May 15, 1937

To the Committee on Graduate Study:

I submit herewith a thesis written by Mr. Hugh T. Ramsey, entitled "Aquiculture", and recommend that it be accepted for nine quarter hours credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Zoology.

Edwin B. Powers
Major Professor

At the request of the
Committee on Graduate Study,
we have read this thesis,
and recommend its acceptance.

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Committee

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AQUICULTURE

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A THESIS

Submitted to the Graduate Committee
of
The University of Tennessee
in
Partial Fulfillment of the Requirements
for the degree of
Master of Science

by

HUGH T. RAMSEY

June 1937

INTRODUCTION

Aquiculture

There is every evidence that the productivity of our ponds, lakes, and streams can be materially increased by the intelligent application of present scientific knowledge to this problem.

For many years it has been recognized that our streams and lakes are becoming more and more barren of fish, and other aquatic life, but remedial measures, until recently, have been applied to only one-half of the problem. Efficient fish hatchery systems are maintained, both state and federal, and millions of fingerlings and legal-size fish are planted each year in an effort to increase the fish population of our waters, and to add to the profit and enjoyment of an increasing army of fishermen. On the other hand, little thought has been given to the fate of these fish after they have been released, and to the ability of our streams and lakes to provide the essentials of life for an increased fish population.

Concurrently with the pushing back of our frontiers has been the wanton destruction of timber, the reduction of underground water tables, increased erosion and silt, increased temperature and pollution of streams, a quick run-off of surface water with consequent floods, a decrease in the volume of water in creeks and rivers during the dry seasons, as well as many other factors which have a direct bearing upon the productivity of streams and lakes.

With the advent of the automobile, followed by the extension of our highway system to virtually every nook and corner, there are now

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few streams of any size that are not accessible to the ardent fisherman. As distance from a stream is now a negligible factor, the number of fishermen is growing each year and the sportsmen feel that they are entitled to some return for the money invested in the purchase of a privilege license. The answer to this problem apparently lies in the extension of the principles of aquiculture, heretofore more or less restricted to the hatcheries, to include our public waters.

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CHAPTER I

WATER

Since water and life are so intimately bound up together and since water is so commonplace, one is inclined to give only transient thought to the role it plays in the life processes of living organisms. Life as we know it today could not exist in the absence of water; thus before taking up the cultivation and control of aquatic organisms some thought must be given to the nature of the supporting medium.

Water possesses certain distinctive properties and characteristics peculiar to itself which fit it particularly well to support life. This is a natural assumption when one considers the fact that the protoplasm of living organisms is made up to a large extent of water. We shall therefore consider these characteristics in brief, in an effort to provide a background for the application of certain principles of aquiculture.

Water has the greatest heat capacity of all solids and liquids under ordinary conditions. That is, raising the temperature of water one degree requires several times as much heat as is required of other common substances, except living matter itself. Thus, as a constituent of protoplasm, the heat produced by the activities of protoplasm does not cause an injurious rise in temperature before it can be thrown off at the surface of the body. Water is a poor conductor of heat, if compared with metals, but is a better conductor than other liquids. Thus it makes for easy transference of heat within the body when convection is not possible.

Water is found in solid, liquid, and gaseous states. Its latent heat is the amount of heat required to change it from one phase to another without changing its temperature. The small calorie is by way of definition, the amount of heat required to raise one gram of water from 0° to 1° Centigrade. Eighty calories are required to convert one gram of ice at 0°C. to one gram of water at 0°C. Five hundred and thirty-six calories are required to change one gram of water at 100°C. to vapor at the same temperature. Thus it can be seen that the amount of heat required to vaporize one gram of water would raise the temperature of 536 grams of water through one degree Centigrade. "The latent heat of water is greater than that of all other liquids except ammonia. The latent heat of evaporation is greater than that of any other liquid not even excepting ammonia." (1). It is therefore apparent that its high capacity for heat and its great latent heat do not permit of rapid temperature changes under natural conditions, and that when present in a large body it has a stabilizing effect upon the climate of that particular region. Its effectiveness in this regard is well illustrated in the fact that "the known range of temperature in the sea is only 39°C. (from -3.5°C. to 35.5°C.), whereas that on land is more than 120°" (2). In melting, ice absorbs large quantities of heat, and in freezing this heat is given off again. Because of the high latent heat of evaporation of water it inhibits the evaporation of all the water from the land surfaces.

1 Chapman, Royal N., Animal Ecology, (1931), p. 250
2 Borradaile, L.A., The Animal and its Environment, (1923), p. 180.

Fortunately water reaches its maximum density at 4°C. and when cooled below this temperature it expands and becomes lighter. This unusual property is of great biological significance. Were it not for this fact, all bodies of water that freeze in winter would have the ice formed at the bottom instead of at the top and during continued cold weather would freeze solid. In reality, on the approach of freezing, the colder lighter water accumulates at the surface and the water at the point of maximum density (4°C.) settles to the bottom. Hence, "the congealing process, so fatal to living tissues, generally is restricted to a thin top layer. Here at 0°C. (32°F.) the water freezes, expanding about one-twelfth in bulk in the resulting ice and reducing its weight per cubic foot to 57.5 pounds" (3). As the temperature decreases the viscosity of water increases, being about twice as great at the freezing point as at ordinary summer temperatures (77°F.). Water is 775 times heavier than air and its buoyancy is correspondingly greater. Its density is so nearly that of protoplasm that all living organisms will float in it with the aid of gentle currents or with slight exertion in swimming.

Water can be compressed but very little as it contains more molecules per unit volume than any other known liquid except fused metals. Thus there is but little space between the molecules to permit of compression. Water also has a greater surface tension than any liquid with the exception of mercury. This is sufficiently great to permit insects to move about upon the surface, or hang from it as do certain snails, gnat and mosquito larvae.

(3) Needham, James G., and Lloyd, J.T., Life of Inland Waters, (1930), p. 31.

A greater variety of substances is soluble in water than in any other liquid. However, because of its chemical inertness and stability it exerts little chemical action upon its solutes and these substances come out of solution unchanged. On the other hand, in the presence of suitable catalysts (enzymes) by which these actions can be controlled, it is capable of very important chemical reactions with the substances in solution. "Again, water produces a greater amount of dissociation of its dissolved substances into ions than almost any other solvent, and thus enables all kinds of reactions to take place which do not occur between them in their molecular state. Its own hydrogen ions are powerful catalysts in causing reactions in which they themselves do not take part" (4).

The pressure of water is directly proportional to the depth and is equal to the weight of the superposed column of water. A depth of 10.328 M. will increase pressure by one atmosphere. Generally speaking enormous pressures are not met with in fresh water, but in the sea, animals live at great depths and pressures, so great, in fact, that if brought suddenly to the surface they may burst.

