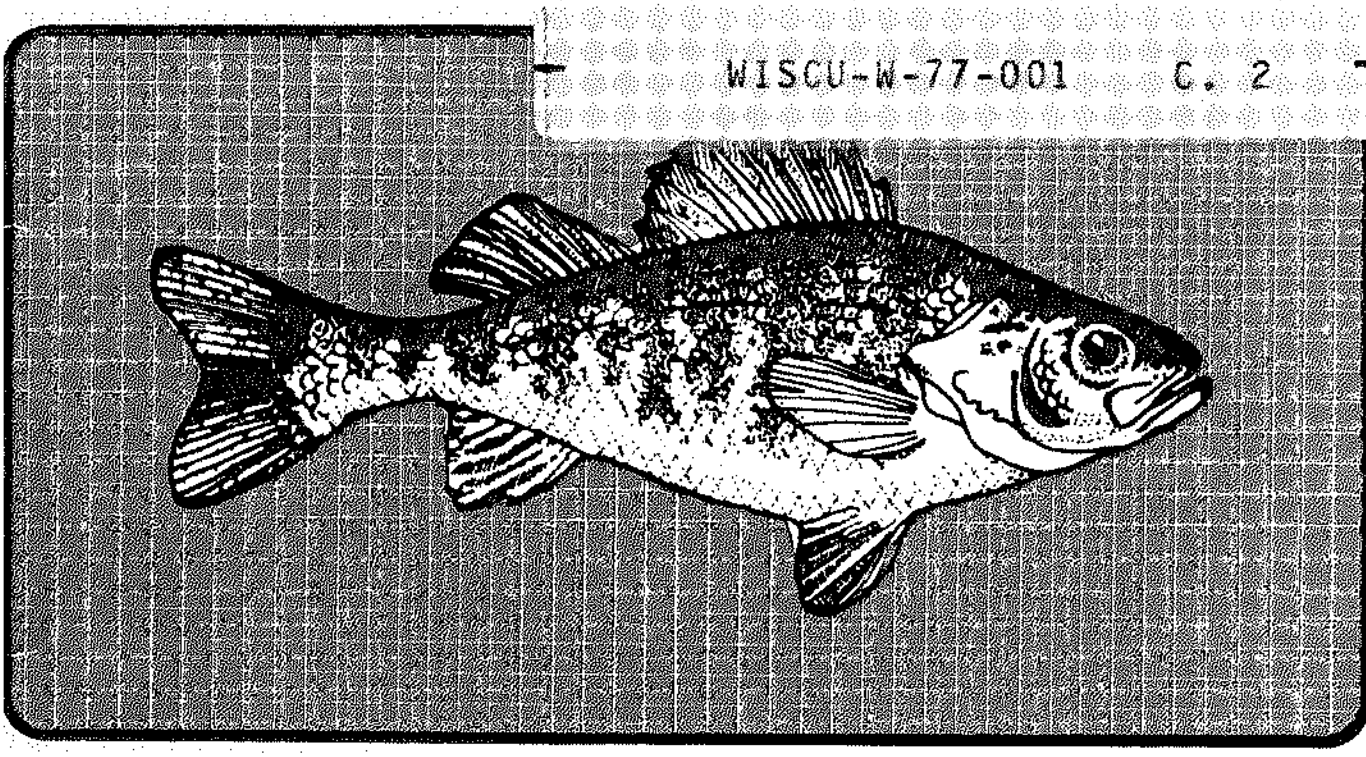
Perch Fingerling Production For Aquaculture



Proceedings of a Conference held at the University of Wisconsin • December 12, 1977

University of Wisconsin Sea Grant College Program
Advisory Report #421

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Edited by

Richard W. Soderberg
University of Wisconsin-Extension
Sea Grant Advisory Services

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Price: $2.50

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The University of Wisconsin Sea Grant College Program is sponsored by the National Oceanic and Atmospheric Administration's Office of Sea Grant, U.S. Department of Commerce, and by the state of Wisconsin.

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WELCOME

Richard W. Soderberg
Aquaculture Specialist, Sea Grant Advisory Services
University of Wisconsin-Extension, Madison, Wisconsin

Good morning and welcome to the conference.

The two major obstacles standing in the way of commercialization of perch aquaculture are excessive energy demands and lack of a reliable fingerling supply. We're predicting that by this time next year we'll be running our growout units on a fraction of the horsepower presently used. Perch fingerling production is the problem we'll address today.

Because of their small market size and limited growth potential, perch aquaculture will be a fingerling-intensive proposition. Larger numbers of fingerlings will be required to produce a given weight of perch than for most other species being cultured. For this reason, purchased fingerlings become a major element in the cost of producing a pound of perch. From an economic standpoint, it is difficult to fit a five to 10 cent fingerling into the cost of producing a fish that will sell for 30 to 40 cents when grown out.

The purpose, then, of this conference is to present what we consider the state of the art in perch fingerling production to help reduce the cost of this element of perch aquaculture.

We have an impressive group of speakers here today to accomplish this task. Dr. Harold Calbert, leader of the aquaculture research program, will get things started with a summary of the University of Wisconsin's efforts in perch aquaculture. Terry Kayes, Department of Food Science, will give an accounting of his research on the reproduction of perch. Dr. Ken Hokanson from the United States Environmental Protection Agency will present the EPA's findings on the environmental requirements of larval perch. Sherman Stairs, manager of the Lake Mills National Fish Hatchery and his former assistant, Graden West, will relate their experience in the pond production of perch. I'm the extension agent for fish farming in Wisconsin and I'll have a few words to say on preparation of a financial budget for a pond fisheries operation. Ron Henry from the Fish Control Laboratory in La Crosse will wind up with comments from his experience in pond construction, fish tank design and other practical aspects of fish culture.

THE PRODUCTION OF YELLOW PERCH FINGERLINGS

Harold E. Calbert
Professor, Department of Food Science
University of Wisconsin-Madison

The development of any sound system of aquaculture depends on many factors. One of the most important of these is a dependable source of young organisms that can be grown and marketed at the proper time. An aquaculture system for producing yellow perch is no exception.

To have a successful aquaculture system for yellow perch production the grower must have available a dependable supply of fingerlings at a reasonable cost. These fingerlings should be as free of disease as possible, be efficient converters of feed, be fast growers and should develop into fish of a quality that will meet market demands. Perch fingerlings meeting these criteria have not been regularly available to the aquaculturist. The purpose of this seminar is to discuss some of the steps and problems involved in producing a better quality fingerling.

The fingerlings that have been available on the market have been mainly from wild stock. They have resulted from the incidental hatches from ponds, streams, lakes, etc. These have been seined and sold to help meet the market demand for fingerlings. The quality of these fingerlings has been quite variable with respect to the desirable characteristics just mentioned. Many times the supply has not been sufficient to meet the demand. The price per fingerling has varied with availability, size and other factors. This is not to criticize the producers and sellers of these fingerlings. It is the best that they can do and represents most all of the fingerlings that have been available from commercial sources.

One of the major goals of the University of Wisconsin's aquaculture research program is to conduct research and develop the technology that is needed to produce better perch fingerlings. As this information is developed, it will be brought to the public as quickly as possible by means of publications and bulletins, seminars and meetings and by our extension personnel. This meeting serves as an example.

This past 1977 season is the first one in which we have produced perch fingerlings in quantity as part of our research program. All that we have produced are being used in our research program. From the experiences that we have had during this past season, we have learned various things that will guide us in our future work.

All perch fingerlings hatched at the same time and exposed to the same environmental conditions and feed supply do not grow at the same rate. Figure 1 illustrates this point. The two fingerlings pictured are from the May 1977 hatch. This picture was taken in the latter part of September 1977 when the fingerlings were being removed from the rearing ponds. During the intervening time both fish had been exposed to identical environmental conditions with respect to water temperature, food supply, light conditions, oxygen levels, etc. Yet the larger fingerling weighs about 10 times as much as the smaller fingerling. Why? Is it due to some inherited traits? We do not know. These are not two isolated fingerlings representing the largest and the smallest of the hatch. We had many of both sizes and sizes in between these.

Figure 1. Yellow perch fingerlings of same age and grown under similar conditions during the 1977 season.

If we could be assured that a large percentage of a perch hatch would result in fingerlings like the larger one shown, we would be well on the way of reaching one of our research goals.

To attempt to find the answer to some of these questions, I would like to tell you as briefly as possible about some of our research plans for the 1978 season.

Presently we are carrying about 450 adult perch in a specially designed tank that duplicates, up to a point, the conditions that these fish would experience in a natural lake. By being exposed to light and temperature conditions that influence spawning, we hope that these fish will have a normal spawning cycle in the 1978 season. At the proper time eggs will be stripped from the females and milt from the males. The eggs will be artificially fertilized. The fertilized eggs will be hatched under various conditions.

One group of fertilized eggs will be placed directly into the fingerling raising ponds. They will be allowed to hatch there and the larvae will remain in the pond as will the eventual fingerlings. These will spend the summer in the ponds and be grown on natural and supplemental feed. They will be removed from the ponds in the late summer of 1978. Figures 2 and 3 show this type of activity in the 1977 season.

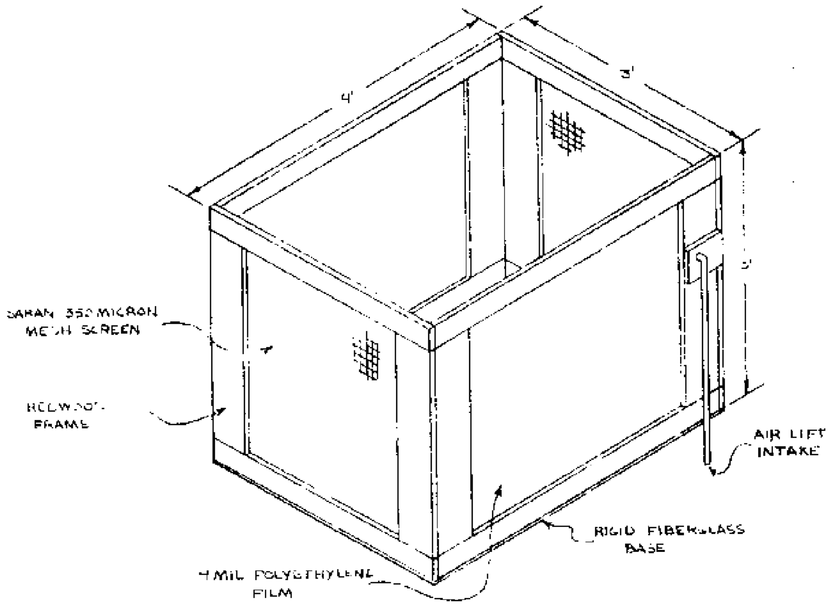
Another group of fertilized eggs will be hatched in the laboratory. Attempts will be made to carry the newly hatched larvae from egg-sac stage through the fingerling stage in the laboratory. This means that they will need a source of nutrients once the yolk-sac is utilized. We had modest success in the 1977 season with some formulated feeds used for this purpose. We have several other feeds that we wish to try in the 1978 season. Once these fish reach the small fingerling stage, we have no trouble carrying them on formulated feeds.

Some fertilized eggs will be hatched out in the rearing ponds and allowed to develop into fingerlings on the natural feed available in the pond. However, they will be in cages that have been so designed that they will be isolated from other larvae and fingerlings in the pond. Figure 4 shows the design of this type of restraining unit. By the use of air pumps, the water in the pond can be circulated through the cages, thus bringing the natural nutrients in the pond to the larvae as they hatch and develop into fingerlings.

The best fingerlings from the various hatches will be grown out to adult size with the anticipated use as brood stock. It is hoped that in this manner a strain of yellow perch can be developed that will be most suitable for controlled environment aquaculture. It will take many years and many generations of fish to reach this goal.

Figure 2. Removing perch fingerlings from rearing pond, September 1977.

Figure 3. Seining fingerling rearing pond, September 1977.



FRY ISOLATION UNIT

Figure 4. Restraining cage used to isolate perch hatch in rearing pond.

REPRODUCTIVE BIOLOGY and ARTIFICIAL PROPAGATION METHODS for ADULT PERCH

Terry Kayes
Food Science Department
University of Wisconsin-Madison

Intensive fish culture requires either an abundant and harvestable supply of young fish from natural sources or some mechanism for controlling reproduction in captured or domestic stocks. The commercial culture of perch ultimately depends upon the latter approach because state and federal regulations prohibit the harvesting of game fish from public waters and because environmental disturbances and normal year class fluctuations make natural supplies undependable. At best, harvesting wild perch fingerlings would be difficult and probably very expensive.

