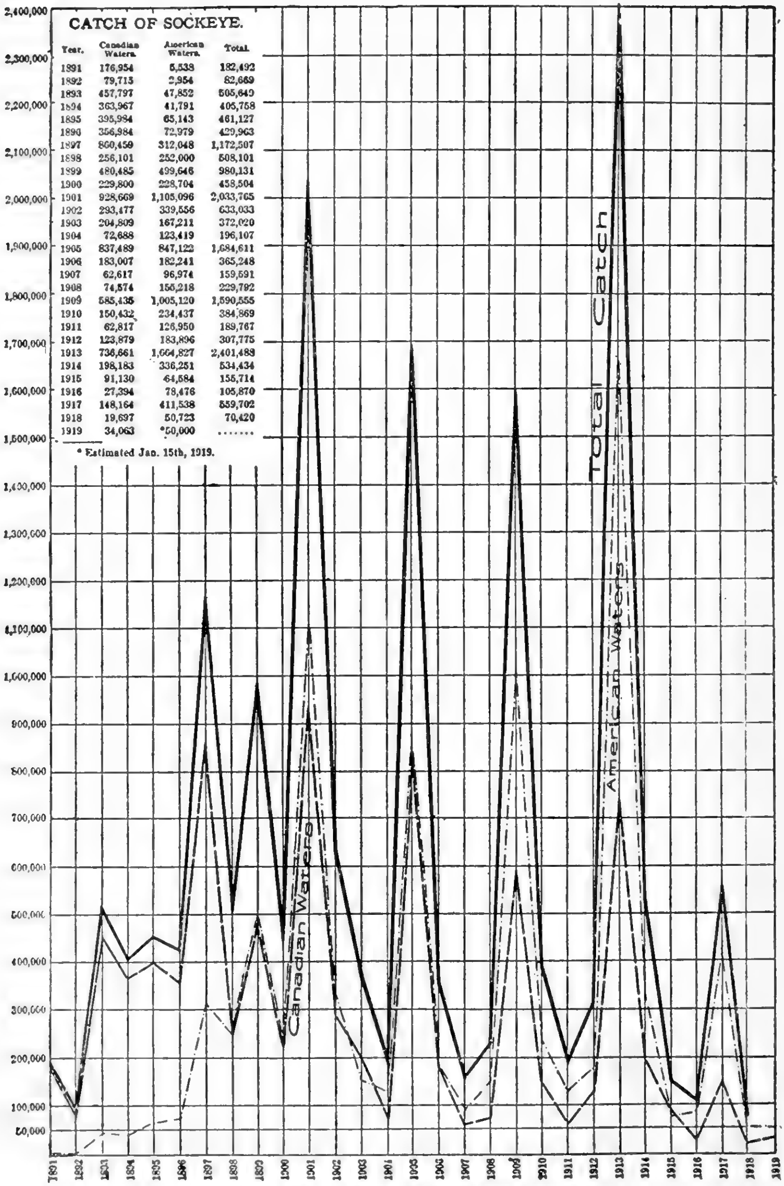
During the following period of four years (1897, 1898, 1899, and 1900) the traps on Puget Sound became an important matter. While the British Columbia pack shows little or no reduction, it was met by a pack on Puget Sound which nearly equalled it. The total captures during the three off-years of this cycle nearly doubled those of the preceding years and exacted an average toll of about 10,000,000 fish from the spawning run of those years. The total pack of the three small years of this cycle was over 2,000,000 cases.

The result was quickly apparent. If 5,000,000 fish could be safely spared, this figure nevertheless must have been near the upper limit of safety, for when 10,000,000 fish were abstracted, the small years of the following cycle showed such a marked decline as to indicate that we had far overstepped the line of safety. It was then during the cycle of 1897-1900 that the first serious damage was done to the sockeye run of the Fraser River. By doubling the pack of the three small years, not only was the surplus fully taken, but the necessary spawning reserve was seriously encroached on, with the result that in the small years of the following cycle (1902, 1903, and 1904), in spite of the increased amount of gear employed, the pack was cut in half, while the spawning beds at the same time were but sparsely seeded.

The inevitable and disastrous trend of events should have been evident to the dullest. But the parties in interest refused to hold their hands and proceeded with the slaughter of the spawning remnant. The result was quickly apparent. In 1902, 1903, and 1904 the total sockeye pack of the Fraser River system was cut to 1,200,000 cases, and in succeeding years it has suffered still further reduction. The pack of the three small years never again equalled 1,000,000 cases. In 1906-08 it was 750,000 cases; 1910-12, 880,000 cases; in 1914-16, 796,000. And with each year the amount of gear employed has increased by leaps and bounds. The small years of the present cycle may be expected to register a smaller total than any which have gone before.

The total catch of sockeyes in the Fraser River system in the past two small years of the present cycle demonstrates the correctness of Dr. Gilbert's forecast. The catch of 1918 produced a pack of but 70,420 cases, as against 534,434 cases in the preceding fourth year; and the catch in 1919 gave a pack of but 98,414 cases, as against 155,714 cases in 1915.

The evidence of the decline in the runs of sockeyes in the Fraser River system is overwhelming. The runs in all years have already become so depleted that it is evident that under



CATCH OF SOCKEYE.

Year.	Canadian Waters.	American Waters.	Total.
1891	176,954	5,538	182,492
1892	79,715	2,954	82,669
1893	457,797	47,852	505,649
1894	363,967	41,791	405,758
1895	395,984	65,143	461,127
1896	356,984	72,979	429,963
1897	860,459	312,048	1,172,507
1898	256,101	252,000	508,101
1899	480,485	499,646	980,131
1900	229,800	228,704	458,504
1901	928,669	1,105,096	2,033,765
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1915	91,130	64,584	155,714
1916	27,394	78,476	105,870
1917	148,164	411,538	559,702
1918	19,697	50,723	70,420
1919	34,063	*50,000	....

* Estimated Jan. 15th, 1919.

CATCH OF SOCKEYE SALMON.

Fraser River System, 1891 to 1919, inclusive.

existing conditions the sockeyes will be exterminated within a short period.

The Fraser River basin has an area of 90,903 square miles. It contains sixteen great lakes and many rivers that have a total area of 2,351 square miles. No other river on the Pacific Coast drains so extensive an area of lake water adapted to the propagation and rearing of sockeyes. In the past it has produced greater runs of sockeyes than any other river because this great spawning area was abundantly seeded every fourth year. It has been shown that sockeyes spawn in streams tributary to lakes and on the shoals of lakes, and that their young remain in the lake-waters for a year or more after hatching and then migrate to the sea. Knowing that the sockeyes were bred in the watershed of the Fraser, we therefore know that the great runs of sockeyes in the big years 1901, 1905, 1909, and 1913 originated there. The runs of those years produced an average pack of 1,927,602 cases and at the same time afforded in the first three named years a sufficient number to seed the entire spawning area. Therefore the amount of the average pack of the big years 1901, 1905, 1909, and 1913 may be safely taken from the run without an overdraft, whenever the spawning beds are as abundantly seeded as they were in 1901, 1905, and 1909. The spawning area of the Fraser has not been lessened or injured. Its spawning beds have not been damaged or interfered with by settlement, factories, mining, or irrigation. Its gravel beds and shoals are as extensive and as suitable for spawning as they ever were. Its lake-waters are as abundantly filled as ever with the natural food for the development of young sockeyes. The channels of the Fraser are open and free to the passage of fish. All that is required to reproduce the great runs of the past is a sufficient number of spawning fish to seed the beds as abundantly as they were seeded in 1901, 1905, and 1909, and in former big years. The fishery cannot be restored in any other way.

The great sockeye salmon fishery of the Fraser River system has not been destroyed without efforts having been made to prevent it. Canada throughout has stood for conservation. She has put forth earnest and conscientious efforts to conserve the supply and to prevent depletion. Her record is clear and unmistakable. She failed because she did not have jurisdiction over the entire system. She alone could not provide adequate protection, but she did all that was possible under the circumstances. Commercial fishing for sockeye salmon began in Canadian waters in 1876, under the general fishery regulations of the Dominion. In 1878 Canada passed an Order in Council providing that "Drifting with salmon nets shall be confined to tidal waters" and "that drift-nets for salmon shall not obstruct more than one-third of the width of any stream," and further that "fishing for salmon shall be discontinued from 8 a. m. Saturdays to midnight Sundays." All fishing in her waters has been under license and none but bona fide resident fishermen have been permitted to fish.

In 1889 the Dominion fishery regulations for British Columbia were amended to provide that "the Minister of Marine and Fisheries shall from time to time determine the number of boats, seines or nets or other fishing apparatus to be used in any waters of British Columbia," and all the provisions of the regulations of 1878 were continued. In 1894 the order was further amended to include the provision that "the meshes of nets for catching salmon other than spring salmon, in tidal waters shall not be less than 5¾ inches extension measure and shall be used only between the first day of July and the twenty-fifth day of August and between the twenty-fifth day of September and the thirty-first day of October." Canada has maintained close seasons in her waters ever since. In recent years the weekly close time has been extended and the fishing limits further restricted.

During the period 1876 to 1890 sockeye fishing was confined to Canadian waters alone, and it is a matter of record that the catch did not in any one year produce a pack in excess of 300,000 cases, representing a catch of less than four million sockeyes, and that during that period Canada hatched and planted in the Fraser twenty-five millions of sockeye fry.

Canada began the propagation of sockeyes in the Fraser in 1885 with the establishment of a hatchery at Bon Accord. Between 1900 and 1907 Canada built five hatcheries on the Fraser having a capacity of one hundred and ten million sockeye eggs, and she has since built two auxiliary stations. The hatcheries built in 1901 at Shuswap and in 1903 at Seton Lake, have been closed since 1914, because a sufficient number of eggs to warrant operations could not be collected from the tributaries of those lakes. With the exception of the years of the big run, the hatcheries of the Fraser River have never been filled beyond thirty per cent of their capacity since 1905, because eggs to fill them were unobtainable.

Canada established a patrol force on the Fraser in 1878 and her waters have been effectively policed every year since. Canada inaugurated a method for the inspection of the spawning area of the Fraser River basin in 1901, and has annually conducted such investigations every year since. No other sockeye stream has received such close and discriminating study.

The reports from the spawning beds since 1901 have been the basis of Canada's contentions. Following the disclosures made in the reports from the spawning beds in 1902, 1903 and 1904, that there had been a great reduction in the numbers of sockeyes that reached the beds in those years, and with the knowledge that the catches in those years were also far less than in the preceding four years, Canada laid the facts before the Governor of the State of Washington, and obtained the appointment of a joint commission to investigate conditions affecting the salmon fishery of the Fraser River system. That commission, consisting of five representatives from the State of Washington and five from Canada, unanimously reported that the runs of sockeyes to the system in the small years had been seriously depleted by excessive fishing and were in danger of being destroyed, and recommended that all fishing for sockeyes in both state and provincial waters be suspended during the years of 1906 and 1908. It was believed by the Commissioners that by prohibiting fishing in those years, the runs four years later would be restored to their former proportions. Canada accepted the finding of that commission and at once passed an Order in Council prohibiting sockeye fishing in 1906 and 1908, provided the State of Washington passed a similar act prohibiting fishing in her waters. A bill to that effect was rejected by the Washington Legislature in 1906. Consequently Canada recalled her order, and fishing was conducted in both those years with renewed vigor and with disastrous effect. The catches were smaller and the spawning beds less seeded.

Following the failure of the State of Washington to adopt the measure Canada turned for help to the Federal Government at Washington, D. C., and secured the appointment in 1907 of an international commission to inquire into conditions in the Fraser River system. After a year of investigation that commission unanimously recommended, as necessary to prevent further depletion, the adoption of joint and uniform regulations restricting fishing. A treaty embodying its recommendations was drawn and signed at Washington in 1908, by Great Britain for Canada, and by the President of the United States. The United States Senate rejected it. Therefore fishing was continued as before and, although the amount of gear was greatly increased, the catches in the small years continued to decrease, and the reports from the spawning beds grew even more alarming.

The progressive decline in the catch in the small years, and the disastrous effect of the blockade in the Fraser channel at Hell's Gate in 1913, caused Canada to renew her overtures to the United States Government for the adoption of remedial measures. In 1917 Canada and the United States created a joint international fishery commission to deal with the subject, consisting of the Honorable Sir J. D. Hazen, Chief Justice of New Brunswick, G. J. Desbarats, Deputy Minister of

Naval Service, Ottawa, and William A. Found, Superintendent of Fisheries for the Dominion of Canada, representing Great Britain; and the Honorable Wm. C. Redfield, Secretary of Commerce, Edwin F. Sweet, Assistant Secretary of Commerce, and Dr. Hugh M. Smith, United States Commissioner of Fisheries, representing the United States. Following an extended investigation, that commission, like the commissions of 1906 and 1908, unanimously found that the situation was critical and recommended joint action on the part of Canada and the United States. Subsequently a treaty was signed at Washington, D. C., in 1919. Canada at once approved the treaty. That treaty now awaits the action of the Senate of the United States.

Canada stands today, as she has stood since the beginning, ready to adopt any measures which promise to restore the runs of sockeyes to the Fraser River system. She can accomplish nothing without the cooperation of the United States. Neither Canada nor the United States acting singly can provide measures that will ensure restoration of the salmon.

Deplorable as the conditions on the Fraser system are, the runs of sockeyes can be restored by concurrent action on the part of Canada and the United States. It has been shown that in the big years 1901, 1905, 1909, and 1913, the Fraser system produced an average of 1,927,602 cases of sockeyes, and at the same time afforded an ample supply to seed all of the spawning beds. The average catch of the four big years named may again be taken whenever the beds are again as abundantly seeded as they were in the brood years that produced those big runs. The spawning area of the Fraser basin has not been lessened or damaged in any way. Its spawning beds are as extensive and as suitable for salmon propagation as they ever were. Its lake waters are as abundantly filled as ever with the natural food for the development of young sockeyes, and the channels of the Fraser are open and free to the passage of fish. All that is required to reproduce the great runs of former years is to seed the spawning beds as abundantly as they were formerly seeded.

The spawning area of the Fraser requires no expenditure of money to bring it into bearing. If permitted to reach the beds in sufficient numbers, the fish will seed them, the young will feed themselves, and furnish their own transportation to and from their feeding grounds in the open sea. If permitted to do so, the fish will do all the work necessary to produce a catch worth thirty million dollars a year. All that is necessary is for the Governments of Canada and the United States to adopt measures which will afford a free passage through their waters to a sufficient number of sockeyes to seed the spawning beds. The runs of sockeyes to the Fraser River system cannot be restored in any other way.

FISH RESCUE OPERATIONS

By C. F. Culler

Superintendent, U. S. Bureau of Fisheries, Homer, Minn.

Perhaps no branch of the fish-cultural work of the Bureau of Fisheries has attained more rapid development during the past few years than that addressed to the rescue of fishes from the overflowed lands bordering the Mississippi River. The development and growth of the work is manifested not only by the ever-increasing numbers of food and game fishes rescued each season, but it is also marked by a decreasing unit cost of production.

Several times each year the Mississippi overflows its banks, but it is the annual freshet known as the June rise that is of greatest importance to the fisheries. As the river rises the adjacent lowlands are submerged. The quiet backwaters thus formed provide very attractive spawning areas for the food and game fishes indigenous to the river. The eggs are laid under conditions favorable to their development and the young fish attain a rapid growth before the freshet begins to subside. At this time the adult fish find their way to safety in the main channel, but the young do not react promptly to the falling waters, and enormous numbers are cut off and become permanently landlocked.

The pools and lakes left by the falling waters are of various sizes; some of them may become dry in a few days or weeks, while others may persist into the winter months. In either event, the fish remaining in them are doomed to certain destruction unless a rescue party comes to their aid and returns them to the open waters of the river. If any of the fish are able to survive the frightful conditions that exist in these landlocked pools, and which as the summer advances become more aggravated, the arrival of cold weather is sure to end the story. The shallower pools freeze solidly, while in the deeper ones the fish are so highly concentrated that death by smothering is inevitable even though the pool does not freeze to the bottom.

The need of some sort of salvage work has long been recognized, and the first attempts to save a few of the stranded fishes were made in the late nineties. It is only in very recent years, however, that the work may be considered as approaching a point commensurate with the need.

During the fiscal year 1920 the number of fish rescued by the Bureau of Fisheries was 156,657,000. All of the important food fishes are represented in the collections, but the staple fishes, which contribute largely to the food supply and support the commercial fishery, largely predominate.

The territory covered by the rescue operations during 1919 extended from Minnesota and Wisconsin to Arkansas and Mississippi, though the so-called upper river districts, with headquarters at Homer, Minn., and substations at La Crosse, Wis., and North MacGregor and Bellevue, Iowa, were by far the most prolific fields.

Of interest in connection with this work is the very moderate cost of operations. A few years ago when the work was first undertaken and when comparatively small numbers of fish were secured, the cost per thousand was about $3.18. During 1919 the average cost per thousand was less than 20 cents, while between 75 and 80 per cent of the total number were rescued at a cost of only 13 cents per thousand fish. To further show the moderate cost of rescue operations, it may be interesting to compare the work with that of a station devoted to the artificial propagation of the warm-water species similar to those rescued. Such a station may produce from 250,000 to 1,000,000 fingerling fish 2 to 3 inches long in a season. The cost varies from $4.50 to $5.50 per thousand fish. From these figures it appears that it would have required at least 345 established plants to produce the numbers of fish rescued during 1919, and that the actual cost of production would have been in excess of $800,000. These figures do not include the cost of the regular station employees, nor any consideration of the initial cost of construction. The aggregate cost of the rescue operations for the fiscal year 1920 was $31,000. Following this line of thought, it is surely a conservative estimate to assume that 25 per cent of the fishes may be expected to survive and reach a legal marketable size, with an average weight of not less than 1½ pounds in two or three years. If they are then placed on the market and sold by the fishermen at the prices prevailing in December, 1919, the salvaged fishes have a prospective value of $6,527,000.

A rescue crew consists usually of six men and a foreman. A launch is employed in going to and from the field of operations, and the equipment consists of two seines 50 and 75 feet long, 6 feet deep of ¼-inch mesh, six galvanized iron tubs of 1½ bushels capacity, small dipnets, two tin dippers, and a small flat-bottomed boat, the latter being used in ponds too deep for wading. After a haul has been made, the fish are sorted in the tubs by species and size. The number of fish per tub is ascertained by noting the displacement of the water in the tub, one or more rings having been made on the inside of each tub and the number established by actual count. The count is verified several times during the season, as the fish are in some instances subject to rapid growth.

Inasmuch as the fish when first taken from the warm waters will not safely stand a long railway journey, those intended for distribution are taken to the nearest holding station where they are hardened for several days in cool running water. While the numbers of fish diverted for supplying applicants in other parts of the country may seem large in the aggregate, they represent less than one per cent of the total collections. Such diversions during the past year amounted to 983,794 miscellaneous fishes. Included in this number are more than 500,000 allotted to the fish commissions of the states bordering the Mississippi River where the Bureau's work is conducted. It is more than probable that many of these fish were replanted in waters connected with the Mississippi River drainage system.

The importance of this work is receiving each year more recognition from members of state fish and game commissions and from other public officials having the interest of the fisheries and the conservation of the country's resources at heart. The Bureau of Fisheries receives numerous letters from various sources urging the extension of this valuable work to new fields; but until such time as Congress recognizes its importance by providing adequate funds and a suitable personnel, new fields cannot be opened. The possibilities for the further extension of operations are very great. Even in the districts where it is now being conducted, the field is only partially covered, while there are many unbroken miles of river, on which no rescue work has been undertaken, where the floods are annually causing the destruction of large numbers of fish. The major tributaries also offer a field of unknown possibilities.

Under present arrangements, Congress makes no special appropriation for this particular work. It is financed by a part of the general appropriation for the propagation of food and game fishes, while the regular personnel and equipment are drawn temporarily from other branches. What is needed in order that operations may be conducted on the scale that their importance justifies, is direct recognition by Congress through the provision of special funds and personnel. Thus the work would not be more or less contingent on the necessities of other duly established activities for which money from the general fund must be allotted.

It should be made evident that the rescue work is of more than local interest. The food fishes of the Mississippi River receive a wide distribution in the trade, while the numbers diverted for the stocking of other waters is of importance. In fact, the importance of this work as a means of maintaining and increasing the food supply of the country, can hardly be equalled in any other field, when cost, results, and quick returns are considered.

TROUT FEEDING EXPERIMENTS

By Chas. O. Hayford

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In the accompanying tables an attempt has been made to indicate as clearly and concisely as possible, the results obtained from some experiments in the feeding of fingerling brook trout (*Salvelinus fontinalis*) and brown trout (*Salmo fario*) conducted at the hatchery operated by the State of New Jersey at Hackettstown. The work was carried on under the immediate supervision of Robert W. Hodgson, chemist, formerly instructor in bacteriology and assistant to Prof. William F. Foster in pathological and bacteriological work at the A. E. F. University, France.

A large stock of trout is constantly maintained at the Hackettstown hatchery, the fish varying in age from newly hatched fry to adults two and three years old. To feed this large stock, from 75 to 100 tons of meat products and fish are required annually; and it was for the purpose of determining the relative values of the different articles used as fish food, and by a comparison of prices to effectuate a possible reduction in the maintenance cost of the fish, that the experiments were undertaken. Careful arrangements were made to hold all the fish involved in the experiments under identically similar conditions, in order that any possible variation in the results might be attributed solely to the kind of food used. Nursery troughs of the same size were used, each being supplied at uniform rate with an independent flow of water from the same source. The water used was derived from five springs with a minimum flow of two and one half million gallons per day. A chemical and gas analysis of the water gave the following results:

	Parts per million
Chlorine	11.5
Alkalinity	129.0
Total hardness (Soap method)	162.5
Total solids	175.
Mineral residue	152.
Loss on ignition	23.
Carbon dioxide	4.2
Oxygen (66% saturation at 51° F.)	7.5

As the materials in most general use for the fish food at the Hackettstown hatchery are pork melts, sheep plucks, beef liver, and butterfish, these articles, either singly or in combination, were the ones principally considered, though certain insects and their larvæ were introduced. The average cost per pound of the different articles used is as follows: Beef liver, 13 cents; sheep plucks, 5 cents; pork melts, 3½ cents; and butterfish, 4 cents. It is difficult to estimate the cost of maggots, but since waste material was used in their production it is safe to say that the cost was low.

As it appeared important that each lot of fish should be uniform in size and weight, they were carefully graded as to size before being placed in the troughs selected. Several lots from each trough were then weighed and the average weight from each trough recorded. In weighing the fish, a uniform method was followed throughout the course of the tests, and the average weight of each lot of fish was obtained and recorded every ten days. Two waxed paper cups were filled with water and balanced on a standard laboratory scale. The fish were taken from the troughs with a small dip net and allowed to drain for one minute. They were then transferred to one of the cups and weighed. By exercising care, there was no loss of weight through splashing or slopping of the water.

Feeding occurred twice each day, the daily ration of food being approximately two per cent of the weight of the fish. The food was prepared fresh each morning, weighed, and placed in the troughs in the usual manner. The food chopper was washed thoroughly after each lot of food was prepared to prevent mixing of foods at the time of preparation. In all other respects the fish were treated in a manner similar to all hatchery fish. The dead fish were removed each day and the losses properly recorded. Each morning unconsumed particles of food and other refuse were removed from the troughs, and every second morning the troughs were thoroughly cleaned in the usual manner.

It should be noted that the brown trout used were culls, and that the troughs in which they were confined were divided by wire screens into three compartments, each compartment containing 100 fish, or a total of 300 fish per trough. The object of the screens was to provide a more equal distribution of the food. The troughs containing the brook trout were not so divided, and only 100 fish were allotted per trough. With this exception all of the fish were held in environment identical in all respects; the only point of difference was the variety of food supplied. The brown trout were considerably smaller than the brook trout.

Among the more pronounced points developed from a study of the tables are the wide variations in mortality and growth, brought about, it seems fair to assume, by the different varieties of food. Sheep plucks at 5 cents per pound seem to be entitled to first consideration, while beef livers at 13 cents per pound, and perhaps quite generally considered one of the best of fish foods, is only a poor second. The fly larvæ or maggots also produced very satisfactory results.

Water temperature throughout the course of the experiment was unchanged at 51° F. or 28.3° C., and the percentage of hemoglobin remained constant in all cases, regardless of the kind of food used. The insect forms of food were: Corixæ; black-fly larvæ; and Mayfly and stonefly nymphs.

The difference in results obtained from feeding the various foods to fish of different ages is surprising. When the fish are two or three months old they seem to do well on certain foods, and at five or six months they do better on other foods. This goes to show that in order to obtain successful results, we ought to administer a balanced ration. We blame many of our troubles to the temperature of the water, and other things, whereas it may be that the difficulty is caused by a lack of vitamines or something that we can furnish.

EXPERIMENTS IN FEEDING BROOK TROUT

(Fish in Experiments I and II 5 months old at beginning.)

Food used.	Number of fish at beginning.	Average weight.			Number of fish at end.	Mortality.	
		Initial.	Increase.	Final.		First half.	Second half.
		Grams.	*Grams.*	*Grams.*		*Percentage*	*Percentage.*
EXPERIMENT I.*							
Beef liver and maggots	100	2.700	1.284	3.984	56	25.00	25.33
Maggots	100	1.300	1.216	2.516	78	16.00	7.14
Beef liver and asellus	100	1.300	1.164	2.464	75	17.00	9.63
Butterfish	100	1.860	1.151	3.011	51	24.00	33.18
Pork melts	100	1.860	1.150	3.010	64	14.00	25.50
Beef liver and snails	100	1.300	1.072	2.327	57	23.00	25.94
Sheep plucks	100	1.860	1.020	2.880	75	18.00	8.53
Beef liver	100	1.860	.981	2.841	75	18.00	8.53
EXPERIMENT II.†							
Sheep plucks and maggots	100	1.580	1.616	3.196	58	31.00	18.84
Butterfish and sheep plucks	100	1.580	1.570	3.150	38	45.00	30.90
Butterfish and pork melts	100	1.580	1.266	2.846	41	46.00	24.07
Butterfish and maggots	100	1.580	1.262	2.842	28	64.00	22.22
Butterfish and asellus	100	1.580	1.130	2.710	31	51.00	36.73
Sheep plucks and asellus	100	1.580	1.110	2.700	52	42.00	10.34
Pork melts and maggots	100	1.580	1.120	2.690	46	43.00	19.30
Asellus	100	1.580	.916	2.496	29	48.00	44.23
EXPERIMENT III...‡							
Insects	100	5.826	1.969	7.795	29	63.00	21.62

* Experiment continued for a period of 40 days.
†Experiment continued for a period of 48 days.
‡ Experiment continued for a period of 36 days.

EXPERIMENT IN FEEDING BROWN TROUT

(Experiment continued for a period of 60 days with fish 4 months old at beginning.)

Food used.	Number of fish at beginning.	Average weight.			Number of fish at end.	Mortality.	
		Initial.	Increase.	Final.		First half.	Second half.
		Grams.	*Grams.*	*Grams.*		*Percentage.*	*Percentage.*
Sheep plucks	300	.361	.515	.876	263	8.00	4.71
Beef liver	300	.361	.467	.828	251	15.33	1.19
Pork melts	300	.361	.429	.790	233	17.66	8.04
Beef liver and maggots	300	.361	.414	.775	246	15.66	2.76
Maggots	300	.361	.402	.763	242	16.66	3.2
Butterfish	300	.361	.361	.722	227	15.33	10.62
Beef liver and asellus	300	.361	.339	.700	241	15.33	5.11
Beef liver and snails	300	.361	.269	.630	215	24.66	4.86

Discussion

Mr. John W. Titcomb, Albany, N. Y.: Would it not be possible to get these same comparisons between different species at the same age?

Mr. Hayford: It would be possible, but the difference is in the weight.

Mr. Titcomb: In comparing the growth of these different species, did you get a record of the weight of different kinds of food used?

Mr. Hayford: We gave each species one-fiftieth of its weight daily, divided into two foods. It might be possible to use a cheaper food and more of it. This is a matter that requires a good deal of consideration because under different temperatures it works differently. What might be good at 51 degrees might work differently at another temperature.

Mr. Titcomb: Do I understand you to say that in feeding you used sheep plucks and livers ground together?

Mr. Hayford: Yes, all ground together. The best results were obtained from the beef liver and maggots in the case of the brook trout, and from the sheep plucks in the case of the brown trout.

Mr. Titcomb: I suggest that anyone who wants to carry this test along with the maggots produced from fish will find that it is a very much less offensive operation than producing maggots from meat. It is a very simple matter to produce tons of maggots from cold storage fish, and the odor does not extend very far beyond the building where they are produced. In connection with our fish-cultural operations we catch a great many carp and bill fish. They are placed in cold storage and eventually taken to one of the game farms and changed into maggots for feeding the pheasants. Every particle of the fish is used except the skin and the bones. It is a very simple process.

THE RELATIONSHIP OF THE SO-CALLED BLUE PIKE AND YELLOW PIKE OF LAKE ERIE AND LAKE ONTARIO

By Dr. William Converse Kendall

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The relationship of the pike perches, locally designated as blue pike and yellow pike, has been more or less a moot question, and the status of their idenity has, from time to time, given rise to investigation of the subject. Each inquiry, however, has resulted in the conclusion that there was no distinguishable difference.

In connection with the name given by Rafinesque to the Mississippi Valley fish, Jordan and Evermann say:

> The name *salmoneum* has been applied to the so-called "blue pike" originally described from the Ohio river, but more common in the Great Lakes, particularly Ontario and Erie. It is smaller and deeper in body than the ordinary *vitreum* and different in color, but it is not likely that any permanent distinctions exist, this species, as usual among freshwater fishes, varying largely with the environment and with age.*

The fact referred to by Jordan and Evermann, that it is usual for freshwater fishes to vary largely with environment and age, is without significance in a study of the relationships of fishes unless the way in which they vary and the cause of variation are considered. Their statement implies that distinctions to be of taxonomic value must be permanent. Conversely, if a distinction is permanent it is of specific value.

So far as the blue pike concerns the fishermen and fish dealers, there is a permanent distinction, that of color. The question, then, is how permanent this distinction is. Is it restricted to young fish and is it therefore, a distinction that disappears with age and maturity? If it is a distinction deter-

* Jordan and Evermann. Fishes of North and Middle America. Bull. 47, U. S. National Museum, vol. 1, p. 1021. Washington, 1896.

mined by environment, and not particularly restricted to young fish, what is the environmental factor affecting certain aggregations of fishes associated, at least part of the year in the same waters, with other aggregations in Lake Erie and Lake Ontario, which latter are at all ages distinguished by color? And does the distinction disappear if removal from one environment to another takes place? These are points which cannot be determined by cursory inspection of a few individuals.

In connection with a biological survey of the Great Lakes, the U. S. Fish Commission Report for 1902, page 127, states that Dr. Raymond Pearl undertook a demonstration by statistical methods of the relations of the blue pike to the yellow pike (*Stizostedion vitreum*) of the Great Lakes, and that enough was learned to know that the wall-eyed pike is a species of remarkably low variability, and that there are no structural differences between the blue and the yellow varieties, this being in accord with other observation.

It is not my purpose to discuss the question of nomenclature of the pike perch, or so-called wall-eyed pike. But, as concerns the species which Rafinesque called *Perca,* or *Stizostedion salmoneum,* there is no indication in his description that it is the form recognized in Lake Erie and Lake Ontario as blue pike. It is the common pike perch of the Mississippi Valley which, as Rafinesque stated, occurred all over Ohio, and in the Kentucky, Licking, Wabash, and Miami Rivers, during the spring and summer and was known as salmon, white salmon and Ohio salmon.

In accordance with the wishes of the United States Commissioner of Fisheries, I have recently examined a series of each form, for the most part representing Lake Erie and Lake Ontario. In view of the fact that previous discussions have been to the effect that the blue pike were immature fish, I selected a series of 20 specimens of yellow pike which in their maximum lengths would include the lengths of the available blue pike. The yellow pike ranged from 91 mm. (about

3 2-5 inches) to 600 mm. (about 23 2-5 inches), and the blue pike from 280 mm. (about 11 inches) to 436 mm. (about 17 1-6 inches). The majority of each form in which the sex could be distinguished, were either gravid females or females just past the spawning season.

The fish were first laid out and compared as to general appearance. The contrast in color was most pronounced in fresh specimens. The blue pike were darker, and had no trace of yellow which the yellow pike always showed as tints or reflections. The fins were never yellow, while in the yellow pike they were often so colored. The belly of each was always white, although in the larger yellow pike and a few of the smaller it was sometimes tinged with yellow. Most of the blue pike had ventrals and anal strongly marked with dark shades or spots, in some faint, but never entirely absent. In the case of most of the yellow pike, these fins were plain, but in a few faintly spotted.

Aside from color, the general appearance of the blue pike suggested a more slender head, narrower interorbital width, and noticeably larger eye, particularly in the smaller specimens, than the yellow pike. Fin ray and scale counts, though variable, revealed nothing distinctive. Closer inspection showed that as a rule, the preopercular teeth were more numerous and finer than in the yellow pike, in which the teeth were simple and not bifid or trifid as in the blue pike. One specimen each was skeletonized and no difference detected in the cranial bones or number of vertebræ.

Besides counting series of scales and the fin rays, various measurements were taken of the head and body and reduced to percentages of head or body. The percentages were then tabulated in the order of the total lengths of the fish, from the smallest to the largest, regardless of whether they were yellow or blue pike; the two kinds were indicated by different colors of ink. Thus those of similar lengths were brought in juxtaposition.

In following the figures down the column, it was found in practically every instance that each form contains measurements so close to the other that very likely one would unhesitatingly pronounce the fish specifically identical. But with a little closer scrutiny, it was observed that the percentages practically throughout graded variably from a higher to a lower or from a lower to a higher percentage in each form, in some of the measurements in the order of the size of the fish.

This fact suggested averaging available percentages of the two forms and flattening the variation by overlapping the percentages from one group to another of equal number. Taking 18 specimens of each form, five groups of six figures each resulted. Group 1, composed of the smaller sizes, and Group 5, of the larger sizes, were, of course, unaffected by the overlapping. In this way it was found that there were considerable variations, irrespective of the size of the fish, some of which variations were possibly attributable to inaccuracy or lack of uniformity of measuring between two points not always positively determinable.

Graphs of these results show, in many instances, more or less crossing, which suggests individual variation not associated with difference in size of the fish. But in others, they show distinctly, and, in some cases, widely separated, more or less parallel, converging or diverging upward or downward trends. In but one or two instances, however, does the percentage of one or more groups of one form remain wholly distinct from that of one or more groups of the other. But where they are alike in size ranges, the larger blue pike are nearly always like the smaller yellow pike.

The study of these measurements has not been completed, but enough has been learned to suggest a divergence of the two forms. An important point is that there are mature breeding fish of both kinds in practically the same range of sizes. In order to ascertain, if possible, the ages of the fish, scales were taken and mounted; but they have not been studied carefully enough to arrive at any positive conclusion. Photographs have been made of several of each which show, although not as distinctly as one could wish, certain lines of growth, whatever they may signify. If the crowded lines are interpreted in the same way as in the case of salmon scales, they indicate that some of the smaller blue pike are older than some yellow pike of larger size.

The lack of time and the incompleteness of study of the measurements do not permit a detailed consideration of results at the present; but I shall refer to six of them which will indicate what measurements may be of importance in deciding the relationship of these two forms, especially when a large series of each of an equal range of size is studied and compared.

The overlapping groups referred to were respectively composed of fish of average total lengths, as shown in the following table of total lengths, given in millimeters.

Average Total Lengths of Groups

Kind	Group numbers and averages 1	2	3	4	5	General Average
	mm.	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*
Yellow Pike	210	269	303	331	416	306
Blue Pike	296	317	342	367	400	344

These averages, arranged in the order of size from the lowest up, are as follows: Yellow, 210 mm.; yellow, 269 mm.; blue, 296 mm.; yellow, 303 mm.; blue, 317 mm.; yellow, 331 mm.; blue, 342 mm.; blue, 367 mm.; blue, 400 mm.; yellow, 416 mm.; yellow, average, 306 mm.; blue, average, 344 mm. These figures show a fairly close running sequence of both forms, with the exception of the first average of yellow pike, which reduces the general average of that form.

In order to check up the results shown in the group averages, 6 fish of each form of approximately the same lengths were selected. These range from a little over 280 mm. to 370 mm. in length. The sexual condition and the overlapping groups of averages in which each fish appears are shown in the following table:

GROUPS INTO WHICH INDIVIDUAL YELLOW AND BLUE PIKE OF APPROXIMATELY SAME LENGTH FALL

Yellow Pike.				Blue Pike.			
Group from which selected.	Sexual condition.	Total length.		Group from which selected.	Sexual condition.	Total length.	
		Mm.	Inches.			Mm.	Inches.
2	Immature	288	11-11/32	1	Mature	284	11- 6/32
2	Immature	295	11-24/32	1	Immature	295	11-24/32
3	Mature	302	11-29/32	1	Mature	303	11-30/32
3	Immature	325	12-25/32	2	Mature	327	12-28/32
4	Immature	342	13-18/32	2	Mature	346	13-20/32
4	Mature	370	14-18/32	4	Mature	370	14-18/32
Average	....	320.33	13-13/32	Average	....	320.83	13-14/32

HEAD MEASUREMENTS

Distance from Tip of Snout to Posterior Edge of Preopercle. The averages show a converging difference from the smaller to the larger fish, thus indicating a decrease in the distance with increase of size of the yellow pike, and an increase of distance with increase of size of the blue pike, the yellow pike having the greater average. The average of Group 4, of the blue pike, reaches the average of Group 2, of the yellow pike, which are respectively composed of fish averaging 367 and 269 mm. in total length. The six individuals of each form show that this dimension in the second yellow pike 295 mm. long equals that of the fourth blue pike, 327 mm. long, the yellow pike being immature and the blue pike a mature fish; this suggests that youthful characteristics of the yellow pike are maintained in older or larger blue pike.