Water in the liquid state is practically transparent. At great depths it appears blue since it absorbs more long waves from the sun than those of shorter length. As the waves of longer length are heat waves it makes a very effective heat screen. Light penetrates clear water to great depths; however, penetration in fresh water is not usually as great as in the sea. As depth increases the intensity of light decreases, and the photosynthetic activities of plants are

(4) Borradaile, L. S., The Animal and its Environment, 1923, p. 178.

impeded in proportion to the decrease in the intensity of the light from the sun. Suspended matter in the water causes turbidity and limits photosynthesis to that area of water near the surface.

Natural waters always contain varying amounts of dissolved gases. These gases may come from the atmosphere, from the bed of the stream or lake, from organisms or substances within the water or from drainage and go into solution in natural waters. These gases are of vital importance in aquatic biology. Atmospheric air is made up of 79.2 per cent nitrogen, 20.5 per cent oxygen, and 0.03 per cent of carbon dioxide with traces of other gases. Though the amount of free oxygen that can be dissolved in a given amount of water is much less than that contained in the same volume of air, yet as it is more soluble than nitrogen, its proportion to that gas is higher in the gases dissolved in water than in air. Water absorbs them from the air in the percentages of 34.91 per cent oxygen and 65.09 per cent nitrogen with a trace of carbon dioxide. Each gas is absorbed from the air independently and in proportion to its own partial pressure. The surface waters being exposed to the atmosphere tend to come into equilibrium with it. Wave action, waterfalls, and agitation tend to speed up the absorption of oxygen. Diffusion of gases from the surface area to the deeper strata is a slow process and is considered a minor factor in internal distribution of gases in water. The higher the temperature of water the less gas it will hold and when water is boiled the gases in solution are set free.

A number of other factors help to determine the gaseous content and distribution of gases in water. These are in part the photosynthetic activities of plants, respiration of aquatic animals,

decomposition and oxidation of organic matter, temperature and depth of the water, vernal and autumnal overturns in deep lakes, inflow of underground waters, and chemical combination with materials in suspension or solution. In addition to carbon dioxide, oxygen and nitrogen, other gases frequently found in natural waters are methane, ammonia, sulphur dioxide and carbon monoxide, and hydrogen sulphide in certain bodies of water.

In order to support animals and plants continuously water must contain certain minerals in solution as well as gases. "Salts of magnesium, calcium, potassium, sodium, and salts of iron and silicon are practically always in solution in water and their presence in definite proportions is believed to be essential to the life of organisms." (5)

Water is either acid, neutral or alkaline. The degree of acidity or alkalinity may vary from day to day or there may be a considerable variation at different times during the same day. This is measured or expressed in terms of pH, or hydrogen-ion concentration. Some animals thrive best in an acid medium while others prefer water which is alkaline. There is also a great difference in the ability of animals to compensate for rapid or gradual changes in the pH of the water.

5 Ward, Henry B., and Whipple, George C., Fresh Water Biology, 1918, p. 36.

CHAPTER II

FRESH WATER FAUNA AND FLORA

To the casual observer the vertebrate animals with a few of the larger invertebrates and plants constitute the life of a body of water. Little does he suspect that, numerically speaking, these plants and animals constitute an infinitesimally small part of the living organisms inhabiting a body of water. With the invention of the microscope by Jansen in 1590 and its subsequent perfection, an entirely new world of life was opened up to us. Unbelievable millions of microscopic forms inhabit the water carrying on their life processes, predators and preyed upon, some sessile, some swimming actively, complex animal and plant communities heretofore unknown. These microscopic forms play a major role in the productivity of water, forming a link in the food chain that is indispensable.

Nature is dependent upon microscopic colorless plants called bacteria to bring about the decomposition of dead organic materials and thereby reduce their constituent elements to a form that can be again utilized by living organisms. These bacteria are found in water in enormous numbers when compared with higher forms of aquatic life. The majority of bacteria found in water is not pathogenic - the pathogenic forms found being a result of the pollution of streams by man due to the emptying of sewage and other waste materials into our streams and lakes. Other minute colorless plants found in water are moulds and fungi which also assist in the breaking down of organic matter and in some cases attack living organisms causing their death. The fish culturist knows

all too well the results of the attack of these fungi on fishes whenever an abrasion on the body of the fish permits them to get a start. They will also attack the eggs of fishes during incubation.

Another very interesting and multifarious group is the Algae. These chlorophyll-bearing microscopic plants assume many beautiful shapes and forms, as well as considerable color variation. They are able to carry on photosynthesis and convert inorganic materials in solution in the water into organic compounds. The Algae are used as food by the protozoans, zooplankton, and even some fishes. Indirectly they serve as a most important link in the food cycle of higher animals and they also appreciably affect the gaseous content of the water.

Another group of minute animals existing in great numbers in water is the protozoa. The members of this phylum consist of only a single cell throughout their existence and are found in almost all aquatic situations. Some exist as parasites in the bodies of animals and are disease-producing. Few of them are large enough to be seen without some magnification and they vary greatly in form and behavior. Their food consists largely of bacteria, diatoms, and algae while some forms are carnivorous and feed on other Protozoa. These one-celled animals serve as food for many of the smaller metazoans which in turn are eaten by fishes. They therefore form another important link in the food cycle of higher animals. Most everyone is familiar at least with the amoeba and paramecium used in virtually every school biology laboratory to typify this phylum.

Pond Societies

Ponds, lakes, and streams each have a characteristic fauna and flora. While there is of course a great deal of overlapping and many forms are common to all three situations, there are some animals and plants more restricted in their habitats and have become so specialized that they can adjust themselves to varying conditions only within narrow limits.

The importance of plant life to aquiculture has been mentioned and in addition to the fungi, bacteria and algae, there are plants that are characteristic of ponds and standing fresh water where wind and wave action are not too great, and where the water is not too deep. Near the shore one will find such plants as cat-tails, bur-reed, water plantain, pickerel weed, arrow-arum, manna grass and other such forms. Beyond this zone will appear the rooted aquatics with floating leaves such as the spatterdock, white water-lily, and potomogetons; also the free floating forms as duck-weed, water fern-worts and liverworts. Next will follow a zone of submerged plants consisting of certain species of pond-weeds, eel-grass, stone worts, etc.

These plants serve to convert inorganic materials into organic; to increase the oxygen content of the water; as places of shelter and refuge for aquatic animals; as places for attachment for sessile forms; as anchors for egg masses for many aquatic animals and as a depository for insect eggs for those forms whose immature stages are aquatic; as a means for emergence from the water to pupate for aquatic insect larvae; and as food for aquatic organisms both while living and during the

disintegration process after the death of the plant.