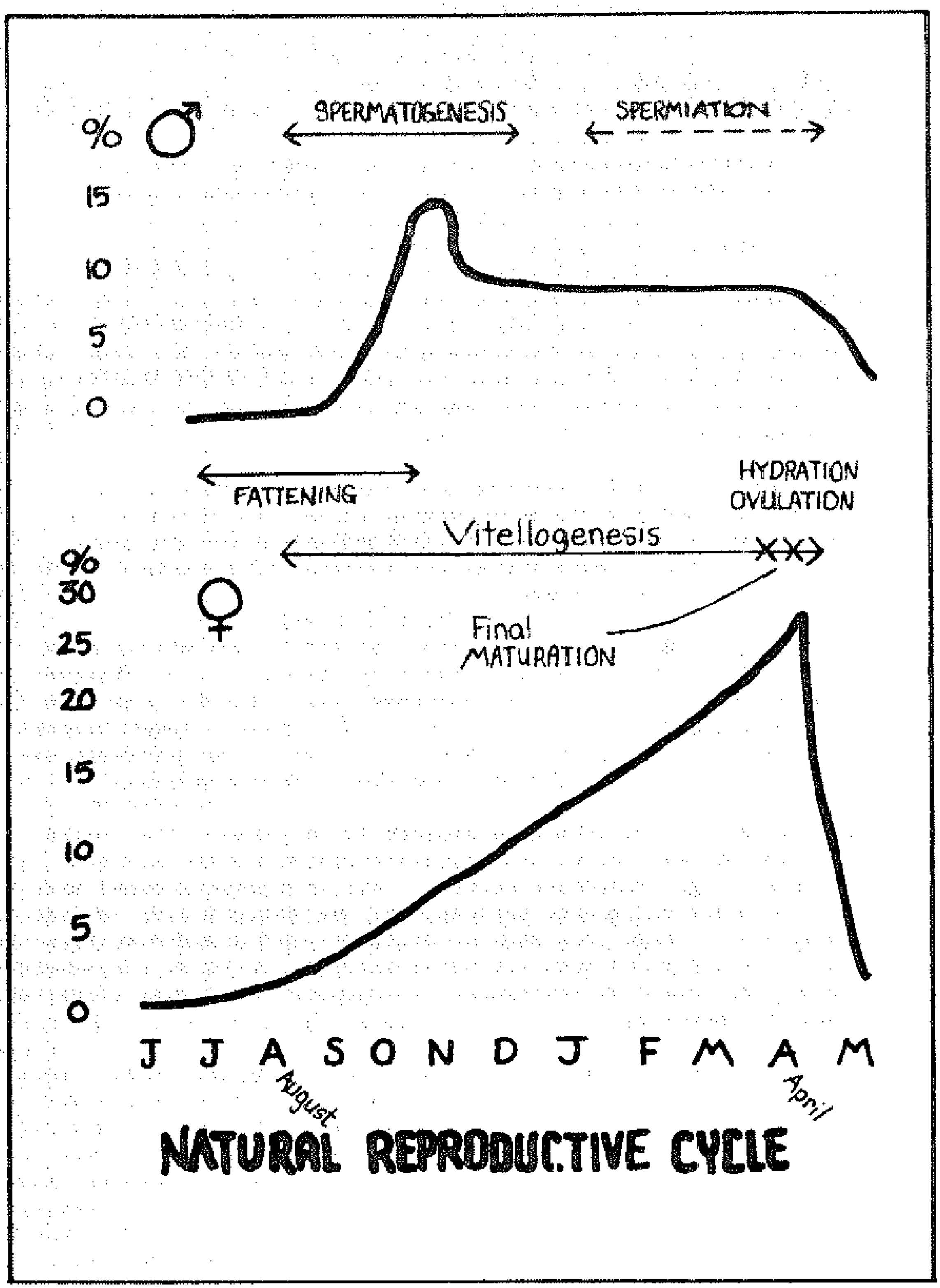
Methods are presently available for intensively propagating several species of fish. Unfortunately, perch is not one of these, so three years ago I began a research program to answer two major questions: First, can the annual reproductive cycle be manipulated to suit the needs of high intensity aquaculture? and, Second, can perch be propagated on a large scale when sexually mature fish are available? The answers to these questions are maybe and probably.

Today I am first going to outline some pertinent details regarding the reproductive physiology of perch. Then I will detail some methods of propagating this species under controlled conditions. Time and experience will show the extent to which these methods can be applied to mass culture.

The perch has an annual reproductive cycle during which the size and maturational state of the gonads fluctuate dramatically. The maturational state of the gonads is generally reflected in their size. The term that denotes this is the gonadic sematic index, which is essentially the size of the gonads relative to the body.

Figure 1 shows how the gonadic sematic index increases through the season. Note the males start out at zero and the gonads increase in size until they occupy about 15 percent of the total body weight. In females, the index reaches 30 percent. In both sexes, the gonads begin to increase in size in August and September and continue to develop throughout the winter until the fish finally spawn in the spring. The winter period is not a passive or resting phase; it is a period of active development.

The reproductive cycles in fish are controlled or influenced by a host of complex factors and interlocking mechanisms. Reproduction, as a physiological process, is controlled by the endocrine system, which in turn is controlled by the brain.



%
♂
SPERMATOGENESIS
SPERMIATION
15
10
5
0
FATTENING
HYDRATION
OVULATION
Vitellogenesis
%
30
♀
25
20
15
10
5
0
Final
MATURATION
J J A S O N D J F M A M
August
April
NATURAL REPRODUCTIVE CYCLE

Figure 1.

Maturation of the gonads and spawning of fish are two separate processes. The gonads obviously have to be mature before eggs can be released. The important mechanisms that control maturation of the gonads in fish can be divided into internal factors and external factors. Obviously a fish has to be well nourished to develop good gonads. Availability of a nutritionally proper food is a very important and basic requirement. Tied to this is the internal requirement for relatively good health. Photoperiod or day length is one of the cardinal factors influencing reproductive cycles. In the spring and fall, photoperiod is either increasing or decreasing and evolution has caused this to be a primary key mechanism in the environment to tell animals what time of the year it is. Another factor is temperature and there are also internal biochemical mechanisms. A final factor is tissue "readiness." The gonads contain a variety of tissues that give rise to eggs and sperm. Hormones, experimental temperature regimes or photoperiods can be used to try to stimulate the gonads, but this only works at certain times of the year. The very simple reason for this is that at certain times of the year, the tissues will not respond to any type of stimulation.

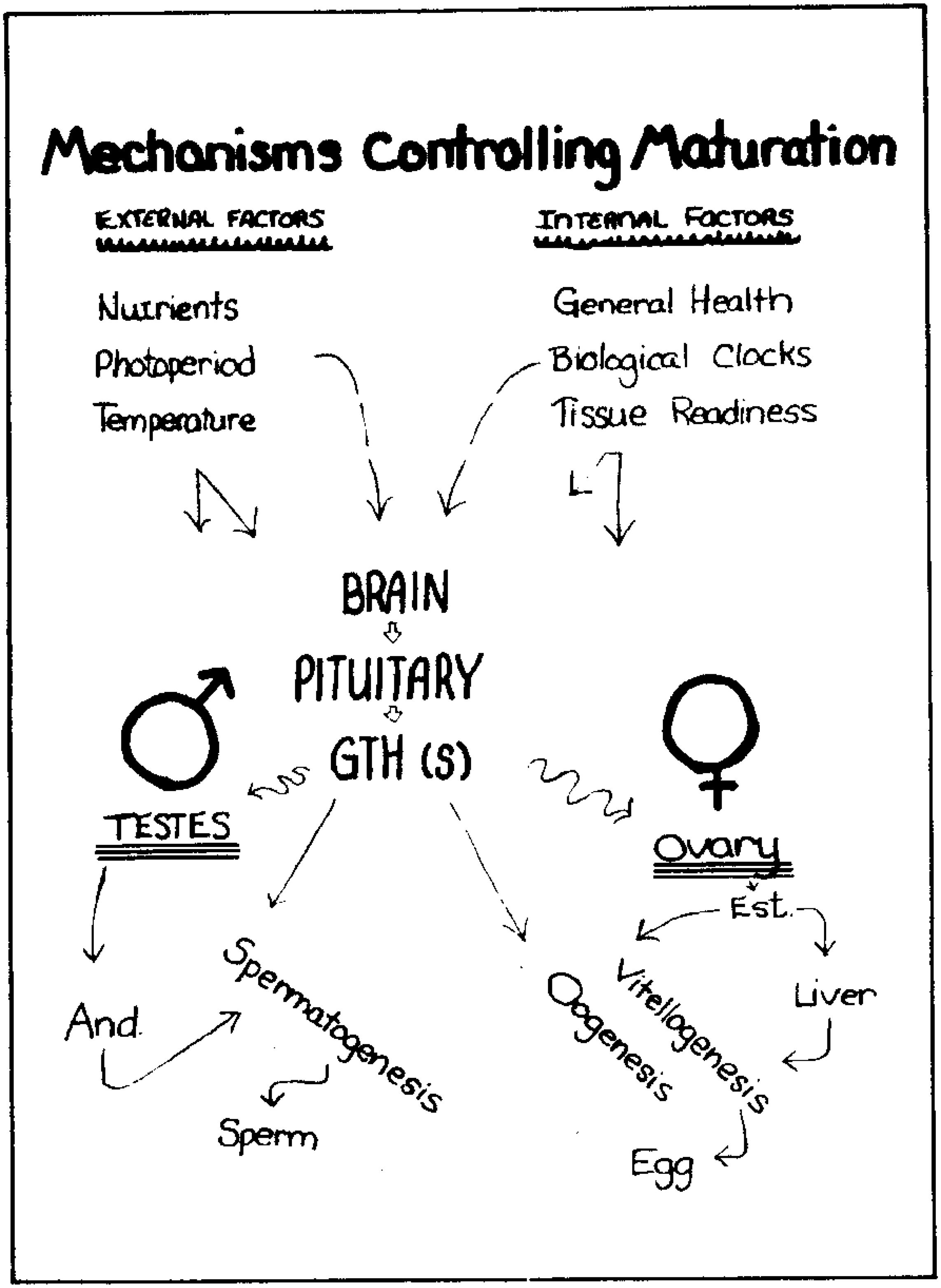
The brain picks up stimuli from the environment and, through the pituitary gland, controls the reproductive cycle. The pituitary excretes a variety of hormones, one of which is called gonadatrophic hormone or GTH. These gonadatropins are secreted on a seasonal cycle to control reproductive rhythms.

In the case of the male, the gonadatropin enters the bloodstream and reaches the testes, which are also endocrine glands capable of secreting hormones which are primarily androgens. The gonadatropins also stimulate spermatogenesis or sperm production. Sperm are only present in the testes of fish at certain times of the year. The androgens excreted by the testes apparently are involved in this process.

A rather similar type of mechanism appears in the ovary. The gonadatropins travel to the ovaries and stimulate production of estrogen, and oogenesis or egg production occurs. This is also a seasonal phenomenon. The major difference between eggs and sperm in fish is that the egg has a very large yolk made up primarily of fat and some protein. These proteins and fats are synthesized in the liver and synthesis is under the conrol of estrogens. Yolk collection begins after the initiation of oogenesis.

Fish generally spawn at the time of year that is best for them. Trout spawn in the autumn, whitefish in the winter, carp and bluegills in the summer and perch and walleye in the spring. There are a number of external factors that tell the fish when it is time to spawn. One possibility is runoff from snow melt to stimulate spring spawning fish. Runoff is known to have an important influence in controlling spawning of such fish as carp, but it is not known whether or not it influences spawning of perch. Photoperiod is probably the most important influence on perch spawning.

Other factors influencing perch spawning are temperature, spawning ground and behavior. It has long been known that perch spawn when the water reaches 10°C (50°F). Often fish will not spawn unless an active spawning ground is available—they will simply absorb their eggs. The female may also absorb her eggs if a male is not present to make a behavioral stimulus. Walleyes will not spawn without the presence of a



Mechanisms Controlling Maturation
EXTERNAL FACTORS
Nutrients
Photoperiod
Temperature
INTERNAL FACTORS
General Health
Biological Clocks
Tissue Readiness
BRAIN
PITUITARY
GTH (S)
TESTES
Ovary
Est.
Liver
And.
Spermatogenesis
Sperm
Vitellogenesis
Oogenesis
Egg

Figure 2.

male, but perch will, under some conditions, if other internal factors are working.

There is a regular chronology of events that occur in fish when they spawn that begins with a mature gonad and the various accessory organs that are involved in spawning. There is a fluid shift into the gonads as they hydrate and begin to ripen. In the females, there is a great deal of abdominal swelling. The next step in most fish is ovulation and spermiation. Ovulation is simply the release of eggs from follicles in the ovary into the internal structure where they are ready to be released. Spermiation is the release of sperm from lobules of the testes into the interior where they can be released on spawning. Finally, spawning itself takes place and again, the endocrine system is involved. Gonadatropic hormones have been used in fish culture to stimulate the process of spawning. It is known that these hormones, either directly or indirectly, stimulate the final maturation, hydration, ripening, ovulation and spermiation. There is some evidence that the actual act of spawning, as opposed to ovulation and spermiation, is under the control of another set of hormones, vasotacin and isotocin, that cause violent muscle contractions.

In the summer, fish have a lot of food available, they eat well and are healthy. In the late summer and early fall, they put on an enormous amount of fat. I frankly believe that this prematuration fattening is critical to the later maturation of the gonads. These fish need a fat depot in order to get full development during the winter.

In the male, spermatogenesis is initiated in August or September. By late autumn, it is very active. After a time, most of the sperm cells in the testes convert to sperm and milt can be produced as early as December or January, but I don't know if it is viable. The gonads are in a rather quiescent state until spring when the water warms and spermiation occurs. Eventually, perch have a very copious milt.

Females start maturing at about the same time. Vitellogenesis occurs actively throughout the entire winter. I have used gonadatropins to stimulate the release of eggs as early as December but they were not fully developed. In the spring, in rapid succession, final maturation of the eggs, hydration, ovulation and spawning take place. The entire period of spawning in a given lake is extremely short, lasting only a week or two, and is surprisingly consistent from year to year.

During the period of initial development of the gonads, temperatures in the range of 16-20°C are required. Decreasing photoperiod also plays a part in this initial step, but temperature is the most important factor. After about December, it doesn't matter what photoperiod is maintained, but I would suggest duplicating the natural light conditions through the winter. While photoperiod is not too important during the winter, low temperatures are very important for this stage of development. Dr. Hokanson will discuss this fact in his presentation, but it is important to note that if brood stock are held at well head temperatures of 10°-11°C through the winter, the eggs will be in very poor condition when spawning occurs in the spring.