Interorbital Width.—A narrower interorbital width obtains in the general average of the blue pike than in the yellow pike. The yellow pike changes but little from the smaller to the larger fish, while the blue pike, at first considerably narrower than the smallest yellow pike, approaches the yellow pike in Groups 4 and 5 of larger fish. The next to the largest of the six individual yellow pike has the narrower interorbital, which corresponds to the interorbital of the largest blue pike.

Eye.—The length of the eye affords the clearest example of the manner in which the blue pike differs from the yellow pike. In the general averages there is a uniform decrease in size of the eye with the increase in size of both forms, the blue pike having the larger eye of the two. Here the very smallest of the yellow pike has eyes equal to the average as shown in Group 3 of the blue pike, and the very largest blue pike equals Group 3 of the yellow pike. As to eyes, the six individuals of each kind are widely different, comparatively speaking; the blue pike have constantly the larger eye, though in this kind it is the most variable. The larger eye of the blue pike is a youthful characteristic, as all young fishes have proportionally larger eyes than adults.

BODY PROPORTIONS

The only dimensions to which I shall refer in this connection are the position of the ventral and anal fins and the distance between dorsals.

Distance from Base of Pectoral Fin to Base of Anal Fin.—The distance from the base of the pectoral fin to the base of the anal fin, as shown by the general averages, is greater in the blue pike than in the yellow pike, but the dimensions are equal in the different groups. The blue pike of Group 1 with an average length of 296 mm. equals the yellow pike of Group 4 of 331 mm., and the blue pike of Group 4, averaging 367 mm., equals Group 5 of the yellow pike which averages 416 mm. in total length.

In the six individuals of each form, the same tendency to increase the distance with increase of size of the fish is maintained, as in the general averages, and the blue pike maintains the greater dimension. In this characteristic, the blue pike is the more variable, and it is the smaller blue pike which equals the larger yellow pike.

A blue pike 295 mm. long is slightly less in this dimension than a yellow pike 325 mm. long; and a blue pike 303 mm. long about equals a yellow pike of the 342 mm. length. A blue pike 327 mm. long equals a yellow pike 370 mm. long; a blue pike 370 mm. long differs from a yellow pike of the same length by about one per cent. In both forms, the dimensions approach each other with increase in size of the fish, but the average greater dimension is that of the blue pike.

Distance from Base of Ventral Fin to Front of Base of Anal Fin.—In the general averages of both forms, the distance increases with the increase of the size of the fish; the blue pike has the more posteriorly situated anal fin as relates to the ventral. The difference, however, decreases with increase in the size of the fish. In the six individuals of each kind examined, the same tendency to increase the distance with increase of size of the fish is observed, but it is very irregular and variable. The blue pike is the more variable, this dimension sometimes being less than that of the yellow pike.

Distance between Dorsal Fins.—In the general averages, the distance between the dorsal fins is constantly greater in the blue pike than in the yellow pike and it decreases as the size of the fish increases, while in the yellow pike the distance increases with the increase in size of the fish, so that the averages converge, although they do not meet. The greater difference, by far, is in the smaller fish. In the six individuals of each kind, the blue pike still maintains the greater distance, but with the increase in size of the fish there is a slight tendency to increase the dimension. This dimension in a blue pike 284 mm. long is equal to that of a yellow pike 302 mm. long; in a blue pike 295 mm. long it is equal to that of a yellow pike 342 mm. long.

CONCLUSIONS

The study has not proceeded far enough to warrant any positive conclusions, and the material is hardly sufficient to permit of generalization. Certain indications, however, some of which I have mentioned, suggest possibilities of our being able to find positive proofs of the structural divergence of these two forms, not depending upon immediate ecological relations, but of phylogenetic significance. Some of the distinctive features, such as that of the size of the eye, indicate that the blue pike maintains youthful characteristics, as judged by the young of the yellow pike, in well-advanced maturity. So, while there are no specific differences recognizable by the ordinary methods of the systematist, there is in each an aggregate of correlated small differential characteristics. The fish are constructed on two somewhat different models, so to speak, the yellow pike on the whole being the more symmetrical. The adult blue pike resembles younger yellow pike, and is more variable than the yellow pike. Except in color, there appears to be scarcely a single characteristic in the one, so far as the inadequate number of specimens examined reveals, that is not found in the other; but it is believed that even with the specimens at hand, a careful study of the tables of measurements, combined with age determination by means of the scales, will show that all blue pike will differ constantly from yellow pike of corresponding ages. If so, what does this fact mean? To me, the youthful, and more generalized characteristics suggest that the blue pike is a retarded development more closely resembling the ancestral form of the species. It is possible to absolutely prove this point only through biometrical studies of a large amount of material, and by study of the life history, habits, and geographical distribution of the pike perches. Particularly should the geographical limits of the blue pike be defined.

Yet this limited amount of study has revealed that the blue pike are not all young and immature fish; that the color appears to be constantly correlated with certain though small differences of structure; and that blue pike, even as small as some immature yellow pike, are mature fish. So, whether or not taxonomical rules permit them to be endowed with a binomial or trinomial designation, for all practical purposes, it would seem to me, they should be regarded and treated as distinct species.

Discussion

Mr. J. W. Titcomb, Albany, N. Y.: This is a very important paper. In the matter of blue pike and yellow pike, a curious situation prevails on the Great Lakes, affecting Ohio as well as New York and Pennsylvania. In these districts the law protects the yellow pike under a certain size, but it does not protect the blue pike. I was hoping it would be settled definitely whether they were two distinct species or not. But it is a fact that young blue pike, or blue pike in a spawning condition, are allowed to be taken in the Great Lakes, while the yellow pike is protected.

Dr. Kendall: The name does not amount to anything. A taxonomical species is one thing, and a natural form another. Taxonomically, we are considering these fish as we find them on a horizontal plane. In this case it seems to me that we should take into consideration more than their relation to each other on this horizontal plane. The fact is that you have a divergence, and whether you call it a species, or a subspecies, or a variety, or what not, does not affect the situation at all. You have two things that are recognized by the fisherman and by the markets and by everybody as two distinct forms, and for all practical purposes they are as distinct as though taxonomically so regarded, and it does not matter what you call them.

Dr. R. C. Osburn, Columbus, Ohio: Mr. President, in the first place I want to express my admiration for Dr. Kendall's nerve in tackling these two very much mooted questions as to the relationship between the rainbow trout and the steelhead trout, and the blue and yellow pikes. I desire also to commend him for the admirable scientific way in which he has undertaken to solve these problems by such careful and minute study. It is the only way in which such questions can be handled if we are ever to arrive at a solution of the problems involved. It seems to me that these forms may be still very closely related; they may be physiologically different species, but, perhaps, have not diverged sufficiently so that we can separate them satisfactorily by structural characteristics, and that as the ages progress, such data as Dr. Kendall has worked out will enable the William C. Kendalls of a few thousand years hence to make comparisons with the figures of the present day and to say whether the divergence is growing wider as the ages go on. I do think that such studies as these have a biological importance in addition to any practical value they may have in connection with the fisheries.

Dr. E. E. Prince, Ottawa, Canada: I agree with Dr. Osburn that these two studies are really among the most beneficial contributions to our proceedings of this meeting. Dr. Kendall has taken up some of the problems which have been causing trouble wherever the steelhead and rainbow trout are known, and wherever the blue and yellow pike are marketed. The markets have always distinguished between the edible qualities of the blue and of the yellow pike.

One other point I would like to mention in this connection is this: I visited New Zealand some time ago and saw a great deal of their fisheries. Much importance has been attached to the size attained by rainbow trout in New Zealand. There the brown trout, which in Europe is a comparatively small fish, frequently run to ten, twelve, or fourteen pounds. In the case of the rainbow trout, I saw a catch of 200, none of which was under 20 pounds, some of them even going up to 25. The large steelhead trout I used to be familiar with on the Fraser River were unlike these large rainbow trout. I hope that Dr. Kendall will continue his studies and that we shall have something further from him at future meetings of the Society. The study of the blue and yellow pikes is, of course, of great importance from a commercial standpoint.

RELATION OF CERTAIN AQUATIC PLANTS TO OXYGEN SUPPLY AND TO CAPACITY OF SMALL PONDS TO SUPPORT THE TOP-MINNOW (GAMBUSIA AFFINIS)

By R. L. Barney, *Director*

and

B. J. Anson, *Scientific Assistant*

U. S. Fisheries Biological Station, Fairport, Iowa

In attacking the broad and complex problem of furnishing fish with those conditions which best fulfil their requirements for growth and propagation, there are three considerations of paramount importance. These have been well discussed in a recent publication by Dr. R. E. Coker,* U. S. Bureau of Fisheries, who suggested therein as the biologically fundamental factors governing the success of fish-cultural enterprises, the provision of sufficient oxygen, the provision of sufficient food, and the proper association of species. Much is known generally of each of these necessities; comparatively little experimentally. A fish culturist and a stock raiser know very well that their charges require plenty of oxygen and plenty of food if they may be expected to attain maximum size and maximum productiveness. The stockman takes no thought of the first factor, knowing that oxygen for his purpose is as free as the air, whereas, for the fish culturist, such a condition does not always exist.

There is, too, the relatively larger consumption and possible utilization of all the oxygen in the fish pond, since depletion of this life-supporting element occurs from the chemical oxidation of much material in the water, as well as through consumption by the respiration of aquatic animals. To be

*Coker, R. E.: Principles and problems of fish culture in ponds. *The Scientific Monthly*, Vol. VII, No. 9, August, 1918. Garrison, N. Y.

added to these facts, indicating the limitations of oxygen supply in water, there is that of the limited capacity of water to dissolve oxygen—its period of greatest capacity occurring when the water is cold and when, apparently, it is of less value to the fish, since metabolism of all cold-blooded animals is very slight through the winter months. It seems a paradox that the increased need for oxygen for metabolic processes during the spring, summer and early fall should come when the power of water in dissolving and in holding oxygen should be continually decreasing, the capacity of water to dissolve oxygen decreasing with the increasing temperature. There is, however, the compensating factor of increased oxygen production by submerged plant life during the warm weather, which factor is negligible in winter.

In this general connection there also arises the question of the actual capacity of a pond or body of water to support animal life; how much fish life a body of water of given size can be expected to bring to maturity and hold under certain conditions where predacious species have been eliminated. There is, of necessity, in this problem a consideration of the means whereby, and of the quantity in which, oxygen and food reach the fish, since oxygen and food, other factors being the same, become, possibly, the most important criteria on which the capacity of a pond may be estimated.

EXPERIMENTAL OBSERVATIONS

In 1913 four small ponds were built by throwing dirt embankments across the very sluggish stream, Cypress Bayou, Mound, La. These ponds average in size 30 by 12 feet, varying in depth of water, because of seepage, from 10 inches to 2½ feet. The banks were kept clear of weeds, while the waters were provided with four differing habitats by introducing into three of the ponds certain aquatic plants of different habits of growth and by keeping one pond free of all vegetation other than microscopic. A description of the vegetative environment of each pond follows:

Pond 1. Supplied abundantly with the submerged aquatic plant Ceratophyllum. Surface kept entirely open and clear of all surface-growing plants.

Pond 2. Kept entirely clear of all visible vegetation.

Pond 3. Supplied with a quickly and thickly growing surface-trailing plant, *Jussiaea diffusa.* No other surface plants present; no submerged plants present.

Pond 4. Supplied with a heavy surface covering of Lemna and Spirodela, in which Wolffia filled in the interstices between the leaves of Lemna and Spirodela.

After removing predacious species, there were introduced into each of these ponds ten male and forty female *Gambusia affinis,* all adults, the females being heavily gravid. The date of this stocking was July 1st. On September 1st, sixty days afterward, the ponds were seined, with results as follows:

GAMBUSIA PRODUCTION OF PONDS IN 1918

Pond No.	Surface vegetation.	Submerged vegetation.	Gambusia production.
1.	None.	Abundant Ceratophyllum.	2575
2.	None.	None visible.	1361
3.	Trailing plant *Jussiaea diffusa.*	None visible.	1040
4.	Heavy mat of Lemna, Spirodela and Wolffia.	None visible.	247

The ponds, averaging in content about 450 cubic feet, had doubtless reached their capacity for supporting animal life; and a further month's opportunity for increased output would have changed the above figures very little.

These results quite plainly indicate the effect aquatic vegetation may have in partly supplying fish with the conditions which best suit their requirements. The pond having the submerged vegetation produced a much greater output than any of the others, the production decreasing by approximately half in the pond with the open surface and the pond with the surface trailing *Jussiaea diffusa.* The pond having the heavy surface mat of Lemna, Spirodela, and Wolffia seemed to be least able to support Gambusia life.

By careful approximation and averaging of the volume of the different organisms found in the stomachs and intestines of 105 Gambusia collected at Mound, La., during the summer, fall, and early winter of 1916, there were found the following: Crustaceans, mostly entomostracans, 23.9%; insects, mostly dipterous larvæ and pupæ, 7.2%; rotifers and protozoa, 6.1%; algæ, mostly blue-green filamentous, 47.7%; and unrecognizable debris, 14.4%. These examinations were made at the U. S. Biological Station, Fairport, Iowa, by H. Walton Clark.

Referring to the most important considerations of pond culture outlined on a previous page, we may now well take up the matter of food production in these ponds. Gambusia is a plankton feeder.

For this study, then, the production of plankton and the factors that influence its abundance must be given especial consideration. The extent of plankton production in fresh water, as is the case in plant production on land, depends primarily on the amount of nitrogenous material available for the metabolic processes of the plankton organisms. Needham and Lloyd* point out that:

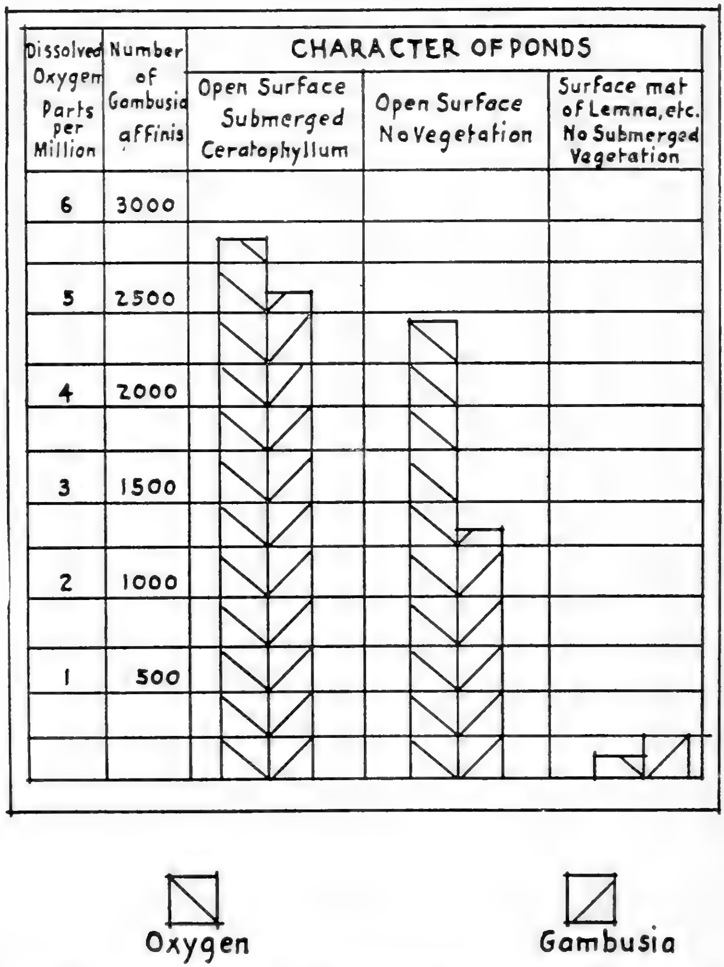
> The supply of nitrogen for aquatic organisms is derived from the soluble simple nitrates (KNO_3, $NaNO_3$, etc.). Green plants feed on these and build proteins out of them. And when the plants die, their dissolution yields two sorts of products, ammonia and nitrates, that become again available for plant food.

Kofoid has indicated the effect of temperature on plankton production in a planktograph in his work on the plankton of the Illinois River.† In the four ponds herein considered, abundant plankton production was guaranteed, before the vegetative features of the habitats were added, by the presence on

*Needham, James G., and J. T. Lloyd: The life of inland waters. Ithaca, N. Y. 1916. P. 48.

†Kofoid, C. A.: The plankton of the Illinois River, 1894-1899, with introductory notes upon the hydrography of the Illinois River and its basin. Part I. Quantitative investigations and general results. Bulletin, Illinois State Laboratory of Natural History, Vol. VI, Art. II, November, 1903, p. 626. Pl. VIII. Champaign, Ill.

the bottom of each pond of layers of decaying vegetation, the result of the annual deaths of aquatic plants. It is evident that plankton abundance in ponds 3 and 4, which were thickly covered with Lemna and Jussiaea, would be considerably de-



creased, as the matted condition of the surface vegetation tends to keep the temperature of the water under it lower. The production of plankton may also be regulated to some extent by the amount of light. The introduction of certain plants in ponds also has a tendency to modify plankton production, as the plants become competitors with the plankton organisms for the available nitrogen. In his conclusions, Kofoid says:

> Summer heat pulses often attend plankton increases. * * * Light affects plankton production. The half year with more illumination and fewer cloudy days produces from 1.6 to 7 times as much plankton as that with less illumination and more cloudy days. Seasons of unusual cloudiness are accompanied by depression in production. * * * Lakes rich in submerged vegetation produce less plankton than those relatively free from it.*

In view of the fact that plankton production is modified by temperature, light and the presence of vegetation in the water, it is safe to say that our open-surfaced pond 2 produced more plankton than pond 1 with submerged vegetation, and that production in ponds 3 and 4 was smaller than in either 1 or 2, since the waters of the former ponds had lower temperature, less light, and contained competitive plants. Inasmuch, however, as pond 1 produced more fish than pond 2, the conclusion can be fairly reached that the quantity of food in each was at least sufficient, and hence was not a determining factor in Gambusia production. Very possibly the production of Gambusia in the surface-covered ponds 3 and 4 was limited because of scarcity of food. At least, this is probably one cause for the small output of these ponds.

Passing from the consideration of food supply we are confronted with the question of the other important factor, oxygen supply. Oxygen may become dissolved in water by two methods, mechanical and natural. Oxygen is introduced into the water through the surface by mechanical means, such as the effect of the wind, waterfalls and current, by the addition of falling rain, by the movement of animals on or in the water, or by means invented to churn the water and cause air to bubble through it. The natural means are of equal, if not of greater, importance in ponds and small lakes, oxygenation

**Ibid.*, pp. 572, 573.

occurring through the liberation of infinite numbers of tiny bubbles of oxygen from the leaves of submerged plants, a by-product of their metabolic process, photosynthesis. The results of the pond studies previously outlined being so indicative of the value of certain plants of differing habit of growth in pond culture—more ultimately of the value of dissolved oxygen in different quantities—a number of observations on oxygen content of three of the four type ponds were carried out in 1919. The banks of the original ponds having been destroyed by high water and by the burrowing of crayfish, four new ponds of larger capacity were built in another section of the bayou supplied with the same vegetative environmental features as had obtained in the former observations, with the exception of pond 3, which was supplied with a heavy submerged growth of Ceratophyllum in addition to a solid surface mat of Lemna, Spirodela and Wolffia. The new ponds were supplied as follows:

Pond 1. Submerged Ceratophyllum.

Pond 2. Open surface; all visible vegetation removed.

Pond 3. Heavy growth of submerged Ceratophyllum and heavy surface-mat of Lemna, Spirodela, and Wolffia.

Pond 4. No submerged vegetation, but a heavy mat of Lemna, Spirodela, and Wolffia.

Beginning our determinations approximately at the time of the stocking in the year previous, and extending them through August 15th, two weeks before the date of the seining operations of 1918, twenty-six determinations of dissolved oxygen for each pond were made, water samples being taken at about 3.00 p.m. on days representing differing weather conditions. The method of collection and determination of these samples was that outlined in detail in Standard Methods of Water Analysis. The determinations are listed and averaged as shown in table on the following page.

It will be noticed from this tabulation that the pond with the open surface and the submerged vegetation, Ceratophyllum, averaged 5.73 parts of dissolved oxygen per million, the average amounts for each of the other ponds being lower. The lowest average record was 0.26 parts per million for the pond with the heavy mat of vegetation and with no submerged plants. The pond with a similar mat of vegetation but containing a quantity of submerged plant growth averaged nearly five times this record, with 1.23 parts per million. The

DISSOLVED OXYGEN CONTENT OF EXPERIMENTAL PONDS

Date of observation	Dissolved oxygen in parts per million			
	Pond 1	Pond 2	Pond 3	Pond 4
1919				
June 24	4.81	4.81	2.75	1.33
25	5.91	4.83	2.93	2.19
27	6.90	5.40	0.60	0.35
28	7.90	4.90	0.43	0.15
30	5.76	5.69	1.50	0.79
July 1	7.00	4.68	2.10	0.10
2	7.44	6.76	1.16	0.00
4	8.40	5.96	0.81	0.00
5	7.08	6.10	0.61	0.05
7	8.50	5.80	0.70	0.07
22	5.78	5.48	1.70	0.00
21	4.68	4.26	0.72	0.00
23	5.88	5.49	1.41	0.05
24	6.79	5.50	1.73	0.06
29	4.70	4.14	0.97	0.00
25	4.82	5.37	2.02	0.09
31	6.15	5.05	1.56	0.14
Aug. 2	3.89	4.15	. . . .	. . . .
5	4.12	3.47	2.00	0.36
4	4.25	4.31	1.40	0.08
6	4.63	3.87	1.11	0.09
8	4.80	4.00	0.53	0.00
7	5.20	4.20	. . . .	0.00
9	6.20	4.75	0.36	0.12
11	3.70	3.60	0.80	0.44
15	3.25	2.65	0.21	0.00
Average	5.73	4.80	1.23	0.26

pond with the entirely open surface and none but microscopic vegetation yielded an average record of 4.80 parts of dissolved oxygen per million. The cause of the variation in dissolved oxygen content in each individual case seems to be evident.

OXYGEN RECORD OF PONDS IN 1919

Pond No.	Surface vegetation.	Submerged vegetation.	Dissolved oxygen. Parts per million
1	None.	Abundant Ceratophyllum.	5.73
2	None.	None visible.	4.80
3	Heavy Mat of Lemna, Wolffia and Spirodela.	Abundant Ceratophyllum.	1.23
4	Heavy mat of Lemna, Wolffia and Spirodela.	None visible.	0.26

It is reasonable to believe that pond 1 should have been observed to have dissolved in it a larger quantity of oxygen than pond 2, and pond 3 more than pond 4, from the fact that ponds 1 and 3 contained abundant submerged plants, whereas ponds 2 and 4 had none. It plainly indicates the value of submerged plants in oxygenating ponds. That ponds 1 and 2 should both have had higher dissolved oxygen records than ponds 3 and 4 is logical, since their surfaces were open to allow for wind action and for the penetration of the sun's rays to assist in photosynthesis, while ponds 3 and 4 were covered with a heavy surface growth that permitted no wave action and allowed a mimimum of sunlight to pass through to cause photosynthesis in those plants which may have been beneath the mats.

These ponds were stocked similarly to those of 1918, but their larger size (30 x 50 x 5 feet) and the physical impossibility of drawing a seine through them because of immovable snags, or of clearing them of fish with a dipnet, led to giving up the idea of noting their production. Such ascertainment of the output of Gambusia of these ponds would have been of minimum value for our purpose under the conditions, since the effect of predacious fishes could not be eliminated or measured.

The oxygen determinations and the differing plant combinations of 1919 were, however, available for comparison with the results of the 1918 experiments in numbers of fish in the sixty day output, and capacity of the ponds in raising and supporting Gambusia life. The effect of predacious fish had been eliminated from consideration in the 1918 fish-cultural observations. The 1919 oxygen determinations had also been made in similar ponds, in the same water system, and in three of the four ponds with vegetative environmental features exactly alike. The period in 1919 during which observations on oxygen content of the ponds were made was approximately the same as that in which the fish-cultural study was carried on in 1918, the oxygen determinations beginning the last week in June, 1919, while the fish cultural studies began on July 1, 1918. On the basis of these facts a direct comparison of the observations of the two years seems to be warranted.

The results are shown in tabular form as follows:

Relation of Aquatic Plants to Oyxgen Supply and to Capacity of Ponds to Support the Top-Minnow, *Gambusia affinis*

Vegetable environmental features		Dissolved oxygen. Parts per million	Gambusia production
Surface vegetation	Submerged vegetation		
None	Ceratophyllum	5.73	2575
None	None visible	4.88	1361
Trailing *Jussiaea diffusa*	None visible	....	1040
Mat of Lemna, Wolffia and Spirodela	None visible	0.26	247
Mat of Lemna, Wolffia and Spirodela	Ceratophyllum	1.23	....

CONCLUSIONS

In general terms of fish culture, there appears from the cited data to be a correlation between the habits of growth of certain aquatic plants in ponds, the dissolved oxygen content of the water, and the capacity of ponds to support plankton feeding fishes.

Specifically, there is a direct correlation between the presence of the submerged aquatic plant Ceratophyllum in a small open-surfaced pond, the dissolved oxygen content of the pond, and the capacity of the pond to support the top-feeding fish, *Gambusia affinis.*

Specifically also, there is a direct correlation between the presence of a heavy mat of surface-growing aquatic plants (Lemna, Spirodela, and Wolffia) in a small pond, the dissolved oxygen content of the pond, and the capacity of the pond to support the top-feeding fish, *Gambusia affinis.*

FIGHTING POLLUTION IN OHIO — A DEMONSTRATION OF METHODS

By John T. Travers

Superintendent of Streams, Ohio Bureau of Fish and Game Columbus, Ohio

My purpose, on this occasion, is to explain, in as brief a manner as possible, the progress the Ohio Fish and Game Department is making in its efforts to control pollution and eliminate it from Ohio streams. In this explanation I will avoid all terms and phrases of a technical nature that might have a tendency to confuse, or cover up the actual point we are aiming at. It is my desire to present to you the results of our investigation of this problem, following with a number of demonstrations, made with raw industrial waste taken from manufacturing plants at various points in Ohio. All the facts presented to you here are the results of my findings, through actual experience in wading around in polluted water for the past year. This was necessary for me to do, in order to note and observe, at first hand, the exact conditions as they exist in the streams. In this investigation I have not taken anything for granted, or accepted anything as a fact, unless it could be proved as such. No tests of pollution have been made by proxy. All tests have been made at the sewer or in the polluted stream.

The history of stream pollution and of the contributing causes leading up to it, as it exists today, are as familiar as an open book. Thousands of pages have been written on this subject and the problem has been studied from all angles by the ablest men in the country. The progress made so far has not come up to expectations. Outside of the process developed by the Ohio Fish and Game Department, the results so far have been very unsatisfactory. I believe I am safe in saying that pollution of streams in the United States has increased more in the last five years than it did in the twenty years preceding, and until now there has been no practical or satisfactory solution offered for its control. It is conceded by all authorities on the subject, that stream pollution is a real and serious menace that threatens not only to exterminate all fish life from our inland streams, but also its deadly effect is becoming very noticeable in our lakes and larger bodies of water.

Stream pollution dates back to the time of our forefathers. When they were settling up new territory, they found our streams a very convenient place to dispose of all manner of refuse and trash for which they had no further use. By throwing it into the stream it would soon float away and out of sight. Later on, as the population became more congested, and industries of all kinds began to develop along our waterways, following the established order of things, the waste liquor was allowed to flow into the creeks and rivers, destroying everything with which it came in contact. Those once beautiful streams, teeming with fish life, have been converted into seething sewers of filth, a breeding place for all manner of disease germs, continually throwing off an unbearable stench that is detrimental to human health and causing an uncalled for depreciation of property values wherever the stench reaches. This crime must not be allowed to continue, if we have a remedy that will correct the evil. If we hand down to our children of the coming generation streams devoid of all fish life and flowing full of all manner of filth, they will look back on us with pity and shame, as being only partly civilized in allowing our waterways to become so contaminated with filth that they are a disgrace to all mankind. Instead of flowing with pure, sparkling water, a place for recreation and pleasure, they will be places to be avoided by both man and beast. In looking at the surface of the water it is hard to realize the slow but deadly changes that are taking place in the bottom of a polluted stream.

You will say the manufacturers are the ones that are responsible for this destruction. I say, when we sit idly by and do not raise our voices in protest against this wanton destruction of our streams by pollution, that we, as intelligent human beings, are just as much responsible as are the manufacturers. I find that the general public has a very wrong impression regarding the attitude the manufacturer holds towards stream pollution. I find that he evinces more interest in this matter than the average citizen does, and is very willing to make all waste liquor harmless, if shown how it can be done.

The effect of pollution in Ohio streams was first noticed about eight years ago. Our attention was first called to it in the twenty-two large coal producing counties of the state. Copperas water from the mines was killing fish by the wholesale. At that time and continuing for seven years, we followed the time-worn and out-of-date system of collecting samples of polluted water from infected districts, and submitting them to the proper state boards for relief. This system resulted in our department accumulating a vast amount of long, learned reports on the subject. Those reports gave us, in a very technical manner, just what the water contained in the way of sulphates, acids, and organic solids; also the amount of oxygen this foreign matter would consume. But this was not what we wished to know. We wanted to know how this poison could be removed from the water, so that fish could live, without hampering the industries in any way. This is what we had a perfect right to expect from state boards that had made a special study of this question. However, they were all silent on recommending a remedy. In the meantime there was a tremendous increase in stream pollution all over the state.

A little over a year ago Mr. A. C. Baxter, Chief of the Fish and Game Department, realizing that we had not made one step forward in this matter in seven years, detailed me to undertake a special study of the question. At that time I found hundreds of miles of streams so terribly polluted that no living thing could exist in them. Steel mills and coal mines were dumping into the streams millions of gallons of an acid pollution, destroying everything with which it came in contact, not only depleting the streams of all fish life, but making the waters extremely dangerous for live stock to go near. Strawboard and sugar beet factories, slaughter houses and packing plants, creameries, leather-board and tankage plants, tanneries and city sewage systems, all were putting into the streams their millions of gallons of pollution every day. Pollution of this kind is organic in character, and where it is in excess of what nature can take care of by self-purification, it is just as deadly as an acid pollution. I soon had all known pollutions placed for my purposes in two classes, acid and organic.

I discarded the use of calcium oxide, sulphate of iron, alum, etc., as being too expensive for the treatment of industrial waste. In my efforts to find something to cheapen the treatment of trade waste, and not work a hardship on the manufacturers, I found a clay marl deposit on the Kibler farm, near Circleville, Ohio, of which I could use from seventy-five to ninety-five per cent and get better results than I could get from any other chemical. This marl used in combination with any of the well known agents for coagulation will, when applied to any organic pollution, cause a very rapid precipitation of all organic solids out of the water to the bottom of a tank or vat. It renders the water very clear, and where such water flows into a stream the fish will live and do well in it. I also found that water, treated by this process, will not ferment afterwards, or have any odor to it, indicating that everything of a harmful nature is removed from the water. This same marl will also neutralize an acid pollution and make it harmless.

I have here a number of samples of polluted water, taken from manufacturing plants, before it reached the streams and became diluted with other water. I will treat each one separately, giving you its history and how it is formed. [Tests were made as the speaker proceeded.]

1. *Coal mine pollution.* Copperas water from a coal mine is very deadly to all fish life, being acid in its nature. When first formed in a coal mine it is harmless, but as it flows through the old workings of a mine before being

pumped out, it decomposes the iron pyrite and sulphur, forming ferrous sulphate. This combination, going out into a stream, will consume all the oxygen in the water, killing off all fish life. Five minutes after treatment by this process, fish will live in the water so treated.

2. *Steel mill pollution.* An acid solution is put out by steel mills. Where pickling vats are used, the mills dump into our streams from three to ten thousand gallons a day of from 1 to 4 per cent solution of sulphuric acid. It is very deadly to fish life. An application of this marl combination neutralizes the acid in a very short time. The amount necessary to apply is very small, depending on the acid strength of the solution.

3. *Canning factory pollution.* We have an organic pollution put out by a canning factory, of which there are a number in our state. Pollution of this kind is very deadly to fish life on account of the very fine particles of corn and peas held in suspension in the waste as it leaves the factory. This water is very impure, but about 100 grains of the marl combination to 1 gallon will make the water clear as crystal. This pollution is very offensive and is the cause of considerable complaint. All organic pollutions are handled in the same manner. The marl is applied by means of an automatic dry feed machine in a tank of large enough capacity to slow down the waste liquor as it issues from the factory. The solids in the water drop to the bottom of the tank, and the clear water, free from pollution, flows into the stream. I find that not all organic pollutions, when they first flow out of a plant, are necessarily fatal to fish life. However, after they are out in the stream forty-eight hours or so a very decided change takes place. In the process of nature, foreign matter held in suspension will first precipitate to the bottom of the stream, where it will soon commence to ferment and generate poisonous gases which rise through the water, causing a deficiency of oxygen. Where fish get into water charged

with such gases they will soon die. It is very essential that the tanks at the factories be so constructed as to retain the residue or sludge and not allow it to enter the stream. This sludge, if taken care of, makes a very valuable fertilizer, which often more than pays for the treatment of the sewage and gives the manufacturer a profit.

4. *Leather-board factory pollution.* This water is taken from a leather-board works. The deep red color is caused by the small invisible particles of leather held in suspension and also by the great amount of anilin dye used in the process of making leather-board. Seventy-five thousand gallons a day of this pollution is put into the Hocking River at Lancaster, Ohio. All life in the river is destroyed for miles. This plant is now constructing a tank and arranging to use our process for the treatment of all their waste liquor before permitting it to enter the stream.

5. *Creamery pollution.* This sample of pollution comes from a large creamery at South Charleston, Ohio. The plant puts out about 100,000 gallons of waste liquor every day. It is contaminated mostly by the rinsing of milk cans, along with some buttermilk. This pollution, after being exposed to the sunlight for one day, throws off a very offensive odor. It also causes a deficiency of oxygen in all water it mingles with, making it deadly to fish life. You will note the action of the marl combination on it. The firm has just about finished a tank to treat all the waste by our process. The residue, or sludge, when utilized as a fertilizer filler, is expected to more than pay for the treatment.

6. *Sewage disposal plant pollution.* This sample of water, although it looks clear, is very impure. It comes from one of our many sewage-disposal plants and is put into the streams as pure water. You can notice that the smell is very offensive. I find that odor is a very good indication of organic impurities in water. You will note that an application of the marl combination causes a very de-

cided change in the water, driving away all the disagreeable odors that were present before it was applied. The control of the stench, as well as the poison, by this process, is, in my opinion, very important.

7. *Straw-board factory pollution.* This sample is taken from the sewer of a straw-board factory at Cedarville, Ohio. This firm puts 500,000 gallons of polluted water every day into large retaining reservoirs twenty-five acres in extent, and the longer it remains in those reservoirs, the more poisonous it gets. The upkeep and maintenance of these acres of reservoirs is quite expensive. This firm is arranging to convert them into chemical precipitation tanks, and to use our process in treating the waste water. It is their intention to use this water over again in their factory, not allowing any of it to enter the stream. Government reports, based on a number of tests conducted over a period of three years, show that the residue from this kind of pollution is of the same value as barnyard manure, making the by-product a very important factor.

8. *Natural copperas water pollution.* This is a sample of what is known as copperas water. It is very poisonous to any stream into which it flows. Millions of gallons of this kind of water flow naturally from the earth in places. In order to show you how easy it is to eliminate organic matter from polluted water and make it pure so that fish can live in it, I will take a few drops of this copperas pollution and put it into this tube of tannery waste. I will now apply a very small amount of this marl which I will shave from a lump of the material as it is taken from the ground, and you will note that all the organic solids are quickly removed, along with the odors.

Discussion

Mr. Dwight Lydell, Comstock Park, Mich.: Have you among your samples any water from a sugar beet factory?

Mr. Travers: No, but I visited the sugar beet factories at Toledo and Paulding. They put out an immense volume of water, but this process treats it very quickly. At Cedarville, where they put out 500,000 gallons of water a day, they will feed this marl in at the factory and let it run through the sewer to their retaining places, where it will be precipitated. In doing that, there is always a sort of scum that comes on all polluted water. A baffle-board is put across to keep it from going over. This marl is fed in and allowed to run down, and it will precipitate as soon as it slows up; the scum is kept back and the clear water will go on under the baffle-board to the next compartment. This factory is going to pump its water back and use it over and over again; they are not going to let it flow into the stream. A sugar beet factory can be run the same way. Unfortunately, one of the sugar beet factories that I visited had adopted an inside treatment by the time I got there. I made an examination of the plant and was asked to offer suggestions. They applied it all right, but it was a very complicated and expensive system. They let the water, after being treated, go down into a reservoir five acres in extent, and there the residue is allowed to decompose and generate gases—which, of course, should not be permitted; as soon as the organic matter is removed the water should be allowed to go into the stream. When gases are created, the water becomes fouled again.

Mr. Lydell: In some of these large factories they have a couple of tanks through which the water is allowed to run, and while one is clearing up they let the water run into the other; then the water is allowed to flow into the stream in a pure state.

Mr. Travers: At most sugar beet factories and straw-board factories, places of this kind have already been constructed, usually somewhere out in the fields.

Mr. W. E. Barber, La Crosse, Wis.: In the application of this purification system, when the water stands still, all the organic matter settles to the bottom. Now, if your stream is flowing all the time, the water will not clear as it flows along, will it?

Mr. Travers: Oh yes; you do not have to stop the flow of water in order to precipitate it. At one factory a waste vat has been constructed to take care of 150,000 gallons a day. It is fifty feet long, six feet deep at one end, and three feet deep at the other. The water comes over from the factory and the clay is fed into it. The water is pumped over to the vat and as it strikes the end it is slowed up, the heavier part drops down first and the water flows to the other end. It has to go under the baffle-boards, and the water that goes in first must be the first out; and when it gets over to the sewer it is as clear as crystal.

Mr. Barber: The sanitary engineer connected with our Wisconsin Board of Health recommends a filtration plant constructed of coke. They are going to compel manufacturing plants, turning out paper, sulphite, etc., to install that kind of arrangement.