Lake Societies

No sharp line of demarcation can be drawn between pond societies and lake societies. Through erosion lakes will eventually become ponds and the commonly accepted difference is one of size and depth. Obviously in a lake or larger body of water the influence of the plant zone near shore is not as great as in a smaller body of water or pond. Lakes on the average are deeper than ponds and as a result are not subject to as great temperature variations. In ponds, since they are comparatively shallow, there is usually enough light for the growth of green plants over the entire bottom, while this is not generally true of lakes. Since ponds are shallow there is, as a rule, complete circulation of the water causing rather uniform conditions throughout. Most lakes are deep enough to have marked thermal stratification with a corresponding variation of other factors in the different strata. Vertebrates are comparatively few in ponds as compared with lakes and the variety of species and numbers of fish in ponds are generally much smaller than in lakes. The essential factors in modifying the animal life of a lake from that of a pond are temperature, gaseous content of the water, silt, turbidity and quantity of plant life in proportion to volume of water. Since these factors are not constants no attempt will be made to distinguish between the flora and fauna of ponds and lakes.

Stream Populations

In swiftly flowing streams there are few plants because only certain species are adapted to withstand the current and agitation. In sheltered

areas and near the banks, however, one may find a fair representation of aquatic plants. Swift waters are plankton-poor waters and most of the plankton present is the result of being washed in from above by the tributary streams or the result of development in the quiet pools or basins of the stream. This plankton is constantly passing on down stream with the current and to increase its production, more still water areas must be developed. These deep quiet pools are further advantageous in that they offer a harbor to animal life not particularly adapted to swift water and they provide a refuge for fishes when the water in the stream becomes low because of drouth conditions.

In the sand on the bottom may be found mussels, gastropods, the burrowing forms of may-flies and dragon-flies, as well as the larvae of the order Trichoptera with their cases of sand. Behind the moss patches on the rocks will be found the larvae of certain Chironomids, Simuliids, Parnid beetles, soldier-flies and crane-flies. Among the leaf drifts one will find the immature forms of the Tipulidae, or typical crane-flies, the nymphs of stone-flies of the family Nemouridae and many Plectoptera nymphs. Attached to the rocks either by sucking discs or silken anchors will be found the Hydropsyche, the larvae of the black fly Simulium, the caddis-worm, Brachycentras, and Blepharocerid larvae. Clinging to the rocks will be many stone-fly nymphs, "water pennies", Psephenus lecontei, annelids and gastropods. Attached to the rocks and living in cases are many caddis-worms and Chironomids. Underneath the stones will be found the larvae of the dobson fly, Corydalus cornutus, and the larvae of the fish-flies and alder-flies.

Entomostracans and the smaller crustaceans are few in comparison with the numbers found in still waters. Crayfish are present in some abundance, as are frogs and salamanders. Turtles and water snakes are also present along with a great many species of fish. The numbers of the above mentioned animal forms may be correlated in a measure with the size of the stream and the swiftness of the water. In small swiftly flowing creeks the greater number of fish are made up of species of minnows and darters. In larger cold water streams with a pronounced fall, trout will be added to the fish population while in our rivers and large streams many species may be represented. There are a number of factors upon which the population of a stream depends and it is the purpose of this paper to show some of the inter-relationships that exist in the population of water bodies, and to point out ways and means of increasing the productivity of ponds, lakes, and streams.

CHAPTER III

FOODS OF AQUATIC ORGANISMS.

There is too great a tendency upon the part of intelligent people to assume that all of our streams, lakes and ponds should be teeming with fish when in reality there is more cause to wonder how they are able to survive at all under existing conditions. These factors will be discussed later, but for the moment let us concentrate upon the food relationships of aquatic organisms. Elton (1) states that "the primary driving force of all animals is the necessity of finding the right kind of food and enough of it". It is common knowledge that many animals demand specific foods in order to carry on their life processes while others are not so specific as to their food preferences and are virtually omnivorous. Among aquatic animals we find carnivores and herbivores as well as those that eat both plant and animal tissues. Some of these are plankton eaters, cannibals and scavengers. It is obvious that the amount and kind of food of an aquatic environment is a big factor in determining the type and numbers of its population. This will become more evident as the different factors involved are introduced.

All animals are ultimately dependent upon plants for food since animals are not capable of synthesizing inorganic materials into organic compounds. As animals can use only organic materials as food, one should at once be interested in learning something of the method by which plants are able to bring about this conversion upon which the very existence of the animal kingdom depends. This process is known as photosynthesis, the

1 Elton, Charles. Animal Ecology, 1927, p. 56

word itself meaning to change by means of light .

Plants contain within the plastids of the cytoplasm a complex chemical substance called chlorophyll. It is this substance which gives to plants their characteristic green color, and which is capable of arresting and transforming a part of the energy of the sunlight so that the protoplasm can utilize this energy for food synthesis. Carbohydrates are formed by a combination of carbon with hydrogen and oxygen. These elements are derived from water and carbon dioxide by a dissociation of the molecules and a recombination to form glucose or fructose with free oxygen being given off during the process. The usual formula used to illustrate this is:

$$\underset{\text{(Carbon dioxide)}}{6\ CO_2} + \underset{\text{(Water)}}{6\ H_2O} = \underset{\text{(Glucose or fructose)}}{C_6H_{12}O_6} + \underset{\text{(free Oxygen)}}{6\ O_2}$$

After the formation of a sugar the plant transforms it into a starch and stores it for further use as a fuel or as a basis for further synthesis. The green plant can then add nitrogen in the form of nitrates to the CHO basis already constructed, and by the addition of other elements from phosphates, sulphates, etc., protein may be formed. During this process synthesizing enzymes, or catalytic agents, play a vital part in bringing about the chemical transformations necessary in the formation of these complex compounds.