In Lake Mendota, we set our nets when the ice goes out and get our first green fish about April 1. Spawning peaks about one week later. On about April 9 we get our peak catch of females and on about April 21

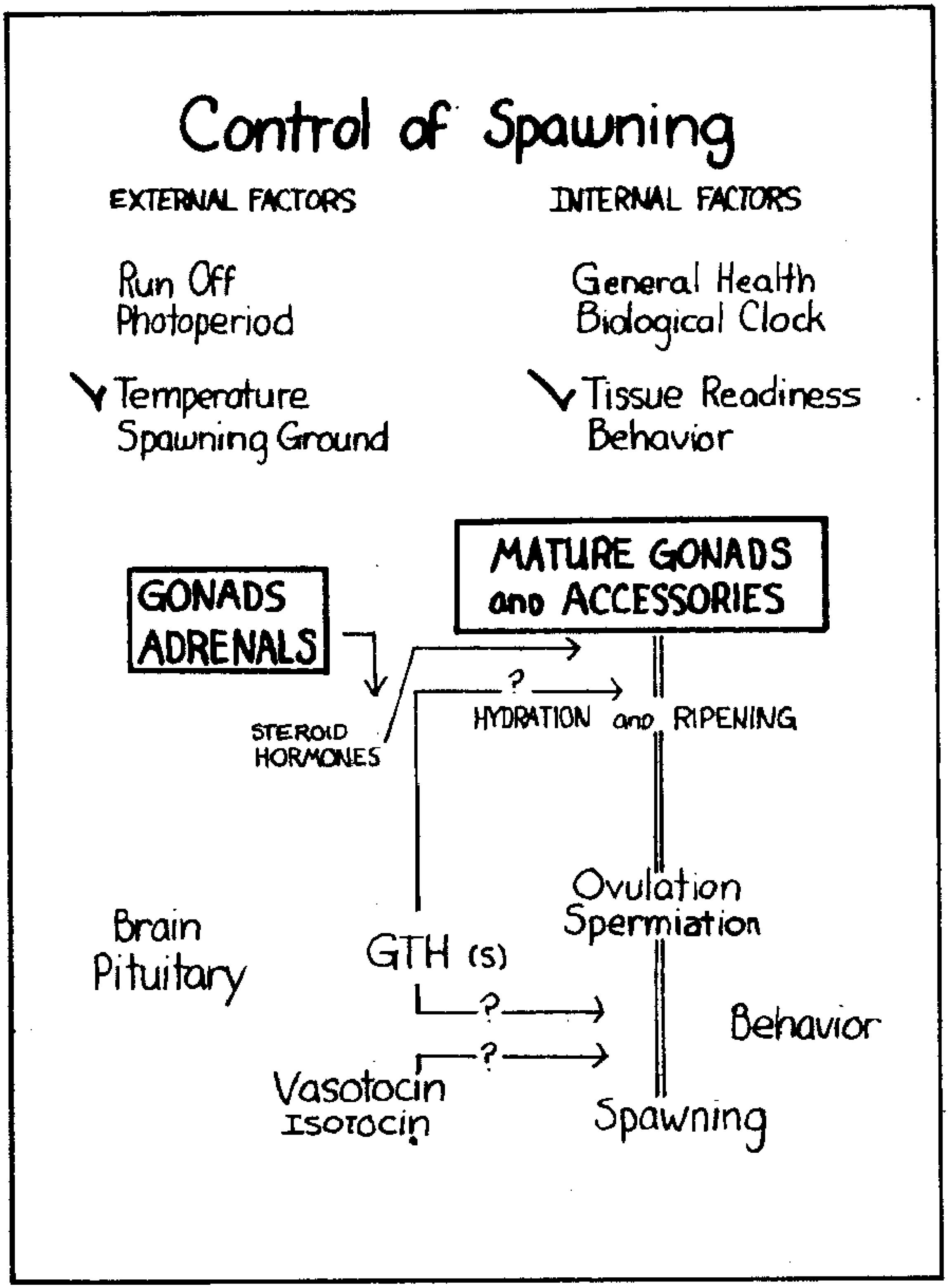

Control of Spawning
EXTERNAL FACTORS
INTERNAL FACTORS
Run Off
Photoperiod
Temperature
Spawning Ground
General Health
Biological Clock
Tissue Readiness
Behavior
MATURE GONADS and ACCESSORIES
GONADS
ADRENALS
STEROID HORMONES
?
HYDRATION and RIPENING
Ovulation
Spermiation
Brain
Pituitary
GTH (s)
?
?
Behavior
Vasotocin
Isotocin
Spawning

Figure 3.

we normally see our last green fish. I have followed this cycle for three successive years now and it is almost identical each year.

Figure 4 shows some experimental results of natural spawning of perch in tanks. I compared the cumulative percent of females that spawned on two different photoperiods. The control group was at the normal spring photoperiod of about 13-1/2 hours and the experimental photoperiod was six hours, corresponding to a normal winter day. Starting in February, I gradually increased the temperature to 10°. There is a certain amount of fluctuation, but the interesting point is that irrespective of the photoperiods, the first spawning in the laboratory occurred almost the exact time as spawning started in the field. The difference was less than a week.

This suggests a number of things, including the notion of biological clocks and tissue readiness. Regardless of the photoperiod and temperature regime, captive females will spawn during the month of April. These eggs, however, won't be any good unless the fish has been under the proper conditions for maturation.

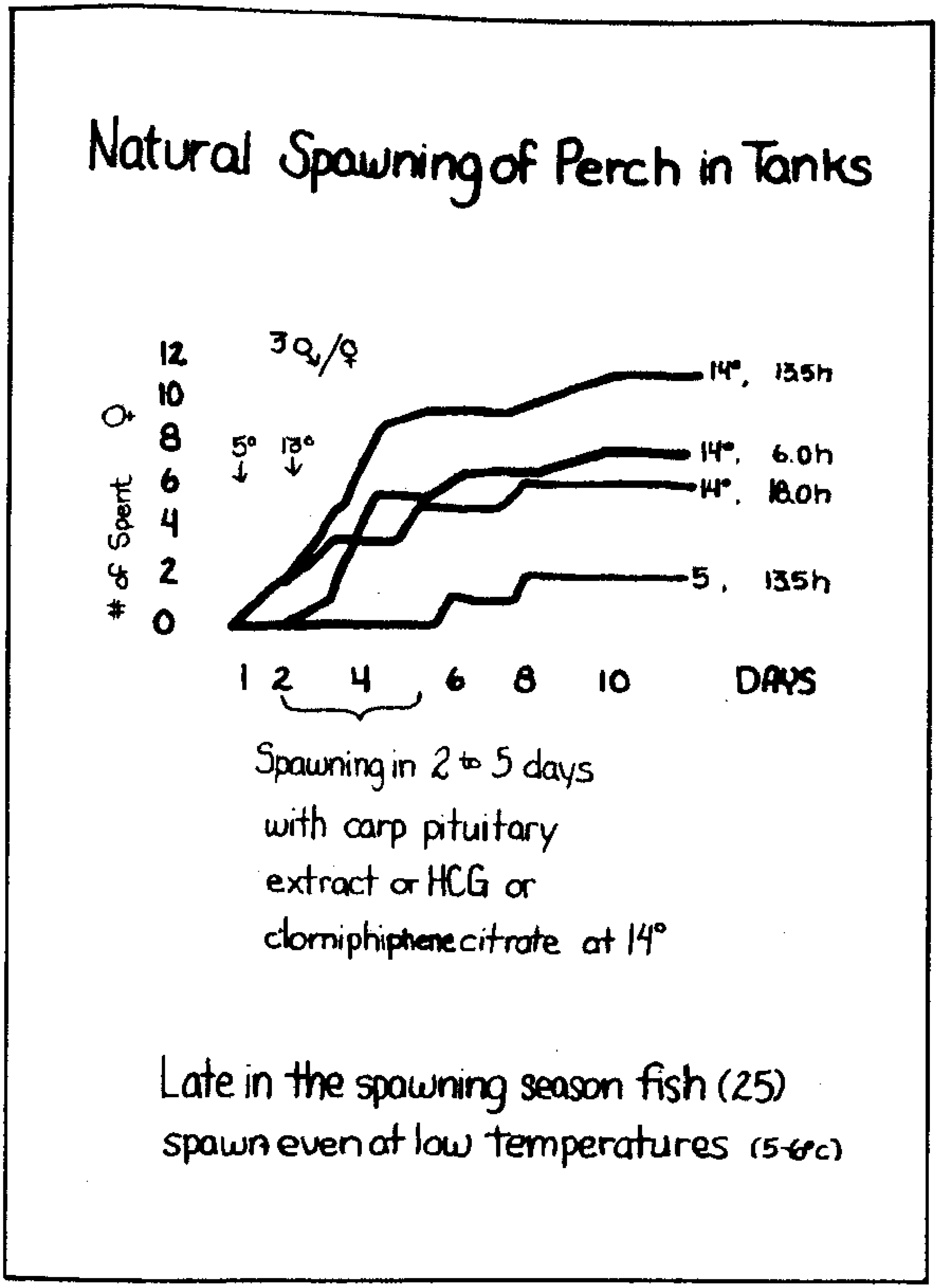
Methods have not been developed for manipulating the perch's annual reproductive cycle under controlled conditions. It may be indeed possible, but if ever such methods are developed, they will have to take into consideration the fact that perch reproductive tissues are slow to respond and may be preconditioned by prior reproductive history. Elaborate environmental controls may be necessary to control temperature and photoperiod. Good long-term nutrition will be required, especially in the females.

Now I will discuss procedures that have been developed for increasing the predictability of perch spawning and for artificially fertilizing perch eggs.

We performed an experiment in which we brought wild fish into the laboratory as soon as the ice went out in Lake Mendota. Twelve females and 24 males in the green condition were placed in a 200-gallon tank and subjected to a variety of different photoperiods and temperatures. The greatest amount and predictability of spawning were at a temperature of 14°C and a natural photoperiod of 13-1/2 hours. If the photoperiod was excessively long or short, all the fish still spawned eventually, but over a longer period of time. If the fish are held at 5°C, spawning will be delayed about a week, but it will still occur. While fish will spawn, if forced to, at this temperature, they will not be successful, as the eggs will often water harden before being released, killing the female, and the males won't fertilize the eggs at this temperature.

The point I'd like to make on these tank spawning experiments is that the females will drop their eggs but the males will not necessarily fertilize them. In fact, a female will drop her eggs without a male present. This is an additional reason for developing methods for artificially fertilizing the eggs.

Figure 5 diagrams natural spawning in perch. In nature, spawning is continuous over a period of about two weeks, so there is relatively little predictability. If these fish are to be spawned artificially, the predictability must be increased so the eggs can be obtained approximately when required.



Natural Spawning of Perch in Tanks
3♂/♀
12
10
8
6
4
2
0
# of Spent ♀
5°
13°
14°, 13.5h
14°, 6.0h
14°, 18.0h
5, 13.5h
1 2 4 6 8 10
DAYS
Spawning in 2 to 5 days
with carp pituitary
extract or HCG or
clorniphiphene citrate at 14°
Late in the spawning season fish (25)
spawn even at low temperatures (5-6°C)

Figure 4.

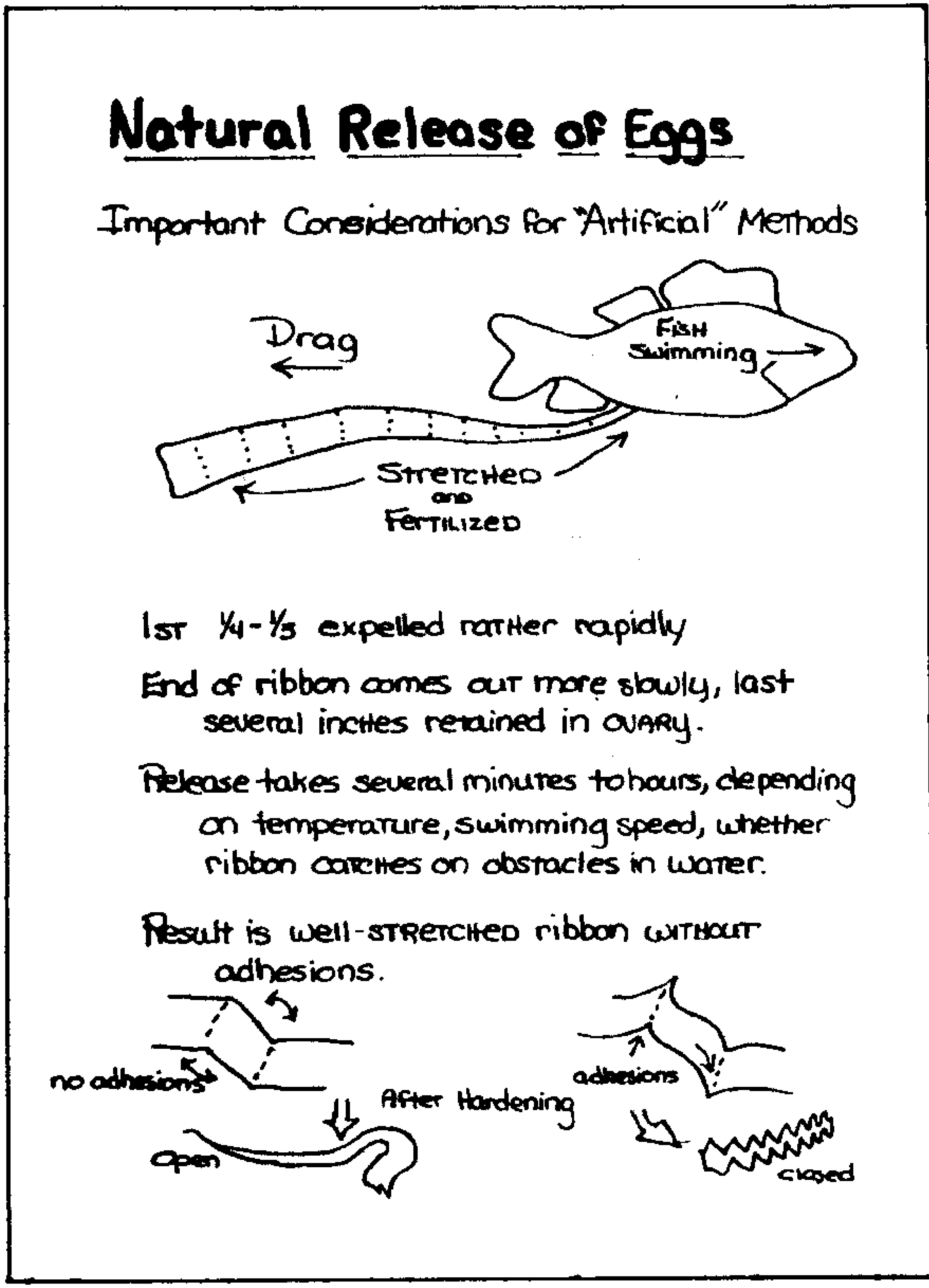

Natural Release of Eggs
Important Considerations for "Artificial" Methods
Drag
Fish Swimming
Stretched and Fertilized
1st 1/4 - 1/3 expelled rather rapidly
End of ribbon comes out more slowly, last several inches retained in ovary.
Release takes several minutes to hours, depending on temperature, swimming speed, whether ribbon catches on obstacles in water.
Result is well-stretched ribbon without adhesions.
no adhesions
adhesions
After Hardening
Open
closed

Figure 5.