Mr. Travers: It will probably break some of them to do so, because it is a very expensive outfit. I recently visited a disposal plant at Canton, Ohio, which is constructed along that line. They have 16 coke filtering beds, each half an acre in extent. The city of Canton is instituting a suit for damages to the extent of $20,000 on the ground that this disposal plant is not carrying out the work for which it was intended. They are putting out city sewage. About four or five million gallons of city sewage is very easy to control by the process I have outlined. Five or seven grains will control all the organic matter in a gallon of ordinary domestic sewage. But in the case of a white paper factory, forty grains will be required—there are 7,000 grains in a pound. The next in line would probably be the creameries, taking 75 grains. The very highest I have come across so far would take 185 grains. I am not a believer in coke filtering plants; I believe in chemical precipitation, a system which has been used with great success in the old countries for a long time.

Mr. W. H. Rowe, West Buxton, Me.: Your samples show a precipitation of from 10 to 15 per cent. I should think that if you let it run into your streams or rivers, you would soon fill them up.

Mr. Travers: We do not let it run into the rivers or streams; that is the idea of these tanks. The first precipitation represents about 10 per cent. That is drawn off through a hole in the bottom of the vat to an auxiliary tank where it is allowed to settle down again; or it is taken immediately from there and passed through a centrifugal drum built on the plan of a cream separator. It turns very rapidly, drives the water off and brings it down to 40 per cent moisture. Then it is available to handle, store away, or dry for use as fertilizer. But we aim not to let any of it get into the stream as it would be useless to precipitate it and then let it go into the stream.

Mr. Lewis Radcliffe, Washington, D. C.: Are you finding a commercial market for many of these sludges you are securing from the factory wastes?

Mr. Travers: That is a matter to which I have not given much thought. There was one concern at Canton that was figuring on spending a million dollars on a purification plant. I told them that if they invested an amount not exceeding $500 for a feeder, they could utilize two of their vats and dispense with the use of sixteen, and that they would get better results than in any other way. After I had made my demonstration, a gentleman who was there said he would pay for the treatment of the water by chemical precipitation if they would allow him the sludge. Now, the International Harvester Company really is an authority on fertilizer values, and I have a statement here made by them with regard to the value of cattle, horse, hog, sheep, chicken manure and sludge from domestic sewage. This list was issued before the war; the values have increased considerably since. They state the value of sludge taken from domestic sewage to be $8.61 a ton. Our Government reports, carried over a period of three years, show that the sludge taken from a straw-board factory, consisting of fine particles of straw, have about the same or even greater value than barnyard manure. A test was made by planting various crops and fertilizing in one case with manure, in another with no fertilizer, and in another case with the residue from the straw-board works. It was found that the results from the straw-board works residue were a little better than from the application of barnyard manure, ton for ton. It also brings humus to the soil; that is not taken into consideration in these values.

Mr. J. G. Johnson, Riverside, R. I.: Is that clay found on a certain farm in Ohio?

Mr. Travers: The only place I know where it is found is on Kibler farm, Pickaway County, Ohio. The Geological Survey says that in only three places in the United States are deposits of this kind found. Two are in New Jersey and one is on the Kibler farm. I do not quite agree with that, though. The first two carloads were shipped last week, one to the Loudenslager Company, of Columbus, and the other to the American Tinplate Company, of Cambridge. The day after a car arrived, the superintendent told me that it was working fine and giving far better satisfaction than the old treatment of calcium oxide and sulphate of iron.

Mr. Johnson: Is the supply of clay unlimited?

Mr. Travers: There are about 500,000 tons, as near is I could judge. It will not last very long when it comes into general use.

Mr. Titcomb: What does it cost per ton to produce?

Mr. Travers: It lies right on top of the ground; about two dollars a ton, I suppose.

Mr. Radcliffe: Then there is danger of exhaustion of this source of clay supply, is there?

Mr. Travers: There really is, I believe. The matter is of so much importance that I think the National Government should take hold of it and keep private individuals from grabbing up the raw deposits and charging an exorbitant price, thus nullifying the good work which may be done through its use.

Mr. William F. Wells, Albany, N. Y.: There is a good deal of misunderstanding about the whole subject of stream pollution, and I should like to bring out one or two of the fundamental characteristics of pollution. It is usually necessary in treating wastes to take out most of the solid suspended matter before discharge into a stream. The suspended matter settles out and forms deposits which, as Mr. Travers said, ferment and bring about a very foul condition in the stream. If all the suspended matter is taken out the soluble organic substances are left, and even a clear solution may still be very putrescible and cause trouble when run into a stream. In other words, the question of putrescibility depends on the power of the soluble as well as the suspended organic substances to absorb oxygen from the water. Any organic material, of course, furnishes food for living organisms, the minute organisms being just as real as fish or other animals, and in the aggregate they require a great deal of oxygen. For instance, if you take one of these fluids and put into it a little methylene blue, it will be blue today and colorless tomorrow, showing that the oxygen has been used up, and if you put a fish in there, it will not live a minute, any more than it would live if put in water which has been boiled, and the oxygen taken out in that way.

The whole problem of coke beds, trickling filters, broken stone, etc., is to allow thin layers of liquid to flow over large surface areas so that bacterial life can go on and exhaust the food material in the waste, obtaining the oxygen from the air with which it is in contact, and oxidize or burn out the organic matter. Unless this is done the oxygen must be supplied by the stream.

This process, as I see it, is a precipitation process similar to iron and lime. Of course, precipitation does not account for all wastes, such, for instance, as you get from wood alcohol factories or the wood distillation factories, which are toxic, and, though all suspended materials are precipitated, still contain deadly stuff in solution. All wastes differ and the problem of treating varies according to conditions. Even where precipitation is all that is needed you have the sludge to get rid of, and that is one of the biggest problems in connection with sewage disposal. When the cost of manure is compared with the cost of drying sludge, you find that it is a rather expensive process to take the water out of a ton of sludge. Of course, you can take out some of the water by centrifugal machines, but that is a fairly costly operation. The question of sludge removal is quite a serious one.

Mr. Barber: No more important matter confronts the Commission of Conservation of Wisconsin than that of taking care of waste products from manufacturing plants. We have probably 40 paper mills, sulphite plants, etc. We have been able to take care of the solid waste matter, but the chemical waste is a problem that the state boards of health are now working on. We find that the paper, sulphite, and other mills are ready and willing to install any sort of system that is recommended by the Conservation Commission. Now, Mr. Tulley, Sanitary Engineer of the State Board of Health, recommends coke filtration. The problem is that many of these plants have been constructed rather close to the water's edge, and there is no room for the installation of a filtration plant so that the water can filter through it from their mills. May I ask Mr. Wells whether it is his opinion that the coke filtration is practicable and will fill the bill?

Mr. Wells: A great deal depends upon analysis. I do not doubt that Mr. Tulley has complete results to justify his opinion in the case you mention. The degree to which purification of a sewage is demanded depends also upon the water into which it goes. First, the amount of oxygen absorbed by a given amount of sewage is determined, and second, the amount of oxygen in a given volume of water; we then know whether the sewage will use up all the oxygen, or what percentage, as the case may be. By knowing the necessary amount required for any particular use of the water, the question of how much treatment is necessary can be solved. The coke bed treatment is a rather thorough treatment, though a more complete treatment is possible by passing the water through sand beds, if the case demands it. Dr. Huntsman brought out the point that the water has to carry the atmosphere of the fish—the air and the oxygen. The total amount is very limited and it does not take much organic matter to use it all up. If that is done, it is the same as if we all sat in this room, closed the windows, and burned charcoal until the supply of oxygen was completely exhausted; in this case we could not live.

The problem of preventing pollution is only one phase of the general water conservation problem—the conservation of the quality of the water. The value of quality in water has been very little appreciated as a whole. Water is the greatest of our natural resources and almost all of its uses are dependent upon its suitable quality. The fishing interests are but one small part of its value. Its use for city water supplies, industrial purposes, and recreational advantages all depend upon quality. Everybody is thus interested in maintaining a suitable quality of water, and more can be accomplished by uniting the efforts of all parties working together, than by each trying to solve the whole problem alone. The fishermen, instead of looking at the problem of pollution as their problem, should undertake to join with health authorities and all others who are trying to stop pollution. It is a really broad conservation problem which should be taken up as a whole by some official body in a position to obtain cooperation. In New York State the logical place is the Conservation Commission. Rhode Island has just created a purity of waters board which must pass upon matters affecting the quality of the waters of Narragansett Bay.

MR. BARBER: We have the right sentiment, and we have the cooperation of the manufacturers. Everything is ready for you scientific men to tell us what to do. If you will just show us a plan and say: "This will do it," all we have to do is go to our manufacturers and say to them: "Here is a plan." The manufacturers are ready to agree to do it. It seems as though the question were solved, with the exception of the work you men must perform.

MR. WELLS: We are in the same position in New York. We said to the milkmen: "You are putting all this milk waste into the water." They said: "What can be done about it?" We said: "We do not know; that is your job." They said that they were willing to cooperate with us in a solution of the problem and they appropriated $10,000, which was turned over to Cornell University to be applied to experimental work. That is evidence of progress. The moment we get to that point of view, we are on the right road. Of course, we should not expect the manufacturers to stop putting in that stuff tomorrow.

MR. BARBER: We cannot arrest our manufacturers, as they put their institutions there at the request of the people in the first place. The people wanted the plants in order that employment might be afforded to members of the community concerned. They knew nothing about this matter of the pollution of streams, but most of the plants have reached such a stage of development that we do not longer want their waste matter deposited in the streams or lakes, so we say it has to be stopped. The manufacturers in turn ask us what we want them to do; they say that they themselves do not know what action to take. It would be folly to arrest the manufacturers for polluting streams when we have no remedy to offer them.

Mr. Wells: In England they have had this problem, much more acutely, of course, than we have. Over there the quality of the water is most important. The question of water power, irrigation and all that sort of thing it not such a big problem in England as it is in this great country, a new country in process of development. There the quality of the water is looked upon as very important, because they have only a certain amount of it, and vast industries are dependent upon it almost for their existence. In England a royal sewage commission was appointed with a view to arriving at some solution of this problem. They worked for 17 years, and in their final report said that the only solution was the appointment of a central authority to take up all these problems and to adopt regulations applicable to individual cases rather than to make prohibitory provisions or adopt any uniform law, every single piece of water being a law unto itself. Then, in the case of rivers, there would be boards for the regulation of the waters of those rivers, subject to appeals to the central authority. I think this country is going to come to that; the day is drawing near when we are going to unite these different aspects of the work—quality of the water, irrigation, water power, storage, and so on—into one group, and work together toward a common end. Decisions will be made in regard to individual cases, and there will be courts of appeal. It will be possible to say that in this place, sand beds are necessary to prepare sewage so that it may go into that stream. But that course may not be necessary in another case. In a river like the Passaic no treatment at all is needed. That stream is a sewer, and as such is most valuable to the industries in its vicinity. The fish in the stream are of small value when compared to the value of that river as a means of carrying away the waste of industries that are worth millions of dollars. But where a stream is more valuable as a trout stream than as anything else, for a little factory to ruin it is not right. So different standards suit different conditions, and these can only be determined by an examination and consideration of the particular circumstances.

Mr. Barber: You think, then, that the deposits from creameries are deleterious to fish life?

Mr. Wells: Many of our worst complaints are with regard to the damage done by the waste from creameries. There are many of them in New York State, located along the fishing streams.

Mr. Barber: What do you recommend to take care of the deposits from these creameries?

Mr. Wells: There are two kinds of waste which come from creameries. First, you have the concentrated organic wastes, such as skim milk, sour milk, whey, and buttermilk. These wastes are concentrated and they are serious because a small volume means a great deal of organic matter. This kind of waste must not be put into the streams; it can be disposed of in other ways. They can use it for hog feed or bury it, or spread it on land, but the stream is not the place for it. Then, there is the wash water, used in the washing of cans and other kinds of apparatus. There is a large volume of this water; you cannot bury or feed it to hogs, and the only thing to do with it is to allow it to go back into the stream. However, this kind of waste is not so hard to treat. We are working on methods of treating it, and the results of our investigations will be available very soon.

Dr. R. C. Osburn, Columbus, Ohio: Of course, it is possible to neutralize any kind of pollution by some chemical method. It may be very expensive; in some cases it undoubtedly will be. But the main point, as it appears to me, in what Mr. Travers presented this afternoon is that he has found a method, very much cheaper than anything heretofore produced, for getting rid of a number of our greatest sources of pollution, rendering the water pure so far as fish are concerned—pure, because fish will live in it, as has been demonstrated by actual test. Another point is that there is absolutely no danger in the use of the material which Mr. Travers has discovered; you could put any quantity of it into the streams and no damage whatever would result to the fish; it is absolutely harmless in itself.

Mr. Travers: Do not get this treatment confused with the question of treating domestic sewage. In our experiments we have not considered what is known as ordinary domestic sewage as being detrimental to fish life, because it will purify itself after it flows a few miles. If we were figuring on treating domestic sewage, it would involve the question of treating a very large volume of water; but we do not do that. The pollutions of which I have been speaking are concentrated pollutions issuing from factories, the volume of which is not great, and the treatment of which, before it goes out, will do away with the possibility of the pollution of large bodies of water. This treatment is distinctly intended for industrial wastes, not domestic sewage.

ANTAGONISM AND ITS POSSIBLE UTILITY IN POLLUTED WATERS

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During the past few years much has been said and written about the pollution and contamination of streams, especially as its bears upon the problem of the perpetuation of our most important food fishes. Much injury and destruction of food fishes is caused, for instance, by the ill-considered methods of factories of getting rid of by-products. These pass unheeded by the general public, and the protest of those most interested is often ineffective. Frequently the money spent to improve the condition serves only as a sedative for the public conscience. In most cases this is not intentional but is the result of ill-directed remedial measures.

The first thought is to add something to the stream that will counteract the harmful effects of the contaminating products. This is suggested by the work that has been done on antagonistic substances. Experiments presented in this paper suggest the possibility that under certain conditions the addition of an antagonistic substance to a polluted stream might prove detrimental rather than beneficial—might tend to accentuate rather than counteract the toxic element. For this method to be most effective, great care must be exercised in determining the exact quantity of the remedial material or materials that should be added so as to be most efficient.

A few experiments were run with calcium chloride and sodium chloride in connection with the work on toxicity of salts to fish (Powers, 1920) to ascertain if there is any relation between the antagonism and the toxicity curves of these two salts. Through these experiments it was hoped to throw some light on the method of treatment of polluted streams.

A 0.297 N. calcium chloride solution, to which varying amounts of sodium chloride were added, was used for testing

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the antagonistic effect of sodium chloride on calcium chloride. In these experiments, Table I, the antagonism of the sodium chloride did not, at any concentration tested, amount to more than the additive effect of the sodium chloride solution itself. That is, there was always more or less of a decrease in the survival time of the fish when the sodium chloride was added, over that in the pure calcium chloride solution. By compar-

I. DATA ON THE BLUNT-NOSED MINNOW, *Pimephales notatus* (RAFINESQUE), WHEN KILLED IN 0.297 N. CALCIUM CHLORIDE TO WHICH DIFFERENT AMOUNTS OF SODIUM CHLORIDE HAVE BEEN ADDED

[Column one gives the normality of the sodium chloride of the 0.297 N. calcium chloride solution. 20° C.]

Normality of NaCl	Weight of fish in grams	Survival time of fish in minutes	Velocity of fatality 100/t
0.00	1.2	35	2.86
0.00	1.6	61	1.64
0.00	1.8	61	1.64
0.00	2.3	61	1.64
0.00036	2.0	53	1.88
0.00036	2.1	53	1.88
0.00074	1.7	62	1.61
0.00074	1.7	68	1.47
0.00148	1.8	34	2.94
0.00148	3.1	31	3.22
0.00297	1.4	70	1.42
0.00297	1.5	50	2.00
0.00594	1.6	65	1.54
0.00594	2.0	52	1.92
0.0119	1.8	73	1.37
0.0119	1.9	38	2.63
0.0237	1.5	99	1.01
0.0237	2.0	54	1.85
0.0445	1.7	34	2.95
0.0445	2.5	29	3.45
0.0817	1.4	47	2.13
0.0817	1.6	39	2.56
0.119	1.5	51	1.96
0.119	1.6	28	3.57
0.156	1.3	26	3.85
0.156	1.6	46	2.17
0.230	1.6	31	3.22
0.230	2.2	38	2.63

ing Table I with experiments on which the same fish, *Pimephales notatus* (Rafinesque), were killed at 22.8° C. (Powers, 1921, Table I), it will be seen that the actual antagonistic effect of the sodium chloride was increased up to the largest amount of sodium chloride added. That is, the falling off of the survival time of the fish was less rapid in the mixture of calcium and sodium chlorides per actual concentration of salts than an equivalent concentration of pure calcium chloride or sodium chloride.

In the experiments with a 0.297 N. sodium chloride solution, to which varying amounts of calcium chloride were added, there was a greater antagonistic effect than the additive effect of the calcium chloride. The antagonistic effect of the introduced calcium chloride increased over that of its additive effect until the calcium chloride in the solution amounted to approximately 10 per cent of that of the sodium chloride. From this point on the survival time of the fish fell continuously, up to the highest concentration of calcium chloride employed, equalling that of the pure sodium chloride when about 1.156 N. calcium chloride had been added. Following this the antagonistic effect of the calcium chloride amounted to less than its additive effect.

These experiments show that there is no relation between the antagonism and toxicity curves. They also show that the antagonistic effect of calcium chloride and sodium chloride is most pronounced when they are present in the ratio in normalities of about one to ten. These results agree fairly well with those of Osterhout (1914) who found the most effective ratio for the antagonism of these two chlorides to be one of calcium chloride to twenty of sodium chloride.

These experiments show, in addition to the fact that a definite ratio must exist between two antagonistic salts to be most effective, that if this ratio is not approximated, the addition of the antagonistic salt to a toxic salt solution may be detrimental rather than beneficial. That is, if a toxic salt solution requires more than an equivalent amount of another approximately equally toxic salt to have the greatest antagonistic value, any amount, no matter how small, of this salt when added to the solution will be detrimental rather than beneficial. On the other hand a toxic salt solution can be benefited by an addition of another approximately equally toxic salt, provided that it requires less than an equivalent amount of the second salt to have the greatest antagonistic value. Thus in all treatments of natural waters contaminated with a toxic substance, the ratio for the greatest antagonistic value of the substance added must be determined for the treatment to be most effective.

II. DATA ON THE BLUNT-NOSED MINNOW, *Pimephales notatus* (RAFINESQUE), WHEN KILLED IN 0.297 N. SODIUM CHLORIDE TO WHICH DIFFERENT AMOUNTS OF CALCIUM CHLORIDE HAVE BEEN ADDED

[Column one gives the normality of the calcium chloride of the 0.297 N. sodium chloride solution. 20° C.]

Normality of Ca Cl2	Weight of fish in grams	Survival time of fish in minutes	Velocity of fatality 100/t
0.00	1.5	50	2.00
0.00	1.5	67	1.49
0.00	1.7	41	2.44
0.00	1.8	59	1.69
0.00	2.2	65	1.54
0.00	2.9	48	2.08
0.00036	2.0	64	1.56
0.00036	2.2	64	1.56
0.00074	1.7	84	1.19
0.00074	1.8	55	1.32
0.00148	1.3	44	2.22
0.00148	1.7	66	1.51
0.00297	1.6	57	1.75
0.00297	1.6	60	1.66
0.00594	1.7	66	1.51
0.00594	1.8	78	1.28
0.0119	1.5	85	1.17
0.0119	1.8	78	1.28
0.0237	1.6	82	1.22
0.0237	2.3	111	0.90
0.0445	1.6	75	1.33
0.0445	1.7	73	1.37
0.0817	1.6	54	1.85
0.0817	1.7	68	1.46
0.119	1.6	59	1.69
0.119	1.7	75	1.45
0.156	2.0	46	2.17
0.156	2.0	55	1.82
0.193	1.6	33	3.03
0.193	2.2	33	3.03
0.230	1.7	29	3.45
0.230	2.2	22	4.55
0.267	1.4	20	5.00
0.267	1.4	21	4.76
0.297	1.7	23	4.35
0.297	1.7	20	5.00
0.297	1.7	21	4.76
0.297	1.8	20	5.00

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SOME RECENT OBSERVATIONS ON THE FRESHWATER EEL

By Hugh M. Smith

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Mr. President, I fear that there is nothing I can say which is not already known to you or which some other members could not present in a much better way than I can—Professor Prince, for instance.

The freshwater eel presents the very interesting anomaly of a food fish that does not require any protection. There may be some others—perhaps the carp is one of them, but there are not many migratory food fishes in this country or anywhere else in the civilized world that do not require protection. The freshwater eel is very much less important in this country than it is in western Europe. Nevertheless, in some of our own states, such as Pennsylvania, Maine and Massachusetts, the eel supports a considerable fishery; as a matter of fact there are eel fisheries all the way from Canada to the Mississippi River.

I have here what is probably the smallest specimen of freshwater eel that any of you have ever seen. In spite of all that has been learned about the eel, its migration, its growth and spawning, it still remains a creature of mystery to the layman, and some extraordinary views in regard to it are entertained, as most of you are well aware. If you consult the proceedings of the American Fisheries Society of a dozen years ago you will find some discussion of new observations of the eel made by Grassi in the Mediterranean. You will find that we then thought we had learned nearly all there was to be learned about the eel and we would have to go to the Mediterranean in order to follow up the life history of the eel—that is, the European eel.

I may say that nearly all we know about the eel is the result of studies of European biologists. Thanks to the studies of Dr. Johannes Schmidt, of Copenhagen, we are now in a fair way to learn the complete life history of both the European and the American freshwater eels. Dr. Schmidt, who has been the greatest authority on the eel during the past 15 years, has recently completed an extremely important and interesting expedition all the way across the Atlantic Ocean from Gibraltar to New York in an exploring vessel, having in view the primary object of collecting specimens of freshwater eels. I cannot do better than quote from a letter that I have received from Dr. Schmidt. It was written only a short time ago and will, I believe, give you the very latest ideas about the freshwater eel. It is as follows:

I think I am now able, after so many years' work, to chart out the spawning places of the European eel (*Anguilla vulgaris*). The great center seems to be at about 27° N. and 60° W., a most surprising result in my opinion. I have had enormous trouble through the occurrence of larvæ of *Anguilla rostrata* in the very same hauls as those of our species, so much indeed that I wished I could send all the American eels to the Pacific, but after all, we have the difficulties in order to overcome them, and the fact seems to me to be so interesting that I enclose a copy of the measurements of the anguilla larvæ from one haul at a station southwest of Bermuda. When you arrange the measures graphically you find the figure to the left, but if you count the number of myomeres you will find the graph split up in two, showing that your American eel must spawn before *Anguilla vulgaris*, and further that the specimens of the latter nearly all belong to the 1920 fry except a few measuring about 4 1/2 cm. in length and belonging to the 1919 fry, of which there are still a few left in these waters. (I have many graphs showing the same as that of which I send you a copy.)

As far as I can see from my collections which I have not been able to work up thoroughly on board this small ship, the American eel seems to have its spawning places in a zone west and south of the European, but overlapping. I hope the collections made by you will help clear up this question. Unfortunately it is not easy to distinguish the two species in their earliest larval stages, i. e., before the postnatal myomeres can be counted with certainty, but I am sure I can do it down to a length of 15 mm.

The larvæ of both species appear to pass their first youth together, but when they have reached a length of about 3 cm. they say good-bye, the one species turning to the right, the other to the left!

When we are taking the facts shown by this cruise into consideration, it is most astonishing to think of the almost complete "pureness" of the samples of eels from Europe and America, respectively. As far as I remember, the number of American specimens in European samples only amounted to a few per thousand. The whole eel question, in my eyes, has become much more interesting than when I started work 15 years ago, and when it was believed that the problem had to be solved in the Mediterranean (from Grassi's publications). That the theatre has been moved to 60° W. longitude and that the problem of the European eel can only be solved in close connection with that of the American species, makes the whole question of still more interest, in my opinion at least.

I should mention that our work is done by towing 3 nets (2 meters in diameter) attached to the wire in the same way as described in Hjort and Murray's "Depths of the Ocean." The deepest net has 150 meters of wire out, then follows the second with 100 meters of wire out, and finally the third with 50 meters of wire out. (You understand that all three nets are towed at the same time.) The nets are towed with a speed of 2 1/2 knots in two hours *during night.* The leptocephali undertake vertical migrations during the night, and it is therefore absolutely necessary to use more than one net at the same time. It has happened to us to take the enormous number of 800 anguilla larvæ in the 50 meter net and nearly none in the two others towed at the same time, and the following night all the larvæ were taken in the 100 or 150 meter net! As you are aware, hauls made during the day will give no results at all in regard to leptocephali. The smallest and most important larvæ occur deepest down, and we used to get them in the 150 meter net only.

These larvæ which Dr. Schmidt has collected out there in mid-ocean pass to the shores of the respective continents, requiring about a year to make the journey. They change their form and size as they come shoreward, and begin to take color when they get within close distance of the continents. They start their upstream migration in spring. Many of you have seen eels coming up the small streams in spring. There is a very early separation of the sexes, the females for the most part going to the headwaters of the streams, and the males remaining lower down, many of them doubtless not going beyond tidewater. The females remain in the upper waters until they attain a considerable age—probably five, six or seven years or older—and then they start downstream in the fall on their first and only spawning migration. All eels of more than 15 inches in length are females; no males have ever been found that were more than 15 inches in length.

These creatures go to sea to the region indicated on the chart exhibited. They doubtless spawn at considerable depth, probably 1,000 feet or more. No eel eggs have ever been collected, probably for the reason that when they are brought up in collecting nets from that great depth they rupture and we never get anything in the way of a perfect egg.

The young eels gradually come to the surface and pass to the shores of the respective continents. Just as in the case of the Pacific salmons, the freshwater eels of America and Europe spawn only once and die. It is not known exactly what happens at the spawning time, but there is reason to believe that a gelatinous degeneration of the entire animal takes place, as is known to occur in some other species of eel. I believe I have seen a freshwater eel in Japan that had begun to thus degenerate. It was obtained far out at sea and brought into a little inn on the Japanese coast where I was staying. It had the consistency of blanc-mange; you could cut it with a fork. I believe that is all I need say.

ARTIFICIAL PROPAGATION OF OYSTERS

By William Firth Wells

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As long ago as 1879 Professor Brooks, of Johns Hopkins University, working at Crisfield, Md., on the shores of Chesapeake Bay, demonstrated that spawn could be taken from the female oyster, fertilized in much the same manner as are the eggs of fish in hatcheries, and that the young oysters could be kept alive until they had absorbed their yolk—a period of about six days. In the forty years which have elapsed since that time other scientists have worked at the problem, but no records have been published which indicate any material advance in the artificial propagation of oysters. None of these investigators has been able to carry the young oyster beyond the stage when it has used up the food material bequeathed by the mother and seeks to secure its own food. In other words, no means has heretofore been devised for feeding the young oysters.

The chief cause of this failure is the microscopic size of the young oyster, which, at the time it starts to seek food, is so infinitesimal that it would require four hundred of them to reach one inch. Previous experimenters have frankly admitted that they could proceed no further because they had no method of changing the water—and thus supplying fresh food—without losing their minute charges. The difficulties were therefore chiefly technical, and the attempt this summer, which has led to success, was to develop the technical methods so as to be able to handle the forms in such a way that the water could be changed, enemies eliminated, and food, air and other necessary factors provided.

For this purpose we conceived the idea of using a centrifugal machine, a De Laval "milk clarifier," by which the tiny oysters could be separated from the water as readily as specks of dirt are separated from milk. At first it might appear that such delicate animals would be injured by passing through a centrifugal machine, but we found that, being enclosed in shells which afforded protection, they could be concentrated in the machine without injury. In this way millions of little oysters were separated from a large volume of water, and transferred in a small bowl to another volume of water containing fresh food and other necessities of life. The same machine was also used to eliminate from the water dirt and various enemies of the oysters—which are not the less dangerous because they, too, are of microscopic size.

In an improvised laboratory in the plant of the Blue Point Oyster Company, at West Sayville, L. I., our first trial began on June 10th and led to immediate success in keeping countless numbers of young oysters, developed from artificially spawned and fertilized eggs, for a period of eleven to fourteen days. Five different batches were included in this experiment, and they increased in size and changed in form. All were lost, however, through improper attention at a time when the writer was obliged to be absent for a few days.

New batches were started on July 4th, 5th, 10th, 16th and 21st. These all continued progressively to the "setting" stage, and thus for the first time an oyster "set" was obtained artificially under controlled conditions, and when the progress of development could be observed from day to day. By "set" is meant the habit of young oysters, after a preliminary period as free swimmers, of sinking to the bottom and attaching themselves to shells and other hard objects. The time of development from spawning to setting was established by our experiment to be approximately a month. It may be somewhat less in open waters, but circumstantial evidence of varying conditions leads us to think it cannot be much abbreviated. Early investigators thought that the period was very short, and even those who had determined that it was a matter of weeks underestimated the interval that was actually found to elapse.

The far-reaching significance of our success and the possibilities for which it opens the way can be seen in the fact that the set is the starting point of the commercial oyster industry; and the continuous and unexplained failure of the oystermen to secure a satisfactory set of young oysters is the main cause of the declining yield of oysters in northern waters within recent years. Once getting his set, the oysterman is familiar with methods of handling the oysters to raise them for market; but if the young oysters do not attach themselves to the shells which the oysterman deposits for that purpose, his business naturally fails. Our work thus fills in the baffling gap between the previous studies of scientists and the practical knowledge of the oystermen.

It is not now beyond the bounds of reasonable anticipation to look forward to the day when the crop of oysters may be vastly increased, either by stocking the beds with artificially secured sets, or by liberating at the proper time artificially developed young oysters which will make their own set in shell-planted waters. As a single oyster will discharge from 10,000,000 to 100,000,000 eggs each season, the day may be not far off when oysters will come to be a common food of the people, instead of being gradually forced into the class of a luxury for the epicure.

Our outfit consisted, during the latter part of the work, of a battery of nine glass bottles—having grown to these proportions from one bottle used at the beginning of the experiment. The bottles were five-gallon carboys ordinarily used to contain Saratoga waters. These were inverted and a tube inserted through the stopper so that the air could be withdrawn from above the surface of the water. Another opening in the stopper contained a porous wooden plug which permitted the air to rise in a cloud of fine bubbles, and kept the water well aerated, giving it at the same time a gentle circulating motion in close imitation of the natural motion of the water in nature. All water was obtained by going out to the bay in a rowboat and bringing back bottles filled with fresh sea water. After the fresh water was prepared, the little oysters were concentrated by the centrifugal machine from the bottle that was ready to be changed and the transfer made.

A close watch was kept of the conditions of development by taking a small portion of the forms when they were concentrated, and placing them under the microscope. It was evident at a glance whether the forms had developed naturally, whether they were active and in good condition, or whether many were dying. In this way their progress was observed at every stage, from the egg to the time when they became set. Abundant material also was thus offered for the study of the life history of shellfish, which has been very incomplete in the past.

In our experiment, probably a million young oysters reached the stage when they began to seek their own food. The first change of water was then effected and was continued at two-day intervals. There were naturally cumulative losses as a result of handling and observation. However, a uniformly high percentage of development was secured for about two weeks. From that time on it is believed that crowding tended to kill off or stunt the weaker forms. Some at this period began to forge ahead and develop more rapidly. Over a thousand reached the setting stage, and attached themselves not only to shells which were placed in the bottles for that purpose, but even to the glass sides of the bottles themselves. The youngsters then began to grow apace, development being much more rapid after the setting stage had been reached. Before winter the oysters will be as large as one's finger nail.

In conjunction with the U. S. Bureau of Fisheries, we took the opportunity during the investigation to test the effects of certain trade wastes upon the delicate young oyster forms, in order to determine whether the presence of chemical substances and other contaminating wastes in the setting areas of Connecticut and New York has been sufficient to explain the failure of the set. The quantity of such pollution necessary to injure the forms was determined and the basis laid for the intelligent regulation of waste matter in its effect upon the oyster industry.

Data are now at hand for proper design and technical routine required for the artificial development of young oysters. The experiment has worked perfectly on a laboratory scale, and on a larger scale the efficiency should be greatly improved. There is every reason to believe that the method can be practically applied on any scale desired, and that it would work equally well for clams and other shellfish, such as scallops, which multiply in practically the same manner as oysters.

Discussion

Mr. Wells: Mr. President, I do not suppose that very many here are deeply interested in the shellfish industries, and for that reason it has not seemed necessary for me to go into great detail as to the results of the work which we have carried on this summer, or to apologize for not presenting more from the abundance of material. This little paper was prepared by the Commission's publication bureau, based upon notes which I took; it gives a popular account of what we accomplished.

Most of you realize, perhaps, that shellfish culture is very much like agriculture; if we can obtain abundant seed, the methods from then on are well developed, and the shellfish industries can look out for themselves. The problem of getting the seed has become very difficult in recent years. The amount of seed, rather than the amount of ground, naturally determines the amount of the product, and any system which will develop or increase the amount of seed will, of course, increase the total product in direct proportion.

Earlier investigators had isolated information as to the different events in the oyster's life, while we obtained a continuous series of accurate observations in their proper sequence and were, therefore, able to determine the time intervals corresponding to the different stages of development. Unfortunately, with all that wealth of material we were not able to do more than hurry along and take what we could, the period of the oyster's growth, of course, determining the time that we could devote to our investigation.

After the oyster egg is fertilized a period of about six hours elapses before it can swim around in the water—six to nine, depending on the temperature. At that stage it looks like a microscopic blackberry, being divided into small cells. A little later it begins to grow a shell, the time depending on the temperature; in some cases the shell appears more rapidly than in others, but after a couple of days (sometimes in twenty-four hours) it will be covered with thin transparent shell. Oysters were reared to this stage by Prof. W. K. Brooks. I would call it the termination of the embryonic stage of the oyster, which up to this time has lived entirely upon the material in the egg, and has shown no sign of increasing in size. Several investigators have carried the oyster through the embryonic stage, but so far as I can find, no one has ever shown any evidence of bringing it to the next critical stage in which it obtains food from the water and grows. I would compare it to the difference between the chick when it breaks from the shell and the brooder chick which you have every reason to believe will, if left alone, become full-grown.

The next stage is marked by a new growth of shell, having a crescent moon effect, around the edge of the embryonic shell. What I call the crescent moon stage, then, marks the scientific distinction between the embryo and the larva, the embryonic stage being divided into the pre-shell and the shell stage. The embryonic shell has a straight hinge and is known as the straight-hinged stage. The larval stage extends from the embryonic to the time the oyster attaches or "sets," which has been called the dissoconch stage. The early larva looks like a transparent soft clam, but as it develops becomes more round and deeper until it exactly resembles a hard clam.

FURTHER NOTES ON RAISING FRESHWATER MUSSELS IN ENCLOSURES

By Roy S. Corwin

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The results of experiments in propagating freshwater mussels of the species *Lampsilis luteola* in Lake Pepin continue to shed light on phases of the problem of raising these molluscs in enclosures. From three experiments information has been obtained which guides one in answering these questions: (1) When do fishes infected in late summer or fall drop the young mussels? (2) What is the average number of mussels produced per fish from a single infection? (3) How many mussels to the square foot can be raised in an enclosure?

LONG PARASITIC PERIOD IN LATE SUMMER INFECTIONS

On August 19 and September 4, 1919, two lots of pike perch, or so-called wall-eyed pike, were infected with the glochidia of *Lampsilis luteola* and confined in enclosures.

Of the first lot, infected August 19th, 5 were surviving on October 24th, at which time they were carrying practically the original infection. These fishes were marked with aluminum tags bearing numbers and were disposed of as follows: Numbers 1, 3 and 5 were placed in a wire netting cage 10 feet square and 4 feet high, and submerged in the lake in 12 feet of water; and numbers 2 and 4 were taken to the Bureau of Fisheries station at Homer, Minn., and kept for examination in a tank of running water.

Of the second lot, infected September 4th, 8 were alive on October 24th and carrying apparently an undiminished number of glochidia. These fishes were also marked with tags and separated, Numbers 6, 7, 8, 9 and 10 being placed in the cage just described, and Numbers 11, 12 and 13 taken to the Homer station and kept under observation.

Examination was made of the pike perch at the Homer station every two weeks during the winter. Any decrease in the number of glochidia carried could not be detected, and inspection of sediment from the bottom of the tank failed to disclose any young mussels.

Pike perch No. 4 died March 31, 1920, or 225 days after infection. At the time of its death it carried 3,495 mussels on its gills. Several, scraped off and placed in water, demonstrated that they were alive by thrusting out the ciliated foot. Pike perch No. 2 died May 3, 1920, or 258 days after infection. The glochidia on the gills of this fish were not counted, but were conservatively estimated to be 3,000. Numbers 11, 12 and 13 died on different dates between March 18 and April 24, 1920, from 195 to 233 days after infection. None had dropped any appreciable number of glochidia, and all were carrying living mussels at the time of death. It should be explained that the death of these fishes was due to lack of food and attacks of fungus when the water became warmer, 46 to 48 degrees F.

On June 3, 1920, the cage containing the companion fishes was raised from the lake bottom. Seven of the eight pike perch were alive and vigorous; the eighth fish was dead but its body was recoverable. Pike perch No. 5 was identified by the tag, but Numbers 1 and 3 could not be identified because they had lost their tags. The gills of No. 5 were almost free from glochidia; three were removed, and, being placed in water, were active after two hours. This took place 289 days after Numbers 1, 3 and 5 had been infected.

Fish No. 6 was also identified by means of the numbered tag. Although it had dropped nearly all glochidia, two were removed alive. The remaining fishes had lost their distinguishing badges and could not be identified positively. Each fish resembled the two on which the tags had remained, in that they had dropped all the young mussels except a few scattered ones; but from each several lively infant *luteola* could be obtained. For pike perch Nos. 6 to 10, inclusive, this was 273 days after infection. The temperature of the lake water on June 3d was 67 degrees F.

Since the fishes at Homer station were carrying approximately the original infection as late as May 3d and those in the lake were about free from glochidia on June 3d, it appears that the month of May is the time when pike perch, infected as late in the summer as August 19th and September 4th of the previous year, drop the larval mussels.