An expenditure of energy is necessary in plants as well as in animals in order that they may carry out their life processes. The required energy is obtained from water , either as oxygen dissolved in it from the atmosphere or as that set free during photosynthesis. "This intake of free oxygen by the cells and outgo of carbon dioxide and water, the

chief products of combustion, is known as respiration." (2) The equation for respiration is the reverse of that for photosynthesis:

$$C_6H_{12}O_6 + 6\ O_2 = 6\ CO_2 + 6\ H_2O$$

Respiration "is essentially the securing of energy from food, involving the exchange of carbon dioxide for oxygen by protoplasm". (3)

We have seen that in photosynthesis nitrogen in the form of nitrates is necessary before it can be utilized by plants in the synthesis of protein. The free nitrogen of the atmosphere cannot be utilized by the green plants as such, neither can the nitrogen locked up as proteins in the bodies of dead plants and animals. Were there not some means of reducing dead organisms into their component parts or into simpler compounds capable of being utilized by plants, it is obvious that it would soon be possible to exhaust these vital elements from the soil, making photosynthesis impossible and thereby cutting off our food supply. Fortunately there is a group of plants without chlorophyll which must depend upon the decomposition products of organic matter for their food. These plants are present in water as well as on land and there is no natural water that is free from bacteria and fungi. Since they have no means of getting carbon from the air they must obtain it from "carbonaceous organic products usually from some carbohydrate, like sugar, starch, or cellulose. Some of them can utilize the nitrogen supply of the atmosphere but mose of them must get nitrogen also from the decomposition products of pre-existing protein". (4) The disintegration process of

2 Woodruff, L.L., Animal Biology, 1933, p. 34
3 Ibid, p. 34.
4 Needham, James G., and Lloyd, J. T., Life of Inland Waters, 1930, p. 139.

dead animal and plant tissues is greatly speeded up by these organisms due to the active ferments which they produce. Some bacteria are anaerobic and can live without free oxygen.

Carbohydrates and fats are broken down by the bacteria, molds, yeasts and fungi into carbon dioxide and water. Proteins are broken down by these organisms into carbon dioxide, water, ammonia and free nitrogen. Since the green plants can use nitrogen only in the form of nitrates, it is necessary to have further reduction. This is brought about by different kinds of bacteria. The nitrite bacteria act upon the ammonia and change it into nitrous acid. This unites with other elements forming potassium nitrite, ammonium nitrite, etc., which is then acted upon by nitrate bacteria and oxidized to form nitrates. These are in a form that can be utilized by green plants. There are, however, certain denitrifying bacteria which convert nitrates into gaseous nitrogen which escapes as free nitrogen. This, fortunately, is offset by another group of bacteria known as nitrogen-fixing bacteria which can take free nitrogen and fix it in the form of compounds with other elements which may be utilized by the plants in the synthesis of vegetable proteins.

Since in aquiculture most people are interested primarily in increasing the production of fish, and since food is a limiting factor, it is necessary that we have a fairly comprehensive knowledge of what fish eat under natural conditions. It is also necessary to know something of the food habits of the organisms that constitute the food of the fish in order that an intelligent program may be worked out to

increase the productivity of our natural waters.

Two tables are submitted herewith to show something of the food habits of some of our game and food fishes. Difficulty in compiling these data was experienced since much of the information available was somewhat general. The stomach contents of the fish examined by the investigators were in such condition that classification in many cases could not be carried beyond that of the class or order. General data have therefore been disregarded in several instances and no claim is made that these tables present the complete picture of the feeding habits of any particular species. They do, however, give us a working basis and indicate the importance of certain species and groups of organisms common to the diet of some fish of economic importance in this area. One must remember, however, that fish are opportunists and that they vary their diet within certain limits according to the season of the year and the type of food most prevalent. Practically all fish are plankton-feeders at some time during the fry or fingerling stage, and many of them change their diet completely with an increase in size and ability to overtake and consume larger food. Therefore, the stage in development of the fish examined would decidedly alter the stomach contents.

TABLE I

ORGANISMS (EXCLUDING INSECTS) EATEN BY SOME OF OUR COMMON FISHES

	Protozoans	Oligochaete worms	Amphipods	Isopods	Copepods	Entomostrachans	Cladocerans	Cambarus	Mollusks	Other fish	Amphibians	Algae	Vegetation	Fish eggs
Micropterus dolomieu		X	X	X	X	X	X	X		X	X	X	X	
Micropterus salmoides		X	X		X	X	X	X		X	X	X		
Pomoxis annularis			X		X	X	X							
Pomoxis sparoides		X	X		X		X		X	X			X	
Ambloplites rupestris		X	X		X	X	X	X	X	X		X	X	
Lepomis pallidus		X	X		X	X	X	X	X			X	X	X
Ameiurus nebulosus						X	X	X	X	X			X	X
Ictalurus punctatus					X				X	X			X	
Salmo irideus		X	X		X	X	X		X	X		X		
Perca flavescens		X	X	X		X	X	X	X	X		X		
Catostomus commersonii	X		X		X	X	X		X			X	X	X
Cyprinus carpio	X	X	X		X	X	X	X	X				X	
Ameiurus natalis			X			X		X	X	X			X	
Moxostoma aureolum	X	X				X			X			X	X	

TABLE II

INSECT NYMPHS AND LARVAE EATEN BY SOME COMMON GAME AND FOOD FISHES

Name of fish.	Plectoptera nymphs	Chironomid larvae	Plecoptera nymphs	Trichoptera larvae	Anisoptera nymphs	Zygoptera nymphs	Megaloptera larvae	Culicid larvae	Corethra larvae	Tipuloidea larvae	Hemiptera larvae	Coleopterous larvae	Simulid larvae	Tabanid larvae	Lepidoptera larvae
Micropterus dolomieu	X	X	X	X	X	X	X	X		X	X	X			
Micropterus salmoides	X	X	X		X	X	X			X	X	X			
Pomoxis sparoides	X	X		X		X			X		X	X			X
Pomoxis annularis		X													
Ambloplites rupestris	X	X		X	X	X					X	X			
Lepomis pallidus	X	X		X	X	X	X								
Ameiurus nebulosus	X	X			X										
Ictalurus punctatus	X	X	X		X	X	X						X		
Salmo irideus	X	X		X	X				X				X		
Salvelinus fontinalis	X	X		X	X				X		X	X	X		
Perca flavescens	X	X		X	X	X	X		X		X	X	X		
Catostomus commersonii	X	X		X	X	X	X		X	X	X		X	X	
Cyprinus carpio	X	X		X									X		
Ameiurus natalis	X														
Moxostoma aureolum	X	X		X						X				X	X

In order better to illustrate the food inter-relationships and to show how the smaller animals constituting the food of fishes are able to incorporate the microscopic and lesser macroscopic organisms into their diet and thus into food for fish, the following table has been prepared. The crucial part played by algae, green plants and bacteria in the food cycle has been pointed out, but since the algae and bacteria are too small to be used as food by many adult fish and since the fish are not capable of getting them in sufficient numbers to meet their food requirements, animals of intermediate size are needed to bring about this conversion. The animals whose food, in part, is shown in the following table are taken from the known diet of our common fishes as proved by an examination of their stomach contents and as illustrated in the preceding tables.