Hormones and drugs have been used for this in aquaculture for many years and Figure 6 summarizes some of our experimental results. The bottom graph shows the spawning pattern of fish injected with a saline solution. Spawning was spread out over seven days. The top graph shows how carp pituitary extract makes all the fish spawn on the same day. Human Chorionic Gonadatropin had a very similar effect. Clomicin citrate, a drug which stimulates the pituitary to secrete its own gonadatropin, didn't work quite as well in improving the predictability of spawning.

It was long thought that perch spawn at night. Actually, perch usually spawn first thing in the morning. If injections are given on two successive afternoons, the fish will spawn the next day. About 80 percent will spawn in the morning, so not only can hormones be used to predict the day these fish will spawn but also the time of day.

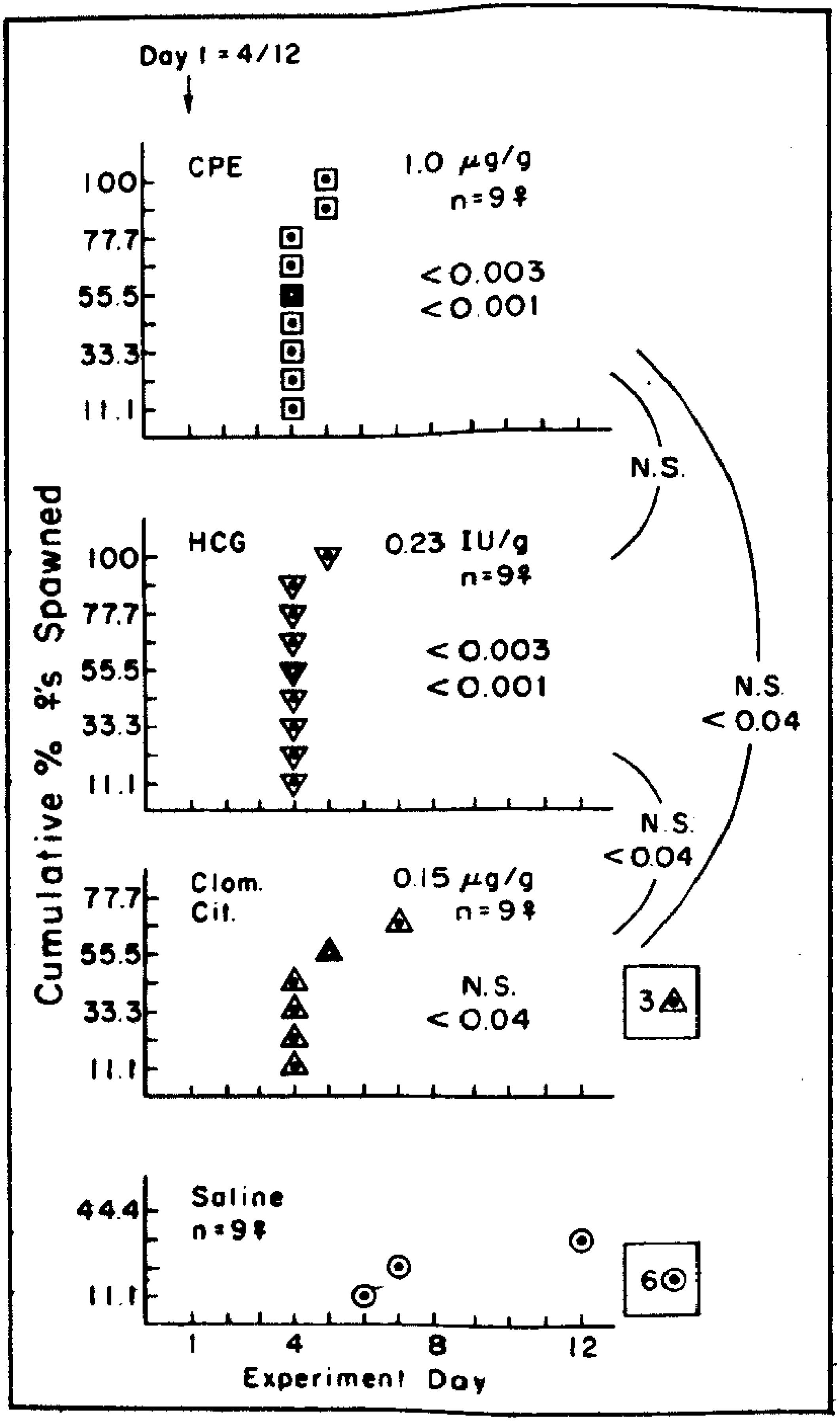
When the female spawns, she is swimming and the ribbon starts to come out and unfold like a very long concertina. The drag caused by the movement of the fish causes the ribbon to stretch. The first quarter or third of this ribbon is expelled rather explosively and the rest comes out more slowly. The last several inches is sometimes retained by the female. Release of the entire egg ribbon takes several minutes to hours depending on swimming speed, temperature and whether or not the ribbon catches on an obstruction to aid in its removal. With no obstructions present in 14-15° water, the entire egg ribbon will be expelled in two to three minutes, but in 5° water it takes hours or even days for the female to rid herself of the egg mass.

As the female is expelling the egg ribbon, a pod of from two to five males follow to fertilize it. The males lay down a path of milt alongside the female and she drags the egg mass through this cloud.

Because of the accordion-like nature of the egg mass, it is important that it be mechanically stretched so sperm can reach the inside folds. Even if the entire mass is fertilized, the eggs will die if the ribbon folds back, robbing them of oxygen. This stretching normally takes place in nature, but if the fish is confined to a small tank where it can't swim as well and nothing is present to catch the ribbon, it won't be mechanically stretched.

Because of this unique egg mass and necessity to keep it stretched, perch egg culture presents some incubation problems not encountered with other fish.

Figure 7 summarizes our results in natural spawning of perch in tanks. I would like to emphasize here that no substrate or males are necessary for perch to drop their eggs. I looked at 80 females spawned during two seasons and got 41.8 percent fertility by natural fertilization. This was in 180-gallon tanks with 10 to 15 females and 20 to 30 males. Fifty-seven of the 80 ribbons showed fertility and of these, 58.6 percent of the eggs were fertile. In another experiment, I used a 45-gallon tank with one female and three males. Out of 40 ribbons, I got 70 percent fertility and 85 percent fertility of fertilized ribbons. This 85 percent figure agrees well with some of the old literature in fish culture. Next I'll discuss how this can be improved upon.



Day 1 = 4/12
CPE
1.0 μg/g
n=9♀
<0.003
<0.001
HCG
0.23 IU/g
n=9♀
<0.003
<0.001
Clom.
Cit.
0.15 μg/g
n=9♀
N.S.
<0.04
Saline
n=9♀
N.S.
N.S.
<0.04
N.S.
<0.04
3
6
Cumulative % ♀'s Spawned
100
77.7
55.5
33.3
11.1
44.4
1
4
8
12
Experiment Day

Figure 6.

Natural Spawning in Tanks ~14°C

♀'s Not necessary for release
No substrate necessary

Tank Volume * Fish	2/r n	% Fertility $\bar{x}$ SEM	
–180 gal.*	80	41.8 ± 4.5	All ribbons
21-24 ♀ 28 ♀	57	58.6 ± 4.7	Only ribbon with signs of fertility
– 45 gal.	40	70.1 ± 6.2	All ribbons
1 ♀ 3 ♀	33	85.0 ± 4.3	Only ribbons with signs of fertility

. . . .

* Handled and injected every other day.

Manual of Fish Culture 1897 – 79% of 955,000 eggs hatched in "SHAD JARS." Natural spawn in concrete tanks, infertile ribbon rare. No details.

Needs more work on effects of VOLUME, DENSITY, ♀/♀

Control - light intensity, noise, disturbances.

Figure 7.

Artificial spawning is the mechanical stripping of the eggs from the female and milt from the male, mixing the two and culturing the eggs. Hormones help increase the predictability, and close observation is necessary. A fish cannot be stripped before she is ripe. It takes experience to develop the skill required to perform this operation.

Trout and walleye eggs are normally fertilized by the dry method. Sperm and eggs of fish are deactivated very quickly by exposure to fresh water. Sperm loses its capacity to penetrate the egg 30-60 seconds after contacting water and eggs begin to water harden immediately so that they cannot be fertilized after a few minutes in water. In the dry method, the eggs and milt are stripped into a dry container, mixed thoroughly and then water is added to activate the sperm and permit fertilization.

Perch eggs are difficult to fertilize by this method because the nature of the ribbon makes mixing difficult; the ribbon doesn't get stretched and the sperm glutenates like cooked egg whites. In a sample of 30 fish, I got 80 percent fertility using the dry method.

An older technique of artificial spawning is the wet method in which the eggs are stripped, water is added immediately and the milt poured in and mixed as quickly as possible. I tried this with 51 fish and got 83 percent fertility, which is very close to the results obtained by the dry method. To examine the importance of the time factor, I tried adding the water and waiting one minute before adding the milt. I got the same level of fertility but a tremendous increase in the number of deformities in the developing larvae. If five minutes elapse before adding the milt, fertility drops to 15-16 percent and nearly all larvae that survive are deformed. In practice, the fish culturist has enough time to add the milt if he is well organized.

Carp have very glutinous eggs and to facilitate fertilization, a variety of solutions has been used instead of fresh water. These solutions, usually containing tannic acids or salines, have two basic functions. First, they tend to cut the mucous that covers the eggs to facilitate sperm penetration. Secondly, sperm life is increased and water hardening is decreased slightly in saline solutions. As this has been used for quite some time in carp culture, I tried a solution of .5 percent sodium chloride on perch. When I used the wet method with this saline solution, I got 97 percent fertility. I only had the chance to do this with eight to 10 fish so it needs to be replicated, but I think it can be improved so it will be feasible to increase the success of fertility by the artificial method to very near 100 percent.

QUESTIONS AND ANSWERS

Do you use any fungicide treatment on the eggs?

Kayes: If you are using some type of incubator rather than a pond to incubate eggs, it is definitely required, especially when the incubator is loaded heavy. When culturing eggs in Heath Technicabinets, we pour in 30-40 ml of formalin periodically. The flow through the incubator is great enough so this treatment doesn't seem to hurt the eggs, and it keeps the fungus down.

Do you treat the brood stock after handling them to cut down on fungus problems?

Kayes: This is rarely necessary because the whole sequence of events is of rather short duration. I rarely handle a fish more than twice in the spawning process.

Do you have a procedure by which you can accurately determine the spawning date of all your females?

Kayes: Most of the work that I have done has been experimental and not for production purposes, so I don't have a set formula for injecting fish on a large scale.

Is hypothesization a good method for perch?

Kayes: It is used very routinely with many kinds of fish. The problem is that some fish have a great deal of species specificity to a particular hormone. Most of these hormones are proteins so within different species they may be interchangeable, but at the biochemical level they differ somewhat. A good example of this is that bluegills, bass and similar fish do not respond to mammalian hormones. You can buy mammalian hormones on the market but you can't generally buy fish hormones, so you have to collect your own pituitary glands from the species in question. You can buy acetone extracts of carp pituitary material from two or three different sources in the country. Some of them aren't very good, however.

What is the incubation time and is it temperature dependent?

Kayes: The incubation period is about 10 days and it is influenced by temperature—but not as much as you might think. There are ideal conditions for incubating the eggs and under these conditions they will hatch in about 10 days.

How well do the fish spawn naturally in indoor tanks?

Kayes: Our success in this has been variable. Sometimes the males will fertilize the eggs and sometimes they won't. It's easy to determine whether male perch are capable of spawning as they put out more milt relative to their body size than most fish and it flows freely during handling. The question is, then, why don't they fertilize the eggs? The answer is often bright lights, loud or abrupt noises or other disturbing influences.