AVERAGE NUMBER OF JUVENILES PER FISH

Attempts to determine the average number of juvenile mussels per fish host have resulted variously. In previous years it was suspected that the larval mussels were devoured by enemies, or, on dropping from the host, were swept out of the enclosure by waves. The outcome of one experiment this year was significant. Two enclosures, each 10 feet square and 9 feet high, were made, one with sides of galvanized wire screen of 12 meshes to the inch, the other with sides of 1-inch mesh poultry netting. These enclosures or pens were placed in the same locality fifty feet apart.

Of ten pike perch infected with *Lampsilis luteola* on May 21, 1920, five were placed in each pen. Both lots had dropped the larval mussels, were free from infection and were released alive at the same time.

The enclosures were not disturbed until September 11, 1920, at which time they were brought to shore and their contents examined. Few organisms, other than the young mussels, were present on the bottom of either pen; hence it is inferred that neither crop of mussels suffered greatly from predaceous enemies. From the fine screen enclosure were recovered 4,150 living juvenile *Lampsilis luteola* and 19 pairs of valves of dead *luteola,* making a total of 4,169, or an average of 833.8 mussels per fish. From the enclosure made of poultry netting were recovered 1,152 living juveniles and 5 pairs of valves of dead *luteola,* making a total of 1,157, or an average of 231.4 mussels per fish.

In view of the fact that the fishes in both enclosures had received the same infection and doubtless had dropped the same number of larval mussels, it appears that the enclosure of fine-meshed screen prevented young mussels from being washed out by waves, especially when, after releasing themselves from the host, they descended through the water to the bottom, and as a result produced 3,012 more juveniles than the other enclosure. It may be supposed that screen sides of finer mesh than 12 to the inch would be even more effective in confining the larval mussels within an enclosure.

MAXIMUM DENSITY OF MUSSEL POPULATION IN ENCLOSURES

Evidence regarding the maximum number of mussels which will live and grow inside an enclosure is still being sought. Records are available of such dense populations of juvenile *luteola* on the bottom of a pen as 41 and 77 to the square foot at the close of the first season, but the greatest number of juvenile inhabitants which can advantageously pass their second year in an enclosure has not been thus far satisfactorily determined. The best record, however, obtained from the work in Lake Pepin will be cited.

On October 11, 1919, there were replanted in a half-section of an enclosure 10 feet square, 1,060 live first season *luteola,* this being at the rate of 21.2 for each of the 50 square feet. These mussels ranged in size from 4.0 to 21.6 millimeters when replanted. After lying undisturbed for eleven months, the enclosure was examined on September 10, 1920, at which time 945 live second season *luteola* were recovered, from 16.5 to 49.4 millimeters in length. Thus, the average population was 18.9 for each of the 50 square feet. This figure does not accurately represent the condition prevailing, because the mussels were found crowded together in the corners and against the sides of the enclosure, whence they could be removed in numbers from 22 to 50 to each shovelful of approximately one square foot of the sand and mud from the bottom. From the middle of the area few, if any, mussels were taken. Eight pairs of valves of *luteola* which had succumbed before their second year were found, leaving 107 of the original 1,060 not definitely accounted for.

How many second season *Lampsilis luteola* to the square foot will live and grow during the third year of their existence? The present highest record is 8.94 to the square foot, obtained when 447 second season *luteola* of the 461 replanted, passed their third year in a space 10 feet long and 5 feet wide, increasing in average length from 19.1 to 41.6 millimeters. Seven pairs of valves of dead second season *luteola* were found, leaving 7 of the original 461 whose disappearance cannot be explained.

SUMMARY

1. Pike perch, infected as late in the summer as August 19th, carry glochidia until the following May.

2. The average number of living juvenile *Lampsilis luteola* produced by one pike perch from a single infection is at least 833. The use of more finely meshed enclosures may raise this figure.

3. Eighteen first season mussels to the square foot will thrive in an enclosure during their second year; and 8 second season mussels to the square foot will flourish during their third year. Further investigations may show that a more dense population would not be detrimental to the growth of the mussels.

SPAWNING HABITS OF THE SPINY LOBSTER (PANULIRUS ARGUS), WITH NOTES ON ARTIFICIAL HATCHING

By D. R. Crawford

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Since the spawning act among the larger crustaceans has been observed so infrequently, any additional information is of interest and value. Herrick records no direct observation of the spawning act of *Homarus americanus*. Scott records one observation on the spawning of the European lobster, *Homarus gammarus*.* Although the available literature has been searched, no record of the direct observation of the spawning of the blue crab or spiny lobster has been found.

The difficulties surrounding observations of this sort are numerous and often insurmountable, and the one who has an opportunity to observe the spawning act is indeed fortunate. It seems that crustaceans rarely spawn in captivity unless they are captured just prior to the time when spawning would have occurred under natural conditions. Close confinement often causes abnormal conditions to which the crustacean does not become adapted. It is pointed out that the spiny lobster, which was observed in this case, was confined but one day before the act of spawning took place.

A brief review of the external features of the anatomy which are peculiar to the female will be helpful in understanding what is to follow.

The fifth claw of the female, which differs from that of the male, is considerably modified. At the articulation of the dactyl with the propodus, there is a small chela which is composed of spur-like extensions of the propodus and dactyl. The inner surfaces of this chela are concave and the rims are com-

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*Report for 1902 on the Lancashire and Sea Fisheries Laboratory at University College, Liverpool, and the Sea Fishery Hatchery at Piel, pp. 20-27. Liverpool, 1902.

posed of dense, hard chiton. There are silky tufts of short setæ on the dactyl. The pleopods of the female differ from those of the male in the development of the endopodites of the last three pairs, the first pair of endopodites resembling the exopodites. The last three pairs of endopodites are bifurcated and fringed with long, hair-like setæ protruding in tufts from the margins which are reenforced by thickened scutes at these places. All of these hairs are not the same in character, for it is found that some of them are plumose and shorter than the others which are simply rod-shaped. These simple hairs carry the eggs when they are laid.

The spermatozoa are carried in a vesicle which is deposited on the sterna of the female between the last three pairs of legs. This vesicle has no internal connections with the ovaries and fertilization of the eggs necessarily takes place after they leave the oviducts. The oviducts open on the coxæ of the third pair of legs which is anterior to the great bulk of the vesicle. The eggs, therefore, must pass over the vesicle before they reach their place of attachment on the pleopods.

On May 5, 1919, at the U. S. Bureau of Fisheries Biological Station at Key West, Fla., a female spiny lobster which had been captured the day before, was observed resting in one corner of the enclosure with the pleon slightly flexed and the margin of the telson resting lightly on the bottom. There was nothing unusual to suggest that spawning was about to occur.

Presently, the fifth pair of legs was carried slowly foreward and the dactyls reached underneath the body in the region of the seminal vesicle. The poking action continued for about five minutes when the spiny lobster was removed from the water. It was observed that the exterior of the seminal vesicle was being scraped off. After replacing the animal in the water, this action continued for half an hour, after which time it was observed that the posterior third of the vesicle was scraped off, showing a pinkish interior.

Forty-five minutes after the observation started, the movements of the fifth pair of legs were quickened and they passed backward to the pleopods. It is not supposed that the eggs were being carried backward by the chelæ of the fifth pair of legs. A number of estimates showed that a female spiny lobster carries about 700,000 eggs. This large number, together with the time in which they were deposited and the way in which they were attached to the hairs of the pleopods, precludes the possibility that they could have been deposited with the aid of the chelæ. These appendages are used to remove the surface of the vesicle and, later on, to manipulate the eggs after they are laid. Whether or not small pieces of the vesicle containing spermatozoa were conveyed to the pleopods is not known, but the action of the fifth pair of legs suggests this possibility.

The pleopods during this time beat slowly and rhythmicly from side to side. That eggs were being extruded was suggested by the continuous attacks of small fishes which darted in toward the pleon. It was very desirable for various reasons to learn, if possible, how long the eggs were carried, and so the female was not disturbed. It, however, was noted that the eggs were all laid six hours later when the spiny lobster was removed for observation. Whether the time for egg laying is any shorter than six hours was not learned from this, or subsequent observations of several other females which spawned in captivity.

The eggs may be extruded with considerable force since the mature ovaries are very large in proportion to the other viscera and they must be under considerable pressure. The fanning motion of the pleopods could have carried the eggs backward against the endopodites. The fact that the eggs are fastened to no other parts of the body than the simple hairs of the last three pairs of endopodites suggests that the cementing substance, whatever it may be, is secreted from the endopodites. Glands for this secretion, however, have yet to be demonstrated.

Unfortunately, this spiny lobster died, but observations of three other females which spawned in captivity showed that in three cases at least, the incubation period of the eggs is eighteen days. Probably three weeks is more exact for natural conditions, since the water at this time was very warm.

It was observed that the remains of the seminal vesicle are picked off a few days after the eggs have hatched. It is thus possible to estimate within close bounds the spawning time of any number of females which may be caught. If conditions are favorable, the females molt ten days or two weeks after the vesicle is picked off. Mating takes place, as observed in one instance, shortly after molting, while the shell is still soft.

The eggs are bright coral red when they are first laid, but they change to brown and finally clear, light gray as the developing embryo absorbs the yolk material. The approximate age of the eggs can be judged by observing their color. The newly laid eggs are slightly oval, measuring about 0.45 mm. by 0.5 mm. They increase slightly in size and become spherical as the embryo develops.

Experiments in artificial hatching of the young were carried on at the Biological Station at Key West in 1917 and 1918. The first apparatus consisted of boxes made of wooden frames covered with cloth in which a female bearing eggs was placed. The eggs were allowed to hatch and the female was removed when the larvæ were observed at the surface. This apparatus proved unsuccessful in rearing the larvæ. In 1918, more extensive experiments were carried on. A small battery of McDonald hatching jars was set up and supplied with running salt water. A wooden trough was provided to catch the overflow from the jars and a device was developed to keep the water circulating upward from the bottom.

The eggs were found to be rather difficult to strip since they adhered to the pleopods quite securely. At first, only those eggs which were known to be about to hatch were placed in the jars. It was not difficult to select females bearing such eggs, for it was observed that when the eggs are in such an advanced state of development, the females are less active than those bearing newly laid eggs. The females do not take food readily while bearing eggs, and the reduced activity may be caused by starvation. The eggs which are about to hatch are clear gray and the embryo can be seen plainly through the outer membranes. They are semi-buoyant and the flow of water through the jars must be gauged carefully.

The first larvæ to emerge in the jars hatched abnormally because of evident injury to the eggs while stripping them. These larvæ did not succeed in casting off the embryonic sheath which covers all parts of the exterior and in which the exopodites of the natatory appendages are folded down closely to the endopodites. These larvæ quickly died. The first normal larvæ emerged during the night. It was observed that just before hatching, the eggs became buoyant and as they floated upward, the larvæ ruptured the outer shell and emerged much doubled up like flecks of cotton waste. In a few seconds, the larvæ straightened out and began actively swimming about. The larvæ have two movements; the first is a rotary movement which causes the larva to proceed by a series of summersaults; the second movement is spiral, the larva rotating on its longitudinal axis as it moves forward.

The first stage larva, or phyllosome, is quite small, the body, excluding the antennæ and legs, measuring 0.9 mm. in length and about 0.7 mm. in width. It is transparent except for the dense black eyes and yellowish liver mass. The legs which are developed in this stage correspond to the third maxillipeds and the last three pairs of legs in the adult. The first two pairs of legs posterior to the maxillipeds have well-developed exopodites with which the larva swims. The exopodites on the last pair of legs are reduced to short spurs. The legs are very long in proportion to the body and they are provided with numerous setæ and spines. The first two pairs of dactyls are very long and curved slightly while the last pair of dactyls is short and hook shaped. It was observed that these long legs became entangled when the larvæ were crowded and that it was impossible to separate the larvæ. Consequently, they sank to the bottom in tangled mats and soon died.

Experiments with newly laid eggs were unsuccessful because they adhered in compact masses which could not be separated. None of them developed to the stage in which the eye of the embryo can be seen. Stripping evidently injured most of them before they were placed in the jars. Under natural conditions, the eggs on the pleopods of the female are manipulated with far greater care.

Although none of the larvæ was reared beyond the first stage, the experiment was important because it showed that fluctuations in the temperature of the water are detrimental to hatching and that the optimum temperature is not far from 75 degrees F. This temperature was observed at the hatchery only at night during a rising tide when the water was flowing in from the open sea. This strongly suggested that the temperature of the water in which the eggs naturally hatch is about 70 degrees, since the incoming water would rise in temperature as it mixed with the much warmer shallow water over the flats, thus accounting for the higher temperature observed at the hatchery.

This fact is rather important for it tends to disprove the common belief that hatching naturally takes place in shallow water. Extensive observations over a period of two years showed that the fluctuations in temperature of the shallow water are too great and too sudden and that the maximum temperature frequently rises beyond that which was observed to be the thermal death-point of the larvæ, viz., 98 degrees F. Although occasional females may stay in shallow water while the eggs hatch, it does not seem likely that any great number of the larvæ survive. The fact that large numbers of spawn bearing females are caught in shallow water does not prove that they remain there while the eggs hatch, for it is well known that large numbers of spiny lobsters migrate shoreward during the night and on stormy days when the inshore water is cool for the purpose of feeding. No females with well-developed eggs were ever taken at the station in traps set in shallow water, and among many hundreds brought into the market at Key West none was observed with brown or light gray eggs unless the fisherman had set his traps in deeper water than usual. That the eggs hatch normally while the female is in deep water seems all the more likely since Waldo L. Schmitt, of the United States National Museum, states that he found the phyllosomes of the closely related species of California, *Panulirus interruptus,* far off shore in 75 fathoms of water.*

Any further experiments, therefore, must take into account the fluctuations in the temperature of the water. If this factor can be controlled, one very difficult obstacle will have been removed. It was found necessary to shade the trough in which the larvæ were kept, since they are heliotropic and tend to crowd together with the result that they become tangled inextricably and die. Water which is heavily laden with sediment is detrimental to the welfare of the larvæ, since the silt settles on them and weighs them down, causing death.

The problem of feeding the larvæ is difficult because of their small size, although their mouth parts are well developed, even in the first stage, and the mandibles are fully capable of masticating small copepod larvæ. Any artificial food must be very finely divided, such as the particles of beef liver that could be squeezed through fine bolting cloth.

As far as the writer is aware, none of the many experiments in rearing the larvæ under artificial conditions has resulted in success. The reasons advanced for these failures are numerous and varied, but they may all be summed up in the statement that the natural conditions for larval existence and

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* Waldo L. Schmitt. Early stages of the spiny lobster taken by the boat "Albacore." California Fish and Game, vol. 5, number 1, p. 24-25. Sacramento, Jan., 1919.

development have not been met in the aquarium. It is very easy to place a spawn bearing female in any sort of floating contrivance and allow the eggs to hatch, for they will hatch readily under such conditions, but there is no gain or improvement over natural conditions unless many of the young can be reared beyond the larval stages.

THE ECONOMIC HISTORY OF COPEPODS

By Arthur Willey

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It is perhaps superfluous to repeat the time-honored statement that the ultimate object of the scientific study of organisms is to give precision to the facts of common observation, to extend biological knowledge, and to apply it when opportunity offers. No single line of investigation is competent to supply all the information necessary before we can undertake to interfere with the course of nature and with the custom of fishery. It is hardly a fair question to ask what is the use of a particular contribution, because new and striking developments may arise from the most unexpected quarters. This paper has to deal briefly with one small branch of the subject, but it is one which has been cultivated much in our own time.

Crustaceans were called Malacostraca by Aristotle who meant to include under that term only the higher forms (crabs, crayfishes, shrimps, prawns, langoustes and lobsters) whose shell has to be crushed, in contrast with the Ostracoderma or shell-bearing mollusks whose shell must be shattered to get at the soft parts. In more recent classification crustaceans comprise three principal subdivisions, beginning with those of small size, then passing to those of larger average dimensions, and finally the largest: Entomostraca (water-fleas and copepods); Arthrostraca (sand-hoppers, scuds, and fish-lice); and Malacostraca, still employed in the Aristotelian sense.

The name of the order Entomostraca was introduced from Denmark in 1785, but some of the members of it had been seen in the 17th century, in the early days of the invention of the microscope. One feature which nearly all of them possess in common is a single median eye. It may be divided by notches into three parts, in which case it presents a tribolate appearance; and the parts may, in rare instances, become separated, but the single eye is typical of the group. On account of this one-eye character, Linnæus placed all the Entomostraca known up to his time under the genus *Monoculus* (1766, *Systema Naturæ,* 12th edit.). The leading copepod of the sea over the fishing banks of Norway, a widely distributed species now known as *Calanus finmarchicus,* was originally named *Monoculus finmarchicus* in 1765.

The name Copepoda ("oar-footed") originated in France (1840) and is applied to those Entomostraca, inhabiting fresh and salt water, which have five pairs of two-branched swimming feet on the forebody, and a five-jointed footless abdomen terminating in a forked tail. Fertilization is effected by means of spermatophores attached externally by the male to the genital segment of the female; the eggs are carried about in one or two ovisacs (according to the species), or are shed directly into the water. The young hatch out as minute free-swimming larvæ provided with three pairs of swimming appendages corresponding to the future feelers and mandibles. These larvæ are known collectively, irrespective of specific distinctions, as nauplii or nauplius-larvæ. After shedding the outer skin or cuticle, the nauplius becomes transformed into a metanauplius and after further exuviation the so-called copepodite stages begin, each stage being preceded by a casting of the cuticle. Altogether there are six copepodite stages, the last of which is the adult form. But the adult form still grows and expands before reaching complete maturity.

While the zoological history of the Entomostraca began about 1669 and the foundation of their classification was laid down in 1766, their economic history dates only from 1867, when their importance as fish-food in general and herring-feed ("Sildeaat") in particular was established by a Norwegian carcinologist, Axel Boeck.

The identification of these little animals, whose length ranges from half a millimetre to five and even eight millimetres, naturally preceded their nutritive valuation, and unless the original description is adequate and subsequent determinations correct, work upon them is apt to be thrown away. Much praiseworthy pioneer work had been accomplished in various countries up to 1882, when a better combination of textual description and tabular illustration came into vogue as the result of operations conducted in the inner bay of Kiel. The open water species, *Calanus finmarchicus,* already mentioned, does not penetrate into the Kiel Inlet, although it occurs in the outer bay or Kiel Bay proper. An almost equally abundant North Atlantic species, *Temora longicornis,* does occur there. In the winter and spring of 1872 the herring fishery at Kiel was one of unprecedented magnitude. For three weeks in January and February it was estimated that 240,000 herrings were taken daily. Their stomach contents consisted mainly of *Temora longicornis* whose total length is 1.5 mm. Often in five or six successive samples examined under the microscope, nothing more than *Temora longicornis* could be detected, filling the stomach of the herring with a compact pinkish bolus. The number of individuals in such a mass ranged up to the astonishing figure of 60,000. Professor Möbius considered it safe to assume that on the average every herring caught in Kiel Inlet had consumed 10,000 Temora during its stay there, and the total number ingested during the three weeks amounted to 43,200 millions of individuals. Tow-nettings showed that Kiel harbor at that time was swarming with *Temora longicornis.*

The animals and microscopic plants which pass their entire lives swimming or drifting in the sea and carried along by the currents from the shore line to the high seas, from the surface downwards, were not united under any comprehensive name capable of world-wide adoption until 1887, when the term "plankton" was successfully introduced by V. Hensen, the originator of the Plankton Expedition of 1889. Since that date quantitative results have been obtained methodically, thereby throwing much light upon the movement of life in the sea, the circulation of food, and the reproduction of fishes. The animal portion of the plankton is conveniently termed zooplankton, and the plant portion is the phytoplankton, the latter consisting of microscopic vegetable organisms known as diatoms and peridinians. Four kinds of plankton gatherings are distinguished by the relative numbers of the leading types (K. Brandt, 1898) as follows:

1. Peridinian plankton, with excess of peridinians, chiefly *Ceratium*, to which a great part of the phosphorescence in northern waters is due.
2. Diatom plankton, with excess of diatoms, especially *Chætoceras.*
3. Mixed plankton, rich alike in diatoms, peridinians and copepods, occurring in balanced proportions.
4. Copepod plankton, in which copepods and other animals prevail.

From a biochemical analysis of mixed plankton it is possible to arrive at some idea as to the relative nutritive values of the organisms. The figures, when reduced to roundness and consistency, are of this order: 1 copepod = 125 peridinians = 2,500 diatoms. A rich vertical haul through 20 metres of water taken in Kiel Bay on September 28, 1893, contained: 273,000,000 diatoms, 11,600,000 peridinians, and 96,000 copepods.

In Canadian waters there is still a wide field for qualitative work which is an essential preliminary to progress. The division of copepods to which Calanus and Temora belong is called Calanoida. There is another division, not so well known on this side, named Harpacticoida, whose members are only occasionally taken in the plankton net, and are more generally found swimming and creeping amongst seaweed. These are particularly abundant around Passamaquoddy Bay, where young herrings assemble in immense numbers year after year and are caught in fish-weirs for the sardine factories. A couple of young herring, 4½ inches long, examined recently at the Atlantic Biological Station, St. Andrews, N. B., presented stomach contents consisting of newly-ingested copepods, of which harpacticoids made up more than fifty per cent. Many of them are identical with species found on the northern coasts of Europe, but some are peculiar to the northern coasts of America. It is interesting to note that the two leading species of Passamaquoddy Bay are the same as the two most abundant species in Kiel Bay, namely, *Idyæa furcata* and *Harpacticus* *uniremis*. These enter conspicuously into the food, not only of young herring, but also of the winter flounder, *Pseudopleuronectes americanus*.

Just as Passamaquoddy Bay is a great resort for young herring on the coast of the Bay of Fundy, so Miramichi Bay which opens into the Gulf of St. Lawrence, is, as I learn from Dr. A. G. Huntsman, equally attractive to the smelt (*Osmerus mordax*). A plankton sample taken from the Miramichi River on June 7, 1918, under the direction of Dr. Huntsman, contained very many young smelt swimming, with mouth wide agape, in the midst of a copious copepod pabulum. The smelt larvæ varied in length from 6.5 to 11.5 millimetres, with an average length of 8.15 mm. The average total length of the copepods was 1.12 mm.; but as their oily nutriment is chiefly lodged in the forebody, we may neglect the attenuated abdomen and consider their average effective length to be 0.75 mm. In point of numbers, in a small fraction of the sample examined under the binocular microscope in a watchglass, there are about 100 fish larvæ to 3,000 copepods. By taking into account the dimensions of the copepods and young fishes in the three directions of length, breadth and height, we arrive at the conclusion, drawn from enumeration and from measurement, that one larval smelt is approximately the equivalent of thirty copepods. Amongst the multitude of the more ordinary pelagic copepods found in this region, the Miramichi plankton contains a Calanoid form hitherto unrecorded from American waters and perhaps representing an undescribed genus.

The Shubenacadie River of Nova Scotia, opening into Cobequid Bay, which in turn opens into the Basin of Minas at the head of the Bay of Fundy, is known as a shad river and is now under investigation by the Biological Board of Canada. The shad (*Alosa sapidissima*) ascends this river to spawn. Its stomach contents sometimes consist of copepod chyme, as reported recently by Mr. A. H. Leim, of Toronto University. Amongst the common species so far identified from the stomach of a shad of intermediate size, taken in Scotts Bay, just outside of the Basin of Minas, there are two, one a calanoid, the other a harpacticoid, offering peculiar and interesting features. A plankton gathering taken by Mr. Leim at the surface in the ebbing tide at Shubenacadie on July 31, 1919, and submitted to me for determination, contains 75 per cent of a harpacticoid genus named *Canuella,* new to Canada and differing from the European species.

All of the bays mentioned in the preceding paragraphs have special hydrographic conditions and therewithal a characteristic population of copepods. Plankton studies and hydrographical observations are thus seen to be inseparable and an integral part of fishery investigation.

CLIMATES OF OUR ATLANTIC WATERS

By Dr. A. G. Huntsman

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The word "climate," coming from the Greek word κλίνειν,—to lean, was at first used in reference to the changes in the elevation of the sun at midday on travelling from the equator to the north, the sun getting lower and lower in the heavens. The earth was, therefore, considered to slope from the equator to the pole. From this usage it came to mean one of a series of zones of the earth's surface running parallel to the equator, twenty-four in all, and later to mean the complex of conditions in the atmosphere that characterize any place and distinguish it from another not only in a different latitude but also in the same latitude. It may be used in the same fashion for the complex of conditions in the water or hydrosphere that may characterize a place, and in that sense we wish to discuss the question of the varied climates that are to be found in our Atlantic waters as well as some of their effects on the fishes living in those waters.

Conditions in the hydrosphere are more stable and in some respects less variable than those in the atmosphere. For example, although the water is warmed by sun's rays just as is the air, its specific heat is so great compared with that of air that heating and cooling are much delayed, midwinter in the water with us occurring at the end of February and midsummer at the end of August. The total range in temperature may be considered as only from 29° to 80° F. as compared with from —50° to 105° F. for the air. Movements, to a very much greater extent than temperature changes, are more limited in the water than in the air. The much greater weight of water as well as its greater viscosity makes it harder to set in motion and more difficult to stop. Currents in the water are slower and more constant than those in the air.

Differences of temperature are dependent largely upon latitude, the heat coming from the sun. Currents, both horizontal and vertical, are also a potent factor in such differences, often transporting the conditions of one region to another distant one. As the sun's rays penetrate such a comparatively short distance into water, currents that are more or less vertical are concerned in all important differences in temperature at any considerable depth.

Naturally we cannot speak of moist and dry climates in water, but there are differences that to some extent correspond with the varying moisture content of the air, namely in the amount of inorganic salts in the water or its salinity, much salt tending to abstract water from the animals and, therefore, resembling dryness. The ocean contains a very uniform mixture of a series of salts, but the amount of this mixture present in a given quantity of sea water varies considerably with the place and depth. Such differences are dependent upon the amount of fresh water entering by precipitation from the air, by melting of ice and by inflow from the land, and upon the amount leaving by evaporation.

Light is a most important element in the ensemble of climatic conditions, and we are familiar with the great differences in the amount and distribution of sunshine, our chief source of light, depending upon latitude and the presence of moisture and other particles in the air. These differences hold for the water, and to them are added others which depend upon the absorption of light waves by the water, the intensity and character of the light changing with depth, and upon their stoppage by particles of various kinds suspended in the water. The light conditions are consequently more variable in water than in air.

The extent to which certain gases as, for example, the oxygen and carbon dioxide of the air, are dissolved in the water, determines the character of the climate in the ocean. So significant are these gases that they have been invoked to explain the movement of fishes. Much oxygen in the water has been given by Roule as the factor that determines when and where the salmon make their spawning ascent of the rivers. Also the presence of sulphuretted hydrogen gas from the decomposition of organic matter is considered by Shelford as explaining the abandonment by the herring of certain of their former haunts. The influence of these gases can be readily understood, seeing that they are present in air and affect man. Although in the atmosphere differences in their abundance are usually slight, very local, and temporary in nature owing to the equalizing effect of the vigorous air currents, nevertheless in the hydrosphere they vary considerably in abundance, and such differences are maintained for a considerable time, the currents being comparatively weak.

Quite different from anything to be found in air are the conditions of alkalinity and acidity which characterize water. They are opposed conditions and between them is a more or less definite neutral ground or point. Water dissociates into hydrogen and hydroxyl (hydrogen plus oxygen) ions. When the former ions are in excess, as when furnished by some dissolved acid which dissociates in solution giving hydrogen but not hydroxyl ions, the water is said to be acid in reaction; when the hydroxyl ions are in excess, as when furnished by some dissolved and hence dissociated alkali, it is said to be alkaline in reaction; and when both kinds are in equal amount, it is said to be neutral. The importance of these conditions in their effect on the development of the life in the water has only recently come to be recognized.

Currents, as we have already indicated, have a very definite effect upon the climate. Their action tends to eliminate differences, but they are not so uniformly present as to have the general equalizing effect they have in the air. In certain places or at certain seasons there will be equalization of conditions and not at others, depending upon the presence or absence of the currents. To illustrate their effect we may instance the influence of the Gulf Stream on both the water and the air climates of the coast of Europe, and also the mixing of surface and deeper water that occurs in the autumn when the surface water is being cooled. Another case is the action of the tidal currents which churn up the water and not only carry the surface conditions into the deeper water, but also bring the less variable bottom conditions to the surface, making the surface water, as in the Bay of Fundy, cooler and more salt than it would otherwise be. These currents change not only the temperature of the water, but also its salinity, its gas content, and its alkalinity or acidity.

Of a very different nature are the effects of depth upon the water climate. We have already referred to the absorption of the sun's rays by water. In the most transparent sea the red rays are nearly all stopped before a depth of 250 fathoms is reached and not many rays of any kind penetrate deeper than 500 fathoms. The depths of the sea experience a never ending starless night and the intermediate waters enjoy a brief daily bluish twilight. In coastal waters invariably with more or less sediment, sunlight penetrates the water to a very much slighter depth.

The gain and the loss of heat occurs at the surface of the water, and as the latter is a poor conductor, the circle of the seasons is felt only in its upper layers except when vertical currents come into play. These currents are chiefly caused by the density of the surface water becoming greater than that below. This occurs in autumn when cooling is in progress, the water becoming denser as its temperature falls. The situation is complicated in fresh water by the fact that below 40° F. water becomes less instead of more dense as it gets colder, and in salt water by the fact that the density of the water depends not only upon the temperature but also upon the salinity.

Water gains and loses at its surface not only heat but also many of the gases it contains. They diffuse but slowly through its substance and, therefore, only its upper layers, except where vertical currents interfere, will have a rather constant content of these gases in equilibrium with their condition in the air. Elsewhere the local production and consumption of the gases by organisms will dominate their abundance.

We may conclude that extremely varied and most interesting conditions of climate are to be found in the water, and that the differences that exist there are much more easily studied and the order of events more easily discovered than is the case with the conditions in the atmosphere, seeing that in the latter changes occur so rapidly. Nevertheless as water is not the medium inhabited by man, the science of its weather is as yet only in its infancy.

The early classification of our Atlantic coast had to do merely with such major divisions as correspond with changes in latitude. Such were the Arctic province extending from the pole south to Hudson Strait, the Syrtensian from the latter to Cabot Strait and including Labrador and Newfoundland, the Acadian from Cabot Strait to Cape Cod, the Virginian from Cape Cod to Cape Hatteras, and others still farther southward.

In the light of our present day knowledge such a division of the waters is far from adequate. Any classification that might be attempted now is fairly certain to be premature, yet an indication of the varied waters we have as regards salinity and temperature, the only elements of the climate hitherto investigated with us, may be of interest and value. Without giving figures we may refer to different stages in salinity and in temperature as follows: excluding fresh water, four grades in salinity from most to least salt, namely, oceanic, bank, coastal, and estuarial; three grades in temperature, warm, cool, and cold. By combining these we get twelve kinds of climate, nearly all of which are to be found along or off our Atlantic coast; and each of these supports a more or less special fauna and flora to show how important its influence upon life is. We have the great ocean currents to thank for the varied conditions in our waters. The Gulf Stream with warm oceanic climate comes opposite our shores and exhibits not only tropical conditions but also a tropical assemblage of plants and animals. The Labrador current brings the icebergs of the arctic regions to our latitudes and displays a cold oceanic climate. In it many arctic species find congenial surroundings far from their usual home.

We may mention several other types of climate, types that are more natural to the temperate zone in which we are situated. The inlets of the Magdalen shallows, which form the southern part of the Gulf of St. Lawrence, have warm estuarial waters and harbor such southern forms as can survive the winter's cold, for example the oyster. A cool bank climate is to be found on the fishing banks off the mainland of Nova Scotia, where the haddock and hake abound. Cool estuarial conditions may be met with in many of the inlets opening into the Bay of Fundy, and as this bay is farther south than the Gulf of St. Lawrence, we have an exemplification of the way in which our waters defy a classification according to latitude. A cold bank climate occurs on the fishing banks off Cape Breton and Newfoundland, and its characteristic commercial fish is the cod. Cold coastal conditions are found around Newfoundland and on Labrador, and these favor the presence of the capelin, which in Greenland is said to form the daily bread of the natives.

We cannot very well overestimate the value of a knowledge of the climate in enabling us to predict what may or may not be done in extending our fisheries and in increasing our stock of fishes. In almost every problem it is a basic consideration. For each of our commercial fishes we must put these questions and seek for the answers to them. In what climate or climates will the species succeed sufficiently well to be profitable? Where are such climates to be found? Are different climates needed for the different stages in its life history? From the last question it can be seen how complicated the situation may be. It is well known that some fishes spawn in special waters very different from those in which they pass the greater part of their lives. The salmon attains its best development in the coastal waters of the sea, but it must enter fresh water to spawn. The eel thrives in fresh water lakes and ponds often hundreds of miles inland, and yet its eggs must be deposited out in the middle of the ocean. Many, many instances could be given of the movements of fishes to special spawning places or the passive movement of the eggs or larvæ to waters not frequented by the adults.

Not always does nature provide the proper conditions for the eggs, for the young, or for the old. During the year 1920 we obtained eggs of the smelt laid in the intertidal zone at the head of tidal water in the Magaguadavic River, New Brunswick, and we could not discover that any of these had developed to the slightest degree, thus explaining the rarity of the fish in that region. On the other hand we have the case of the floating eggs of certain flatfishes and gadoids (most important commercial fishes), which are to be found generally distributed in the spring and early summer in the waters of the western archipelago of the Bay of Fundy. We secure the eggs regularly and yet we have never succeeded in obtaining any of the larvæ there although on other parts of our coast the latter are very abundant and easily found. The larvæ and young of the common starfish are rather abundant on the gulf coast of the island of Cape Breton, but during our investigations of that coast in the summer of 1917 we failed to secure a single adult at any depth, notwithstanding their abundance in our hauls taken at the Magdalen Islands in the middle of the gulf. There can be no doubt that the young settling on the shores of Cape Breton are fated never to reach adult life.

In the literature there have been given several reports of cunners and tautog, which are nearly related warm water coastal fishes, having been found killed in large numbers during especially severe winter weather. Heat may be equally fatal, for in the Bay of Fundy we have observed sea urchins that had been caught by the spring tides in a somewhat higher pool than usual and exposed to the heat of a cloudless day, dying and rotting by hundreds. On the other hand, changes in salinity may prove quickly fatal. In estuaries at the head of tide we have seen specimens of the large jelly-fish, *Aurelia,* that had been caught by some obstacle and left by the retreating tide to be bathed by fresh water, perishing and disintegrating in numbers. The tragedy of unfavorable climate is indeed something that should never be neglected in studying the life in the water.

A large and most important field in this direction is open for investigation and we plead for its exploitation. Much can be done with very simple equipment. Even the amateur can furnish most valuable data as to the conditions where fish live, if he only have the patience to make accurate observations and record them; and we may point out that those that are more or less constantly engaged in the hatching and rearing of fish have unequalled opportunities in this direction.

CIRCULATION OF WATER IN BAY OF FUNDY AND GULF OF MAINE

By Dr. James W. Mavor

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A general movement of the water in the Bay of Fundy and its approaches has been shown by investigations carried on by the writer for the Biological Board of Canada. During these investigations he has had the cooperation of the staff of the Atlantic Biological Station and especially of Dr. Alexander Vachon who performed the titrations of the water samples and of Capt. Arthur Calder and the crew of the *Prince* who set out all the drift bottles and made all hydrographic observations.

Three different and independent methods have been applied to the problem: The actual measurements at different points made with current meters by Dr. W. Bell Dawson have been treated mathematically so as to eliminate the semi-diurnal oscillations of the tidal stream; a large number of drift bottles have been set out; and lastly, a series of hydrographic sections have been made in the bay, and from the temperatures and salinities at the different stations the velocities at right angles to the sections have been calculated by the hydrodynamic method developed by Bjerkan.

During the summers of 1904 and 1907, Dr. W. Bell Dawson,* of the Dominion Tidal Survey, made an extensive series of accurate observations on the currents in the Bay of Fundy and its approaches, using the surveying steamer *Gulnare* and anchoring at 19 different stations for periods varying from two days to one week. Measurements were made half-hourly with current meters working at a depth of 3 fathoms. The results of these observations

*Tables of hourly direction and velocity and time of slack water in the Bay of Fundy and its approaches. Published by the Department of Marine and Fisheries, Ottawa, Canada. 1908.

are published in "Tables of Hourly Direction and Velocity of the Currents and Time of Slack Water in the Bay of Fundy and its Approaches." These tables give the average velocity and direction during each hour of the tide. If we imagine a drop of water at the depth, 3 fathoms, for which Dr. Bell Dawson's tables are constructed, and moving each hour with the velocity and in the direction there stated, the path which it would take during one tide is indicated in Figure 1, where the lines marked *1*, *2*, etc., to *11* and *H. W.* indicate the direction and the distance the drop would go during each hour. At the end of the first tide it would have moved from *a* to *b*. The same final result would have been attained had the drop moved directly from *a* to *b* along the line *ab*. Were there no general movement of the water, and were only the oscillations of the tide at work, the drop would have returned to its original position *a*. The line *ab* therefore represents a general movement of the water, and its direction and length represent to the scale of the diagram what may be called a resultant velocity in nautical miles per tide. The resultant velocities have been determined for each of the stations in the table and placed upon the chart (Fig. 2), where the arrows represent in direction and on the scale of the chart the distance traveled by the drop of water in two tides or approximately one day.