TABLE III

FOOD OF SOME COMMON FISH-FOOD ORGANISMS

TYPE OF ORGANISM	FOOD OF ORGANISM
Cladocerans	Algae - particularly diatoms.
Amphipods	Vegetable matter - living and dead.
Chironomids	Algae - diatoms, decaying vegetation.
Copepods	Algae - diatoms, decaying plants and animals.
Protozoans	Bacteria - other protozoans.
Phyllopods	Protozoans - algae, diatoms.
Isopods	Decaying vegetable and animal matter.
Plectoptera nymphs	Vegetable matter - living and dead.
Plecoptera nymphs	Vegetarians - family Perlidae carnivorous.
Megaloptera larvae	Carnivorous - stone-fly and may-fly nymphs.
Anisoptera nymphs) Zygoptera nymphs)	Carnivorous - aquatic insects, crustaceans, snails.
Ostracods	Scavengers - Omnivorous

Fish production in our natural waters can be correlated rather closely with the production of plankton. "Chemical analyses have shown that the plankton has a high food value. Its crude protein content on a percentage basis is substantially as large as that of beefsteak." (5) The production of plankton in some natural waters reaches rather huge proportions. It is estimated that the plankton crop is renewed every two weeks and "assuming conservatively that the renewal takes place twenty times a year, the annual production ranges from 900 pounds of dry organic matter per acre in the plankton-poor lakes to 4,300 pounds per acre in the plankton-rich waters". (6) It should be remembered that the restocking of natural waters with fish does not insure an adequate fish supply, but that more attention must be given to the condition of the waters and the food organisms contained therein before a satisfactory solution to this problem can be found.

5 The University and Conservation of Wisconsin Waters - bulletin of the University of Wisconsin, Nov. 1933, p. 59.

6 Ibid, p. 60

CHAPTER IV

METHODS OF INCREASING PRODUCTIVITY IN NATURAL WATERS

The first and basic step for increasing the productivity of natural waters is to make a scientific study or survey of every lake, pond, and stream in the state capable of supporting fish life to any appreciable degree. These should be classified by counties and for the state as a whole according to temperature and temperature fluctuations, volume of water and fall of stream, type of bottom materials, acidity or alkalinity and oxygen content, type and concentration of pollution, chemical content of the water, amount of silt, proportion of deep water pools to shallow areas, amount and type of vegetation, and quantity and classification of food organisms present. These factors will vary considerably and in order to get a thorough knowledge of the actual conditions under which fish must live, tests should be made at short intervals throughout the year. After this is once done and a working knowledge is obtained of our natural waters, it would probably not be necessary to repeat this procedure oftener than at five-year intervals, except in the case of those streams in which the drainage basin had been radically modified or in which one had reason to suspect an increase in pollution. As a matter of economy sportsmen's organizations could aid materially in helping to secure some of these data after having been advised by the State Division of Conservation as to methods of procedure. Such constructive work as this should further stimulate the interest of the members of sportsmen's clubs in conservation work and

the proper interpretation of the data obtained would enable them to carry out a much more effective program. A fish restocking program carried on by the trial and error method is a very costly procedure and as stated by Osburn (1933), "I presume more effort has been wasted by planting fish in unsuitable environments than in any other way." (1)

Every species of fish has certain limits of tolerance and certain optimum conditions, and with some species these can fluctuate only within a rather narrow range. It is a well known fact that the small mouth black bass does best in clear cool waters while the large mouth bass gives best results in the warmer lakes and more sluggish streams. The small mouth black bass requires gravel and sand for spawning while the large mouth bass will spawn in waters where the bottom is made up chiefly of mud. Crappie shows a natural preference for muddy water. Its eyes protrude considerably and if introduced into clear water it often becomes blinded. The calico bass is primarily a warm water species while the rock bass and warmouth bass do best in the cooler lakes and streams. The bluegill is adapted to a wide range of conditions and will thrive in most aquatic habitats. Catfish prefer sluggish streams with muddy bottoms, while the brown bullhead "is the only member of the catfish family that is adapted for rearing in private ponds". (2) Other catfish "seem to require some element not found in still waters". (3) These few examples will suffice to show that a knowledge of our waters is necessary for an economical restocking program and that supervision

1 Osburn, Raymond C., Some Important Principles of Fish Conservation. Transactions of the American Fisheries Soc., 1933, p.94.
2 James, M.C., Propagation of Pondfishes, Bureau of Fisheries Document No. 1056, p.40.
3 Ibid, p. 40.

by the state is also necessary in the planting of these fish to see that they are properly liberated and that they go into waters to which they are adapted. Many fish will live under a wide range of conditions, but they are much more specific as to conditions under which they will spawn. Therefore, it is inadvisable to plant fish in waters within their limits of tolerance without first taking spawning conditions into consideration.

In our larger rivers there is not a great deal that can be done to produce immediate results in increasing the productivity of fish. This rather involves a long range program of education, legislation and law enforcement. Unfortunately, the wanton destruction of timber and consequent erosion are burdening our rivers with millions of tons of silt, top soil and humus from once productive farms, being carried in suspension and deposited many miles from its source. To decrease materially the amount of silt, studies should be made of the tributary streams to determine which ones are carrying the greatest silt load. County agricultural agents of the counties located in the watershed of these streams should be notified of existing conditions and urged to carry on a more effective soil erosion program. It may of course take years to get results, as such a program involves the education of the farmers to the need for erosion control, but we have been too nearsighted in our conservation work and such long range planning is now becoming necessary. Reforestation to help prevent erosion will not only retard the rapid run-off of surface waters, but by lowering the underground water table will feed the soil water to the streams more slowly. It will help prevent floods as well as extremely low water conditions,

and at the same time reduce the mean temperature of the streams by several degrees.

It is doubtful that the planting of fish in our large rivers is a practical procedure, but it would seem that permanent improvement can best be effected by the control of erosion and pollution and better regulation of commercial fishing. Fish should be fully protected during their spawning season and, as conditions seem to demand it, closed seasons should be declared for certain species until their numbers can be substantially increased.

The pollution of our streams by municipal and industrial wastes has reached a very serious state. It has been estimated that in Pennsylvania, eighty per cent of the waterways are so heavily polluted as to be practically devoid of fish life. "In no phase of our social behavior has there been such flagrant violation of the property rights of others as in the visitations of pollution on downstream communities and landowners." (4) Cities have been slow to build effective sewage treatment plants because there was no income to be derived from such construction and operation, and because the effect of the pollution resulting from the drainage of sewage into the stream created a problem for the next city downstream and thus it could "pass the buck". Little thought is given by these municipalities and industrial corporations to the effect of pollution on aquatic life; to the curtailment of recreational activities; to the increased cost of the purification of water to the cities downstream; to the decline in property values that is brought about; to the corrosive effect of heavily chemicalized waters upon

4 Reid, Kenneth A., Pennsylvania Angler, Feb., 1937, pp. 4-5.

boilers, plumbing, and machinery, and to the fact that the money spent to make water safe for consumption is attacking the effect rather than the cause, and that this outlay is likely to increase with the natural growth in the population of our cities.