Do you think spawning would be more efficient given three males per female rather than only two?

Kayes: We don't have any data on that but I think it's something that really needs to be looked at, especially for pond raising. Most fish culturists use more males than females but I'm not aware of any real data that suggest the ideal ratio for perch.

Does using the .5 percent saline solution lengthen the period during which the eggs can be fertilized?

Kayes: I haven't had the opportunity to check that out.

Do you try to do it immediately?

Kayes: It is always best to do it as quickly as possible, within about 20 seconds. That's really quite a lot of time and it shouldn't present any problems.

But you wouldn't recommend adding the saline solution at exactly the same time as you put the milt in?

Kayes: I don't think that it would give you any advantage but I can't be sure about that.

By controlling climate, can you get perch to spawn in December, or different months of the year under lab conditions?

Kayes: We've done some work on that but there are a lot of logistical problems. The tissues are very slow to respond, so experimentally the whole cycle hasn't been put together and shown that it can be done. This would be a very elaborate experiment. I have worked with various segments of the reproductive cycle and shown that certain kinds of temperatures and photoperiods are important. But to get a spawning fish through the entire reproductive cycle under controlled conditions hasn't been done yet. Perch do spawn at slightly different times of the year depending upon where they are in the world and they are a widely dispersed species. There is a European species very closely related to ours and they have been introduced to Australia. There is a real reason to think that the first reproductive cycle a fish goes through keys it in on the annual cycle of where it is at that time.

My point is that the finished product is all going to be coming off at the same time.

Kayes: Not necessarily. Once you get the perch fingerlings, you can hold them at lower temperatures for the duration that you need. As to how long you can hold fish back without creating problems is not really known. We have held perch fingerlings for months and months at low temperatures and they didn't grow, so it would be feasible to keep them at reduced temperatures and grow them out whenever you want.

Do you inject the males as well as the females?

Kayes: No, I don't.

Do the males naturally get ready from the females' behavior?

Kayes: The males always have plenty of milt at this time of the year. There is never a problem in males being able to spawn. Behavioral participation of the female is required.

So you never have any problem getting them synchronized?

Kayes: No. When we have gotten good natural fertilization in tanks there has not been a problem of synchronization. I might also indicate here that fresh males generally give far better fertility than those that have spawned several times in the same season.

How many eggs does a perch produce?

Kayes: It depends upon the size of the fish and her nutritional history. A 1/2-pound fish will put out from 25,000 to 50,000 eggs.

Do you see any possibility of holding fertilized eggs in dormàncy over a period of time?

Kayes: I think it is possible from a theoretical point of view but I'm not sure it would have any practical application. We are working on ways of preserving sperm, which is much easier than preserving eggs.

In determining percentage of fertilization, do you make an actual count?

Kayes: Yes, but at what stage of development the count is made is rather arbitrary. One hundred percent fertility does not mean 100 percent hatch or 100 percent larval survival or 100 percent fingerling survival.

What is the life span of a wild perch living in a lake?

Kayes: I don't know. If you consider the survival of all the fish that hatch, I doubt if the average would be a year—it would probably be just a few months. If they can survive predation, they may live six to seven years, but this is certainly not average.

Does holding fish at reduced temperatures result in any retarding of the future growth rate?

Kayes: Not as far as we can tell.

Do you have any indication that the second or third generation fish would have higher viability and growth rates?

Kayes: No. We haven't got third generation fish.

How do you separate the gelatinous mass from the larvae when they hatch?

Kayes: This is very difficult. The most practical procedure is to remove the ribbons from the incubator before they start hatching. The fry can't be fed indoors anyway so the best time to take them to the ponds is just before they start to hatch. They start getting hard to handle on the fifth or sixth day.

Where do you get your brood stock?

Kayes: We catch them in Lake Mendota. We have obtained some from the National Fish Hatchery at Lake Mills.

Where can you buy brood stock?

Kayes: There are very few people in the Midwest selling perch. I don't know of any source right now.

At what temperature do the fish spawn in the lake?

Kayes: We get our best harvest of adult fish when the lake is 8 or 9°. When we get the fish back to the lab, we ice down our tanks to this temperature and let it rise gradually to well head temperature which is about 12°.

Do you have any figures on the number of fingerlings harvested in relation to the number of fry stocked?

Kayes: Last spring was our first real experience with this and we didn't know how many fingerlings we could produce so we stocked about 500,000 eggs in our 1/3 acre of ponds. Only about 1/3 of those eggs were fertile. We harvested between 20,000 and 25,000 fingerlings.

I don't understand the relationship between the outdoor and indoor phases of production.

Kayes: We don't have the technology to raise fingerlings indoors so we do it in ponds. We can raise a relatively large number of fingerlings in a small acreage of ponds. Obviously we can't grow them to market size in that same acreage. That is where the indoor grow-out units come in.

Can you place the eggs in the ponds immediately following fertilization?

Kayes: Yes. That's up to the fish culturist and how much time he has. At any rate, it should be in the first seven days or so following fertilization. It takes 10-11 days from time of fertility to time of hatch. Two to three days before they hatch they become very difficult to manage.

You said you fertilize the ponds. What do you mean by that?

Kayes: The ponds can be fertilized with commercial fertilizer or organic fertilizer. We use alfalfa pellets to increase the plankton development. You have to have the pond ready before you put the eggs in.

OPTIMUM CULTURE REQUIREMENTS OF THE EARLY LIFE PHASES OF THE YELLOW PERCH

Kenneth E.F. Hokanson
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My presentation will summarize two major activities in our laboratory. The first set of experiments determined the temperature requirements of the different phases of the yellow perch's cycle. Secondly, we tried to optimize the culture requirements through the life cycle. The purpose of this type of research is to evaluate candidate test species for bioassays to test the impact of toxic substances on the life cycle. This objective is quite different from that of the aquaculturist who is trying to optimize the yield per unit cost of the product. Our objective is basically to optimize the survival and rearing techniques of relatively small numbers of animals.

This paper will describe the temperature requirements of the different phases in the early life cycle of the yellow perch, our experience in the culture of larval yellow perch and some insight on the requirements for growth and survival of juvenile perch.

Development of the perch begins with the cleavage embryo. This is the period when the germ cells are beginning to divide to become a multicelled stage. As the embryo develops, a strip of tissue can be seen that forms a curled band around the yolk sac. The yolk sac provides endogenous nutrition to the larva before it begins to feed. Later larval forms are the pelagic and dimercel stages. The juvenile resembles the adult except for its maturation and reproductive functions.

Reproduction involves a complex sequence of events starting with maturation and leading to spawning migrations. The spawning act itself involves a deposition of viable gametes, the embryo and larval development and the commencement of independent feeding, which is the real bottleneck in the culture of this species.

The important things to review from Mr. Kayes' talk that have relevancy to the series of experiments that I will describe are, first of all, that there is a fattening period, or refractory period, following spawning in the summer months. This is the period in which the remaining residual ova undergo resorption and the new germ cells multiply to make the new complement of ova for the next spawning season. This period lasts roughly from June through August, at which time the ova begin to grow in size. The second important point to recall from Mr. Kayes' presentation is that the principal gonadal growth phase, particularly in the female, occurs during the winter months when body growth is minimal.

In the first year of our experiments at the Water Quality Laboratory in Duluth, we held brood stock at various temperatures, including the natural Lake Superior temperature regime. These fish were introduced into experimental spawning tanks and they spawned very well, particularly those that had experienced a natural temperature cycle. Fish that had been exposed to experimental temperatures greater than 20°C did not spawn at all.

The second year of experimentation, we started earlier so that the fish were in the experimental tanks when the eggs started to grow. Again we controlled the temperatures and the only fish that spawned were those that had been exposed to the coldest temperature.

This led us to a final series of experiments where we wanted to expose the adult perch to a series of low constant temperatures, which we refer to as the chill temperature, for different durations. At the end of the chill period we increased the temperature at a rate of 2°C per week, similar to the natural rise in temperatures in Lake Mendota, which we were trying to simulate. This gave us 16 different types of temperature regimes, some of which were accelerated above the natural cycle and some which were slower than the natural cycle.

Figure 1 shows the experimental results of these last experiments.

The graph shows the proportion of females that spawned plotted against the chill temperatures and the chill duration. We feel that successful spawning really measures successful maturation. Chill temperatures no higher than 6°C are required for 100 percent spawning participation. The chill duration needed to be at least 185 days from October 3. When we accelerated the temperature too soon, fewer and fewer females ripened and matured by the time natural spawning temperatures were available. The experiment ended when experimental temperatures reached 20°C because we couldn't keep the fish alive due to columnaris and we already knew from previous experiments that viable eggs could not be produced at this temperature.

Since these fish had freedom to select their own temperatures to spawn, we measured the temperature at the time the egg masses were found in the experimental tanks. We found that the fish on the accelerated cycles spawned a little sooner than the controls. We obtained spawn as early as March and as late as late June in the overall treatments. Figure 2 shows the chill duration and temperature plotted against the temperature at which the fish spawned.

Over 80 percent of these fish spawned at the temperatures that are normally observed on the spawning grounds in late April through May when this stock of fish spawns naturally. The time of spawning can be advanced or delayed slightly but then the fish are spawning when the water is either warmer or colder than the normal spawning temperature.

There are natural perch stocks in southern latitudes that spawn as early as late February and northern fish that spawn in early July. I feel that the adaptation of the adult reproductive cycle is probably occurring at the time of first maturity. This needs experimental verification but manipulation of a given adult cycle is very difficult.

Additional insight on temperature manipulation was gained in our experimental work with northern pike. We raised pike over the winter at ambient lake temperature and at 20°C. When we sacrificed these animals in the spring, the pike held at normal temperatures were small, but they had very large ova. The fish held in warm water were much larger, but had very small ova. What happened is that at high temperatures, we retarded the rate of development of the ova. The males held at normal

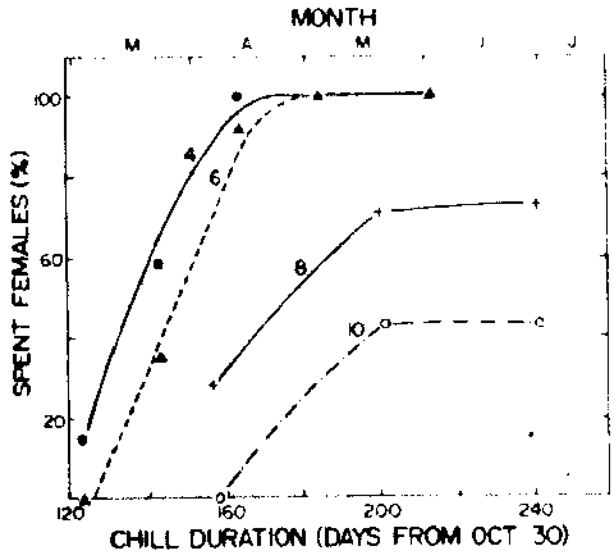


FIG. 1. Percentages of female yellow perch (*Perca flavescens*) that spawned during exposure to four chill temperatures (4, 6, 8, and 10°C) of different durations (123–242 days from October 30). Temperature was increased at a rate of 2°C/wk to a maximum of 20°C after termination of the exposure to the various chill temperatures (from Jones et al., Environmental Research Laboratory-Duluth, unpublished data).

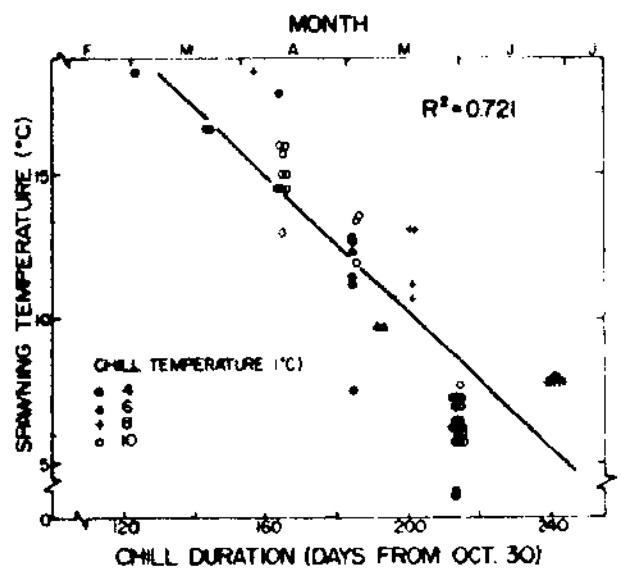


FIG. 2. Spawning temperature observed at the time of laboratory spawning of yellow perch from Minnesota that had been exposed to four chill temperatures for various periods (from Jones et al. Environmental Research Laboratory–Duluth, unpublished data). Chill duration was the time of exposure to chill temperatures from October 30 to beginning of spring rise in temperature at 2°C/wk.

temperatures matured as expected, but those held at elevated temperatures had very large testes in various stages of resorption.

It appears that there are different rates of development in the male and female cycle. When the temperature is too high, the cycle gets out of synchrony.

After obtaining the egg ribbons from these fish we measured the viability by taking a subsample, incubating it and counting the embryos when development became visually apparent. We found that we got maximum egg viability at 8°-11°C with reduction increasing as the temperature extremes of 4° and 18-19° were approached.

Figure 3 shows the results of some work done at the University of Minnesota on the walleye.