From the chart (Fig. 2) it is seen that there is a general movement of the water around the southwestern end of Nova Scotia and into the Bay of Fundy on the Nova Scotia side. This is seen in the direction of the resultant velocities at stations R, N, M, J, H, K, G, F and C. At stations S, Q, P and L the resultant velocities are not in this direction, but towards the shore. This may be due to these stations being in eddies of the general current caused by the shoals which are near them. Within the bay a general movement of the water across it from the Nova Scotia to the New Brunswick side is shown at stations B and A. At station E to the southeast of Grand Manan the general movement is out of the bay,

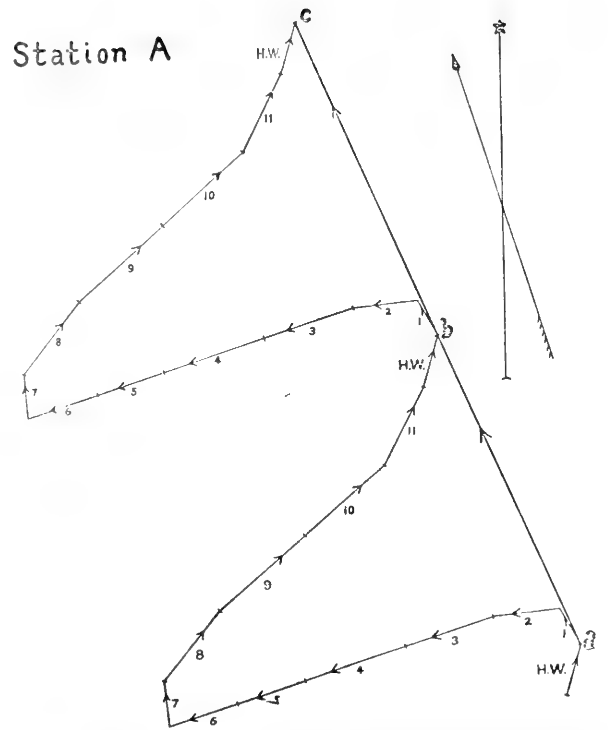

Fig. 1.—Diagram illustrating method of calculating resultant velocity from series of hourly current measurements. For explanation, see text.

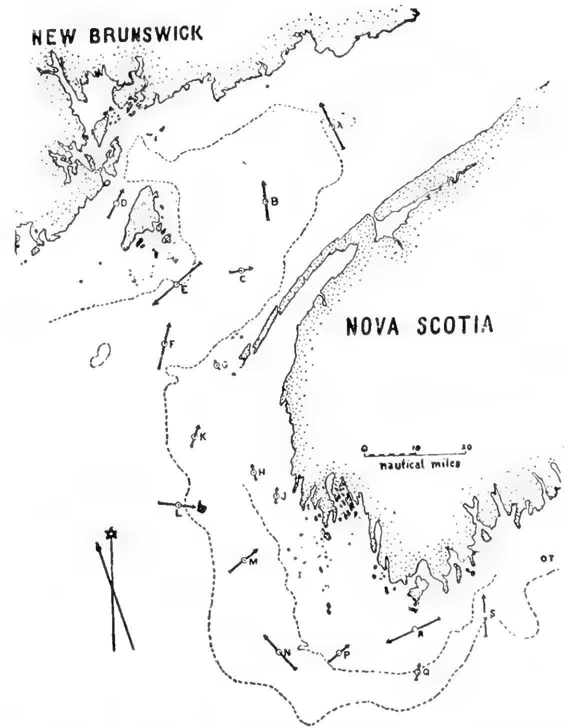

Fig. 2.—Chart of the Bay of Fundy and approaches after Bell Dawson, 1908, on which the resultant velocities calculated by the method described have been represented in direction and to scale, each arrow indicating the distance water would have moved in two tides or approximately one day.

At station D in Grand Manan channel a movement into the bay is indicated.

Nine sets of drift bottles numbering in all 330 were set out during the summer of 1919. Each bottle contained a Canadian post card addressed to the Biological Station, and offered a reward to the finder, who filled in the time and place of finding the card and posted it. By December 31, 1919, 72 of these post cards had been returned to the station. Various kinds of bottles were used.

The first set consisted of ten 8-ounce bottles with rubber corks, and having attached to them by cod line a galvanized iron drag to hang at a depth of 3 fathoms. On June 18th they were spaced in a line between Flag Cove, Grand Manan and Petite Passage, Nova Scotia. Returns were received from two of these; both found on the coast of Maine.

The next set from which returns were received, Set D, consisted of 100 2-ounce bottles with paraffined cork stoppers and without drags. They were spaced evenly between Cape Spencer and Parker's Cove on August 21st. Returns from 23 of these were received. All of the bottles found within the bay were found on the coast of New Brunswick west of Cape Spencer, those set out on the Nova Scotia side tending to come straight across the bay. The chart (Fig. 3) shows the places of finding of the third of these bottles set out nearest the New Brunswick shore. Five of the eight bottles represented were returned by September 4th, or within two weeks.

The prevailing and strongest winds during the latter part of August, as determined by the Meteorological Station at Pt. Lepreaux, were south to southeast; the maximum velocity was 33 miles per hour and occurred before the bottles were put out. Thus the wind could hardly have been responsible for the drift of the bottles westward. Three of these bottles were found so soon after they were set out that their rate of travel is significant as establishing a minimum rate for the

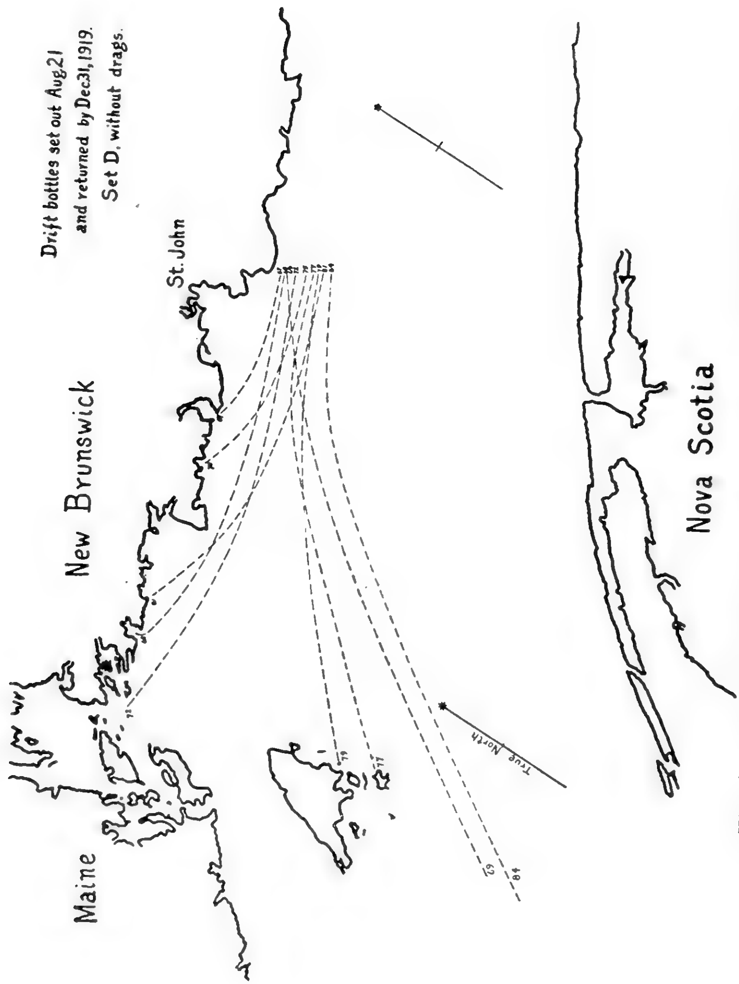

Fig. 3.—Chart showing the places of finding of drift bottles set out half way up the Bay of Fundy on the New Brunswick side.

current in which they were carried. Bottle 67, which was set out near Cape Spencer on August 21st, was found three days later in Musquash Harbor, a distance of about 15 nautical miles, giving a rate of 5 nautical miles per day. Bottle 75, which was set out at about the same time and farther from shore, was found four days and six hours later, at a distance of about 20 nautical miles, giving a rate of a little less than 5 nautical miles per day. Bottle 96, set out also on the same day about a third of the way across from Cape Spencer to Parker's Cove, was found six days later at Little Lepreaux, near Point Lepreaux, a distance of about 30 nautical miles, giving again a rate of about 5 nautical miles per day. Bottle 72, put out on the same day near bottle 75, was found eleven days later in Letite Passage, a distance of about 46 nautical miles, giving a rate of about 4 nautical miles per day. The finding of these bottles therefore indicates the presence of a current running along the New Brunswick shore from east to west at a rate of at least 5 nautical miles per day.

Another set, H, of 50 bottles, similar to those of the set just considered, was set out on September 13th by Dr. Philip Cox from the passenger steamer plying between St. John and Digby. Twelve post cards from these bottles were received by December 31, 1919, nine from the New Brunswick coast west of St. John, one a few miles to the east, and two from the Nova Scotia coast. The drift of these bottles has then in the main repeated that of the previous set put out on a line slightly to the east of them.

Still another set, G, consisting of 100 bottles of the same kind, 2-ounce bottles without drags, was set out to the west of these on a line from Point Lepreaux, New Brunswick, to Petite Passage, Nova Scotia, on August 29th. By the end of the year 27 post cards had been received from these. The drift of the bottles of this set confirms also the presence of a current across the bay, and westward along the New Brunswick shore.

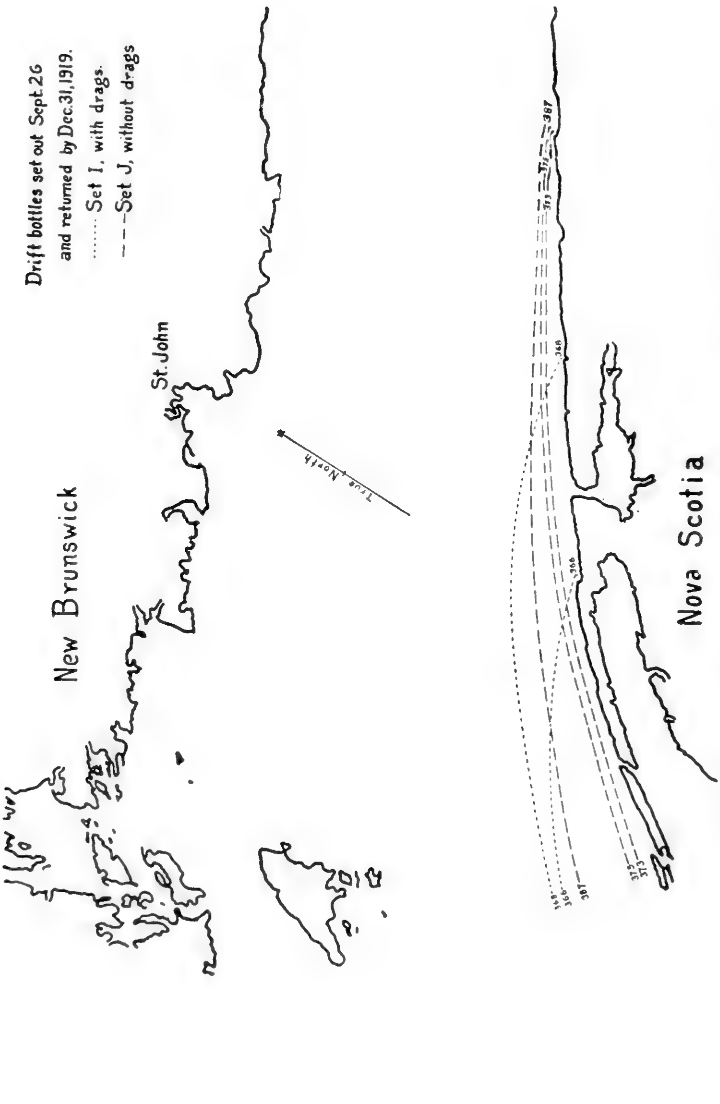

Fig. 4.—Chart showing the places of finding drift bottles set out at the mouth of the Bay of Fundy on Nova Scotia side.

With set D, 30 large 8-ounce bottles with drags attached to hang at 3 fathoms, Set E, were set out. None of these has been reported from the Bay of Fundy, but 4 have been found outside the bay, indicating that being less affected by the wind and therefore not blown on shore these bottles were carried westward out of the bay by the current on the New Brunswick side.

Turning now to another series of 50 bottles, 25 small without drags, and 25 large with drags, which were set on a line NW by N from North Point, Brier Island, Nova Scotia, extending for 10 nautical miles, we find that five of these had been reported before the end of the year, and that they were all found on the Nova Scotia coast in the Bay of Fundy to the east of Brier Island, three of them reaching as far as Port George near the head of the bay, a distance of 70 nautical miles (Fig. 4). One of these bottles, 387, was found at Port George only 17 days after it was set out, giving a minimum rate for the drift along the Nova Scotia shore of over 4 nautical miles per day.

To sum up, it seems clear from the calculations from Dr. Dawson's tables and from the drift of bottles, that the water in the Bay of Fundy has a circulation which may be described as follows: Water enters the bay on its eastern side and flows northeast along the coast of Nova Scotia; it crosses the bay to the New Brunswick side and flows southwestward out of the bay, the bulk of the water probably passing to the east of Grand Manan. The rate at which the water flows is probably somewhere between 5 and 10 nautical miles per day, so that the complete circuit probably takes from twenty to forty days.

A series of five hydrographic sections was made in the Bay of Fundy during the summer of 1919. These sections included 28 stations at which temperatures and water samples were taken from the surface to the bottom at intervals varying from 10 meters near the surface to 50 meters at the lowest parts of the deeper stations. The water samples were titrated and the salinities and densities found by Dr. Alexander Vachon, of Laval University. From the data thus obtained, isotherms, isohalsines and isosteres have been constructed. The form and distribution of these surfaces show that the water in the southwestern half of the Bay of Fundy throughout its depth has during the summer period the cyclonic movement shown by the current measurement and drift bottles to occur at the surface. From the disposition of the surfaces of equal density or, to be more exact, the surfaces of equal specific volumes, called isosteres, the actual velocity of the water between the stations and at right angles to the sections can be calculated. This has been done, using the method of Bjerkan, and the velocities found in this way for the superficial water agree approximately in direction and magnitude with the velocities determined from the current measurements and drift bottles.

All three methods of investigation agree in showing that the water in the lower half of the Bay of Fundy is in cyclonic circulation and the hydrographic sections show that this circulation extends to the deeper layers. It is therefore probable that almost all of the water in the lower half of the bay is completely changed in a comparatively short time, less than one year. The practical agreement of these three investigations justifies the method of each of them for the investigation of the movements of the water in regions comparable to the Bay of Fundy.

Sixteen of the drift bottles set out in the Bay of Fundy have been reported from the Gulf of Maine. An account of the finding of these bottles has already been published by the writer.* The following quotations are taken from that account:

The bottles were of two kinds; two-ounce bottles and eight-ounce bottles; to the latter a galvanized iron drag was attached to hang at a depth of three fathoms, the object of the drag being to minimize the

*Science, N. S. Vol. LII, No. 1349, pp. 442-443, November 5, 1919.

direct effect of the wind. Fifty-five of these latter bottles with drags were set out and six have been found and reported from outside the Bay of Fundy, to date (August 6, 1920). Three of these were picked up on the Cape Cod peninsula, the rest on the coast of Maine. Of the two hundred and seventy-five bottles without drags, ten have been reported from outside the bay. Eight of these ten were picked up on the Cape Cod peninsula, the other two on the coast of Maine.

The times when the bottles were found are significant since they establish a minimum rate for the drift. Seven out of the eleven bottles which went to Cape Cod were found between 70 and 80 days after being put out, the shortest time being 73 days. The distance in a straight line from the Bay of Fundy is about 300 nautical miles. The rate of the drift was therefore about four nautical miles per day.

The drift of these bottles, set out at various times during the summer, indicates a surface movement of the water from the Bay of Fundy through the northwestern part of the Gulf of Maine and striking Cape Cod, the rate of this drift being about four nautical miles per day.

Discussion

DR. A. G. HUNTSMAN, St. Andrews, N. B.: Dr. Mavor's paper on the "Circulation of the Water in the Bay of Fundy and Gulf of Maine" has to do with a subject which, it would seem at first sight, is not very closely related to the fisheries and, perhaps, a subject of little moment. Fresh water circulation is a fairly definite thing. The water comes down and runs through certain definite channels; so there is not much question as to what the circulation is. But in the case of the waters of the sea, the conditions are extremely different. You would at first think that the measurement of currents would be the readiest means of solving this question as to where the water is going, but unfortunately in the sea there are what is known as tides which produce very strong currents which do not always travel in one direction, but which go to and fro. When these currents are extremely strong, as happens to be the case in the Bay of Fundy, with tidal differences of as much as fifty feet, the actual movement of the water in any one direction is entirely obscured by the tremendous to and fro movements of the water, and current measurements may accomplish comparatively little in determining the direction in which the water is moving. For that reason, in order to work out the results set forth in Professor Mavor's paper, a very considerable investigation had to be carried on into the conditions affecting the circulation of the water in the Bay of Fundy and the Gulf of Maine.

The significance of these results as they affect the fisheries is the way in which the floating life in the sea may be carried. The term "floating life" includes not only the microscopic plants and animals that have no directive swimming capacity—that is, swimming in a definite direction to one or the other points of the compass, or against the current—but also the young stages of many of the fishes as well as their eggs when these are pelagic. As a matter of fact, before this work was done, we had obtained definite evidence that the young herring hatched out at the southern end of the island called Grand Manan in the mouth of the Bay of Fundy, were carried out thence southwestward a distance of at least twenty-five miles, while none could be found along the sides of the island itself. All the drift was outward, not inward.

THE FOOD OF THE LARVAL AND POST-LARVAL FISHES OF PLYMOUTH SOUND

By Dr. Marie V. Lebour
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The question of the food of larval and post-larval fishes although carefully studied by those rearing them, yet has had little attention paid to it with regard to the actual food taken by the young fishes in the plankton. It was to supply this deficiency that an investigation was undertaken by the writer during the years 1917-19, many hundreds of pelagic young from those newly hatched up to those of about 15 mm. in length, with a few adolescent stages, being examined and the food inside noted. A full account of the work is given in the Journal of the Marine Biological Association of Plymouth (Vol. XI, No. 4, 1918, Vol. XII, No. 1, 1919, and Vol. XII, No. 2, in process of publication).

By dissecting out the alimentary canal of fresh specimens from the tow-nets and young-fish trawl and by mounting specimens whole as balsam preparations, the food is usually well seen. Young fishes were kept alive in small aerated aquaria standing in tanks at an even temperature, and their feeding habits watched in order to study the food taken and method of feeding.

Some of the most important questions in connection with the food of the young fishes are the following:

(a) What the fishes feed on and whether vegetable food is much eaten.

(b) Whether the young fishes select their food or take it indiscriminately.

(c) Whether fishes which still retain the yolk sac eat solid food.

(d) Whether fishes of different species or genera present in the same place eat the same kind of food and thus those economically unimportant compete with the food fishes.

(a) *What do the young fishes eat?* It is already well known that copepods form a large part of the food of young fishes and it was found that by far the greater number of those examined ate crustaceans, chiefly Entomostraca, even at the very early stages. Copepods and Cladocera are most generally taken, and copepods certainly form the most important food. Remains of green algæ were found in some of the young clupeoids, especially the sprat, also in the sand launce, Ammodytes, and a few others, showing a vegetable diet at the earliest stage, but as a rule there is little sign of this and vegetable food occurs very sparingly in the young fishes. A striking exception, however, occurs in the flounder (*Pleuronectes flesus*), which was several times found to be eating the flagellate Phæocystis.

Diatoms are occasionally recognized among the food remains. An Ammodytes of 10 mm. contained many Rhizosolenia (one of the needle-like diatoms), and fishes that were hatched in the acquarium and fed on very fine plankton also ate diatoms sparingly. Young gobies only a few days old in these aquaria took Asterionella, Thalassiosira, and Chætoceros, but as they all died this apparently is not a suitable diet. A young sculpin (Cottus) of 4.5 mm. from the tow-nets had inside it Bidulphia, Coscinodiscus, and Thalassiosira. All these are diatoms commonly occurring in the plankton, but it is only very seldom that any of these are found even in the youngest fishes.

Of other unicellular organisms coccospheres, peridinians, radiolarians and infusorians occasionally occur, chiefly in the smaller specimens.

Besides Crustacea, larval mollusks are almost the only recognizable metazoa eaten by the young fishes. These occur occasionally in many species with Crustacea. In the herring they often occur in the newly hatched young, and the brill (*Rhombus lævis*) and turbot (*Rhombus maximus*) up to about 20 mm. often contain them, but the only young fish examined that seems to feed habitually on larval mollusks is the garfish (*Rhamphistoma belone*), which up to at least 36 mm. usually contains them, even after the long bill is formed. Oyster spat and the pteropod Limacina were often offered to young fishes in the aquaria and nearly always refused.

Certainly the most important food of the young fishes is small Crustacea, especially the Cladocera, Podon and Evadne, cirripede nauplii, and, most important of all, copepods, both nauplii and adult. Decapod larvæ only rarely occur until the fishes reach a much larger size.

In Plymouth Sound and outside, Podon and Evadne are only available in large quantities in the summer months, cirripede larvæ in late winter and early spring, and again in July and August. When these are in season many fishes eat them, often together with the copepods which form their food at other times. Very young fishes can eat them and they are often to be found in the newly hatched specimens. Copepods, however, undoubtedly form the chief food of larval and post-larval fishes, and those most often eaten are the species that are commonest, but each fish appears to prefer some special species and usually keeps to it or to two or three species, not feeding indiscriminately.

The copepods most frequently eaten are *Temora longicornis, Pseudocalanus elongatus, Acartia clausi,* and *Calanus finmarchicus.* These occur practically all the year round, now and then with short periods of disappearance of one or the other, but they are most abundant and commonly breed in the spring and summer when the young fishes are at their maxima. Many very young fishes eat the nauplioid and small copepod stages; those with large mouths eat the fully developed copepods almost at once and the slightly older forms eat them habitually.

Other copepods fairly often eaten are *Metridia lucens, Euterpina acutifrons, Paracalanus parvus,* and several others.

(b) *Do the young fishes select their food or take it indiscriminately?* Most of the young fishes prefer a certain kind of food and keep to it. Thus a fish may usually eat a species of copepod and only take others when this is not available, or it may like two or three species, or it may take several different sorts of Crustacea. A few may specially like mollusks and very rarely they may be almost exclusively vegetarians, but certainly to some extent, and in many cases to a very large extent, they select their food. Several different species may prefer the same diet; thus most of the species of *Solea* especially eat Temora, often with Euterpina and Podon, and Temora is also preferred by the dab (*Pleuronectes limanda*).

Some hundreds of the thickback (*Solea variegata*) were examined, Euterpina and Temora being the usual copepod food, often with Podon. A specimen of 4 mm. can swallow a Temora 1.5 mm. long. Up to at least 11.5 mm. the same kind of food is taken. The dab eats the same sort of food. Over 1,000 specimens were examined, Podon being the commonest food, Temora coming next. At 5 mm. copepods were present. It is thus shown that the dab competes with the soles for food, a fact which may have an important bearing on the small numbers of soles in certain areas. On the other hand the topknots (*Scophthalmus norvegicus*), although occurring with the soles and dabs, hardly ever eat Temora, their favorite food being Pseudocalanus, Metridia coming next, so that although present in numbers they need not be feared as competitors for the food of the sole. At 3.5 mm. a Scophthalmus contains copepods. One of 4.5 mm. contained a Metridia of 2 mm. It must therefore take copepods almost directly it is hatched and it continues eating them until it is well over 12 mm.

The soles, dab and topknots, as well as the turbot and brill, are all large-mouthed fishes with broad gullets, and these can all take crustacean food almost directly they are hatched, but it is different with the small-mouthed flat fishes, the flounder (*Pleuronectes flesus*), the scaldback (*Arnoglossus laterna*), and the lemon dab (*Pleuronectes microcephalus*); these have very small mouths and narrow gullets and no Crustacea have been found in them until they were much further advanced, not below 8 mm. Most of them are empty in the very young stages and probably eat soft unicellular organisms. This is known to be the case with the flounder whose feeding habits are interesting. Several of the young pelagic stages from 10 to 11 mm. were found to be eating Phæocystis which occurs very abundantly in Plymouth Sound in May and June. Some of these were kept in aquaria and fed on Phæocystis which they ate until they began to feed on the bottom. When still the same size they changed their diet and fed on copepod nauplii and later on they took small copepods, chiefly Pseudocalanus. Specimens of 11 mm. from one of the estuaries having already metamorphosed, were feeding on small harpacticids, and still later stages in the estuaries from 20 to 30 mm. were feeding on harpacticids in the bottom mud. The change of diet is thus coincident with the transition to the bottom stage.

Young pelagic brill, 4.5-6 mm., were eating copepod nauplii, also eggs (probably copepod). The brill migrate shorewards and at the water's edge, those from 10 to 13 mm. being then in the bottom stage, eat principally larval mollusks. Older specimens of from 20-30 mm. feed chiefly on young fishes.

The young gadoids are all specially fond of Pseudocalanus. The whiting (*Gadus merlangus*), being the commonest in this area, was the species chiefly investigated. By far the greater number of specimens had eaten Pseudocalanus, many hundreds, from 3 to 20 mm. long being examined, besides some adolescent stages. Below 5 mm. copepod nauplii are chiefly taken, after this size adult Pseudocalanus may be eaten.

Some young whiting were kept in aquaria and their feeding watched. It was found that if several species of copepods were given, they always went for Pseudocalanus first, Acartia next, Calanus being taken before Temora, which agrees with what is found by examining the insides. Calanus is usually taken by the whiting in early summer when Pseudocalanus is scarce. Specimens of 22 mm. can eat small fish, although copepods are often taken up to 60 mm. or more, with decapod larvæ. Still older specimens eat fish habitually.

All the other common gadoids *Gadus pollachius, G. min-*

utus, and *luscus* in their young stages eat Pseudocalanus more than anything else, Acartia being taken when Pseudocalanus is scarce, and Calanus by the larger specimens. The few ling (*Molva molva*) and hake (*Merluccius*) examined had also chiefly eaten Pseudocalanus and Calanus. Thus the young gadoids as a group seem to prefer the same sort of food.

On the other hand the wrasses, *Labrus bergylta, L. mixtus* and *Ctenolabrus rupestris,* when young all prefer Temora, very small specimens from 3.5 mm. containing Temora nauplii, occasionally mollusk larvæ being found.

Temora nauplii are also almost exclusively the food of the very young mackerel from 5 mm. long. Calanoid nauplii are also eaten and eggs (probably copepod). Larger specimens up to 9 mm. or more eat Temora, their favorite copepod, also Podon and Evadne and an occasional Euphausiid larva. From 9 mm. upwards the usual food is young fishes although crustacea may still be eaten. Species of Trachinus, Blennius and Gobius are often found inside the young mackerel. One of 13 mm. had eaten a blenny of 7 mm. Fish and Crustacea are not found together inside the young mackerel. It is either one or the other, a fact coinciding with the known feeding of the older mackerel which may have half its stomach full of fish remains, the other half full of planktonic organisms, but with a hard and fast line of division showing that each meal consists of a different food which is not mixed. It is thus seen *that the young fishes do select their food, and a certain kind of food is characteristic of each species.*

(c) *Do the fishes which still retain the yolk sac eat solid food?* Not many fishes at such young stages were examined but in some cases it is most certain that food is taken in by the mouth when the yolk sac is still present. The best example of this is the herring. Young herring hatch at about 7 mm. and are to be found in the plankton almost immediately, retaining the yolk sac up to 9 and 10 mm., in rare cases even more. Although the gut in these young herring is very often found to be empty, yet several specimens had eaten larval mollusks, eggs (probably copepod) and copepod nauplii. It therefore appears to be quite usual for solid food to be taken although the yolk sac is present. At 7 mm., the usual length at hatching, food consisting of green remains, larval mollusks or eggs was found inside the young herring. Copepod nauplii are taken a little later, thus agreeing with the observations of H. A. Meyer* with artificially reared herring which first contained greenish matter, later on larval mollusks, copepods and copepod nauplii, the copepod diet increasing as the fishes grew.

Brill from 4 mm. which still retained the yolk sac were found to contain many Temora nauplii. *Gobius minutus* hatched in the aquarium were found to have eaten diatoms when still retaining the yolk sac. A plaice (*Pleuronectes platessa*) of four days old, hatched in an aquarium, ate diatoms from the bottom of the glass when still retaining the yolk sac. These diatoms (Navicula sp.) grew in a dense layer at the bottom of the glass jar.

It is thus certain, as already shown by those investigators who have experimented in rearing fish, that food is taken before the disappearance of the yolk sac, or at any rate in many species.

(d) *Do the food fishes eat the same food as those which are unimportant economically?* Although this question is barely touched on, many fishes unimportant as food have also been examined. These, especially young *Callionymus lyra, Trachinus vipera,* several species of Gobius and Cottus and many others, occur abundantly with the young of the food fishes and eat much the same sort of food, especially the copepods, Pseudocalanus, Temora and Acartia, with Podon. Callionymus ate all these apparently indiscriminately, Pseudocalanus was a favorite with the gobies, and Cottus ate many larval mollusks with copepods and other small planktonic organisms.

It is to be remembered, however, that although these young fishes are extremely abundant and eat the same food as the

*1880, Biological Observations made during the Artificial Rearing of Herrings in the Western Baltic. Report of the U. S. Fish Commission for 1878.

edible fishes, yet they serve to a very large extent as food for many of the rather older food fishes and are of great importance in that connection.

The same species of fish ate the same sort of food from whatever locality it came from, so that the food is really characteristic of the fish.

It is thus seen from the above-mentioned work that Crustacea form the chief food of nearly all the young marine fishes, the principal food being Entomostraca, and that vegetable food is not taken to any great extent except by some of the youngest specimens. That the young fishes do certainly select their food although it usually consists of animals which are common in the plankton. That solid food is taken by the young fishes before the absorbtion of the yolk sac and that many of the non-edible fishes occurring with those that are edible eat the same kind of food.

A SURVEY OF GAME FISH CONDITIONS IN OHIO

By Dr. Raymond C. Osburn

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This paper contains some of the results of a partial survey of the waters of the state, made by the Ohio Bureau of Fish and Game during the summer of 1920. The work was conducted by a scientific research party, temporarily employed by the Bureau for the purpose of the survey. The writer was in charge of the investigations and associated with him were Dr. C. L. Turner, of Beloit College, and Messrs. E. L. Wickliff, Walter C. Kraatz and L. H. Tiffany, instructors at the Ohio State University. The members of the staff were selected because of their special training in different phases of the work and for their ability to cooperate satisfactorily. The whole summer's program was placed in my hands with the exception that Mr. A. C. Baxter, Chief of the Bureau, indicated certain waters which he especially desired us to examine.

We began our work on July 16th, the first day we were free from our college duties, and continued without interruption until September 15th. This gave us three full months in the field, at the time best suited for studying the food and other conditions of growth of the young game fish. As the breeding season was later than usual in Ohio, the young bass and crappie were barely off the nest at the time we began to work, and in fact, many of them did not appear until later. The bluegill and common sunfish had not hatched at this time.

The characteristic game fishes of the inland waters of Ohio

[*This paper by Dr. Raymond C. Osburn and the three which follow, namely, "Food of Young Small-Mouth Bass in Lake Erie," by Edward L. Wickliff; "Food of Young Large-Mouth Black Bass in some Ohio Waters," by Dr. C. L. Turner and W. C. Kraatz; and "The Gizzard Shad in Relation to Plants and Game Fishes," by L. H. Tiffany, constitute some preliminary results of a fishery survey in Ohio in the summer of 1920.]

are large-mouth bass, small-mouth bass, rock bass, crappie, bluegill sunfish, and yellow perch. The little pickerel is common in some localities, and the Ohio River muskallonge, also the wall-eyed pike, are reported as frequently taken in some of the larger rivers. While the catfishes can scarcely be considered game fish, the bullhead and channel cat are common in the lakes and streams and afford many people amusement and food. The channel cat has been satisfactorily planted in many of the lakes by the Ohio Bureau of Fish and Game and is much appreciated.

In Ohio the small-mouth bass is a characteristic fish of the creeks and smaller rivers, while the large-mouth bass is typically a lake fish. In the long, quiet stretches of rivers and back waters where lake conditions are simulated, the large-mouth bass may be found, and similarly in rocky and gravelly parts of lakes the small-mouth bass may occur, but less frequently than in streams. In Lake Erie the small-mouth bass is common to the open waters of the lake, while the large-mouth bass occurs in the weedy bays and inlets.

The main problem we sought to solve was one of practical interest to the state, that of determining whether there are satisfactory conditions for the production of the various game fishes in the waters studied. The comparative number of this year's young was considered usually a good index of the number and condition of the adults and of the general productivity of the stream or lake. The condition of the young, especially as to food, which could be learned from the examination of the stomach contents, was studied to discover whether feeding conditions were satisfactory. To check up on this, however, studies were made to determine the number and condition of various other fishes which serve as food for game fishes, especially the various minnows, suckers, and the gizzard or hickory shad. Also general studies on the abundance, kinds, and distribution of invertebrate animals and of plants, especially algæ, were made in the various waters.

Messrs. Turner, Wickliff and Osburn devoted their time to the study of fishes and their food; Kraatz to collecting the invertebrates, especially insect larvæ and Crustacea; and Tiffany to the collection and study of the algæ.

Naturally, most of our material remains unworked at present, as our field operations kept us on the move to such an extent that often little could be done except to preserve material and to make general notes. Microscopes, however, were taken along and when we had occasional opportunity, use was made of them in the study of stomach contents of the young fish, material in the plankton, and so forth.

For the fish collecting, fine meshed seines of 1/8 to 1/4 inch mesh, about twenty-five or thirty feet long, were used. For a good part of the work, the middle or bag portion of the seine was overlaid with cheese cloth, so that very small organisms were captured. A twenty-five foot seine of this type is about all that two men care to handle, even in still water, but it is astonishing what an amount of material can be taken under favorable conditions. The material brought in by the seine was worked over for invertebrates and algæ in addition to fishes. Messrs. Kraatz and Tiffany also made use of dipnets and townets in the collection of invertebrates and algæ. Temperature records were also made.

Ohio is an exceptionally well watered state, especially in rivers and creeks of suitable size for the small-mouth bass, so it was manifestly impossible for us to cover the whole state in one summer. As a matter of fact we made investigations in twenty lakes and reservoirs and parts of six river systems mostly in the central and northern parts of the state. Usually two or three days were spent in a place, but two weeks were given early in the season to Buckeye Lake, situated near the geographical center of the state, to get a good basis for the comparison and more rapid study of the lakes visited later. Many of the smaller lakes of Ohio are now privately owned, or in the possession of fishing clubs to the exclusion of the general public. I will say nothing about the policy of permitting such natural bodies of water to become individual property, but merely state that with two exceptions we did not include them in our investigations.

The natural lakes of Ohio are all small, rarely being over a couple of miles in the largest dimension. They are all glacial in origin, being usually rather deep for their area and varying from gravelly to muddy and weed-grown shores. Many of them are spring fed almost entirely, except for surface waters in rainy seasons.

The reservoirs, many of them now known as lakes, were mostly constructed in the old canal-building days of the first half of the past century, though some are of recent construction for water power. Buckeye, Indian, Loramie, and St. Mary's Lakes are all old reservoirs of this type and have long ago settled down into permanent conditions. Buckeye Lake especially, presents this appearance, as the water level has been interfered with but little. In the other reservoirs, including East, West and New reservoirs, near Akron, recent fluctuations in the water level give them more or less, according to conditions, a newer appearance about the shores. St. Mary's Lake, formerly known as the Grand Reservoir, has an area of 17,600 acres and is the largest body of water entirely within the state.

All of these bodies of water, natural and artificial, are well stocked with the various game fish native to Ohio, and have been for many years. They are ideal for large-mouth bass, perch, crappie and bluegills and other sunfish. Our survey shows considerable variation in the number of different game fishes, however, with the exception of the large-mouth bass which is plentiful in all suitable waters of the state. It is probable that fluctuation of the water level interferes less with the large-mouth than with other game fish, on account of its great activity, its rapid growth, and its ability to take many kinds of food because of the large size of the mouth. Moreover, the bass spawn earlier than most other game fish and are thus less likely to be interfered with by changes in water level. At any rate it is about as common in waters that are drawn upon for power as in those that are not, while this appears not to be true of other game fish of the lakes. The hatcheries also have devoted a great deal of attention to the large-mouth bass, planting the output chiefly in the lakes. In the western Ohio reservoirs, known as Indian, Loramie, and St. Mary's Lakes, the crappie are exceedingly abundant. They grow to a good size, 1 to 1½ pounds, and one was taken this spring weighing 3¼ pounds. Thousands of people were angling for crappie during the spring season and it was an easy matter to catch the limit of forty fish at these lakes. I venture to say that no better fishing of this kind ever existed in the waters of the state.

St. Mary's Lake is especially interesting because when I examined it just twenty years ago, it was so polluted with refuse from oil wells that it was practically barren. At that time there were 300 oil wells in the lake itself, not to mention those in the near vicinty. At present there are only three wells in the lake and few around it, and they all take care of their refuse pretty satisfactorily. Most of the lake is now in excellent condition, and the rehabilitation of the fish life is a fine thing to observe. Large-mouth bass, crappie, bluegills, and perch have all been planted in recent years, and the bass and crappie afford as good fishing as one could expect in a thickly settled country where there is much angling.

St. Mary's and Loramie Lakes have suffered considerably from occasional lowering of the water in recent years, so the shores present a newer and cleaner appearance than they should, and there is an unsatisfactory lack of submerged plant growth near the shore. While on this subject, I wish to call attention to the necessity of maintaining a high and constant water level in lakes and ponds during the breeding season and the feeding and growing season of the young fish as well. Fluctuation of the water level to any great extent is one of the surest means of causing breeding fish to leave the nest. Lowering the water materially during the season when the young fish are feeding and hiding in the shallow, weedy margins causes many of them to be stranded in the weeds, or, if they escape, it is into the more open water where they readily fall a prey to the larger fishes and where their natural food is much less abundant. If it were possible to maintain a fairly constant level subject only to changes due to evaporation from the first of April to October, I have little doubt that we should see a great increase in the productivity of our smaller inland lakes that are drawn upon for water power or for city use. Such waters are usually under the control of a board of public works or a similar body, which operates too often without knowledge of or consideration for fish life. There should be closer cooperation between such bodies and the state fisheries departments to the end that more fish may be produced.