The control of pollution is essentially inter-state in character since the watershed of many of our rivers involves more than one state. It therefore seems imperative that legislation be passed to enable effective Federal control. It is evident from existing pollution and from existing state laws that the states either cannot or will not enforce legislation to decrease pollution in our natural waters.

Pollution in streams should be measured throughout the year but particularly during the summer months when the temperature of the water is at its highest, and when the oxygen content and the volume of water is at its lowest. The concentration of sewage is, of course, greatest at this time. As high temperatures reduce the oxygen content of the water, the amount required for the oxidation of sewage may reduce it below the point at which fish can survive. The summer of 1936 was particularly destructive to fish life because of extreme drought and temperature conditions. In any fish stocking program we should know our waters at their worst since fish must survive these conditions year after year if the stream is to be productive. A limited amount of sewage for a given volume of water may, on the other hand, act as a fertilizer, such as is applied to small lakes and ponds, and serve to increase fish food organisms and consequently the fish population. Sewage, however, is more or less constant in volume and cannot be regulated in amount, as

can an artificially administered fertilizer, according to the temperature of the water and the gaseous content. For this reason it always serves as more or less of a constant menace, since it is not released according to water conditions.

Pond and Lake Culture

In continental Europe aquiculture is more advanced in some respects than in the United States. Many people have their own private fish ponds and lakes which they keep well stocked with fish and they look upon water farming very much in the same light as they do agriculture. With a better understanding of the principles of aquiculture there is every evidence that water farming can be carried on with considerable profit to the farmer and with a minimum of labor expended. In many cases swamp lands which have proved more or less of a liability can be converted into fish ponds and thus serve as an adjunct to the farm as a source of food. These ponds or small lakes should be, wherever possible, not less than one acre in size, as a body of water of this area is required if many fish of sufficient size are to be produced.

In selecting the site for a fish pond a number of factors should be considered, namely: The productivity and porosity of the soil; location with respect to water supply; amount of excavation necessary; elevation as regards the drainage of the pond, and the slope of the banks as it affects the proportion of shallow water areas so necessary for spawning and the production of food. If a series of ponds is to be used the arrangement should be such that one does not drain into the other, since if the fish in one pond should become infected, the infection would thus be spread to the fish in the other ponds. Drainage outlets are always

to be desired as it is necessary to drain the pond partially if aquatic vegetation, undersirable fish and predators are to be controlled. Best results can be obtained with two or more ponds so that the fish may be transferred from one to the other and the ponds drained alternately. Production seems to be increased if the pond can be drained completely and the bottom materials exposed to the sunlight. This helps to keep down pathogenic organisms and gives one complete control over aquatic vegetation.

The amount of water needed is just enough to keep the pond at a constant level and make up for the loss by evaporation and seepage. The loss by seepage will of course be determined by the nature of the soil. "For a one acre pond, where the sides and bottom are of clay or rich loam, a flow of from thirty to fifty gallons per minute should be sufficient to maintain a proper water level at all times." (5) If the soil is more porous additional water will be required.

If the water supply used is from a spring it should be tested as to the volume of flow during the dry season, as well as for gaseous and chemical content. Where a scientific analysis is not possible a test pool may be built and a few fish placed in it. If they survive then one may feel reasonably safe in using the water. If the fish in the test pool do not live the chances are that the water contains considerable carbonic acid which may be removed by aeration. An open flume may be used to conduct the water to the test pool and by placing obstructions in the flume to cause agitation of the water some of the carbon dioxide is given off thereby raising the pH of the water to

5 James, M. C., Propagation of Pond Fishes, Bureau of Fisheries Document No. 1056, 1929, pp. 21-22.

within the limits of tolerance of the fish. If the source of water is a creek or a river care must be exercised to prevent too great an inflow of silt. This may be accomplished by proper screening of the intake. Bulletins may be obtained from the U. S. Bureau of Fisheries giving detailed information about the proper construction of a fish pond or small lake and concerning the best type of aquatic plants to use and correct methods for transplanting them.

After the pond is properly constructed one must give careful thought to the species of fish selected for propagation. For best results these will have to be determined by the size of the pond, temperature of the water, type of bottom materials and the food organisms that one expects to provide. If the pond is small, with no sand and gravel in the bottom, and the temperature of the water is likely to become high, the small mouth black bass would not be suitable. The large mouth black bass cannot be recommended for propagation in a small pond because of its predacious habits and the difficulty of providing food for a sufficient number of fish; however, for large ponds where forage fish are used it is quite satisfactory. Ordinarily it is better if only one species of game or food fish is raised in a pond but if more than one species is used care should be exercised in making the selection so that there will not be too much competition for the same type of food in a limited body of water. Such competition for food results in cannibalism or the production of fish of inferior quality and low vitality. Where considerable attention can be given to the pond and one can be sure that there is a sufficient supply of forage fish available for food, it is practical

to propagate several different species together.

Fish recommended for pond culture, depending upon water conditions, are the brown bullhead catfish, Ameiurus nebulosus; the bluegill sunfish, Lepomis pallidus; the rock bass, Ambloplites rupestris; the warmouth bass, Chaenobryttus gulosus; the calico bass, Pomoxis sparoides; the crappie, Pomoxis annularis; the large mouth black bass, Micropterus salmoides; and the small mouth black bass, Micropterus dolomieu. A table is submitted herewith to show something of the spawning habits of some of our common fish. This is taken in part from that appearing in volume one of the Roosevelt Wild Life Annals (1928) on page 269.

TABLE IV

BREEDING RELATIONS OF FISH

	Usual Breeding habitat				Breeding Conditions										Where eggs deposited				
	Creeks	Rivers	Lakes	Ponds	Shallow water	In or near riffles	Stream Pool	Rapid current	Deep water	Gravel bottom	Sand bottom	Mud bottom	Water plants	On bottom stones	On water plants	On unprepared bottom	In depression nest	On boards & tin articles
Micropterus dolomieu		X	X	X	X					X				X	X		X	
Micropterus salmoides		X	X	X	X							X	X		X		X	
Pomoxis sparoides			X	X	X										X		X	
Ambloplites rupestris		X	X		X								X		X		X	
Lepomis pallidus			X	X	X								X		X		X	
Ameiurus nebulosus			X	X	X						X	X					X	X
Ictalurus punctatus		X			X													
Catostomus commersonii	X	X			X	X		X		X						X		
Cyprinus carpio			X	X	X								X		X	X		
Moxostoma aureolum	X	X			X	X		X		X						X		
Perca flavescens			X	X	X				X		X		X		X	X		
Eupomotis gibbosus		X	X	X	X		X			X	X		X	X	X		X	

Increasing the Food Supply

The success of any fish-propagating adventure depends in a large measure upon the food supply. Reference to Tables I and II will show many of the larger organisms constituting the known diet of some of our freshwater fishes. Our larger species of fish require smaller fish for food if they are to maintain the growth rate that is to be expected. For this reason considerable study has been made of the suitability of various species to be introduced as forage fish into our ponds, lakes, and streams. These must not be serious competitors for food, must be prolific, must be able to withstand a rather wide range of conditions, must not be destructive to the eggs and fingerlings of the species being propagated, and must be small enough to serve as food for the younger fish as well as for the adults.