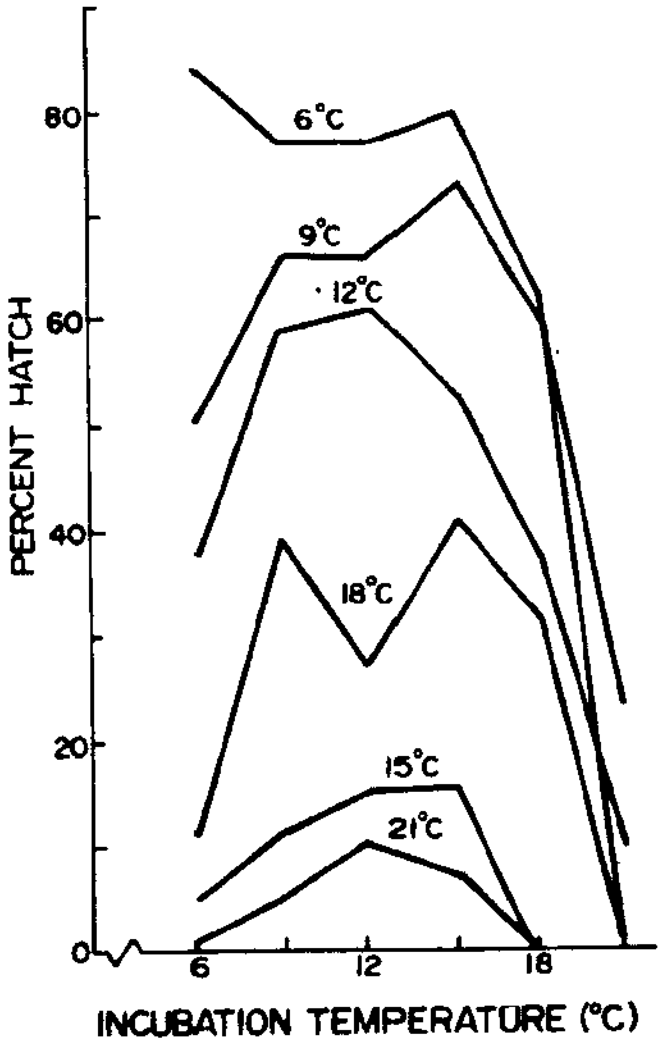
They held adult walleyes at six different temperatures prior to fertilizing the ova. Then they incubated subsamples of each batch of fertilized eggs at different temperatures and finally measured the percentage hatched as a function of incubation temperature. We see that the tolerance ranges from 4° to 20° for walleye, but the real effect of the holding temperature on the adult is to lower the maximum percentage of fertility of the ova. The higher the temperature, the lower the proportion of eggs that are fertile. The percentage hatch is a function of the acclimatization temperature of the adults as well as the incubation temperature of the eggs.

The implications for fish culture are that with modest temperature control, the adults can be preconditioned. We suggest that temperature affects the production of the specific gonadatropin that is involved in the ovulation and the ripening of eggs. It is possible that temperature control could be used in lieu of hormone injection for control of ovulation in fish culture work.

We designed our second group of experiments to examine the temperature requirements of the embryo and early larval stages of perch. First we simply exposed the eggs to constant temperatures right after fertilization. We knew that the temperature requirements changed with the state of development and we wanted to start with the embryo. Secondly, we reared the advanced embryo and exposed this life stage to a series of constant temperatures. In the third series of experiments, we started the larvae at 5°-10°C and exposed them to rising temperatures at different rates of increase. Figure 4 shows the results of these experiments.

Graph A shows the results of incubation at constant temperatures. There is a relatively narrow band of survival to the pelagic stage. Graph B summarizes the results of exposure of test temperatures to a more advanced stage of development. Note that the tolerance range for the hatchability of the larvae exposed continuously is about 7° to 20°C. However, when they are exposed at a more advanced stage, they can tolerate a much higher temperature range up to about 23°C.

These experiments of rising temperatures showed that the best hatchability was obtained when the hatching period was the shortest. It is important that the larvae escape from the egg mass as quickly as possible to minimize mortality from physical and mechanical problems



Percentage of walleye (*Stizostedion vitreum vitreum*) eggs that hatched at various incubation temperatures after fertilization at six temperatures from 6 to 21°C (from Smith and Koenst 1975).

Figure 3.

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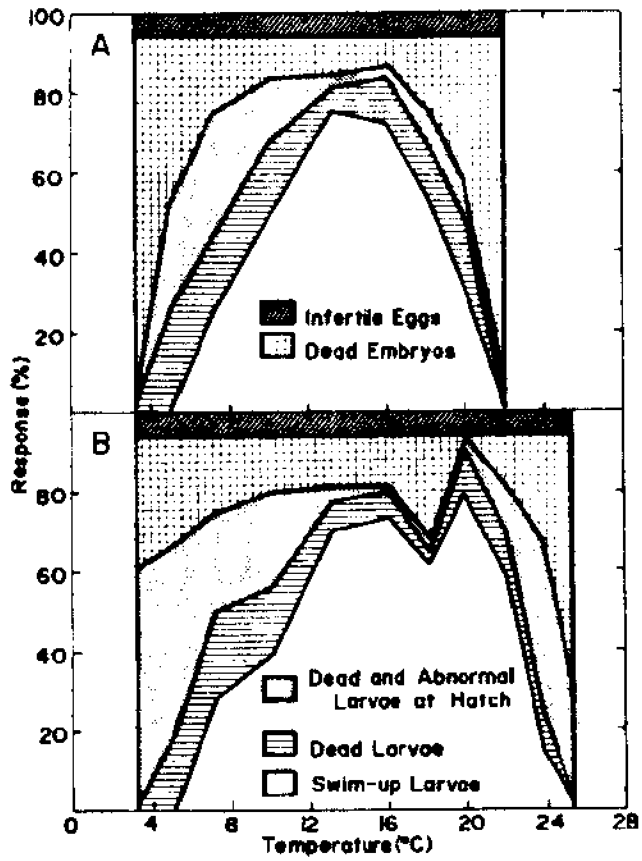
From: "Temperature Requirements of Some Percids and Adaptations to the Seasonal Temperature Cycle," by Kenneth E.F. Hokanson in Journal of the Fisheries Research Board of Canada. Volume 34, Number 10, 1977, p. 1531.



Effect of constant incubation temperatures on percentage total hatch, normal hatch, and swim-up larvae of known aged yellow perch embryos-replicates combined. (A) Embryos incubated at test temperatures from fertilization to larval swim-up stage; (B) embryos incubated at 12.0°C until neural keel formed, then at test temperatures to larval swim-up stage. Fate of eggs shown as percentage differences

Figure 4.

From: Effects of Constant and Rising Temperatures on Survival and Developmental Rates of Embryonic and Larval Yellow Perch, *Perca flavescens* (Mitchill) by K.E.F. Hokanson and Ch. F. Kleiner in, The Early Life History of Fish, Proceedings of a symposium of the Scottish Marine Biological Association at Oban, Scotland. Edited by J.H.S. Blaxter May 17-23, 1973, p. 442.

associated with hatching. Our best results were obtained with fertilization at 10° and increasing the temperature at one degree per day so that hatching took place at 20°-24°. The best rearing condition is the rising temperature sequence which optimizes the requirements of the different stages of development from early embryo to late embryo to the larval stages.

Figure 5 summarizes the time spans of some of the different stages of development of yellow perch. This graph plots the time in days against the mean temperature during incubation. The dashed line represents the time of hatch. The lower curve, labeled 1, represents the time it takes to get to the beginning of the formation of the embryo, referred to as the formation of the neural keel. Curve 2 is the start of the heartbeat and curve 3 is when the eyes are totally black. When the mouth and opercular movements are synchronized in a regular breathing fashion, hatching will occur very shortly.

Curve 6 represents the time when the newly hatched larvae begin to swim up. At this time, swimming is very labored until the larvae reach the surface and fill their swim bladders. After they have taken on air, they become free swimming and begin to feed. One of the significant findings of our work in regard to cultural applications was that the larvae begin feeding as soon as they are free swimming rather than after the yolk sac is absorbed, as is commonly suspected.

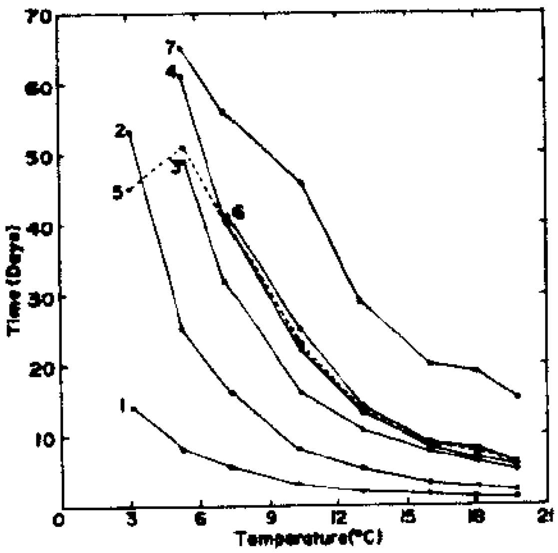
Curve 7 represents the median time it takes an unfed larva to starve to death. A critical period in development is the two days or so after the larvae become free swimming, in which they are capable of capturing prey. It is in this period of between 1/2 day to two days that most of our mistakes in culture are made.

Our work on the culture of larval yellow perch under laboratory conditions began in 1968 when we were looking for candidate test species for chronic toxicity tests. The early experiments involved the mass culture of eggs in six-foot diameter circular tanks and feeding the larvae with brine shrimp. There are at least two kinds of brine shrimp, San Francisco stock and a Utah strain, one of which is larger than the other. We tried both forms and our survival was less than 5 percent with this food source.

At about that time, our laboratory began investigating the first foods of larval fish and found that the perch start feeding on copepod napulii, or similar forms such as cyclops, very large rotifers such as polyarthra and a very few clodocera of that given size range. In other words, they have very specific feeding habits. They need live zooplankton of a certain size and abundance.

Armed with this information and our knowledge of the temperature requirements, we set up a preliminary test in an aquarium. We stocked 50 larvae, set up an optimum temperature regime and gave them a surplus of live zooplankton. After a month, we had about 80 percent survival, which is very good for the culture of percids in general. We found that the best condition involved almost continuous light, presumably because this prolonged the feeding period.

With this preliminary success, our group started to design a series of experiments that would optimize the conditions for rearing perch under



Relationship between temperature and median time of development of yellow perch embryos and larvae. (1) Neural keel; (2) heart beat; (3) retinal pigmentation; (4) branchial respiration; (5) mass hatch; (6) swim-up larvae; (7) unfed larvae mortality

Figure 5.

From: **Effects of Constant and Rising Temperatures on Survival and Developmental Rates of Embryonic and Larval Yellow Perch, *Perca flavescens* (Mitchill) by K.E.F. Hokanson and Ch. F. Kleiner in, The Early Life History of Fish, Proceedings of a symposium of the Scottish Marine Biological Association at Oban, Scotland. Edited by J.H.S. Blaxter May 17-23, 1973, p. 444.**

continuous flow, because our chronic toxicity tests involve a continuous flow apparatus. Some of the general conclusions from this work were that better survival was obtained with slower water exchange rates, and survival was better in dark tanks than those with light backgrounds. This is probably related to improved perception of prey against a dark background. We generally found that at least 250 zooplankton organisms per larva per day were required to obtain a survival of at least 50 percent. At this time, fish have the highest metabolic rate per unit body weight and they have a relatively rapid turnover time of food. When these fish start feeding, they may be gaining 20 percent or more of their body weight per day and the turnover time of food in their gut is probably less than one hour.

Not only do we need adequate quantities of food but we need to feed frequently. Many of our cultural mistakes are made in getting the right quantity of food of the right size at the right time to these fish. This is where the observation of the turnover time of water in the tank comes in. The faster the water flows, the faster food organisms are flushed out of the rearing tank and food density is reduced.

I would suggest that for future work on larval feeding, smaller strains of brine shrimp should be investigated.

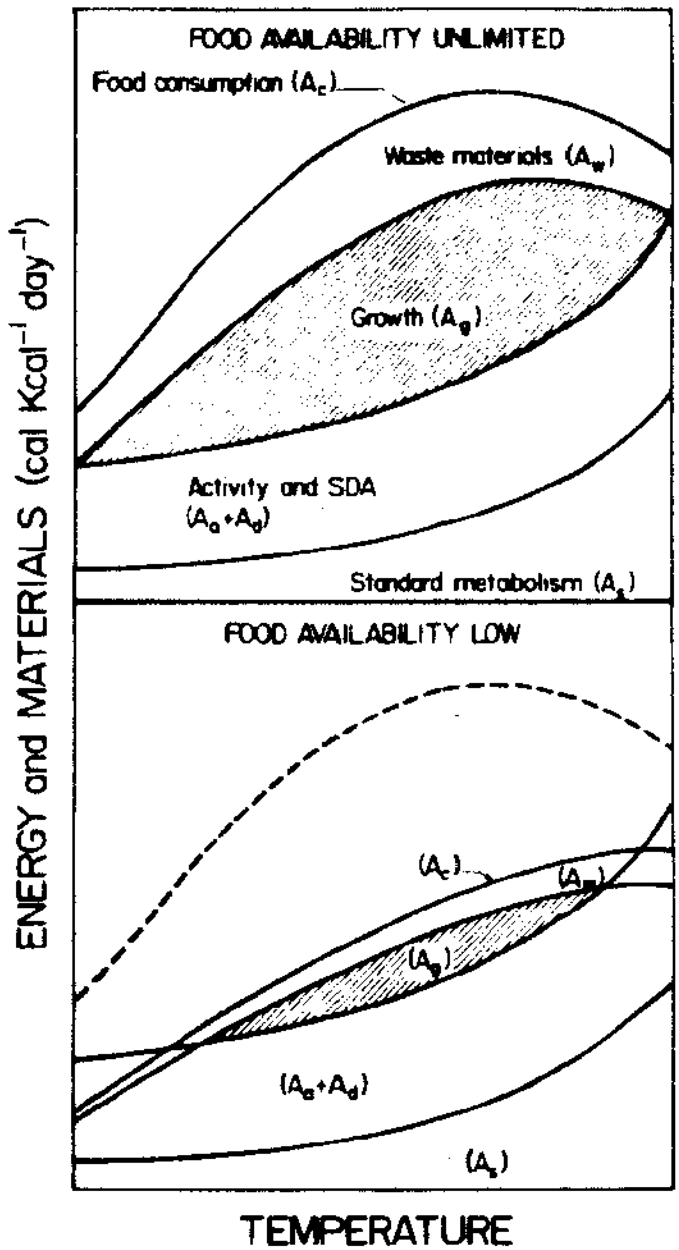
Probably the only practical way to produce large numbers of fingerlings is in ponds. The state of Minnesota has been doing this for years in their walleye program and the same principles would apply to perch culture. It is very important that eggs be placed in the ponds before they hatch as the larvae are extremely sensitive to any handling, even in a bucket.