At the Louisville meeting of this Society, Mr. James Nevin presented a paper on "Changing Food Conditions of the Trout Family," printed in the Transactions for December, 1919, in which he mentioned the damage done to trout streams by cleaning them up too well. The same thing applies very forcibly to our game fish waters in Ohio, both streams and lakes, and there is a striking difference in most of these waters as compared with even twenty or twenty-five years ago.

The banks of our lakes and streams are becoming very much appreciated by the people of our cities for playgrounds and summer residences and, naturally enough, wishing their surroundings to present a neat appearance, they remove all fallen trees and other debris from the water. Stumps interfere with boating and one may also lose a hook on such an obstruction, so they wish the stumps removed. Because vegetation interferes with fishing, several inquiries have been received recently as to how to remove it. Of course, it is a false notion of cleanliness that requires these things to be done, for there is nothing unsanitary in a fallen tree, a decaying stump, or submerged vegetation in the water. But the main point is that when you remove the weed you take away the refuge of the perch and the bluegills, and when the fallen tree or the old stump is removed, the favorable lurking place of the big old bass goes too. If it were possible to have a perfectly clean body of water with no decaying organic matter in it, such a body of water would be a fish desert absolutely. I may add that it is not the policy of the Ohio Bureau of Fish and Game to remove the old stumps from our magnificent reservoirs, but to preserve them as fish refuges as long as they will last. In many cases the stumps have been there nearly a century, and as they are still sound they are likely to remain to bless coming generations of sportsmen for a long time. In some cases, smaller rivers and lakes that were once good bass waters have been cleaned and controlled until the "old swimmin' hole" and the big fish have both disappeared.

Like most other states, Ohio has suffered by the removal of too much of her forest growth from the hills, with the result that we have higher freshets than formerly, and lower water in periods of drought. Smaller streams that once afforded good fishing are now, in some cases, practically barren. Forestry work should cooperate with fishery work when possible.

Pollution, too, has played its part in the reduction of game fish, though we are not as bad off in Ohio as in some other states. Only one lake in the state is now known to be badly polluted, namely, Summit Lake, which is nearly surrounded by the city of Akron and which, in addition to some sewage, receives chemical wastes from a large salt works in the city. Twenty years ago this lake was teeming with good game fish. In the streams all sorts of conditions are found. An occasional river is so polluted that it is absolutely devoid of all life. In other waters the game fish are entirely wanting or they are few in number or in bad condition, with only a few hardier kinds, such as the catfish, present.

Some of our streams have been satisfactorily cleared of pollution. Thus the Licking River from Newark to Zanesville, a distance of 25 miles, was polluted a few years ago until everything in it was destroyed. A large glass manufacturing plant which caused the damage was made to take care of its chemical wastes, and one of the finest bass streams in the state is being restored. Restocking was necessary of course. An examination of it by our party this summer showed that while conditions are not yet quite normal, the hatch of young game fish is excellent and within a couple of years the effects of pollution may no longer be noticeable. With the perfection of our new method of controling pollution, it is hoped that the state may rapidly proceed with its clean-up campaign. Otherwise it is only a question of a few years until there will be little angling in our streams.

Perhaps I should not have dwelt so long on the unfavorable conditions, for Ohio is much better off than many of the states, especially those to the east of us. We still have numerous fine streams where there is excellent fishing. Where there is no pollution, breeding conditions are usually satisfactory and there is an ample supply of fish food. There is a great deal of angling, astonishingly great as compared with a generation ago. We must, therefore, expect the individual catch to be smaller, but the legal limit is very often attained, and the fish are as large as in former years. With the bluegill and perch there is a serious falling off, but these fish are easily caught by the inexperienced angler and there should be more protection devoted to them during the breeding season.

In regard to the non-game species of fishes, it may be said that many of them appear to be much less numerous than in former years. It was my privilege to make a fairly thorough survey of the fishes of Ohio during the summers of 1897, 1899, and 1900, and in the twenty years that have elapsed many species of the smaller fishes seem to have become rare or to have disappeared entirely from the waters surveyed during the past summer. Pollution may be responsible for this in some cases, causing the disappearance of the more delicate species. Pollution farther down the stream may be a barrier to some of these fishes, preventing them from running up stream at the spawning season. In other cases the construction of dams may now prevent certain species from running up stream to breed. It would seem that the reduction of the number of individuals of these smaller species can not help having an effect on the production of game fish by limiting their food supply.

Crawfish, an important element in the food of bass, are fairly abundant, except where pollution is evident.

Ohio has been doing excellent work in fish production and protection for years, but little mention has been made of the fact. Except where conditions beyond the control of the Bureau of Fish and Game have interfered, game fish are plentiful and are reproducing in satisfactory numbers. There are occasional reports of seining and trapping, but the game protectors are an excellent body of men, and their work results in the seizure of much of the illegal fishing apparatus and the apprehension of the owners. Moreover, the education of the public in conservation, through publicity afforded by the press and through the medium of sportsmen's associations, is having a noticeable effect. An educated public which will not wink at violations of the law or place obstacles in the way of the warden's performance of his duty, is a necessity to the production of fish in any region where the population is at all dense.

A few observations showing how weather conditions may affect the breeding and food of fishes were made incidentally during the course of the survey. In the open water of Lake Erie, about the islands, where in 1919 small-mouth bass fry were very abundant, there were no fry to be found in the summer of 1920, although a special effort was made to find them. The only ones taken were in a sheltered locality in Put-in Bay harbor, where a gravel bar afforded protection. The only explanation that presents itself is that a succession of storms during the nesting season had destroyed the nests before the eggs were hatched. At the same time there was an excellent hatch of large-mouth bass in the enclosed harbors, where the storms had little effect.

More positive evidence of the effect of storms was noted in Mosquito Creek, a tributary of the Miami River, at Sidney, Ohio. This creek, which is an excellent small-mouth bass stream, was set aside as a breeding sanctuary early in the season when the bass were observed making their nests. A series of freshets washed out the nests or silted them under, destroying the whole hatch and, although we searched carefully for a mile and a half, only one bass fry was taken and only a few other young fish were observed. The Miami River above Sidney showed a similar effect by the absence of young fish of nearly all kinds, though yearling and older fish were abundant. The fishes present showed the effects of the unusual number of rains by their underfed condition. The water had been high and very muddy all the spring and until in July at the time of our observations, making it difficult for the predaceous fish to obtain food.

To sum up, the game fish conditions in Ohio are as satisfactory in the lakes and reservoirs as could be expected in a region as densely populated and where there is so much angling. The catch per person has been greatly reduced within the past generation, and even the productivity of the lakes is not as great as formerly when the water level was interfered with less and the water along the shores was not kept as clean. Over-fishing, especially during the breeding season, is also responsible for the decrease in number and size of bluegills and perch. The laws afford much better protection for the basses than for the other species, especially those whose breeding season does not quite conform to that of the basses.

Conditions in the streams are usually much less satisfactory. Pollution by mills, factories, mines and so forth is one important reason, while stream control, deforestation and over-fishing have all played a part in decreasing the productivity. While there is excellent angling in many of our streams there is no doubt that there are fewer fish than formerly in practically all of our rivers and creeks. Elimination of pollution and more protection during the breeding season will go a long way toward reestablishing and maintaining good fishing in our streams.

Discussion

MR. LEWIS RADCLIFFE, Washington, D. C.: Some of the references made by Dr. Osburn to the feeding of bass remind me of the results of the study of the food of the squeteague or weakfish in North Carolina. At the beginning of the season we find the squeteague feeding on crustaceans and other material; later on, as they get larger, they begin to feed on menhaden. As they increase in size the number of menhaden appearing in the stomach contents increases until constituting the bulk of food, the reason being that in the earlier stages it is impossible for squeteague to swallow the menhaden that occur in those waters at that time. As to the gizzard shad being an item of food, it may be of interest to know that in our southern markets, Baltimore and Washington, the gizzard shad is sold as winter shad.

DR. OSBURN: How do they manage to eat them?

MR. RADCLIFFE: They are used fresh. They are also very good fish when salted. Of course, they are rather bony.

DR. OSBURN: You can get a little slab of meat off the sides, but the network of bones is so heavy that it would discourage almost anyone, I should think, unless he had plenty of time.

MR. RADCLIFFE: They are used in southern districts, largely by the colored people.

DR. OSBURN: I understand that some of the foreign population catch them and put them through a grinder. I would not be surprised if they could be made use of in that way. While I think of it, may I ask whether it would not be possible to make use of the young gizzard shad as sardines, as is done in the case of young menhaden?

MR. RADCLIFFE: I think not; they would not equal the sardine, nor would they command as good a market. At least, this will be the case so long as we can get sardines in such abundance.

FOOD OF YOUNG SMALL-MOUTH BLACK BASS IN LAKE ERIE

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The small-mouth bass (*Micropterus dolomieu* Lacepede), is one of the most important game fishes of Ohio waters and is especially abundant about the Bass Islands and other islands of the western end of Lake Erie. Because of the high esteem in which sportsmen hold this fish, it seemed advisable to make some study of the food and feeding habits of the younger stages in their most characteristic breeding places under natural conditions. My thanks are due to Dr. Raymond C. Osburn, and the Ohio Bureau of Fish and Game for the opportunity to make this study.

The work was begun in the summer of 1919 at the lake laboratory of Ohio State University at Put-in Bay. The youngest stages could not be obtained that season, but these were added in 1920, when the breeding season was somewhat later. Collecting was done with a 25-foot minnow seine, reinforced with cheese cloth over the middle third.

The bass fry were obtained chiefly about North, South, and Middle Bass Islands, but in all seventeen islands within reach of Put-in Bay were visited and specimens were obtained from fifty-one stations. The young bass were preserved at once in a 5 per cent solution of formalin which killed them instantly and preserved the stomach contents. If the fish were above ¾ inch in length, the body wall was slit to allow formalin to penetrate more rapidly.

The young fish were found in nearly all types of environment, such as sandy, gravelly, and stony bottoms, but none was obtained on mud bottom. Very few were found directly in vegetation, although they were abundant at the edge of aquatic plants. The young bass has a wide range in its feeding habits, and its distribution was found to be more universal than that of any other fish seined in shallow water in that region. This bass, however, is an inhabitant of the open waters of the lake in shoal regions and near shore, and is not found commonly in the weedy bays and harbors. In such situations it is replaced by the large-mouth bass.

The stomach and intestinal contents of 313 young bass, ranging from 8½ to 65 mm. have been examined to date. The results obtained from the study of those above the 45 mm. stage are not considered complete, as only 14 specimens from 45 to 65 mm. have been examined, but they are not as important as those on the food of the younger bass. The food of the bass beyond 45 mm. in length differs but little in character from that of the adult.

The growth of the young bass is directly related to the food supply, and it was estimated from the daily collections that the rate is about .8 or .9 of a mm. per day, although there were wide differences in length from the various islands.

To show the feeding capacity of the young bass, the following table was made for 210 specimens:

FEEDING CAPACITY OF YOUNG BASS

Condition of stomach.	Number of bass.	Percentage.
Stuffed	53	25.2
Filled	78	37.2
Moderately full	52	24.8
Very little food	25	11.9
No food	2	.9
Total	210	100.0

This shows that over 60 per cent of the bass had the stomach either stuffed or filled, and 87 per cent at least moderately filled, which would indicate the bass did not suffer from lack of food. From observations made on eight of the bass from 16 to 28 mm. in length, it was estimated that 12 hours are required to empty the stomach and 24 hours to empty the intestine. The young bass feed throughout the entire day and probably at night, or at least early morning, as bass caught at 7 a. m. had their stomachs well filled.

For convenience, the bass were divided into various stages, each stage representing a difference in length of 5 mm. except the first, where there is a difference of 6½ mm.

In the following table is given the various stages, the number of bass in each stage examined, the seven most important articles of diet, and the percentage of the total number of bass in which each article is found in the different stages.

PERCENTAGE OF YOUNG SMALL-MOUTH BASS CONTAINING SEVEN MOST IMPORTANT ARTICLES OF DIET

No. of fish	Length	Copepods	Cladocera	Midge pupæ	Adult insects	Midge larvæ	Fish	Mayfly nymphs
	Mm.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
80	8.5-15	81.5	93.4	10.5	5.2	13.7	1.3	1.3
23	16 -20	87	30.5	8.7	4.3	26	21.7	13
46	21 -25	80.4	32.6	32.6	16.9	30.4	23.9	19.6
48	26 -30	56	25	43.7	37.9	25	8.3	14.6
47	31 -35	65.9	14.9	36.1	46.8	12.7	23.4	21.2
30	36 -40	36.6	23.4	40	30	23.3	30	13.3
25	41 -45	9	16	36	40	12	32	20
6	46 -50	0	17	16.5	50	33	33	0
4	51 -55	0	0	25	25	25	50	0
2	56 -60	0	0	0	50	50	50	0
2	61 -65	0	0	0	0	0	50	0
313	......	61.0	39.9	27.4	24.9	19.8	17.8	12.1

Copepods, as shown by the table, are the most important article of diet in the food of the young bass. They were found in 61.9 per cent of the bass examined. The copepods are utilized as food principally in the younger stages. They are very abundant up to the 35 mm. stage, after which there is a sudden decline to 45 mm., and from here on no copepods were found Twenty-six bass ate copepods exclusively, and the number eaten varied from 1 to 500. The copepods eaten in order of their prominence are: *Epischura lacustris, Cyclops leuckarti, Cyclops bicuspidatus, Diaptomus sicilis, Diaptomus minutus, Cyclops serrulatus,* and *Cyclops albidus.*

Cladocera, like copepods, are very important in the food of the young bass. They were found in 39.9 per cent of the bass.

In 1919 Cladocera ranked fifth in importance in the fish examined, and only at one island (Old Hen) did they surpass the copepods in number. In 1920 they were found in much greater numbers than the copepods in the food of the young bass, and ranked second. This makes the difference in the 8½-15 mm. stage. The percentage of bass eating copepods in this stage (8½-15 mm.) is lower than the next (16-20 mm.) because of the smaller number eating copepods in 1920, and the percentage of bass eating Cladocera in the 8½-15 mm. stage is much higher than the rest for the same reason. The table shows that cladocerans, like copepods, are important in the younger stages, but are eaten up to the 50 mm. stage, or a little later than the copepods. The number eaten by a single fish varied from 1 to 202. Thirteen bass ate Cladocera exclusively. The cladocerans eaten were, *Daphnia retrocurva, Diaphanosoma leuchtenbergianum,* and *Sida crystallina.*

Midge pupæ ranked third and were found in 27.4 per cent of the bass. They ranged in number from 1 to 41. Midge pupæ are unimportant up to the 21 mm. stage, but from here on up to the 45 mm. stage they are very important. After the 45 mm. stage there is a dropping off in the number of bass eating them. Some of the important midge pupæ eaten were, *Chironomus, Cricotopus,* and *Tanytarsus.*

Adult insects were found in 24.9 per cent of the bass. They are unimportant up to the 21 mm. stage, but from here on there is an increase, and the larger the bass the greater the number eating insects, up to 45 mm. Eight orders of insects are included in the food of the young bass. Of the total number of bass eating insects, mayflies were found in 52 per cent, two-winged flies in 32.4 per cent, caddis flies in 10.8 per cent, moths and bugs each in 8.1 per cent, beetles in 2.7 per cent, and Hymenoptera and Physopoda each in 1.3 per cent.

Taking insects as a class and including the larvæ, pupæ, and adults, 180 bass or 57.4 per cent of the total number fed upon them.

Midge larvæ were found in 19.8 per cent of the bass, and ranged in number from 1 to 85; twelve bass ate them exclusively. Midge larvæ are important in the food of the bass throughout the period they were examined, although they are less important in the 8½ to 15 and 41-45 mm. stages than the others. They are particularly abundant between 16-40 mm. The most important larvæ are: *Chironomus, Tanytarsus, Orthocladius, Cricotopus,* and *Tanypus.*

Fish are not important in the food of the very young bass between 8½ to 15 mm. but increase as the bass grow older. Above 16 mm. they are common in the diet of the bass, and gradually increase except in the 36-40 mm. stage. The youngest bass to eat a fish was 12 mm. long and 25.4 per cent of the bass eating fish ate them exclusively. Fish were found in 17.8 per cent of the bass. The fishes eaten were the ones most often associated with the bass, except in the case of the perch. Those eaten, in order of their importance, are: Minnows (spot-tail, most important), stone rollers, fan-tailed darters, carp and the darter *Cottogaster copelandi.* One young bass was eaten, which points to a slight amount of cannibalism.

Mayfly nymphs rank last of the seven important foods of the young bass, being found in 12.1 per cent of the fish. They are unimportant up to 15 mm., as they were found in only 1 bass below that length. They are very important between 16 and 45 mm., and are not found after the 45 mm. stage. The number eaten varied from 1 to 41, and three bass ate mayfly nymphs exclusively. The most common mayflies were *Hexagenia, Ephemerella, and Bœtis.*

The 29 remaining articles of diet will be grouped together, as they are found in from one per cent to 5.7 per cent of the bass, and are unimportant.

Caddis pupæ were found in 5.7 per cent of the bass, about equally distributed between the 21-45 mm. stages; none was found above or below these stages. Ostracods were in 3.8 per cent of the bass; like the copepods and cladocerans they are more abundant up to the 25 mm. stage, and after that decrease in importance. Seven bass between 21-45 mm. ate caddis larvæ.

The greatest number, 4, eating them occurred between 26-30 mm. Four bass ate crayfish. Their lengths were 40, 45, 48 and 51 mm. respectively. Four also ate amphipods. These were distributed throughout the various stages. Three bass between 12-30 mm. ate mites. One bass 33 mm. long ate two spiders. One stonefly nymph was found in a bass between 41-45 mm., and one damselfly nymph in a 12 mm. bass. Coleopterous larvæ were found in two bass between 21-30 mm.

Vegetation was found in 9 bass ranging in size from 8½-45 mm. It was in such small amounts that it was no doubt either accidental in swallowing the prey, or occurred in the food of the animal eaten. Vegetation does not form a part of the diet of the young bass, although in an indirect way the vegetation forms the basis of all fish food, as the animals the fish feed upon in turn feed upon the vegetation.

Small amounts of unrecognizable material were found in about 5 per cent of the bass. One bass 43 mm. and another 65 mm. long had eaten nothing.

From these results it seems the bass fry and early fingerlings eat practically all the time, and from observation the adults eat intermittently.

COMBINATION FOOD EATEN BY THE YOUNG BASS

The best two-food combination for bass fry between 8½-15 mm. is copepods and cladocerans. Above 15 mm. midge larvæ and pupæ form the best combination.

The chief three-food combinations up to 45 mm. in length, were either copepods, midge larvæ, and pupæ, or cladocerans, midge larvæ, and pupæ, depending upon the season. Between 15-45 mm., midge larvæ, midge pupæ, and mayfly nymphs also made a good three-food combination.

The best four-food combination was either copepods or cladocera with midge larvæ, pupæ, and mayfly nymphs. Add adult insects to the four-food diet and you have the best five-food combination after the 20 mm. stage.

In the 8½-15 mm. stage, 17 different kinds of food were eaten. Although the very young bass is a specialized feeder at first, feeding almost entirely upon entomostracans, it soon becomes a generalized feeder, and up to 45 mm. feeds upon an average of twelve different kinds of food. The 14 bass examined above 45 mm. show a gradual restriction in the kinds of food eaten.

As to the number of stages in which each of the seven most important kinds of food occurred, it is noted that copepods and mayfly nymphs were found in the first seven stages of bass from 8½-45 mm. Cladocera were in 8 stages from 8½-50 mm., midge pupæ in 9 stages from 8½-55 mm., adult insects and midge larvæ in 10 stages from 8½-60 mm., and fish all stages from 8½-65 mm. This shows that in all stages between 8½ and 45 mm., bass ate the seven important kinds of food, a fact which indicates that the bass at least between these lengths is a versatile feeder.

The following table gives the total list of all the materials found in the stomach contents of the 313 bass examined:

MATERIALS FOUND IN STOMACH CONTENTS OF 313 BASS EXAMINED

Order of importance.	Kind of food.	No. of fish.	Percentage.
1	Copepods	193	61.9
2	Cladocera	125	39.9
3	Midge pupæ	86	27.4
4	Adult insects	78	24.9
5	Midge larvæ	62	19.8
6	Fish	56	17.8
7	Mayfly nymphs	38	12.1
8	Caddis pupæ	18	5.7
9	Insect cases	15	4.7
10	Ostracods	12	3.8
11	Vegetation	9	2.9
12	Caddis larvæ	7	2.2
13	Copepod eggs	6	1.9
14	Mayfly eggs	5	1.6
15	Crayfish	4	1.3
16	Amphipods	4	1.3
17	Statoblasts of *Plumatella princeps*	3	.96
18	Nauplii	3	.96
19	Mites	3	.96
20	Naid worms	2	.64
21	Coleopterous larvæ	2	.64
22	Damselfly nymph	1	.32

23	Stonefly nymph	1	.32
24	Ciliates	1	.32
25	Difflugia	1	.32
26	Spider	1	.32
27	Parnid beetle larvæ	1	.32
28	Nematode worm	1	.32
29	Sand	1	.32
30	Pebbles	1	.32
31	Unrecognizable material	12	3.8

Eight orders of adult insects give 36 different types of food.

SUMMARY

Copepods and cladocerans are the first food of the young bass. They are found in from 80 to 90 per cent of the young bass, depending upon the general abundance of each. These minute animals are important up to the 40 mm. stage. From this point on they are not important, and were not found in the 8 bass examined between 50 and 65 mm.

Mixed with the copepods and cladocerans in the 8½-15 mm. stage are a few midge larvæ, pupæ (12 per cent), and adult insects.

After the 15 mm. stage, midge larvæ and pupæ, mayfly nymphs, fish, and adult insects become more important, the midge larvæ especially so up to 40 mm. and the pupæ to 45 mm. The larvæ are important after the 15 mm. stage, and the pupæ after the 25 mm. stage.

Adult insects and fish become more important as the bass increase in length, and these, with crayfish and a few midge larvæ and pupæ, are the chief articles of diet in the food of bass between 45 and 65 mm.

From the few yearlings examined, I would say that crayfish and fish with a few insects are the three important foods.

The food cycle seems to be copepods and cladocerans of an almost pure diet to 15 mm.; then from 16 to 45 mm. mixed with these are mayfly nymphs, midge larvæ and pupæ, with fish and adult insects; and above 45 mm. fish, adult insects, and crayfish are important. Although these overlap, the series is: (1) entomostracans, (2) insects (larvæ, pupæ, and adults), and (3) crayfish and fish.

FOOD OF YOUNG LARGE-MOUTH BLACK BASS IN SOME OHIO WATERS

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and
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Selected specimens of young large-mouth black bass taken, were immediately immersed in 5 to 10 per cent formalin and the contents of the alimentary canal later studied with the aid of binocular and compound microscopes.

The large-mouth bass is well distributed over the state, and probably occurs in every body of water which offers suitable environment and is free from pollution. As compared with the small-mouth bass, the large-mouth prefers relatively quiet and deep waters containing much vegetation, such environment being found in most of the larger inland lakes, sometimes in the larger streams, but seldom in the smaller streams.

The large-mouth bass in Ohio spawns from the last of May to the middle of July, but for the most part spawning is completed by the middle of June. The young bass remain in schools for a few days after hatching, but they rapidly become individualistic, and hunt singly. They appear to be game fish from the time they begin to take food, darting about on the surface and snapping at any small object that moves. In suitable localities they remain near the surface in large numbers, but dart below when disturbed. There is apparently little migration, merely a general scattering out of the school, as food is usually abundant in and about the vegetation.

The young bass considered here are all in their first summer or first year's growth. While a reference is made to one yearling bass examined, it is not considered in the tables, nor within the range of this particular study.

Twenty-six different articles of diet, that is, kinds or groups of organisms or remains of such, were recognized in the contents of the stomachs and intestines of the young bass. These have been arranged in Table 1, giving the length in millimeters of the fish examined; the total number of fish of each length examined, and the percentage of the entire volume of food which each article of diet forms in fishes of all the various lengths.

Cladocera, Copepoda, and the larvæ and pupæ of midges (Chironomidæ) are the most abundant articles of food. Ostracoda occur rather evenly distributed in the stomachs of young of all sizes, but they are found only in very small numbers at best. Amphipoda constitute a fairly important food for the intermediate size of young bass, but are relatively unimportant in the larger ones. Nymphs and adults of Corixa and small fish are taken very freely by the largest of the young bass. Mayfly nymphs are occasionally found in stomachs of the intermediate-sized and larger fish, as was the case of a few coming within the range of this report. However, in a larger yearling fish, 92 mm. in length, 22 mayfly nymphs were found, constituting 95 per cent of its food. Insects recognizable by the hard chitinous parts, but too much broken up for identification, often formed the major part of the diet of a fish, and were sufficiently abundant in the intermediate and larger stages to form a fair proportion of the total diet. The occurrence of filamentous algæ was exceedingly irregular. Sometimes such algæ occurred as small fragments, making a negligible proportion of the food, but in a few exceptional cases formed nearly 100 per cent of the stomach contents. The filaments, wadded together into small pellets, proved to be Spirogyra and Œdogonium. Material, undoubtedly animal remains, but so well digested as to render further identification impossible, was listed as animal debris. The other articles entered in the table were irregular in occurrence and in most cases were very small in quantity.

1. PERCENTAGE EACH KIND OF FOOD TO TOTAL VOLUME OF FOOD OF YOUNG LARGE-MOUTH BLACK BASS

Fish examined. Length	No.	Cladocera.	Copepoda.	Ostracoda.	Midge larvæ and pupæ.	Amphipoda.	Mayfly nymphs.	Corixa nymphs and adults.	Beetle larvæ.	Diptera adults.	Diptera larvæ.	Crayfish.	Isopoda.	Fish remains.	Midge adults.	Lepidoptera.	Water striders.	Mites.	Other insect remains.	Filamentous algæ.	Annelid worms.	Nematode worms.	Trematode worms.	Protozoa.	Animal debris.	Inorganic debris.	Diatoms.
Mm.																											
9	3	22	50	...	28	....	....	....	..	..	...	....	...	....	...	..	...	..	....	.....	..	....	..	..	....	...	...
10	1	70	30	...	....	....	....	....	..	..	...	....	...	....	...	..	...	..	....	.....	..	....	..	..	....	...	...
11	2	45	34.5	...	20	....	....	....	..	..	...	....	...	....	...	..	...	..	....	.....	..	....	..	..	....	...	5
12	10	44	24	...	89	....	....	....	..	..	...	....	...	....	...	..	...	..	....	.1	.1	....	..	.1	....	2.5	.2
13	10	20.5	31	.5	38.5	9.5	....	....	..	..	...	....	...	....	...	..	...	..	....	.....	..	....	..	..	....	...	...
14	10	20	19.5	1	50.5	9	....	....	..	..	..	....	...	....	...	..	...	..	....	.....	..	....	..	..	....	...	...
15	10	15.8	39.4	..	38.2	6.5	....	....	.	..	..	....	...	....	...	..	...	..	....	.....	..	....	..	..	....	.1	...
16	10	18.5	28	.3	33.2	16	...	....	4	..	..	....	...	....	...	..	...	..	....	.....	..	....	..	..	....	...	...
17	1	1	1	...	98	....	....	....	..	..	..	....	...	....	...	..	...	..	....	....	..	....	..	..	....	...	...
18	1	6.5	35	...	....	....	....	...	..	..	...	....	...	....	...	..	...	..	....	....	..	....	..	..	....	...	...
19	10	53.9	....	.1	23.7	2.3	....	....	..	..	6.5	....	...	....	...	..	...	..	....	11	..	....	..	..	...	..	...
20-25	10	23	38	...	15	5	3	....	..	..	...	....	...	....	1.5	..	...	..	4	1	..	....	..	..	....	...	...
25-30	10	33.8	23.9	.5	10.8	8	10	....	..	2	...	....	...	....	...	..	...	1	2.5	.....	..	1	..	..	9.5	...	...
30-35	10	39.4	10	..	6.9	10	....	....	..	..	...	....	...	15	4	..	...	..	4.1	.....	..	10	.6	..	7.5	...	...
35-40	10	3.4	76.1	.5	12.3	45	....	...	..	..	...	....	8.5	1.2	...	..	...	..	....	.1	..	2.7	..	..	....	.2	...
40-50	10	2.4	5.3	4.3	4.7	35.3	....	2.3	..	..	...	....	..	18.5	...	..	...	..	2.5	26.5	..	1.2	..	..	....	...	...
50-60	10	1	....	...	5	....	6.5	30.5	..	..	...	....	...	31	...	8	...	..	.5	.....	..	....	..	..	17.5	...	...
60-70	10	....	....	...	....	....	....	8.2	..	..	...	15.4	...	66.6	...	..	8.8	..	.84	.16	..	....	..	..	....	...	...
70-80	4	....	....	...	3.4	....	....	63.3	..	..	...	....	...	33.3	...	..	...	..	....	.....	..	....	..	..	....	...	...

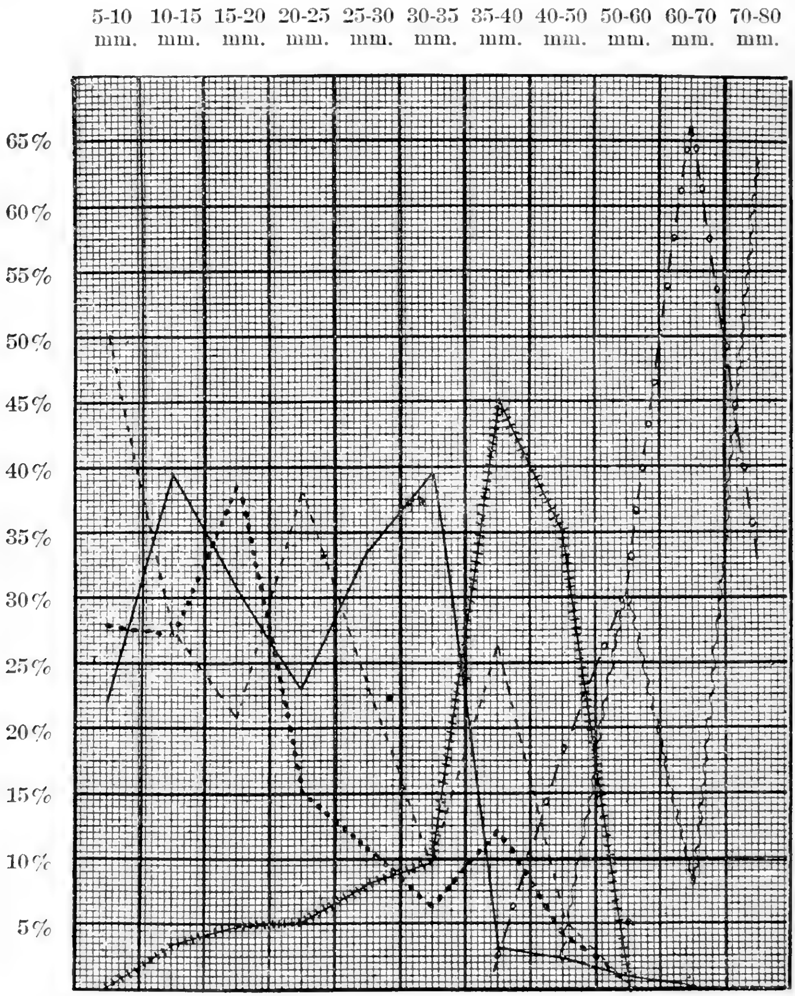
This arrangement of the various articles of diet of the fishes examined, brings to light some interesting facts as to changes in food. For convenience the six chief articles are shown in the graph, the figures and spaces running upright indicating the percentage of the whole which each article forms, and those running crosswise, the length of the fishes in which each was found.

First: The food of the very young specimens consists of few forms and these are all minute. The Cladocera are mainly *Bosmina longirostris* and *Chydorus sphaericus*, and the Copepoda nearly all are species of cyclops. The midge larvæ are fairly abundant, but are very minute, the average length being 1.97 mm. in the 10-15 mm. fish.

Second: The food of the intermediate forms becomes more complex. There is a distinct decline in the number of Cladocera, Copepoda and midge larvæ, while the Amphipoda, of which there are only a few very minute ones in the small fish, become more important, forming 45 per cent of the total food mass in fish of 35-40 mm. in length. There is also the introduction of insect larvæ and nymphs, such as those of mayflies, damselflies, beetles and Corixa, and also of fish remains.

Third: The larger forms have a relatively simple diet again, in which larger insect larvæ, fishes and crayfish become more important. Rarely a larger fish is taken in which the Entomostraca, Amphipoda and very small insect larvæ constitute a considerable part of the stomach contents; but the tendency, as shown by the graph, is for the Entomostraca, Amphipoda and midge larvæ to disappear almost entirely.

The question arises at once as to the reason for these definite changes in diet, and several solutions suggest themselves. It is possible that part of the change may be accounted for in the cycles of organisms that develop within the habitat of the young bass. If this were the case, however, we should expect a correlation between the appearance of an organism in the habitat and its use as food. But in the case of Corixa, for instance, one rather small species was found abundantly



Key to Graph.

Cladocera
Copepoda
Midge larvæ and pupæ
Amphipoda
Corixa nymphs and adults
Fish remains

throughout the summer in the same localities with the bass; and likewise Amphipoda and Entomostraca, of apparently the same or very similar kinds, were generally present. Yet the young bass consumes largely first one, then another, and later still another of these foods. It might be urged that the bass is by nature a selective feeder, choosing certain definite kinds of food. But this would not furnish adequate reason for a definite change in diet. The young bass is not a random feeder, on the other hand, otherwise the stomach contents would offer more promiscuous collections of food. Neither is there any marked change in habit or mode of living that would correspond to the periods of change in diet.

The results of a careful study of the lengths of the chief different articles of food, together with the lengths of the young bass, are shown in Table 2.

It seems that the size of the food as compared with the size of the bass is the most important factor. It is likewise the same factor which brings about a change in the diet later. It will be noted from Table 2 that the 10-15 mm. bass eat Cladocera which average only .35 mm. in length and that with an increase in size of the fish, larger species of Cladocera, such as Daphnia and Camptocercus and others, are eaten. The same general correlation is shown in the size relationship of the Copepoda and of the midge larvæ. Some very minute amphipods appear in fish 12 mm. in length, but in 45 mm. fish the average is 4.31 mm. The table shows that in bass 45 mm. in length the average size of all food animals is approximately 4 mm. to 4.5 mm. Corixa have not been taken, up to this time, although they were present abundantly in the waters. The species is one in which the adult is only about 4.5 to 5 mm. long; a number of old nymphs, 4 mm. long or slightly longer, were found in the food.

Corixa nymphs and adults become important in the food of fish 45 mm. in length and upward, and it seems reasonable that the bass turned to them at this stage because it had attained a size when 4 mm. animals were not too large to be taken most conveniently as food. After 45 mm. the young bass turns more to fish, and there is a definite increase in the size of fish taken, as the bass grows larger. The same principle of size relationship is still more evident in the grand

2. Relation Between Increase in Length of Chief Forms of Food and Increase in Length of Young Large-Mouth Black Bass

Chief article of food	Length of food eaten by —									
	Fish 10-15 mm. in l'gth	Fish 15-20 mm. in l'gth	Fish 20-25 mm. in l'gth	Fish 25-30 mm. in l'gth	Fish 30-35 mm. in l'gth	Fish 35-40 mm. in l'gth	Fish 40-50 mm. in l'gth	Fish 50-60 mm. in l'gth	Fish 60-70 mm. in l'gth	Fish 70-80 mm. in l'gth
	Mm.	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
Cladocera:										
Maximum . . .	.61	.43	.88	1.80	1.30	2.00	.....	.....	.....	.....
Minimum . . .	.26	.31	.31	.52	.55	.47	.....	.....	.....	.....
Average. . . .	.35	.37	.48	1.16	.78	.92	.....	.....	.....	.....
Copepoda:										
Maximum . . .	.71	1.20	1.85	1.65	1.62	1.45	.....	.....	.....	.....
Minimum . . .	.42	.68	.56	.55	.84	.75	.....	.....	.....	.....
Average. . . .	.52	.85	1.04	1.09	1.17	1.22	.....	.....	.....	.....
Midge larvæ and pupæ:										
Maximum . . .	4.00	2.10	4.00	9.00	.....	5.50	10.50	.....	.....	.....
Minimum . . .	1.20	1.40	1.55	3.10	.....	1.40	2.80	.....	.....	.....
Average. . . .	1.97	1.80	2.67	5.41	.....	3.96	5.16	.....	.....	.....
Amphipoda:										
Maximum . . .	.....	.....	.....	.....	.....	2.80	5.25	.....	.....	.....
Minimum . . .	.....	.....	.....	.....	.....	2.15	3.00	.....	.....	.....
Average. . . .	.....	.....	.....	....	.....	2.50	4.31	.....	.....	.....
Corixa nymphs and adults:										
Maximum . . .	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Minimum . . .	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Average. . . .	.....	.....	.....	.....	.....	.....	4.00	4.00	4.50	4.50
Fish:										
Maximum . . .	.....	.....	.....	.....	.....	.....	.....	26.00	36.00	24.00
Minimum . . .	.....	.....	.....	.....	.....	.....	.....	12.00	10.00	14.00
Average. . . .	.....	.....	.....	.....	.....	.....	.....	16.66	16.50	19.00
Grand average..	.95	1.01	1.40	2.55	.98	2.15	4.49	10.33	10.50	11.75

average of the lengths of all the chief forms eaten. The average rises with more or less regularity from .95 mm. in 10 to 15 mm. bass, to 11.75 mm. in the 70 to 80 mm. bass.

The young bass is a game fish from the time that it begins to feed independently, and takes for its food moving objects which it is physically possible for it to capture and eat. As it grows larger and swifter, it takes larger and more active animals for food. If an animal be of suitable size the only limitation to its use as food is its relative abundance and there is little or no choice indicated for any particular animal of the suitable size as long as it is active. This is the most simple explanation. It does not seem necessary to invoke any other complicating factors such as changes in habit, migration, or definite selection on the part of the young bass.