In many places the gizzard shad, Dorosoma cepedianum, has proved highly satisfactory as a forage fish for bass and other species. Examination of the stomach contents of many fish in our natural waters show the shad to be a very popular part of the menu. "It is the most efficient biologically of all the forage fishes. The gizzard shad eats the minute plant life in the water and itself is eaten by the game fishes. It is the only species of fish we have which in anything like that degree acts as a single link in the chain between these elementary microscopic plants and the adult fish." (6) It has a very fine straining apparatus on the gills by which it can strain out minute particles of food from the water. In Buckeye Lake in Ohio and Harrington Lake in Kentucky, which, by reputation, are two of our finest bass fishing lakes, the

6 Hubbs, Carl L., Some Experiences and Suggestions on Forage Fish Culture. Trans. Am. Fish. Soc., 1933, p. 57.

gizzard shad is given no small share of the credit for their excellent production. Another thing in its favor as a forage fish is that it seems to be susceptible to very few parasites.

The golden shiner, Notemigonus crysoleuca, is another excellent forage fish. It is particularly well adapted to pond fish culture; the eggs being adhesive are stuck to the aquatic vegetation. The adult golden shiner will eat bass fry but as its mouth is small the young bass soon grow too large to be taken by it. In small ponds with a limited amount of zooplankton the golden shiner will offer considerable competition in feeding as it consumes large quantities of Daphnia and other Entomostraca.

The blunt-nosed minnow, Hyborhynchus notatus, and the black-head minnow, Pimephales promelas, have also proved excellent as forage fish. They are not predacious on the fry of the species being propagated and they are very prolific. Both these minnows lay their eggs on the underside of flat objects such as rocks, pieces of tin, or of wood, and if such objects are not in the pond these will have to be placed there. The common bull-head catfish makes its nest under boards and rocks and will also require such materials for spawning if they do not already exist. These minnows will need considerable vegetation for protection or else they may all be eaten by the bass and other fishes and none left for brood stock.

The horned dace, Semotilus atromaculatus, is an excellent forage fish for creeks but is not satisfactory in a pond as it requires running water for spawning.

The importance of the nymphs and larvae of aquatic insects in the food of fish cannot be over-emphasized. These forms vary greatly in

size from that of the larvae of the dobson fly, Corydalis cornutus, which may reach a length of three inches, to that of the almost microscopic larvae of some Diptera such as the Culicids and certain Chironomids. The best way to increase the number of the immature forms of aquatic insects in our ponds and streams is to provide a place for the insects to lay their eggs. This can best be done by the propagation of aquatic vegetation both emergent and submerged in the shallow water areas along the shore line.

An article appearing in Outdoor America, February, 1937, by W. Carter Platts, tells of the method used by Lunn on the Test River in England to increase the insect population of that famous trout stream. Two long boards were battened together and sharpened at each end to avoid the catching of drift materials. This raft was then anchored in the stream by a wire fastened to one end. Soon the bottom edges were covered with mayfly eggs. The raft was then floated down stream to a section of the river in which the stock of insects seemed to be depleted and was there anchored to await the hatching of the eggs and the dropping off of the nymphs into the water. Such a device might be used in a pond in which the emergent vegetation is scanty.

The adults of certain species of aquatic insects are weak fliers and never go very far from the body of water from which they have emerged. It may, therefore, be practical to transplant in a newly formed pond the nymphs of suitable species of insects from another body of water. Further research is needed on this point to determine this method's practical value.

The productivity of ponds and small lakes can usually be very materially increased by the use of fertilizer. This involves the supply of an organic fertilizer and a readily available supply of protein. Best results have been obtained with a mixture of cotton-seed meal and 18 per cent commercial superphosphate in the proportion of two parts of meal to one of commercial fertilizer, using about five hundred pounds to the acre of water. No set amount to be used per acre can be definitely established as it is possible to exhaust the supply of oxygen in a small body of water if fertilized too heavily. This will have to be varied according to the amount of dead organic matter in the water, the temperature of the water, the amount of living aquatic vegetation and the oxygen content of the water as determined early in the morning when the oxygen content is lowest. It is far better to use a small amount of fertilizer each week rather than to add all of the fertilizer at one time. This will prevent an excessive drain on the oxygen supply and should help to maintain a steady growth of organisms throughout the summer to serve as food for the fingerlings and growing fish. When the same pond is fertilized year after year the amount of fertilizer used during successive years may have to be gradually reduced as there is likely to be some carry-over from one summer to the next. No high concentration of fertilizer is advisable during the breeding season as low oxygen content of the water at that time will result in a poor hatch.

After the fertilizer is added the first forms to increase noticeably in number are the protozoans, bacteria, rotifers and immature copepods. Following these, there is a large increase in the numbers of Entomostracans and zooplankton crustacea. Chironomids seem to be

attracted to the pond upon the addition of fertilizer and lay enormous numbers of eggs. These organisms serve as the chief food of the developing fish until the fish become large enough to demand larger food. Even the adult fish feed on a surprising number of these small organisms.

The propagation of Daphnia in tanks or concrete pools to supplement the food developed in the fish pond is quite practical and inexpensive. A pool 8 X 12 feet and designed to hold about 100 cu. ft. of water should prove satisfactory. This should be built so that it can be harvested. The water in the pool should be stagnant, only enough water being added from time to time to maintain a fairly constant level. Good results may be obtained by the use of cottonseed meal as a fertilizer.(7) In the experiments by Embody and Sadler one quart of cottonseed meal was used as an initial dose to one hundred cubic feet of water in the tank. On the seventh and fourteenth days one and one-half pints additional were added and the pool was drained into the fish pond on the twenty-first day. Fifty cubic centimeters of Daphnia seem to be sufficient to start a successful culture. Daphnia with winter eggs should not be used and the temperature of the water in the culture tank should not exceed 82° F. Sufficient Daphnia to start the initial culture can usually be obtained from nearby ponds or streams. Such Daphnia ponds usually attract large numbers of mosquitoes that come to the pool and lay their eggs in the water. The mosquitoes, however, may be controlled by spraying the surface of the water with some non-toxic oil

7 Embody, G. C., and Sadler, W.O., Propagating Daphnia and Other Organisms Intensively in Small Ponds. Trans. Am. Fish. Soc., 1934, pp. 205-209.

such as cod-liver oil.