We found that after about three weeks on zooplankton the juveniles could be converted to dry feed.

Another important observation we made is that year-class strength of percids in general is enhanced by increasing temperatures. In general, stronger year classes are produced in warmer years than in colder years, as illustrated in Figure 6.

We can assume that survival is dependent upon growth, particularly in the larval stages. Growth is really the net effect of the environment on several activities: the consumption rate, metabolism and activities of the animal. Temperature affects the distribution rate of the assimilated foodstuffs. For instance, when food is unlimited, maximum growth potential is within a particular temperature range. By lowering food availability the range for growth is much more restricted. Optimum temperatures for growth must be evaluated in respect to food availability.

Figure 7 summarizes some of the other work that was done at our lab on the effects of temperature on the growth and survival of juvenile perch. Juvenile perch were simply exposed to different test temperatures and then the temperature was increased at a rate of about 1°C per day. It's interesting that the maximum temperature perch could tolerate was about 33°C (91°F). The optimum temperature is quite near the lethal limit when food is available in excess. Note also that the mortality rate increases very sharply as the optimum temperature for growth is exceeded. The cultural application to all this is that if feed is in short supply, survival will be increased by holding the temperatures somewhat below the optimum for growth.



Theoretical effects of temperature change on the food consumption, energy budget, and scope for growth of a hypothetical poikilothermic animal having food available in different amounts (from Warren 1971).

Figure 6.

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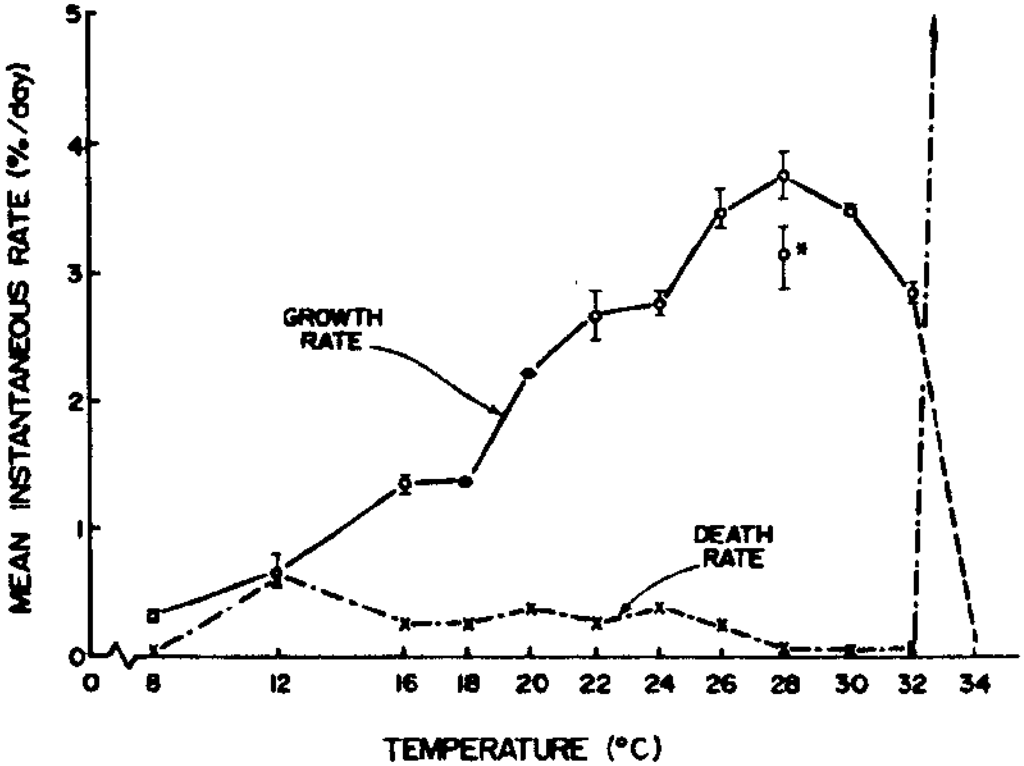
From: "Temperature Requirements of Some Percids and Adaptations to the Seasonal Temperature Cycle" by Kenneth E.F. Hokanson in Journal of the Fisheries Research Board of Canada. Volume 34, Number 10, 1977, p. 1534.



Instantaneous rates of growth and death (%/day) of young-of-the-year yellow perch reared at different constant temperatures with unlimited ration. The horizontal bars above and below each mean indicate the range between duplicates at each test temperature. Variability in growth rates between duplicates was so small at 16° and 18° C that the range bars appear as one. Growth rates of the original replicates at 28° C are marked by the asterisk.

Figure 7.

From: Temperature Effects on Young Yellow Perch *Perca flavescens* (Mitchill) J. Howard McCormick Environmental Research Laboratory, Duluth, MN 55804, USEPA Ecological Research Series, EPA-600/3-76-057, May 1976, p. 7.

Figure 8 displays a generalized pattern of the effects of temperature on the mortality and growth rate of fish.

There is an optimum point for growth of the fish biomass and a population maintenance level where growth rate and death rate become equal. In the case of the yellow perch, the lower limit for growth is about 6°C and the upper limit is about 31°C. Above 31°, perch will still grow, as shown in Figure 7, but there will be a high incidence of spinal deformities and high mortality.

The following chart summarizes my presentation, showing the optimal and allowable temperature ranges for each life stage we've worked with. I've purposely put the temperatures in degrees Fahrenheit to make the chart more useful to practical fish culturists.

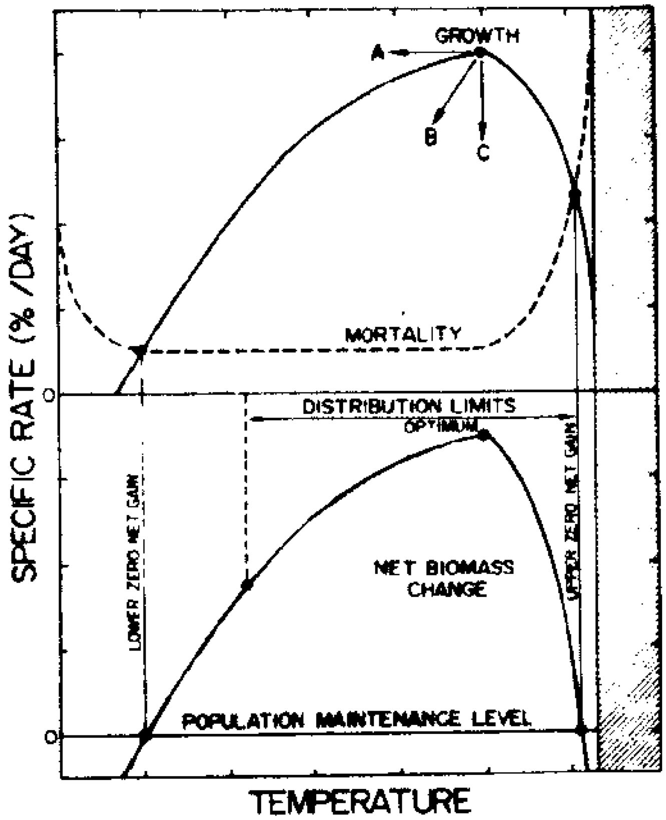
The most important observation here is the need for warm temperatures when the fry swim up. The embryo does fine in cold water but when they hatch, a rising temperature regime must be available. The larvae will perish if the temperature is below 58°F when it comes time to start feeding. The manifestation of this is that a cold period in spring can cause a complete reproductive failure in perch.

Yellow Perch Temperature Requirements

Life Stage	Temperature (F) Optimum	Tolerance Range
Maturation	39-43	< 52
Spawning	46-52	37-66
Cleavage Embryo	46-54	39-70
Embryo	54-61	45-73
Fertilization to Hatch	50-68	44-68
Hatch to Swim-up	68-75	37-82
Feeding Larvae	(68-75)[a,b]	50-(86)[a]
Juvenile - Survival	75-82	32-92
Growth (Excess Food)	75-82[b]	43-88[b]

a) Denotes best estimate based on culture experience.

b) Results obtained on excess ration. Restricted rations or mass culture situations will result in a lower growth optimum temperature and upper growth limit which will be dependent on feeding regime.



Constant temperature effects on specific rates of growth (g), mortality (i), and net biomass change ($k = g - i$) for a hypothetical fish species fed excess rations. The zone of thermal resistance, where survival is time-dependent, is represented by the shaded area, bounded on the left margin by the ultimate upper incipient lethal temperature. Graphical endpoints that have particular physiological and ecological significance are identified by circles and labeled in the lower panel. Predicted shifts in growth response and optimum endpoints attributed to different stimuli illustrated in upper panel: A, diel fluctuation of acclimatization temperature of *Salmo gairdneri* (Hokanson et al. 1977); B, restricted food rations of *Oncorhynchus nerka* (Brett et al. 1969); C, increased initial size of *O. nerka* (Shelbourn et al. 1973).

Figure 8.

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From: "Temperature requirements of Some Percids and Adaptations to the Seasonal Temperature Cycle," by Kenneth E.F. Hokanson in Journal of the Fisheries Research Board of Canada. Volume 34, Number 10, 1977, p. 1534.

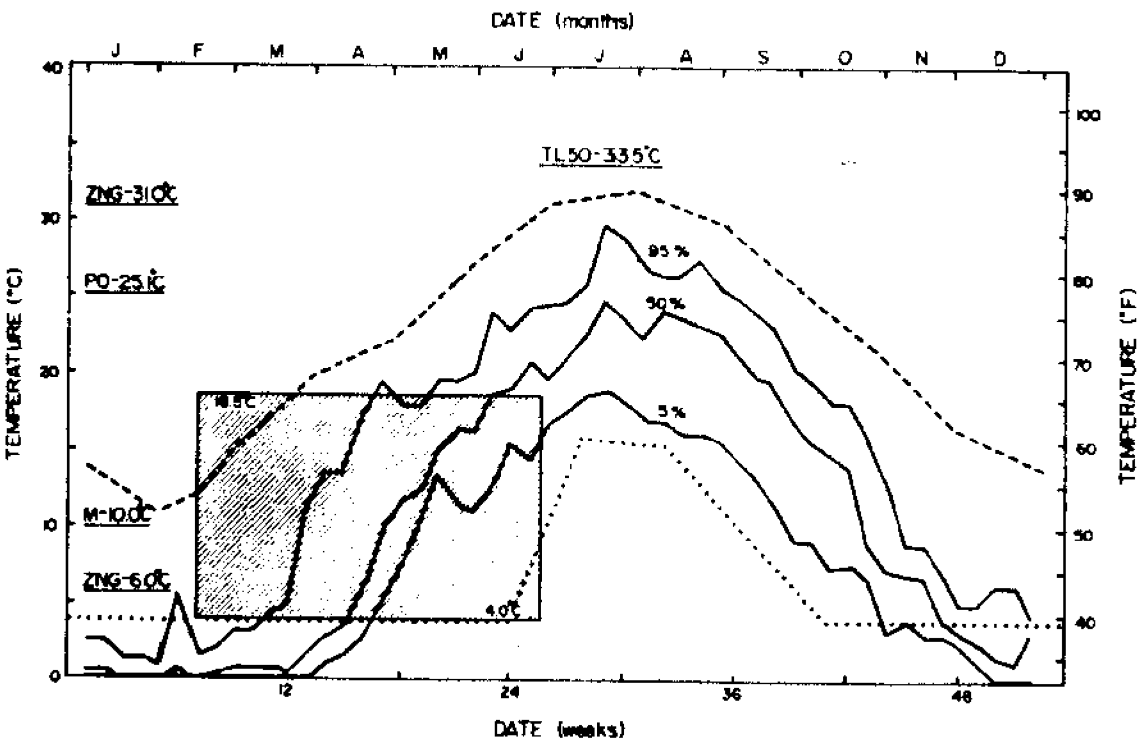
Figure 9 illustrates the limits of the natural temperature regimes that are known to support the production of self-sustaining populations of yellow perch. The top line represents the warmest lake known to support perch and the bottom line, the coldest lake. The shaded box shows the extreme dates and temperatures in which yellow perch are known to spawn viable eggs.

These animals are really adapted to temperatures that favor reproduction at one extreme and growth at the other. This temperature regime optimizes requirements for all stages in the life cycle, not only for the brood stock but for the growth and production of the young, as well.