A comparison of the food cycles of the young large-mouth with that of the young small-mouth bass is of interest, owing to differences in their general habits, causing minor differences in their food cycles. The predominance of Entomostraca and midge larvæ in the food of the very young is common to both species. In the next stage the small-mouth bass turns immediately to other insect larvæ, while the large-mouth bass takes amphipods principally. This is to be accounted for by the fact that the large-mouth bass frequents quiet waters where masses of submerged vegetation afford feeding grounds for innumerable amphipods, while the small-mouth bass is to be found in waters freer of vegetation, and where insect larvæ probably supplant the amphipods. Both species take fish and large insect larvæ principally during the late summer, but the small-mouth bass becomes definitely piscivorous at an earlier age than the large-mouth, the former at 12 mm. and the latter at 35 mm. It is probable that the small-mouth takes up the fish-eating habit earlier because of the lack of other food of suitable size. Crayfish also play a larger part in the food of the small-mouth, which is naturally to be expected in view of the fact that the small-mouth bass and the crayfish both abound in the same habitat.

SUMMARY

1. The food of the young large-mouth black bass undergoes two rather definite changes between the 10 and 85 mm. stages.

2. Up to 30 mm. in length the food consists almost entirely of Entomostraca and minute midge larvæ.

3. From 30 to 50 mm. in length, Entomostraca become negligible in quantity and midge larvæ diminish rapidly, while amphipods form the principal article of diet, and larger insect larvæ and fish are taken in small quantities.

4. From 50 to 80 mm. in length, Amphipoda, Entomostraca and midge larvæ practically disappear from the diet, the food being principally larger insect larvæ and fish.

5. The factors governing both the food taken by the young fish and the changes in diet are: (a) The abundance of suitable food in the water; (b) the size of the food organism; and (c) movement on the part of the food organism.

6. The food cycles in the young of the large-mouth and small-mouth bass are similar, though the changes occur at slightly different ages, and there are minor differences in the animals used as food which follow as a result of the differences in the habitats of the two species.

THE GIZZARD SHAD IN RELATION TO PLANTS AND GAME FISHES

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It is the purpose of this preliminary paper to record some observations on the food and feeding habits of the young gizzard shad (*Dorosoma cepedianum* Le Sueur), and the place it holds as a connecting link between microscopic plants and the game fishes. This species, often called the hickory shad, is very abundance at Buckeye, Indian, and Loramie Lakes, often more than a thousand of the young being taken at one haul of the collecting seine. It is less common in the other localities covered by the survey in Ohio.

The fish collected were put into a five per cent solution of formalin, thus preserving the contents of the stomach and intestine and preventing further digestive action. The examination of the contents of the digestive tract was made with a compound microscope, the highest powers often being necessary for identification of the food. Adult fishes are not considered in this paper, examination being limited to young specimens under seventy millimeters in length, measured from the point of snout to the base of the caudal fin. About two hundred individuals were studied from the localities named above.

Since the excellent work of Forbes* nearly forty years ago, very little study appears to have been made of the food of the gizzard shad. According to Forbes the shad is "a mud lover par excellence"; swallows "large quantities of fine mud containing about twenty per cent of minutely divided vegetable debris"; and consumes, when young, food that is approximately 90 per cent microscopic animals and the rest microscopic plants. From data at hand it appears that these statements

*On the food relations of freshwater fishes: a summary and dicussion. S. A. Forbes. Bulletin, Illinois State Laboratory of Natural History, Vol. II, Art. 8, 1888.

require considerable modification when applied to young fish within the limits of this study.

The food of the young gizzard shad may be roughly grouped into the following kinds, in order of their importance as noted in the examination of stomach and intestinal contents: microscopic unicellular plants (algæ), microscopic animals, and filamentous algæ. Mud usually forms from ten to thirty per cent of the contents, and a similar quantity is unrecognizable plant debris. Mud is often entirely lacking from the stomach contents and it is my belief that it is merely incidental to the manner of feeding. No consideration is given, therefore, to its varying amount in the digestive tract.

The gizzard shad feeds by swimming through the water with its mouth open in an apparently aimless manner. The presence of such masses of microscopic material in the digestive tract is accounted for in part when the feeding apparatus of the fish is examined. The very numerous fine gill rakers on the gill arches oppose the escape through the gill slits of very small objects which enter the mouth of the fish with the water of respiration. Thus like a very fine sieve, these allow the water to pass out through the gill slits as the fish swims along, while the minute organisms are retained and introduced into its alimentary canal.

The gizzard shad is the most wonderful combination of tow net and centrifuge that one could desire. Wherever this fish was found, it was not necessary to do any towing to get an estimate of the number and kinds of microscopic plants, for the stomach contents represented a concentrated sample of the plankton. The number of different kinds of microscopic algæ found in an identifiable condition in the digestive tract of the gizzard shad is markedly large. In a single fish taken at Buckeye Lake on July 1, fifty species and varieties of algæ were found; from the specimens examined to date from the various localities named above, the number of species exceeds 140 and will doubtless reach considerably higher. The majority of these are unicellular and colonial forms included in the group known as Protococcales; a number are desmids and diatoms; and a few are filamentous. The number of any particular kind, especially among the Protococcales, seems to depend directly upon the richness of the plankton present. No attempt is made in this paper to give the identification of the microscopic plants and animals—a further study is necessary before such a report can be made.*

The following table gives in approximate percentages the food of the gizzard shad in a comparative way for each locality:

APPROXIMATE PERCENTAGES OF KINDS OF FOOD IN GIZZARD SHAD

Locality.	Micro-algæ.	Micro-animals.	Filamentous algæ.	Plant debris.
	Percentage.	*Percentage.*	*Percentage.*	*Percentage.*
Buckeye Lake	80-90	0-5	0-2	5-10
Loramie Lake	75-90	2-6	0	5-20
Indian Lake	75-88	3-5	2-4	10-15
St. Mary's Lake	80-90	6-8	0-1	8-12
Chippewa Lake	80-90	1-3	0-1	5-10
Portage Lakes	70-90	10-15	2-5	10-15

One of the outstanding features of the foregoing table is the constancy in the percentage of microscopic plants found in the fishes examined, regardless of locality or size within the range of this study. The kinds of algæ comprising the food were not the same for different localities, and even for the same locality differences were noted in fish collected in June and August. This variation is doubtless due to the geographic distribution of the plants and to the fact that most algæ have rather definite seasonal cycles of vegetative development. But the more or less constant percentage seems to indicate that the gizzard shad is able to utilize a rather large variety of microscopic plants. The writer hopes to be able to follow out some of the seasonal changes for a given locality in the near future. Another interesting observation is the comparative sameness of diet of the fish throughout the period it is attaining a length of seventy millimeters and even more. Many other fishes, like

* A complete list of the algæ determined in the food of the Gizzard Shad appeared in the *Ohio Journal of Science* for February, 1921.

the small and large-mouth bass, make decided changes in the kind of food taken during the period of their growth to a similar length. An examination of two gizzard shad 200 millimeters in length did not materially alter the percentages as given above, with the exception that there was a greater amount of unrecognizable debris.

The animal percentages are not so constant, the amount being sometimes zero, but it seems certain that no discrimination is exercised in food selection. The gizzard shad is chiefly a vegetarian, but the percentages of animal food present are too large to be considered otherwise than as the animal part of the plankton. On the other hand it forms no such large a factor as the report of Forbes would indicate, which means merely that in the present case the plant life was proportionately more abundant. Towing records indicate the same proportions of animal and plant life in the plankton.

The filamentous algæ were always present in small quantities, and there was but a single instance of the presence of any parts of the higher plants. In one gizzard shad the remains of some epidermal and palisade cells of a small leaf were found, but it must be considered purely accidental. The filamentous algæ were largely young plants, broken up into relatively small pieces. No plant was ever observed longer than three-tenths of a millimeter, and the material was never wadded up, either in the gizzard or in the intestine.

Not more than a decade or two ago most ichthyologists were agreed that the gizzard shad was a beautiful but nevertheless worthless fish. That it is beautiful no one will dispute. With its silvery white sides and its graceful rapid dashes through the water near the surface, it makes a very attractive fish. But it is decidedly not worthless. While it is not a game fish and at the present time furnishes very little food for man, it holds a very important place in the life cycle of a number of our best game fish, notably the small and large-mouth bass, the crappie, and the white bass. The younger gizzard shad furnishes excellent food for these fishes, which experience no difficulty in disposing of the too numerous bones.

As noted above, the shad is almost wholly a vegetarian, and thrives on plants so tiny and minute that sometimes 10,000 of them laid side by side would not reach an inch. These minute plants form a very important part of the flora of most unpolluted bodies of water and are present by the millions in nearly every lake of the state. None of the other fishes seems to be able to utilize this great source of food to any considerable extent except when quite young. Thus the gizzard shad does not interfere in the least with the food supply of the game fishes, and is itself excellent food for the majority of our game fishes.

The gizzard shad offers for the game fishes one of the most direct routes from "manufacturer to consumer" that is possible among fishes. Of course, plants ultimately form the basic food for all living organisms, but the cycle is oftentimes a long one. The Chinese proverb, "Big fish eat little fish; little fish eat shrimp, and shrimp eat mud," gives a cycle that comes very nearly standing the test of modern science, if we understand the mud to be microscopic plants and animals. An ordinary food cycle of a fish might be illustrated by a bass feeding on smaller fish; these in turn on tiny animals which may eat the larvæ of still smaller animal organisms; and the latter living on microscopic algæ. But the cycle from the same bass through the gizzard shad to microscopic algæ is a much shorter and more direct route. Thus the gizzard shad holds a rather unique position in that it may completely bridge the gap between our game fishes and the ultimate source of their food supply, the microscopic plants.

In 1888, Forbes wrote this very important paragraph about the gizzard shad, but it is only recently that any practical application is being made of such knowledge:

> Among the soft-finned fishes the most valuable as food for other kinds 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 of that of the

black bass; nearly half of that of the common "pike," or pickerel; two-thirds of 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 (*Ameiurus natalis*) and the young white bass (Roccus). It thus seems to be the especial food of the large game fishes and other particularly predaceous kinds.

It seems important that such information should be widely distributed among those interested in the propagation of fishes. As an illustration of benefits to be derived from such knowledge, mention may be made of conditions at the newly formed Milton Reservoir near Newton Falls, Ohio. This fine body of water with its plentiful supply of microscopic algæ, as ascertained from towed material, offers excellent living conditions for the gizzard shad, and its presence means plenty of food for the bass. Dr. Raymond C. Osburn has already advised in one of his reports to the State Bureau, that this reservoir be stocked with the gizzard shad.

SUMMARY

The observations recorded in the paper may be briefly summarized as follows:

1. The distribution of the gizzard shad is general for the inland lakes of Ohio.

2. Its food consists, in the main, of microscopic algæ, with a small variable percentage of microscopic animals.

3. It seems that mud, though present to some extent in most of the fishes examined, is incidental.

4. The gizzard shad furnishes excellent food for most of our game fishes, notably the large-mouth and small-mouth bass, the crappie, and the white bass.

5. The gizzard shad holds an almost unique position as a direct connection between the microscopic plants and the game fishes, interfering in no way with the food supply of the latter

SOME FEATURES IN THE MIGRATION OF THE SOCKEYE SALMON AND THEIR PRACTICAL SIGNIFICANCE*

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Problems suggested by the striking life history of the Pacific salmon have attracted the attention of naturalists and fish culturists for a long time, and many able men have worked on the subject. Their contributions have given positive information with reference to many factors in the situation, but the subject is too large and too complex to have yielded entirely to their efforts and some questions have been left unsolved. It is also necessary to determine the precise application of these observations and principles to the practical questions that present themselves at the present day.

The importance of the problem can hardly be overestimated. Both of the great countries prominently represented in this meeting count as one of their greatest natural resources the salmon fisheries of the Pacific coast. In both of them the feeling has long been cherished by some well-informed men that this important and valuable resource was in danger of serious diminution, if not of total destruction. One of our great political leaders, himself an enthusiastic out-doors man, a lover of nature, and a vigorous supporter of conservation, recognized the impending danger by appointing in 1902 a commission to investigate the salmon fisheries of Alaska, and the Alaska Salmon Commission under the leadership of David Starr Jordan laid the foundation for a scientific work which has been continued energetically by many investigators in both Canada and the United States since that time.

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* This paper is based on investigations made by the writer while in the service of the Bureau of Fisheries, and is published by permission of the Commissioner of Fisheries.

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Perhaps the outstanding fact in connection with all of these studies is the demonstration that the destruction of the salmon is proceeding with tremendous rapidity, and the danger of its extermination or of the reduction of numbers to a point which will threaten a great industry is a consideration, not of some time many years hence, but of the immediate future.

There has also come out of these studies a firm conviction that joint action on the part of the two governments and their workers is essential for the solution of the problem and the protection of the industry. I think it must be equally clear to all that to provide for joint action there must be thorough understanding on both sides of the boundary. Certainly the first and most fundamental preliminary to such understanding is the demonstration of the essential facts in the situation and their coordination with the practices that are in vogue in such fashion as to indicate the lines of action calculated to protect the species and continue the industry. It is with a view to contributing a little at least to this basis of facts that I present this paper before the Society at this meeting.

For a number of years I have been privileged to conduct studies of the Pacific salmon during the season of its fresh water migration, and to study the factors in the environment and in the organism which, by their mutual interaction, produce the complex conditions that are described in relating the life history of the species. It has seemed to me that part of the confusion and difference of opinion that has been evident in the past might be due to the efforts to solve the entire problem of the migration in a single investigation. The movements of the salmon constitute a remarkable story. At some period in life they desert their feeding grounds in salt water, move towards the estuaries, ascend the streams, fulfill their reproductive function, and perish. The migration is a continuous movement. Whatever the factors that control it may be, they are all united in the fulfillment of the reproductive function. They work without interruption and with striking directness to bring about this consummation. However in dealing with so complex a problem, it is frequently valuable to analyze it into subordinate stages, even though they be somewhat artificial, and to endeavor to solve part of the question in the hope that such solution may indicate a basis for the solution of the entire problem.

With this thought in view, I shall confine myself in this paper to that part of the subject which has been primarily in mind in all the investigations which I have carried out in the field. This is the fresh water period in the migration of the Pacific salmon, the life and activities of the fish from the time when, having left the salt water of the estuaries, it is definitely embarked upon the upstream movement. From the time when it begins to ascend the rivers until the time when the eggs or milt have been discharged and the fish dies, it is under the influence of a more definite and restricted environment than that to which it is subject previously. I shall further limit the discussion to a single species of the five that occur on the coast and visit these waters. This is the red or Alaska salmon, *Onchorhynchus nerka,* also somewhat widely known as the sockeye. This species, being of paramount commercial importance because of its numbers and the price it commands in the market, has received considerable attention at the hands of various investigators both in Canada and the United States. It has not however, I think, been intensively studied during this period with reference to the factors that influence its movements.

Possibly at the outset it is wise for me to confess that I agree fully with those who have commented on the very complex and marvellous character of the migration. I cannot, however, share their view that such complexity is incomprehensible or beyond the power of observation and experiment to explain when ultimately all the factors in the situation have been analyzed in their bearing on the movements of the fish. It seems to me fairly well established scientifically that fish are primarily responsive to environmental stimuli, that their actions are due to external influences which may be difficult to detect and perhaps still more difficult to explain but which nevertheless justify the student in attempting to find an explanation of their actions in the environmental factors and in expecting confidently to secure a solution of the problem ultimately along these lines.

I shall not attempt to enter here into a discussion of the parent stream theory so tenaciously held by fishermen and in the past so vigorously combated by some most distinguished ichthyologists. I do not desire to appear as an attorney for either side in this discussion. It is my object to tell as clearly as possible of certain facts which I have observed so repeatedly that they seem to me to hold a significant relation to the movements of the salmon, and to leave the decision to the judgment of others, both here and elsewhere, who may now and in the future test them as facts and in their relations to the problems under discussion, with a view to determining their correctness and the justification of the relations observed and of the conclusions drawn from such relations.

MIGRATION ROUTE OF RED SALMON

The precise route followed by the migrating fish in any given stream has been discussed by various students of the subject. There is little doubt that in all classes under natural conditions it is uniform and precise. Two somewhat different phases present themselves. These are related to the character of the stream, and may be designated as the route taken by the salmon in streams having a single spawning ground only; and, second, that followed by the salmon in streams which carry fish going to several spawning grounds. In both cases one is struck by the peculiarities of the situation and the difficulty of finding any *a priori* explanation for the facts. In most cases these facts are clear and their invariability is shown by the consistent testimony of the native races which have always depended, as most of them do, upon the salmon for food, at least in those regions where the salmon migration assumes considerable proportions. It is evident that the consistent practices of the native fishermen are determined by the definite movements of the fish. Moreover, however unusual these movements may be, I presume we are right in assuming that some factor or factors determine them definitely, since they are in all cases invariable under natural conditions.

The factors which control existing conditions are difficult to determine. Whether the stream be resorted to by a single run of salmon or visited by several waves, seeking different spawning grounds, the conditions appear on first examination to be equally complex and inexplicable. Many parts of the stream that would afford apparently admirable spawning grounds are never visited. One may even find cases in which the spawning grounds actually visited are apparently inferior in size and fitness to others on the same stream to which no red salmon resort. The study of the mechanical factors that might possibly be determinative has led to no definite results. For such studies the multitude of short, many-branched streams in southeastern Alaska offers a most profitable field for study. The movements of the fish do not depend upon the swiftness of the water, for they pass at times from swift water into quiet, and again from a quiet stream into rapid waters. The waters which they leave are sometimes shallow and sometimes deep in comparison with those which they choose. In fact, it is not difficult to find places where the salmon turn from a stream that is readily passable into one that at the moment is so shallow or so obstructed that they make their way upward with difficulty and may even be blocked for the time being. So many instances of variability in these particulars can be found that one is justified in concluding that the volume and swiftness of the stream are not determining factors in directing the movements of the salmon or in leading them to select one tributary above another or in preference to the main stream itself.

Once embarked upon a stream they strive constantly upward, and yet not with equal pace. In the lower tide-influenced sections of the great rivers it was observed many years ago by

Rutter that the fish alternated in movements, traveling up and then again somewhat downstream as the tide shifted. This may be a uniform response to the current stimulus, for in these regions the current changes with the change of tide, but as the descending stream is stronger and its influence is felt for longer periods of time, so the ascending movements of the fish are superior to its reverse movements, and the salmon ultimately pass into the river above the tidal influence and then mount steadily upwards. The portion of the migration of the red salmon in tidal waters has not yet been followed definitely so far as I know. Once the fish have started to ascend the part of the stream which lies above tidal influences, they press steadily onward. The rate of migration has not been observed for the red salmon with a definiteness to determine, even in general terms, the rate of progress.

I have also made many observations with reference to the character of the water, without being able to find any uniformity in the conditions that conforms to the course of the migrating red salmon. In some places they pass from turbid, silt-laden waters to clear tributaries. In other places they seem to have selected that branch of the stream which carried the larger amount of sediment or was of the milky-white color so characteristic of glacial-fed waters. Furthermore, in southeastern Alaska, where there are so many short and highly-branched streams, one can find cases where the entire basin of the stream is underlaid by a single rock formation, so that the materials in solution must be identical in chemical character, and no doubt also in the amount of mineral substances in solution; moreover, the plant growth is uniform in character, if not in amount, throughout the entire basin of the stream, and it is difficult to formulate a theory which could in any way account for chemical differences in waters of such a limited and uniform area.

The rapid, turbulent character of the salmon streams indicates clearly their extreme poverty in minute organisms and the lakes are strikingly plankton poor so that there is only a scanty food supply for the salmon fry. Further, that food supply is apparently uniform in all parts of the stream basin so that the return of the adult to a definite point does not seem to be correlated with any peculiarly favorable conditions for the development of the young.

It is hardly profitable to recount further the evidence which has led to the rejection of these hypotheses. They are not adequate to account for the movements of the migrating salmon since the influences are not in definite fashion coordinated with those movements. There is one environmental stimulus, however, which has shown a high degree of correlation with the path which the red salmon follows in its migration in fresh water and that is the relative temperature of the different waters. This I propose to discuss more fully but first wish to consider one phase of the generally recognized current stimulus. In fresh water the red salmon moves constantly up stream. While it is not influenced by the strength of the current, for it may desert a strong current to follow more quiet waters, yet in the largest streams it seems to modify its behavior, perhaps necessarily but yet in a way to affect conspicuously its distribution and incidentally its relations to commercial fishing, by sticking close to the shore, or having a route which follows one bank of the stream and is distinct from the route along the opposite shore.

During my last visit to Alaska I had the opportunity of testing some of the working hypotheses previously formed on a new type of stream. The Copper River is much larger than any other stream I have previously studied in which the red salmon is found, and careful attention was given to the special features of the situation with a view to determining the differences, if any, that characterize the migration of the red salmon here in contrast with its movements in smaller streams in other regions. One of the first factors which attracted my attention was the apparent inclination of the fish to migrate upstream near the banks. This was first noticed at the Abercrombie Rapids. Here the river makes a rapid and violent descent for a short distance, and it was evident even on the first inspection of the situation that the red salmon must experience great difficulty in ascending the stream at this point. It seemed altogether likely that the fish would have to follow a course near one shore or the other. On the east bank there are several large eddies in which it is well known that the fish congregate in large numbers. The opposite bank does not possess any such conspicuous places of refuge, but there is a multitude of little eddies formed by jutting rocks, irregular in size and shape, but constituting a series of resting places, so that the fish can make the ascent of the rapids by passing through the series without being drawn into the full current of the river at any point and without being compelled to traverse the more violent stretches of water for more than a few feet.

The fishermen who are working along this shore are very successful in scooping the salmon out of these minor eddies, and have learned the spots at which the fish rest longest, for these are the places where the scoop net functions most successfully. As the water in the stream is exceedingly turbid, it is not possible for the fish to see the fisherman, so the net sweeps through without alarming the fish. Having scooped out the contents of the eddy the fisherman pauses a moment to permit other fish to come in, and then makes another sweep to gather in the salmon which have reached it in the interval. When the fish are migrating rapidly, this fishery is very successful and, I think, likely to catch a large percentage of the fish passing while dip netting is being carried on.

The employees of the cannery located near this point insist upon the view that the salmon also use the center of the stream, since in the period of migration they have often been able to see the fins cutting the water far out from the shore. It must be borne in mind that the turbidity of the stream here is so great as to prevent seeing a fish even a short distance below the surface. The only time at which any fish could possibly be detected, if even a short distance from the shore, would be when it actually comes to the surface and the back fin rises above the water. I have no desire to question the accuracy of the observations, which is insisted upon. I think that the fishermen have seen the back fins of fish appearing at various points in the open stream, and perhaps at certain times these appearances have been so numerous as to suggest a large number of fish passing upstream through that portion of the river. But even a brief study of the rapidity of the stream at this point will, I think, suffice to demonstrate to anyone that even a powerful fish like the red salmon would be unable to stem the current for more than a very brief interval of time.

For myself, I should be inclined to explain the presence of fish in the open current of the river in an entirely different fashion from that just suggested. One who has observed the salmon ascending rapids in a clear stream is familiar with the general actions of the fish under these conditions. They are enough like those of some other species to demand only a brief explanation in order that the situation may be clearly understood. The fish dart from point to point, starting from an eddy or protected position, passing with a rush through a stretch where they are more or less exposed to the force of the current, and aiming to reach promptly another protected place where they hang resting and gathering strength for another rush. In this way, step by step, the long stretch of difficult water is overcome, but at no time do they, in my experience, attempt to pass a long stretch of violent water at a single effort. They act with such care that it seems as if they were clearly bent upon saving themselves as much as possible and spending the minimum amount of energy in overcoming the difficult water. Furthermore, I am sure that everyone who has watched fish under these conditions has seen not one but many individuals from time to time make a rush, get caught by the full current or by broken water before they have actually reached their objective, and be carried downstream, at first fighting powerfully against the force of the current, but later slowing up or again making a rush to reach a protected situation in an eddy or under the lee of some rock. Now if these movements were carried out in a stream which was so dense that it was impossible to see the body of a fish even when near the surface and one could get evidence of position only when the back fin cut the surface, I think it is clear that one might at times note the frequent appearance of fish breaking the surface in the open current. It would, however, be wrong to conclude that these movements were made in connection with the regular upstream rush of the fish. They would rather be the appearance of those fish which had been swept off their course and were either stopped by the current and forced to the surface, or were being gradually driven downstream, after having been caught by the current and forced out of the usual line of movement up the rapids.

But the tendency of the fish to move along the banks, determined by necessity in the region of the rapids, seems to have been followed in other regions also. In travelling up the Copper River and its tributary, the Klutina River, there was not much opportunity for us to make careful study of this point, but we were camped for two days half a mile below the outlet of Lake Klutina, where the stream is broad and rapid, though not broken and tumultuous. While we were at this point the salmon were passing up regularly and we frequently saw them and also heard them jumping in the river at night. Just at the time of our visit the most of the jumping was near the opposite bank, where a projecting point and a little bay behind it made an eddy in which the salmon were abundant. We went up and down the stream to the lake for several days, and in no case did I see a salmon jumping in the center of the stream. They were more abundant along the southwest bank opposite our camp, but they were also jumping at intervals along the shore on which we were encamped.

In Lake Klutina itself conditions seemed to be equally definite. This body of water is crescentic in form and some 25 miles in length, with a maximum breadth at the center of the crescent of about 4 miles. I watched carefully for the appearance of salmon during all of the time we were either moving along on the beach or following close to the shore in our boat. Fish were seen jumping regularly in the water adjacent to each bank, but in no instance did I find them jumping in the open water of the lake. Now this evidence is obviously imperfect, but it indicates the same conditions I have found elsewhere and it agrees with the situation in Lake Tazlina which we studied a month later. It looks much as if the fish in their movements followed the general shore outline of the lake and in the rivers also moved along near the banks. Much more evidence will have to be collected before one can accept this as a final demonstration. Meanwhile, it may be taken as a working hypothesis. There is every reason to accept it as the only possible condition of movement through difficult channels, such as the Abercrombie Rapids, and it will aid in explaining the conditions of movement into subordinate streams.

The situation just pointed out has a very direct and important bearing on fixing limitations on the fishing of the stream. The Copper River is one of those few streams in which fishing for red salmon is allowed in fresh water. Miles Lake, just below the rapids, is viewed as a splendid fishing ground, and large numbers of fish have been taken in the rapids also. At present fishing is confined to part of one shore, and is entirely forbidden on the other bank. It is apparent at once that if the streams of migrating salmon which pass up both banks go to different spawning grounds, then this method is directly responsible for the depletion of the run at one place, and conversely serves for the protection of those fish that go to another series of spawning areas. It is, I think, further evident that netting fish from the rocky banks along the rapids is well calculated to advantage the fisherman rather than the fish, and to work serious havoc on certain waves of salmon migration, for whether the fish go to a set of spawning grounds connected with that bank only or are dispersed more regularly over the different spawning grounds of the upper river, the excessive catching will reduce to a minimum the number of fish that escape, and may even be sufficient, by virtue of the concerted fishing of a line of dip-netters along this bank, to eliminate almost entirely the run that is passing up at the time intensive fishing is practiced.

In general it seems as if river fishing for commercial purposes were inadvisable in Alaska streams.

There is another physical factor which I am led to think exerts a controlling influence in some cases, at least, on the movements of the red salmon, and that is temperature. Of this influence I have spoken more fully in another place. But to avoid possible misunderstanding, a brief general statement must be introduced here. At the start one should bear in mind that the influence may be very real without being absolute. In other words, it is only one of the factors which determine activity and in a given case may be more or less influential than another factor. Again it is contact with a change in temperature rather than the absolute level of temperature which ordinarily at least affects the red salmon. There are two crucial points or types of choice in the fresh-water career of the red salmon. First, when such a salmon, moving upstream, reaches a place where two streams join, it must take one or the other path—and, as already stated, its path is fixed and invariable; it always selects one and not the other. Second, when the red salmon, having attained the lake in which it is to spawn, comes to choose a spawning ground, it selects one or more areas for that purpose. While the choice of the salmon in this respect has not been so generally recorded, yet it is confined in fact to a few places, or even to a single stretch of the shore or a single small inlet, even though other points seem to the observer to be equally favorable. In other words, the choice of a spawning ground is precise and definite. In both of these crucial choices, I think the salmon is influenced primarily by temperature conditions, and I propose now to set forth briefly some of the evidence that leads me to support this view; and then to consider the practical bearing of these views on the problems of salmon culture and conservation. Out of many localities studied, I select two for detailed consideration.

Clear Creek, a small tributary of the Copper River, empties into the easternmost channel of the river, a few miles above its mouth. At the time of our first visit, July 22, the red salmon were schooling in considerable numbers in every pool along the lower course of the creek. There is no lake at any point on the creek. Near the mountains the stream is marshy, sluggish and shallow; but from the moment it leaves this area it is a winding stream with alternating deeper pools and shallows, all with a gravel bottom. Not a single red salmon was seen above the point where the stream came from the broader, shallower and more sluggish area and there was no trace of previous spawning above this point. However, from a point a few yards below that area throughout the more swiftly flowing section of the stream, salmon were abundant nearly up to its junction with the Copper where the waters were deeper and quieter. We also found the fish spawning here on our return from the trip inland. There was, however, at that date, September 6, no opportunity to examine the stream more in detail.

This statement of conditions shows clearly and strikingly how Clear Creek differs from the ordinary spawning ground of the red salmon. Here the fish are spawning not in a lake but in the stream itself. Furthermore, they have not picked out the slower and more quiet portions of the water course but are found only in those parts which have a steady and considerable current. Finally, they have not penetrated to the real headwaters of the stream but are all grouped in the lower half of its course. A series of temperature readings taken with some care showed the following situation:

The east channel of the Copper above the mouth of Clear Creek had on July 22 a temperature of 48.5° F. At the same hour the temperature of Clear Creek fifty yards above its mouth was only 44° F. At the railroad trestle the temperature of the creek had dropped to a level of 42° to 42.5° F. A mile above this and just below the marshy region it was again 44° F. and the same temperature obtained throughout that region. The stream thus showed in the first place that it was 4° cooler than the water of the Copper River at their junction, and that the temperature after falling 2° at the trestle again became warmer some distance farther up at the marshy region. On running a line of temperatures across the stream above the trestle it appeared that near the right bank the water was 43.5° to 44° F. In the center it was full 44° and near the left bank it varied from 41° to 42.5° F. Furthermore, the lowest temperature found was in only one or two limited areas. The exact examination of these places demonstrated the presence of an inflow of seepage water not sufficient in amount to constitute a visible spring or localized at special points, but flowing in over a small area of the bottom in sufficient quantity to reduce the temperature very noticeably at that point.

It should be mentioned in this connection that the temperatures are not constant from day to day, for on the following day, July 23, the stream was about 2° colder, as the temperature at the right bank was 42°, in the center 42.5° and at the left bank 39.5° F. On the same day the temperature of the Copper River where the railroad track crossed the east channel was 49° F.

It was evident that the stretch of Clear Creek above the trestle was supplied along the left bank constantly and largely with seepage water so that the temperature was kept distinctly below that of the stream above, and it was in this section that the fish were most abundant and most actively engaged in nest building, as well as furthest advanced in coloring and consequently nearest the spawning period. Above the point where the stream emerges from the marshy region there was detected little or no cold water seepage from the bank, and consequently the temperature of the water was distinctly higher. The amount of water added to the stream in the way indicated must have been considerable, for the volume of Clear Creek where it flows under the trestle is apparently at least twice as great as where it emerges from the swampy area, a mile or two above the trestle. These facts serve to explain that the situation in the stream accords with the movement of the salmon, which kept themselves in the cooler part of the creek and spawned in the section where a steady inflow of cold water gave the minimum temperatures found in the stream.

Although this spring-fed region is the coldest area of the water during the summer season, it will evidently be the most stable and hence the warmest during the winter. According to the testimony of men familiar with the region, this part of the stream remains open until very late in the year and does not freeze over until long after other waters are solidly covered with ice. Evidently also the gravels in the vicinity of springs are least likely to become frozen and hence afford greatest protection to the developing eggs. Jordan and Evermann (1904) state that freezing kills the eggs, and if any areas in this region avoid that condition in the long, severe winter, it must be the gravel beds in which springs emerge.

On the west side of the Copper River valley at a distance of 20 or 30 miles from the stream and about 150 miles from the mouth of the Copper River are three large lakes that have been said to be important spawning grounds for the red salmon. These three are lakes Tonsina, Klutina, and Tazlina. Lake Tonsina is the farthest south and the smallest. Lake Tazlina lies 50 miles northwest of it and is the largest. Lake

Klutina, located midway between, is intermediate in size. The lakes are alike in being crescentic in form, surrounded, at least in part, by mountains and fed by the run-off of great glaciers. The two larger lakes are 20 to 30 miles long and 5 to 6 miles in maximum breadth. The upper horn of the crescent points pretty nearly east and gives rise to a stream which is the outlet of the lake. The other horn points nearly straight south into the mountains and is in connection with large glaciers. Each lake has several lateral tributaries. In each case certain of these tributaries carry salmon and afford spawning grounds for them, whereas others are without these fish. A stream known as Saint Anne Creek enters Klutina Lake from the northwest. This stream was visited twice during our stay in that region.

Our visits fell fortunately at times that yielded important results for the general problem under discussion. Saint Anne Creek is a small stream which enters from the northwest approximately at the center of the outer curve of the crescent of Lake Klutina. It drains a considerable body of shallow water known as Saint Anne Lake, which is located about six or eight miles from Lake Klutina and is about four miles long by one mile wide. The stream has a gentle fall over a gravelly bottom without rapids or serious obstructions. While the depth does not vary greatly, the creek forms a succession of small curves, in the elbow of which a deeper, more quiet area alternates with the shallower, swifter stretches connecting the quiet pools.

We first visited this creek on August 10, passing up through the stream bed a distance of three miles or more. A large number of spawning fish were seen. The shallow stretches along the inside of the curves made by the stream were covered with dead fish. While many of these fish had been partially eaten by bears, the majority of them were relatively fresh.

This stream has a broad and shallow delta in front of it, so that the water spreads out widely before coming in contact with the main body of the lake. At the time of our visit the current in the outlet was gentle, so that the mingling of the waters with the lake waters must have been very gradual, and this could be followed by the eye since the creek carried clear water whereas the lake waters were milky. No evidence was found at this time that any fish were entering the creek from the lake or were waiting around the mouth of the creek.

At this time the temperatures taken were as follows: In the lake 100 yards from shore and an equal distance below the mouth of the creek, 49.5° F.; 100 yards above the mouth of the creek, 48.5°; in the creek 250 yards from the mouth, 47° F.

On the following day we went to the head of Lake Klutina and did not return until August 19. On that date a trip up Saint Anne Creek a distance of two miles showed that the spawning fish which had been abundant in the bends eight days before had almost entirely disappeared. Only a very few spent fish were still alive. Furthermore, the dead fish which were on hand in large numbers on the shallows had been eaten on the spot or dragged away, so that only scant traces were left of the very considerable numbers conspicuous at the previous visit, and the visible remains were mostly skeletons picked clean. It would have been difficult for anyone who visited the creek on August 19 to have made any accurate estimate of the actual number of fish which were spawning there only a few days before. Fish were still passing up the lake in large numbers, and apparently going by the mouth of this creek. There was no evidence that any had entered the creek recently or were inclined to consider using the stream as a spawning ground.

This instance indicates very clearly that a single visit to a stream, unless it occurs at a time that is distinctly favorable, may give a false impression concerning the utilization of the stream for spawning purposes or the size of the run that visits this particular spawning ground. It will be noted that during the time between our visits the volume of the outflow of the stream had also decreased considerably, for we were able to ford the creek at the mouth, where on the previous visit the water had been 12 to 15 inches deeper and fording was impossible.

Later we visited Saint Anne Lake and a study of the conditions there indicated clearly a marked and constant reduction in volume and a gradual rise in temperature during the period just before our arrival at the lake. For a considerable period the weather had been clear and sunny with very little rain. The general aspect of the country shows that Saint Anne Creek gets the major part of its volume from the lake and only a smaller amount from lateral tributaries. The lake lies in the flat land distant from the mountains, and can not be in receipt of a constant supply of cold water from melting snows. When the winter snows have mostly melted and the storms of early summer are at an end, the water level of the lake stands at its maximum height and the outlet creek carries its greatest volume of water. The lower end of the lake near the outlet, a stretch of two or three miles in length, is very shallow and had warmed up considerably in comparison with the other waters we had tested. In consequence, at the time of our visit its temperature stood at 55° F. Colder water was running into the creek at various places along its course. and the volume of this inflow was sufficient to reduce the temperature of the stream below that of the lake when the discharge from the lake was reduced in volume. During the warm sunny days which characterized this period there was opportunity for the water in the creek to become distinctly warmer than it had been earlier in the year. This evident change in temperature, of which we observed the last stage only, was associated with the cessation of the red salmon run and the termination of the spawning by that species in its waters.

The study of the situation at the head of Lake Klutina, which I have discussed in detail in another place, showed that at the time when the fish had evidently just stopped turning into Saint Anne Creek they were just beginning to locate on the spawning grounds at the head of Lake Klutina. We were exceedingly fortunate in having made by chance our visits to these places at the time when the shift was taking place. According to our observations, then, one may provisionally state the movement of the fish through this section in the following brief form: Those red salmon which, coming up the Klutina River, follow along the left bank of Lake Klutina (the outside of the crescent), turn first into Saint Anne Creek and only later, when the lessened volume of that stream and its rising temperature fail to bring them under the influence of a directive stimulus, do they pass towards the head of the lake, where they meet stimuli attracting them to the spawning grounds in that region.

In the selection of spawning grounds temperature also appears to play an important part. A single illustration will suffice here to show the general conditions which I have discussed more fully elsewhere. At the head of Lake Klutina a series of low, irregular projections of the shore create a succession of small inlets or sloughs. These are highly variable in form and size. They resemble each other in physical conditions as far as these are discernible by the eye. They are not separated from each other by any considerable distance, and there is no physical barrier which would direct the fish towards one rather than another, unless it be the current coming from numerous small channels of the rivers emptying into the lake at this end. However, these channels and their currents are related to the sloughs in variable fashion so that it was not easy to detect any constant difference in the influence that they might exert upon the situation.