Stream Improvement

Aside from the control of pollution there is little that can be done in the way of stream improvement in connection with our larger rivers. This, however, does not hold true with our small rivers and streams. Some mountain streams remain too cold for the maximum production of trout and they have too few deep pools to prevent their being fished out and to provide sufficient protection from natural enemies. Other streams need to be speeded up to prevent undue warming of the water and to have formed alternate shallow and deep areas to take care of greater food production and to provide cover and protection for the fish during drought conditions. W. Carter Platts in his article in Outdoor America entitled, "Improving Trout Streams" and to which reference has already been made states, "Dam it back, put kinks into it, tie it up into knots, shuttlecock the current backwards and forwards from bank to bank. It is the crooked stream that constructs the cozy corners".

Considerable stream improvement work has been done in our national forests and in a few states, particularly Pennsylvania. It is an evident fact that the condition of our streams and the possibilities for their improvement will receive far greater attention from now on than they have in the past. A shallow area of a stream bordered by shelving beaches is an ideal site for a low log dam. This will spread the water out forming a wide shallow pool which is excellent for increasing the food organisms. Double deflectors may be used to speed up the current in trout streams through unshaded areas to prevent warming

of the water. In some streams the current is too swift for the growth of aquatic plants and in these, to produce quiet water areas for plant growth and thus to increase the available food, deflectors are of considerable advantage. The planting of trees along the banks of the streams will help to prevent the temperature of the water from becoming too high as well as lend charm to an otherwise monotonous stretch of water. In streams with smooth bottoms and few hiding places it is well to place brush and logs in the stream, anchoring one end to the bank. This affords a place of concealment for the smaller fish from the many predators with which they are beset. Low log dams in narrow shallow channels will serve to dig out holes below the dam and the force of the water will keep silt from filling these up.

In carrying on stream improvement work it is usually better and more economical to use the rocks and logs found in or near the stream. These lend a natural appearance and usually are available in sufficient quantities to carry out the program. Care must be taken to build deflectors and dams strong enough to withstand the normal floods to which the stream is subjected. Sportsmen's Clubs can, with proper guidance, carry on this work very effectively, since in most cases someone in the club will know the owner of the land bordering the streams. Detailed information as to the proper construction of these dams and deflectors can be obtained from the Pennsylvania Fish Commission and probably from the U. S. Bureau of Fisheries.

Selective Breeding

There has been very little work done so far in the selective breeding of fish. In the work that has been completed and that is now in progress,

there is every evidence that superior strains of fish can be developed just as has been done with domestic animals. Unfortunately commercial hatcheries have had a tendency to sell their fish indiscriminately and to use what was left for brood stock. Recognition of the possibilities offered in this line of research is increasing the number of investigators in this field and no doubt the next ten years will bring about some very interesting and beneficial results.

Enemies of Fish

Among the mammals the enemies of fish are the otter, mink, and raccoon. Certain birds as the kingfishers, herons, ducks, loons and terns are destructive to fish life. Bullfrogs eat an occasional fish, and water snakes are especially predacious on fish. In addition to the animals mentioned above piscivorous fish eat other fishes and many are spawn eaters. There is also the blood-sucking lamprey eel which is particularly destructive in rivers and lakes which are fed by creeks. Add to the above enemies the destructive forces of pollution, disease and parasitic infection and the general depredations of man and it is remarkable that any fish are able to survive.

Research Activities

In conclusion let it be added that there seems to be a very grave need for some central directing agency to prevent too great a duplication of research activities. If certain hatcheries could be assigned definite research problems to be followed through over a period of years to a definite conclusion, it would be far better than working on one problem for a year and drawing certain doubtful conclusions and then taking up a new problem. It seems logical that a follow through of one

problem by the same hatchery would enable it to profit by trial and error and that the experience gained would help in the development of a technique that could not be done by research over a short period of time. One must of course take local conditions into consideration but it is doubtful that it is advantageous to the fisheries industry to have several hatcheries duplicating research activities at the same time. The Federal Hatcheries can be regulated in this regard, but since each state exercises jurisdiction over its own hatcheries there is need for some central agency to coordinate and direct these activities for the several states and in turn to correlate them with the activities of the U. S. Bureau of Fisheries. In many instances the personnel of the state hatcheries is capable only of carrying out the mechanical activities met with in the operation of the hatchery. It would seem much more profitable to hire men who can not only operate the hatchery efficiently but who also have sufficient scientific background to carry on research activities on the problems met with in the operation of their own hatchery, as well as those met with by the industry in general. It is not enough to know that one has had a successful year or a poor year but one should be able to evaluate with fair accuracy the reasons for success or failure. If aquiculture is to be on a par with agriculture a very definite scientific approach to the entire problem is necessary by all those concerned, and political fence building must be relegated to some other field.

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GLOSSARY OF ICTHYOLOGICAL AND ENTOMOLOGICAL TERMS USED

SCIENTIFIC NAME	COMMON NAME
Micropterus dolomieu	Small-mouth Black Bass
Micropterus salmoides	Large-mouth Black Bass
Pomoxis annularis	Crappie
Pomoxis sparoides	Calico Bass
Ambloplites rupestris	Rock Bass
Lepomis pallidus	Bluegill
Ameiurus nebulosus	Common Bullhead Catfish
Ictalurus punctatus	Channel Catfish
Salmo irideus	Rainbow Trout
Perca flavescens	Yellow Perch
Catostomus commersonii	Common Sucker
Cyprinus carpio	European Carp
Ameiurus natalis	Yellow Bullhead Catfish
Moxostoma aureolum	Common Red-horse

ORDERS AND FAMILIES OF INSECTS

Lepidoptera	Butterflies and Moths
Coleoptera	Beetles
Hemiptera	The True Bugs
Megaloptera	Dobson, Fish, and Alder Flies
Odonata	
Anisoptera	Dragon Flies
Zygoptera	Damsel Flies
Trichoptera	Caddice-flies
Plecoptera	Stone-flies

SCIENTIFIC NAME	COMMON NAME
Plectoptera	May-flies
Diptera	
Tabanidae	Horse-flies
Simuliidae	Black-flies
Tipuloidea	All Crane-flies
Culicidae	
Corethrinae	Corethra
Culicinae	Mosquitoes
Chironomidae	Midges
Blepharoceridae	Net-winged Midges

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