In some of the sloughs red salmon were spawning or building nests. In others there was no trace of fish at the present time and no evidence that they had frequented the spot previously. Along this bluntly rounded end of the lake the temperature of the surface water was 49° to 50° F. In the sloughs where the fish were spawning the temperature was from 37° to 40° F. It should be noted also that the water in these particular sloughs was brilliantly clear in striking contrast with the milky water of the lake and more brilliant than the relatively clear water in the other sloughs. A study of bottom conditions showed that the places where spawning was taking place were the seat of small bottom springs or a steady general seepage not sufficient to produce any visible current, but enough in calm weather to extend the influence of the clear waters well out into the milky waters of the lake proper.

Some of these indentations of the shore were branching, and the different branches were distinguished again by temperature only. No place was found where the fish entered the branches which conform in general temperature to the lake, and no branch was found in which the temperature of the water was distinctly below that of the lake in general that did not have at the time of our visit some fish spawning or building nests and showing by their color that the period of sexual maturity was at hand.

Some of the small channels running into the lake at this point were distinctly cooler than some of the inlets and comparable in temperature with the others, as they registered levels of 37.5° and 38° F. We ascended one of these channels and encountered one red salmon in the act of climbing a beaver dam. We were not successful in the time at our disposal in reaching the actual spawning grounds on any of these tributaries.

PHYSICAL CONDITION OF SPAWNING SALMON

The condition of fish on arrival at the spawning grounds has been vividly described by different observers. In the main they have emphasized the fact that during the migration the salmon suffers conspicuous injuries, and often arrives at the spawning grounds in a very dilapidated condition. It was interesting to compare with such statements the condition of fish as observed both on Lake Klutina and on Lake Tazlina. Nowhere were the fish appreciably mutilated; in fact, I do not recall a single instance in which a living fish showed marks that were the result of a struggle with the stream. Despite the fierce current of the Copper River, the strenuous passage of the Abercrombie Rapids, and the still more violent conditions of the Klutina or Tazlina River, the fish that we caught alive in the lakes or saw on the spawning grounds adjacent to them were in perfect condition. It is true, to be sure, that at no point in the course which they have followed was it necessary for these fish to contend with falls. I have discussed elsewhere the jumping of the salmon, and have called attention to the fact that their work is by no means as perfect as sometimes supposed. The facts are that when salmon are striving to surmount a fall not more than a small fraction of the jumps is successful, and many of the efforts result in dashing the fish against the face of the fall or on rocks standing in the stream bed at the foot of the drop. From such adventures the fish drift away stunned, and require some time to recover their wonted activity. They are also badly battered by the collision and in some cases suffer so that they are unable to carry out the migration and reach the spawning ground.

The extent to which migrating salmon suffer from this has been vividly described by several observers, including Evermann* and Rutter. It is not to be wondered that the efforts of the fish in leaping are relatively so little successful, for the base from which they take off is a most inconstant and swiftly changing one as the different currents in the water swing in eddies to and fro at the base of the fall. One has only to watch conditions there to see the difficulties under which the jumping fish labor, and to get a full explanation of the condition of the fish as a result of its many attempts to surmount the barrier. Now the effort to ascend a rapid may be unsuccessful also and even the maximum expenditure of energy

* Evermann (1897) holds the view that these bruises are received after arrival at the spawning grounds. While this is largely true, it is not universal by any means.

may result in the failure of the salmon to reach the spawning ground, but this failure is not the result of injury such as comes from the failure to make the falls at a given leap. It is, then, readily inferable that streams in which rapids form the barrier to migration are on the whole more favorable for the salmon than those which are barred by falls.

One may even go one step further and suggest that at times a little human labor might greatly improve conditions for the salmon run in a given stream, if the worst natural obstructions were removed or made less difficult by the construction of an artificial pathway around the obstacle. The older idea that struggle is essential for adequate production of physical vigor doubtless has its basis in fact, but it is subject to limitations also, and under reasonable conditions our domestic animals, which are protected from dangers and from too great physical effort, yield a much larger return to the human race than ever was secured from range animals. I think it is not unreasonable to look forward to the time in the near future when certain salmon streams, at least those which are peculiarly significant in connection with the spawning of the salmon, shall be so handled as to simplify and expedite the migration of the fish, enabling them to reach the spawning grounds in better condition than they do with the stream as it stands. The investigations of Canadian officials have within recent years shown most conclusively how the additional obstacles which were inadvertently introduced into the channel of the Fraser River have worked havoc with the salmon run of that stream and have prevented an unfortunately large percentage of the salmon entering that stream from reaching their spawning grounds. The readjustment of conditions at this point, which was provided for by the action of the fisheries officials, is precisely in line with what I have suggested for the removal of serious obstacles existing naturally in that or other streams. A comparison of the fish in the spawning grounds of Lake Klutina and Lake Tazlina with those which visit some other places, indicates clearly the difference in the expenditure of energy on the trip from the sea.

It was not merely with respect to the absence of disfiguring wounds that the salmon of these lakes commanded our special attention. They were plump and full-meated, the flesh firmer and the body less wasted than in the case of salmon at corresponding periods of sexual maturity in other regions. It would be unwise to attribute the perfect condition of these fish solely to the favorable character of the highway that had served as the route for their migration. These northern waters are also radically lower in temperature than the waters of more southerly streams, and that factor must certainly have been of some influence. It may also be that the fish at the start of their migration were in better condition, more richly supplied with reserve material, and more vigorous in general than those in other regions. In order to test the character of the flesh, we tried a fully ripe fish on the spawning grounds, and found that the flesh, though not comparable with that of a fish in prime condition, was still possessed of the salmon flavor and in every way thoroughly palatable.

One other item is worthy of note with reference to the condition of these fish. Among the dead specimens which were thrown up on shore were found a number of females in which the eggs were not yet fully discharged. Such fish were frequent enough to attract our attention. They seemed on examination to be in good physical condition; the substance of the body was not in any apparent way more wasted than that of other fish that were fully spawned out; the eggs themselves were ripe, apparently not matted, attached, or in any way mechanically prevented from reaching the exterior; so that one was entirely at a loss to suggest why in this case an amount of eggs totaling in the extreme perhaps one-fourth or one-fifth of the entire egg mass should have remained in the body not discharged by the process of spawning.

DESTRUCTION OF SALMON BY NATURAL ENEMIES

Much has been said and written by various persons regarding the destructive tendencies of some animals that naturally prey upon the salmon for food. Among the enemies thus charged with responsibility for the decrease in the numbers of red salmon are eagles, gulls and bears. Under the terms of a law placing a bounty on eagles, some 15,000 have been slaughtered in Alaska during the past four years. It is possible that these birds take occasional toll of the living fish during the migration, but it is certainly infrequent and constitutes in total an altogether insignificant factor in proportion to the number of migrating salmon and the number destroyed by other means. The gulls pick out the eyes of salmon thrown on the bank by fishermen or of spawned-out fish floating about or cast upon the shore. They also sometimes dig into the body of dead fish to get the liver or such eggs as may not have been discharged. Of course, it is possible that under peculiar circumstances they may attack living salmon but ordinarily any such action is impossible. In any event they exercise no appreciable influence on the situation.

The depredations of the bears are more significant. As I have described elsewhere (Ward, 1919) their behavior when feeding on salmon at the spawning grounds, that element in the situation may be summarized briefly here. The bears there catch and eat chiefly if not solely the spawned-out and dead fish which are floating in the stream or are thrown on the shores, and they do not molest appreciably the spawning fish. Perhaps this condition is modified by food scarcity such as would be associated evidently with a very scanty run of fish, but I have no evidence of any kind to support such a view.

Where the salmon run up small streams or where the water is shallow and conditions favorable, a bear may indulge in the sport of tossing the active fish out on the bank and have a good many fish distributed over the scenery so that it looks as if the destruction wrought had been considerable. From an individual standpoint it evidently is, and no observer can help be astonished and dismayed at the sight if he chance to stumble on such a place and to see a lot of fine fish scattered over the grass or among the bushes alongside of the stream. But a little analysis will serve to show the relation of the occurrence to the salmon run in a fairer light. The places on any stream where this can happen are not numerous, the days on which it is possible are certainly few, stages of water, hours of daylight and periods of salmon migration being duly considered; and finally the bears are after all few in number. In consequence the total loss due to the work of the bears is not large in comparison with the number of fish that visit a given stream. It is unquestionably much less than the losses due to low water, or the accidental obstruction of a stream. It is trivial compared to the toll of fish taken for commercial purposes and could be made good several times over if only part of the wastage in the commercial fisheries were eliminated.

REGULATION OF SALMON FISHERIES

The bearing of these facts on the questions of fish conservation, the effective regulations that should be adopted, and the degree to which their enforcement is essential, can be set down in brief form.

Among the various plans which have been adopted in different places to regulate salmon fisheries and to permit the adequate visitation of the spawning grounds, is one to allow intensive fishing up to certain limits and to stop the taking of fish at that time so that the remainder of the run may reach the spawning ground unhindered. The limits set have sometimes conformed to the calendar, so that fishing was permitted within certain dates and absolutely prohibited before and after the limit, or the restriction may have taken the form of limiting the pack, so that a fixed catch or definite output was granted to the cannerymen, and when that limit had been reached all fishing was stopped, so that the salmon arriving subsequently passed unhindered up the stream.

There are evident difficulties in this procedure, and some of them seem to be very serious. It is clear that in the period in which fishing is permitted, the taking of fish will be pursued with maximum intensity and every effort be made to secure the largest possible number of fish during the open season. If all the fish that entered a given stream were bound for the same spawning ground and if conditions for their progress upstream and for the deposit of eggs at the spawning ground were uniform at all periods, then this method would only have the disadvantage that if fishing were practiced too assiduously during the period of maximum movement or if by weather conditions the run of salmon were concentrated more narrowly than usual, then the percentage of the total run that would be taken might easily exceed that which was desirable. Many observers have noted the fact that when weather conditions hold back the fish, because especially of low water in the streams, and then abundant rains cause the streams to rise suddenly, the fish will go up with a rush. This is a characteristic phenomenon in southeastern Alaska on the smaller streams. It means that the fish are schooled longer than usual in the estuaries, and because of their having been brought together can be seined more easily and the complete run be caught with the minimum effort.

The case is somewhat different in those large rivers provided with numerous spawning grounds. Here the stage of water plays a very minor part, and significant fluctuations are not noticed in the lower courses of the stream. Furthermore, in such cases the migration continues over a much more extended period of time. The evidence which I have given from our studies on the Copper River substantiates fully the observations of Gilbert and Babcock on the Fraser River. The fish which start first are bound to one spawning ground, and those which follow at subsequent intervals are distributed over other spawning territory. In such an instance as this, to permit intensive fishing during the early part of the run would eliminate from reproduction a very large proportion of those going to a particular spawning place, and might indeed subject that portion of the run to total extinction. Our experience with reference to the conditions at Lake Klutina and especially with that part of the Klutina run which spawns in Saint Anne Creek is most illuminating. We did not see this run start, but we were on hand to witness its cessation. All of the fish which came after a certain date went to other spawning grounds, and the fish which spawned in Saint Anne Creek were taken from that portion of the run which reached this place before August 19, approximately. If intensive fishing had been permitted during the time when these fish were passing the canyon, it is not difficult to see that the number which escaped and passed up to this spawning ground might have been reduced practically to zero. Intensive fishing within a limited period is evidently equally dangerous if practiced outside the mouth of a river or on the coastal flats over which the salmon approach a spawning stream.

It is evident that where the limit is set upon the number of fish which may be captured or the number of cases of fish which may be put up, much the same conditions will result. It is of course in the interests of any commercial organization to take its catch in the minimum possible time, and to handle it with the maximum efficiency and expedition. Thereby the cost of the work will be reduced to the lowest figure and the profits be correspondingly increased. The method of limiting the catch by quantity protects the run of fish against the possibility that if the run happens to be concentrated by weather conditions, seining within a limited period may secure much more than the amount that was planned for removal; and a quantity limitation on the catch, if rightly related to the total run, permits the escape of an adequate number of spawning fish, so that the spawning beds may be properly seeded.

Nevertheless, the quantitative limitation is open to the serious objection that it does not take into account any unusual fluctuations of the run. Even if adequate allowance be made for the normal and usual variations in the number of fish ascending a given stream, it is evident that the number of fish taken under a permit based upon such a calculation may easily be distinctly excessive in those exceptional years when for some unknown cause the run of fish drops well below the average minimum. The taking of a set number in such a year may reduce the run to dangerously low margins, and seriously encroach on the normal yield of those waters.

If a quantitative limitation is to be placed upon the fisheries, it must be set so low that in the exceptional year enough fish can get by the fishermen to insure the maintenance of the run in the stream, and if there is a series of imperfectly separated waves of migration in the general run of that stream, then regulations must be so phrased that they will prevent the extermination or even the serious reduction of the run to any single spawning ground. The catch of fish can be distributed equally over the groups of salmon that seek to spawn in different places only when the fishing is more or less continuously carried on throughout the period of the migration and is so limited that no single wave of movement can be deprived of an undue proportion of its fish. *Intensive fishing during a limited period is unwise.*

THE PERMANENT PRESERVATION OF THE SALMON

One other point of fundamental importance enters naturally into this discussion and that is the formulation of a permanent policy with reference to perpetuation of the salmon. Evidently with the development of the country and the larger utilization of its timber and of its surface for agricultural purposes and with the modifications which the streams will thereby necessarily undergo, it will become impossible to preserve everywhere and fully the favorable conditions that exist in the wilderness for the spawning of the salmon. The increase in population and insistent demands for more land and for the utilization to their fullest extent of all natural resources, must and will change conditions rapidly so far as the streams are concerned. When timber is cut off and large areas of land are devoted to agricultural purposes, the volume of the streams will diminish. As lakes are dammed to make reservoirs for irrigation or for hydro-electric power, spawning grounds will be necessarily covered and areas that were formerly resorted to regularly will become unsuitable for the spawning of salmon. It will evidently be impossible to preserve exclusively for the use of the fish all of the streams and all of the spawning grounds upon which they were dependent under natural conditions.

Of course, fish culturists and all of those interested in the preservation of the fish fauna and in the utilization of this important type of food will exert every influence to keep conditions so that spawning may continue to be possible on the old grounds. It is not my thought at all to suggest that the arbitrary changing of channels or filling of streams should be approved, or that the building of dams without fishways should be countenanced. Unnecessary waste and easily avoidable losses should be guarded against constantly so that our magnificent natural resources in fish life may not be wantonly destroyed. Least of all would any thoughtful person seek to excuse the sins of cities and of manufacturing plants which are pouring immense amounts of city sewage or of industrial wastes into streams and are reducing fertile aquatic feeding grounds to barren and loathsome aquatic deserts. The barbarous practices of commonly passing the expenses of the city or of the industry on to those who have rights on the stream lower down, or would utilize it for rational pleasure and profit, deserve the severest condemnation and should be done away with by legal measures and at the earliest possible date.

However, if all of these unreasonable and avoidable destructive tendencies have been eliminated, there still remain legitimate and unavoidable limitations set by the changed conditions which will modify the water courses frequented by the salmon sufficiently to exert a serious influence upon the supply of these fish. So long as rivers flow through a wilderness and so long as the population in the contiguous areas is not large, we may hope to preserve the runs in all their natural wealth and variety. But when the changes come it will be necessary to adopt other plans, and before that time arrives it is wise to consider what policy is to be followed with reference to the new conditions.

It is evident that the short streams with exceedingly limited drainage areas and a brief course from the lake, in which the red salmon spawn, to the ocean from whence the adult fish came, will be the most readily preserved. Under this heading come many streams of importance for the red salmon in British Columbia and southeastern Alaska. On the other hand, long rivers with extensive drainage basins and complex systems of tributaries will offer the greatest difficulties. In this class fall particularly the Fraser River in British Columbia and the Copper River in Alaska. The situation is somewhat the same on the Columbia River and possibly also on the Yukon, with which I am not personally familiar. Perhaps there are also other streams that approximate the same conditions.

In the Fraser River a careful study extending over a series of years has been made of the spawning grounds, and the character of those areas, as well as the number of fish by which they were visited, has been pretty definitely determined. Full data are given by Babcock (1914) and Gilbert (1914). A recent examination has shown that even now some of the spawning grounds are practically unvisited since the fish which would normally seek those areas have been killed off. Now the causes which are responsible for the destruction of these fish, and thus for the total elimination of part of the run of the river, are unfortunate in the highest degree because an earlier recognition of the situation and a more perfect co-operation between all of the interests involved might have spared us this great loss. However, as outlined above, the result is much the same that must be expected with the development of any such region.

Even the Copper River which flows through an area as yet almost unutilized, and drains a region in which the population is exceedingly scanty, has been affected by similar conditions which are already recognizable. This is illustrated by my experience at Chitina. A small creek flows down from two small lakes in the valley a short distance above the town and empties into the Copper River a mile or more below it. The stream is never more than 4 to 8 feet wide and 6 to 10 inches deep. At several points in the town and just above it the course of the creek is nearly blocked so that it was evidently difficult for the fish to work their way up. Indeed, at one point at least it was absolutely barricaded by a mass of brush and rubbish that had been dumped into the water, and fish no longer spawned in the lake above to which, according to the reports of residents, they had formerly resorted.

Drip and waste from a large oil tank on the railroad south of the town had at times, according to reports, spread over that part of the stream and must have done real damage to the aquatic life in the small lake which the creek has formed there. This is a serious menace to the salmon fry that hatch in this stream. The salmon run in Chitina Creek is thus threatened at two points in the life cycle of the fish, viz., the spawning of the adult and the growth of the fry, and unless prompt attention is given to the problem this portion of the Copper River run will soon be only a matter of history. The town is very small and of most recent origin, and the incident serves to show how very early the effects of settlement are observable on salmon streams. A rational policy must recognize such situations and decide in advance on the action to be taken; otherwise the total destruction of the salmon will be surely though gradually, and perhaps insensibly, brought about by the elimination successively of individual units in the run of a given stream.

It is to be recognized then that ultimately the preservation of all the spawning grounds, or even of all the streams, will inevitably become impossible and that the conservationist and fish culturist will be forced to formulate a policy for the handling of the problem. In view of this I think all will agree that it is important to do the fundamental work essential at the earliest feasible date and to outline the policy, as well as analyze and discuss its details, before the situation becomes so serious that action must be taken promptly, and while adequate time is still available for careful study of the situation. It seems to me that the very first step in laying the foundation for this policy in the future must be to make a thorough survey of all the salmon streams after the manner in which this work has been conducted on the Columbia, the Fraser, and possibly a few other rivers, so that complete and accurate information is at hand concerning the size of the run, the precise course or courses followed by the fish in their migration, the period during which the migration takes place, and the actual spawning grounds to which the fish resort. No less than the information obtained by such a careful survey will show the relative importance of all the factors that enter into the situation or enable the fish expert to determine the relative value of different parts of the stream or of difficult runs in it.

Thus if reduced stream flow be the serious factor in the changed conditions with which the fish have to contend, then that part of the run which seeks to make its way to the spawning grounds at the time when the river is sure to be low and decreasing in volume, is much more susceptible to the danger, and consequently much more difficult to preserve than another portion of the run which is so timed in its movements that its migration is completed before the low water should be feared, or which does not start until after danger from such a condition has passed. Such an example shows very clearly also the need of determining all the conditions for the particular stream in question since some streams derive their water supply from territory that is well furnished with ground water during the early part of the summer and scantily supplied later in the season, whereas other streams that have their sources in snow fields or glaciers are dependent for water changes upon the effect of summer temperature in melting these fields and upon the area of the fields themselves, since the period of abundant supply by both factors would be determined. Not only each river basin but even each important tributary would constitute to a considerable degree an independent problem, and the record of all the facts in the case would be essential for the formulation of a permanent policy regarding the preservation of the salmon run in that stream, or of any part of it.

Very evidently one of the serious dangers which the red salmon have to face is the commercial utilization of the streams which they visit. The erection of immense dams and the transformation of large stretches above them into reservoirs so that the water may be used for irrigation or hydro-electric power, is a most serious menace to the salmon runs in such a stream. In many cases it will be apparently necessary to choose between the destruction of the salmon and the abandonment of the project for utilizing the water in the stream. This is by no means a simple problem from the standpoint of general public welfare. To be sure the practice of engineers seems to have omitted from consideration entirely the question of the fish supply of the stream and the fact that it also is valuable. Water rights have been acquired and in some instances utilized without even a superficial attempt to relieve the situation by constructing a fishway that might be made use of by the migrating salmon.*

In many instances, however, even the most perfect provision of this sort would be inadequate and it is difficult to see how an effective fishway could be constructed on any plan yet proposed that would surmount a dam behind which the impounded water varied greatly in level. When the size and

* For a conspicuous instance of this and the evidence associated with it, see the article on the Atlantic and Pacific Salmon (Ward, 1920 a).

quality of the salmon run justifies it, new installations may prove adequate to preserve the fish even under the adverse conditions outlined. The migrating salmon will collect at the foot of the dam and mature there; they can be stripped and the eggs after fertilization cared for in a hatchery located either above or below the dam wherever conditions for its maintenance are most favorable.

Should conditions below the dam be such that the fish can not be held and ripened, then it is feasible, I believe, though more complex, to solve the problem by lifting them over the dam. I have rough sketches of a carrier I designed for this purpose which has been pronounced practicable and not expensive to operate at such a point. Some experiments are necessary to determine its success in actual operation but I am sure the situation is not hopeless as some incline to believe. Such a carrier is readily adjustable to differences in water level above the dam.

The handling of the young fish from such a hatchery involves some complex questions. They could, of course, be planted easily in the new water body created by the dam, and if distributed rationally, would probably find adequate food and protection, though, of course, a careful study should be made of the new environment beforehand and of the salmon fry after planting. The outlet of such an artificial lake must be fully protected, since either irrigation ditches or the turbine of a hydro-electric plant would destroy the young fish. Such protective measures are not difficult to provide, but must evidently be kept in perfect condition during the danger period. Furthermore, provision must be made at the proper time to lift the young fish over the dam and release them in the stream below that they may continue their migration seaward.

Of course it may be possible to plant the fry in another natural lake where conditions are favorable for their growth and where the outlet stream offers no dangerous obstacles to their natural movement towards salt water when the proper time comes. But in my opinion such a lake, if its utilization is to be successful, should not be nearer the sea than the original home of these red salmon fry, nor less abundantly supplied with their proper food, nor unfavorably affected by lack of protected areas, abundance of predatory fish, or temperature changes towards which the fry react unfavorably. Otherwise they may be destroyed or be stimulated to migrate too easily, and Gilbert has shown that salmon entering the sea prematurely must perish since they never return to spawn.

In case it is not feasible to install a hatchery and care for the eggs of the salmon that have been held up below the dam, then they certainly should be enabled in some way to pass this obstruction since they cannot spawn naturally below it, and to prevent their going up stream farther will inevitably result in the destruction of the run. This was demonstrated on a grand scale with the Atlantic salmon more than a century ago and no further experiments are needed to establish the fact (Jordan and Evermann, 1902:164). It must be confessed that under the changed conditions the results are uncertain in any case. The introduction of a new water body of large area in most cases has modified natural conditions greatly. The fish will not be directed by the same stimuli that controlled them before; the current is greatly reduced or entirely lacking, and the temperature certainly highly modified so that the behavior of the salmon cannot be foretold. But when the new lake has not covered the original spawning grounds, one may expect the fish to reach them and to spawn naturally. In this case it will be necessary to protect the outlet of the artificial lake and to lift the young salmon over the dam when on their downstream migration they reach that point. But, as suggested above, even this type of situation is fraught with uncertainties. The impounding of a huge mass of water and the formation of a great artificial lake has modified biological conditions fundamentally. The depth of the water, the current, the character of the bottom, type of materials in suspension and possibly also in solution, and the temperatures of the water at different times and places have undergone striking changes, so that it is impossible to predict their influence on the movements of the fish.

Still further complications are introduced if the new lake covers up the original spawning grounds of the salmon. No evidence has been adduced to show that the red salmon spawn elsewhere than in shallow areas contiguous to the shores of the lake. I have cited above some of the evidence to show that the spawning grounds selected are not only shallow areas of suitable material, but are also locations at which one finds an influx of colder water, reducing the temperature at the spawning period below that of adjacent waters. It is perhaps unlikely that they can find new areas of precisely similar character, and certainly the range of adaptability in the selection of a spawning ground, while unknown, is not likely to be great. However, if the lake made by the dam has covered up the area on which the fish were wont to spawn it is wise to determine experimentally whether they can find another equally fit place or be able to accommodate themselves at all to the new conditions. Nevertheless, after all these possibilities are taken into account, I fear that in some instances one will still be compelled to face the unfortunate dilemma that was suggested above: If the fish are to be preserved the project for the utilization of the stream water must be abandoned, or, if the stream is to be utilized according to the plans of the engineers, the salmon run will be destroyed.

There is, of course, the possibility that in some mechanical fashion the fish could be diverted from the channel which had been their natural route of migration for an unknown period and thus led to ascend some other tributary which would carry them up to a possible spawning ground, and that in the end this new ground might prove suitable, or at least sufficiently so to preserve in part the run of fish. Some experiments have been interpreted as indicating that the red salmon could be forced by circumstances to select new spawning grounds and that these would prove to be adequate for the perpetuation of the species, but the data are involved and scanty and it would be venturesome at the present to maintain that the experimental evidence is really sufficient to establish the possibility of thus modifying the habits of fish.

It has occurred to me as a very interesting possibility that the physical conditions, especially as regards the temperature of water, might be so radically modified by the erection of a great dam, and impounding of a vast area of water, that as a result the fish would find at some junction point in the stream different relative temperature conditions from those that had existed previous to the erection of the dam and the creation of the reservoir. If conditions should be thus changed and the views which I have advanced concerning the directive influence of temperature be correct, then the migration path would be changed, naturally as it were, and the fish would follow to parts of the stream which they had never visited before.

I have devoted considerable time and space to the analysis of the problems presented by the erection of dams since I believe it to be the most serious and immediate danger which faces the salmon in fresh water in some regions. Overfishing can be regulated by law and the run of salmon brought back to a normal level, or at least very greatly increased so that in my opinion the fished-out streams on the Pacific Coast can be restored by appropriate measures. In making this prediction, I am not unmindful of the fact that in the United States and particularly in Alaska the laws governing the fisheries are "obsolete and inadequate," and their enforcement is quite difficult. But some day and most unexpectedly the tide will turn and under sane control the salmon run in those depleted streams will be nursed back to life. Stream pollution, also, which now seems to be at its maximum, will be corrected and aquatic habitats will slowly return to a normal condition. But the wave of development which is just beginning to affect broadly the water power possibilities of the country will bring rapidly changes that are permanent and so radical that unless plans are promptly worked out to meet the situation the salmon will be exterminated in the streams affected and the fate of the Atlantic salmon in the Connecticut River be repeated on the Pacific Coast.*

The value of any particular run of red salmon depends not only on possibility of maintaining the stream as a fish preserve, or of protecting the fish against the changes involved in the utilization of the water for one purpose or another, but also on the condition of the fish on their arrival at the spawning grounds. This may be due in some degree to the length of the trip from the sea to the spawning grounds but it is more largely determined by the character of the stream. If the salmon have to surmount difficult falls and tumultuous rapids, if they must at points fight against a current that is almost insurmountable and are held up by narrows that can be traversed only at certain stages of water, then they are likely to reach the spawning grounds battered and torn, and with energy largely spent. In fact as stated above, in extreme cases a certain percentage of the run does not succeed in surmounting these natural obstacles and so never reaches the spawning grounds or discharges its reproductive function. Evidently then an important factor in determining the proper policy is the character of the stream in so far as it determines the condition of the fish and their ability to reach the spawning grounds. It is, of course, feasible to improve a given stream by blasting away rocks or buildng artificial pools as resting places for fish at difficult falls and rapids. Such improvements have been made and have proved very valuable in a few cases but in general it is not possible to meet the expense of making over a difficult stream.

In determining the relative value of salmon streams one

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* Since this paper was prepared I have received a work by James Ritchie on "The Influence of Man on Animal Life in Scotland" in which these questions are discussed and evidence presented in a remarkably vivid fashion to show the influence of river obstructions on Scottish salmon fisheries and of the river pollution also on the same species. The discussion is illustrated by two striking maps. No one interested in these problems should fail to consult Dr. Ritchie's volume.

must consider also in addition to the foregoing certain other factors such as the magnitude of the run, the average size of the individuals which compose it, the color and richness of the flesh, and similar well-recognized differences between red salmon in different streams. These are too well known to need special consideration here.

The program, then, for the permanent handling of the problem of the Pacific salmon will involve a survey of the territory concerned, the assignment of a definite value to each stream and each spawning ground, and the adjustment of conflicting interests so that the conservation of the important natural fishery resource is not overlooked or neglected in the development of commercial enterprises or in the subjugation of the wilderness to the purposes of settlers. It is of equal importance also to guard the fish against exploitation by fishery interests which are over-anxious for the profits of the present and forgetful of the general public concern for the continuance of the suply on which indeed the perpetuation of the industry is no less clearly dependent.

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'00 Hubbard, Waldo F., U. S. Bureau of Fisheries, Nashua, N. H.
'12 Hunsaker, W. J., Board of State Fish Commissioners, Saginaw, Mich.
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'18 Irondequoit Fish and Game Protective Association, (J. W. Johnston, Cor. Sec.), Rochester, N. Y.
'18 Jackson, R. C., 34 Massachusetts Ave., Cambridge, Mass.
'95 Jennings, G. E., Fishing Gazette, 465 Central Park West, New York City.
'17 Jensen, Harold, Spooner, Wis.
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'03 LAMBSON, G. H., Calif. Fish Commission, Sisson, Calif.
'16 LANDRY, D. J., Lake Charles, La.
'17 LAWYER, GEO. A., U. S. Biol. Surv., Washington, D. C.
'08 LAY, CHARLES, Sandusky, Ohio.
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'16 LIPINSKY, M. N., Winona, Minn.
'19 LLOYD, JOHN THOMAS, College of Agriculture, Ithaca, N .Y.
'06 LOCHER, WILLIAM, Kalamazoo, Mich.
'16 LOWRANCE, W. J., Berwick, La.
'16 LUDWIG, JOHN, Grand Isle, La.
'19 LYDELL, CLAUD, Michigan Fish Commission, Hastings, Mich.
'98 LYDELL, DWIGHT, Michigan Fish Commission, Comstock Park, Mich.
'10 MABIE, CHARLES H., Maywood, N. J.
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'16 MARSCHALK, PAUL, Warroad, Minn.
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'99 MERRILL, M. E., Pittsford, Vt.
'13 MERSHON, W. B., Saginaw, Mich.
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'19 Newark Bait and Fly Casting Club, Split Rock Lake, Boonton, N. J.
'18 New York Public Library, 476 Fifth Ave., New York, N. Y.
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'11 POHOQUALINE FISH ASSOCIATION, care of C. Wetherill, 17th and Lehigh Ave., Philadelphia, Pa.
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'18 RANKIN, EDWARD P., care Miss O'Connor, San Lorenzo, Cal.
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'05 *SAFFORD, W. H., U. S. Bureau of Fisheries, Gloucester, Mass.

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'13 Singleton, J. Ernest, Woonsocket, R. I.
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'91 Smith, Dr. Hugh M., U. S. Commissioner of Fisheries, Washington, D. C.
'99 Smith, Lewis H., Algona, Iowa.
'05 Snyder, J. P., U. S. Bureau of Fisheries, Cape Vincent, N. Y.
'87 Spensley, Calvert, Mineral Point, Wis.
'17 Sportsmen's Review Publishing Co., 15 W. Sixth St., Cincinnati, Ohio.
'16 Spragle, L. H., Henryville, Pa.
'19 St. John, Larry, Chicago Tribune, Chicago, Ill.
'10 Stack, F. George, North Creek, Warren Co., N. Y.
'00 Starr, W. J., State Board of Fish Commissioners, Eau Claire, Wis.
'03 Steele, G. F., Sun Life Bldg., Montreal, Canada.
'03 Stevens, Arthur F., Lodentown, R. F. D. 44-A, Suffern, N. Y.
'12 Stivers, D. Gay, Butte Anglers' Association, Butte, Mont.
'04 Story, John A., U. S. Bureau of Fisheries, Green Lake, Me.
'14 Struven, Chas. M., 114 S. Frederick St., Baltimore, Md.
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'18 Sun, Dr. F. T., President, School of Fisheries, Tientsin, China.
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'19 Taylor, H. F., U. S. Bureau of Fisheries, Washington, D. C.
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'08 Thompson, G. H., Estes Park, Colo.
'13 Tichenor, A. K., Secretary, Alaska Packers Assn., San Francisco, Calif.
'14 Tillman, Robert L., Beacon Paper Co., St. Louis, Mo.
'13 *Timson, Wm., Vice-President, Alaska Packers Assn., San Francisco, Calif.

'92 Titcomb, John W., Conservation Commission, Albany, N. Y.
'01 and '12 *Townsend, Dr. Charles H., Director New York Aquarium, New York, N. Y.
'20 Travers, John T., Bureau of Fish and Game, Columbus, Ohio.
'13 Trexler, Col. Harry C., Allentown, Pa.
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'10 Whitman, Edward C., Canso, Nova Scotia, Canada.
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'14 Work, Gerald, Perkins Hill, Akron, Ohio.
'19 Wright, Prof. Albert Hazen, Cornell University, Ithaca, N. Y.
'16 Younger, R. J., Houma, La.
'99 Zalsman, P. G., Grayling, Mich.

Recapitulation

Honorary	66
Corresponding	12
Patrons	53
Active	467
Total	598

CONSTITUTION

(As amended to date)

ARTICLE I

NAME AND OBJECT

The name of this Society shall be American Fisheries Society. Its object shall be to promote the cause of fish culture; to gather and diffuse information bearing upon its practical success, and upon all matters relating to the fisheries; the uniting and encouraging of all interests of fish culture and the fisheries, and the treatment of all questions regarding fish, of a scientific and economic character.

ARTICLE II

MEMBERSHIP

Active Members.—Any person may, upon a two-thirds vote and the payment of two dollars, become a member of this Society. In case members do not pay their fees, which shall be two dollars per year after first year, and are delinquent for two years, they shall be notified by the treasurer, and if the amount due is not paid within a month thereafter, they shall be, without further notice, dropped from the roll of membership.

Any sporting or fishing club, society, firm, or corporation, upon two-thirds vote and the payment of an annual fee of five dollars, may become a member of this Society and be entitled to all its publications. Libraries shall be admitted to membership at two dollars a year.

Any state board or commission may, upon the payment of an annual fee of ten dollars, become a member of this Society and be entitled to all of its publications.

Life Members.—Any person shall, upon a two-thirds vote and the payment of twenty-five dollars, become a life member of this Society, and shall thereafter be exempt from all annual dues.

Patrons.—Any person, society, club, firm or corporation, on approval by the Executive Committee and on payment of $50.00, may become a Patron of this Society with all the privileges of a life member, and then shall be listed as such in all published lists of the Society. The money thus received shall become part of the permanent funds of the Society and the interest alone be used as the Society shall designate.

Honorary and Corresponding Members.—Any person can be made an honorary or a corresponding member upon a two-thirds vote of the members present at any regular meeting.

The President (by name) of the United States and the Governors (by name) of the several states shall be honorary members of the Society.

Election of Members Between Annual Meetings.—The President, Recording Secretary, and Treasurer of the Society are hereby authorized, during the time intervening between annual meetings, to act on all individual applications for membership in the Society, a majority vote of the Committee to elect or reject such applications as may be duly made.

ARTICLE III

SECTIONS

On presentation of a formal written petition signed by one hundred or more members, the Executive Committee of the American Fisheries Society may approve the formation in any region of a Section of the American Fisheries Society to be known as the ——— Section.

Such a Section may organize by electing its own officers, and by adopting such rules as are not in conflict with the Constitution and By-Laws of the American Fisheries Society.

It may hold meetings and otherwise advance the general interests of the Society, except that the time and place of its annual meeting must receive the approval of the Executive Committee of the American Fisheries Society, and that without specific vote of the American Fisheries Society, the Section shall not commit itself to any expression of public policy on fishing matters.

It may further incur indebtedness to an amount necessary for the conduct of its work not to exceed one-half of the sum received in annual dues from members of said section.

Such bills duly approved by the Chairman and Recorder of the Section shall be paid on presentation to the Treasurer of the American Fisheries Society.

ARTICLE IV

OFFICERS

The officers of this Society shall be a president and a vice-president, who shall be ineligible for election to the same office until a year after the expiration of their term; an executive secretary, a recording secretary, a treasurer, and an executive committee of seven, which, with the officers before named, shall form a council and transact such business as may be necessary when the Society is not in session—four to constitute a quorum.

In addition to the officers above named there shall be elected annually five vice-presidents who shall be in charge of the following five divisions or sections:

1. Fish culture.
2. Commercial fishing.
3. Aquatic biology and physics.
4. Angling.
5. Protection and legislation.

Vice-presidents of sections may be called upon by the President to present reports of the work of their sections, or they may voluntarily present such reports when material of particular value can be offered by a given division.

ARTICLE V

MEETINGS

The regular meeting of the Society shall be held once a year, the time and place being decided upon at the previous meeting, or, in default of such action, by the executive committee.

ARTICLE VI

ORDER OF BUSINESS

1. Call to order by president.
2. Roll call of members.
3. Applications for membership.
4. Reports of officers.
   a. President.
   b. Secretary.
   c. Treasurer.
   d. Vice-presidents of Divisions.
   e. Standing Committees.
5. Committees appointed by the president.
   a. Committee of five on nomination of officers for ensuing year.
   b. Committee of three on time and place of next meeting.
   c. Auditing committee of three.
   d. Committee of three on program.
   e. Committee of three on publication.
   f. Committee of three on publicity.
6. Reading of papers and discussion of same.
   (Note—In the reading of papers preference shall be given to the members present.)
7. Miscellaneous business.
8. Adjournment.

ARTICLE VII

CHANGING THE CONSTITUTION

The constitution of the Society may be amended, altered or repealed by a two-thirds vote of the members present at any regular meeting, provided at least fifteen members are present at said regular meeting.