I would like to close my talk with a few comments on the culture of yellow perch. We had a hard time incubating large numbers of eggs. Work done at the University of Wisconsin has shown that mass culture of eggs is possible but the egg strand has to be spread out so the embryos obtain enough oxygen during development.

Whenever temperature control is employed, the total gas pressure must be kept in mind. As water is heated it becomes supersaturated, so facility design must incorporate aeration after heating to equilibrate the water prior to use in fish culture. Temperature control will be important in perch culture to optimize fertility of eggs and accelerate or delay the development of embryos so they hatch when pond conditions are most favorable.

Finally, I'd like to make a comment on heat sources. There has been a lot of talk about the beneficial uses of waste heat, particularly from electric generating facilities. There are some fish culture operations going on today using waste heat to accelerate fish growth. Our local utility in the Twin Cities has a demonstration project to utilize waste heat to heat a greenhouse. They feel that in ten years they will be able to produce enough vegetables to supply the entire metropolitan area by this method. I think that in 10-20 years we will be burning coal to generate usable heat and power at the same time, and aquaculture is an attractive use for the heat produced.



Seasonal temperature envelope described by percentage occurrences (≤) of weekly mean temperatures where yellow perch were present in 35 stream stations throughout the United States. Temperature requirements of yellow perch for physiological optimum (PO), lower and upper zero net biomass gains (ZNG), ultimate upper incipient lethal temperature (TL50), maturation (M), and spawning (shaded area) are noted for comparison (from Hokanson and Biesinger 1977). Multiple endpoints for field and laboratory observations were averaged before plotting. ------, water temperature in the Darling River at Bourke, Australia, just beyond the lower latitudinal limits of distribution of *P. fluviatilus* (from Weatherley 1963a); ......, mean monthly epilimnetic temperatures of Big Trout Lake, Ontario, from 1959 to 1964, at the higher latitudinal limits of distribution of *P. flavescens* (R. A. Ryder, Min. Nat. Resour., Thunder Bay, Ont., personal communication).

Figure 9.

From: "Temperature Requirements of Some Percids and Adaptations to the Seasonal Temperature Cycle," by Kenneth E.F. Hokanson in Journal of the Fisheries Research Board of Canada. Volume 34, Number 10, 1977, p. 1542.

QUESTIONS AND ANSWERS

How would you evaluate pond culture versus laboratory culture in relation to stress?

Hokanson: To maximize growth, temperature must be optimized, and as the temperature approaches this optimum, food consumption must increase. If the food is not acceptable or nutritionally deficient, the fish will be under environmental stress. An example of this is the white crappie. This fish does better in the laboratory on frozen brine shrimp than on trout pellets because the natural feed is more acceptable even though it is nutritionally inferior to the trout feed.

Light is another important stress factor. With the culture of the white sucker, for instance, growth and survival were enhanced simply by lowering the light intensity. Sudden shocks of light in the laboratory are also harmful, so it is important to have a dimmer switch on the lights.

Daily metabolic rate should also be reduced as low as possible. We found that cyclic temperatures can optimize growth rate with a lowering in mean daily temperature. Presumably this is because the daily metabolic rate is reduced. These fish should be protected from all unnecessary activity, and cycling the temperature can help accomplish this while reducing heating costs.

We have some experimental evidence that a natural substrate improves culture of some aquatic animals.

Would you suggest some lights around the pond to lengthen the feeding period?

Hokanson: This might increase production, especially with larval perch, because if they go all night without feeding, they are starving to death by morning. After about three weeks I doubt that additional photoperiod would be of any benefit.

Are the zooplankton you spoke of available or can they be cultured?

Hokanson: One of the biggest problems in the mass culture of larval fish is getting adequate quantities of the proper feed. If we could find a small enough strain of brine shrimp to grow perch on, it would be a big help in laboratory culture. I believe the only way to culture enough plankton for mass larval culture is in a pond.

Kayes: There isn't so much wrong with pond culture as most of you might think. It's been practiced for hundreds and hundreds of years in Europe and China and it's really a rather sophisticated type of operation. A pond can be managed as any other type of agriculture with proper nutrients and management.

Hokanson: I think that where the laboratory is most useful is in controlling the timing and development of the embryo so the egg mass is ready to be stocked when conditions in the pond are most favorable.

It seems to me that the optimum temperature for the fry to start feeding is probably going to be higher than the actual pond temperature at that time of year.

Hokanson: That is most likely the case. I think we must try to hold back spawning and egg development until the weather is likely to be better for larval survival. The biggest problem in natural populations of perch is cold periods coinciding with first feeding of the fry.

Is food production the problem associated with this temperature limitation?

Hokanson: Our work indicates that the requirement of the larvae is independent of food availability, but food production is also limited by temperature. Below 15°C there won't be any appreciable feeding activity regardless of food availability.

What would you say the temperature of the ponds would be at that time?

Hokanson: I would think, generally, between 50°-68°F. The warmer the better.

Kayes: If fingerling production was in conjunction with a growout unit, warm water from the production facility could be used to warm the fry ponds.

Hokanson: You are dealing with a series of probabilities in getting survival through all the larval stages to a juvenile fish. I think we can account for 90 percent mortality due to the temperature factors alone.

Do you think solar collectors could be used to heat these ponds?

Hokanson: I think it would be more practical to hold back the eggs until the ponds warmed naturally.

Henry: I have an observation to make on flooding the ponds. It seems to work best to fill the pond 7-10 days before the hatched fry will need food. If the pond is flooded for too long, the crop of zooplankton existing when the fry start to feed won't be as good.

INTENSIVE CULTURE OF YELLOW PERCH (Perca flavescens)

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Abstract

Yellow perch (Perca flavescens) averaging 13.6 gram and 108 mm for males and 38.6 gm and 157.5 mm for females were held in a metal stock tank containing 912 liters (32.2 cu. ft.) of water for spawning purposes in late April and early May of 1975.

Synthetic spawning mats and a small section of wire fencing were placed in the tank. The mats were removed later during spawning as they only caused entanglement of the egg envelopes, making it difficult to remove them for incubation.

Three females were sacrificed for egg enumeration with 113.4 eggs per gram found to be the average. This amounted to an average of 4,377 eggs for each of 46 spawns collected naturally from the remaining 47 females. They were incubated in troughs on trout hatching trays and in a Heath incubator.

At or near hatching eggs and fry were placed on floating screened trays in a 0.2 hectare (0.5A) pond for hatching and rearing. From an estimated 102,860 fertile eggs and fry stocked in this pond, 35,880 fingerlings were harvested for a return of 35 percent. Part of these fingerlings were held and fed dry feed. They grew from .38 gram each to 1.36 gram with a survival of 38 percent to distribution.

Observations on characteristics of culture and life history are included.

Introduction

Yellow perch are raised by this station for use by various agencies. Most fish go to the Fish Control Laboratory at La Crosse, Wisconsin for toxicological investigations.

Each spring a 0.4 ha pond is allocated for perch spawning and is generally tied up for most of the production season with that species. If perch could be raised by intensive culture methods, a pond would be free for forage or game fish production.

We fell into this procedure by chance in the spring of 1973 when small perch averaging 20 gm apiece spawned in a holding tank.[5] These eggs were incubated to near hatching when some were stocked in our regular spawning pond and others were sent to the La Crosse laboratory.

To gather more information and attempt a repeat performance the process was undertaken again in the spring of 1975.

Methods and Procedures

One-hundred fifty adult yellow perch were acquired by angling through the ice from Rock Lake, which is the hatchery's source of pond water. They were held in an indoor concrete tank for approximately two months before being stocked into a metal stock tank February 26. The only food offered them was no. 4 trout granules (1.68-2.83mm) and this was terminated April 6.

The fish were very skittish and feeding was not observed although it may have occurred. The tank was partially covered with black plastic to shield them from human activity. This was removed after a few weeks and prior to spawning in hopes they would adjust to people working in their vicinity. Tank dimensions were .89 x 2.29m and was held to .46m water depth giving 912 liters of space. Inflow was from Rock Lake at 12.5 liters per minute.

On March 6 the fish were sorted by sex, weighed, measured and given a prophylactic 3 percent salt dip. Fifty of the smallest females less than 140mm were removed April 4 leaving 50 males and 50 females. The tank was partially drained and cleaned several times through the period the fish were held, including the spawning period.

A few mortalities were experienced with heavily fungused fish, generally females after spawning. No treatments were conducted on brood fish except the previously mentioned salt dip. The fish were probably weakened from the extended period without food. I'm assuming no granules were eaten. Two black synthetic mats with a total area of 1.5 sq. meters were placed on the tank bottom on April 4 as a spawning substrate. A small section of fencing with mesh of approximately 150mm was placed in the tank, more or less in a roll, to provide midwater attachment for egg envelopes. Perch utilize such structures in our outside ponds. We place fencing and branches around the pond edge. Eggs are often draped on and laced through such structures.

Upon discovery of egg envelopes, they were transferred to either trays in trout hatching troughs or to a heath incubator. City water was used with a flow of 4.5-9.5 liters per minute through the heath and 6.1 liters per minute through the troughs. Constant flow formalin treatments at 166-200 ppm for one hour were occasionally used to combat fungus infections. Partway through the spawning period the mats were removed from the tank.

Temperatures were taken each day near noon. This was assumed to be an average between the cool early morning temperatures and the high temperature in the midafternoon.

Water from Rock Lake was introduced into the 0.2 hectare rearing pond, D_1, on April 10. Unfortunately, due to a pipeline breakage, the pond was only partially filled at that time to an average depth of around 0.3 meters. It remained at this level for several weeks until the line was repaired.

When hatching began on the oldest eggs, they were transferred to D_1 on anchored, floating screens with a mesh size large enough to allow newly hatched fry to settle through. Fry are about 6 mm in length. For a week thereafter the remaining eggs were stocked similarly as they began to hatch. Three females were sacrificed to determine ovary egg counts. The smallest female was excluded from determining the average, since she was below the minimum size of females after the 50 smallest were removed. The ovaries were weighed and the eggs, in a fraction of that weight, were counted. That number was expanded to estimate total eggs per ovary.

The number of spawns stocked was used to estimate stocking rate of pond D_1.

An estimated 230 kilograms of hay were added to the pond. This was the only fertilizer that the pond received.

Prior to harvesting, the pond paths were cleared in the extensive rooted vegetation to facilitate fry removal.

Results and Discussion

Two egg envelopes were collected from the spawning tank on April 19 at a temperature of 3.6°C. Four days later at 6.7°C spawning again took place and continued each day with two exceptions through May 5 (see Table 1).

Table 1 - Water Temperature on Spawn Collecting Dates for Yellow Perch

Date	Ave. temp. deg. C	number spawns collected	Remarks
Apr. 19	3.6	2	
23	6.7	1	
24	6.1	2	
25	6.1	2	
26	7.2		
27	7.5	3	
28	6.7	2	
29	7.2	5	
30	7.8	3	
May 1	7.8	5	
2	10.0	12	- - - Includes 3 later in day
3	10.3	6	
4	10.6		
5	10.9	3	

Spawning rarely took place in midday as only three of 46 spawns were collected anytime other than first thing in the morning. This may or may not be normal, since human activity undoubtedly disturbed the fish during the day.

The largest number of spawns was collected on May 2 when the midday temperature was 10.0°C and had risen from 7.8°C the day before. This agrees closely with spawning temperatures for wild perch in Wisconsin of 7.2-11.1 C[1].

The mats placed for spawning substrate were removed on April 24. The envelopes became entangled in them, making removal difficult. Their absence appeared not to inhibit spawning. Wire fencing is not necessary since most egg masses were collected from the bottom, although some may have slipped from the fencing due to agitation from adult swimming action. No midwater spawning structures were used in our outside ponds until 1973 and in previous tank spawning of yellow perch here mats were used but no fencing[5].

Egg Incubation

Occasional constant flow one-hour treatments of formalin at 166-250ppm were not adequate in controlling fungus in the eggs. Treatment should be daily.

Approximately half of the eggs were incubated in troughs and the remainder in a heath shelf incubator. The heath is more desirable to keep better records of spawn and also the eggs are totally contained and cannot float away as on trays in a trough. It is very easy to run out of incubation space with troughs or the heath. We had a conflict with trout incubation needs. We had small females with subsequent small spawns (maximum length around 27cm). If large adults were used, one spawn may totally fill up a heath tray, as wild spawns may reach 213cm in length[1]. Trout egg trays would also be inadequate. Our trays have a screened area of 24 x 46cm. Eggs often float off the tray.

Our 46 spawns were contained in one trough about four meters in length containing around 800 liters of water and in seven shelves of the heath, each with 6.8 liters of water. Total incubation space was around 850 liters with the heath the most efficient using only 50 liters.

If large quantities of eggs were to be incubated, several heaths would be required. Undoubtedly other facilities could be utilized. It is best to have the eggs confined to keep them from drifting or floating off. I believe a jar system such as is used for pike, walleye and suckers might be tried. Eggs could be removed just prior to hatching for stocking into rearing ponds. Eggs could be left in the jars until hatching, and a collection trough or tubes could carry the fry into a common tank, as has been done with walleye[2]. This should work well, since newly hatched fry are pelagic3. They are also photo-positive, as noted while stocking fry into D_1. A fernal pail was used with a centrally located hole in the lid. On two occasions fry were noted to move to this light source. A light placed on the collection tank containing swim-out fry should congregate them for collection if need be.

A possible drawback to jar culture was noted by University of Wisconsin personnel. During the final stage of incubation, the tendency to float may cause the envelopes to rise and block the outflow[6].

Due to this tendency to float, an old method of trout egg incubation might be suitable. I have not seen the system but it consisted of a deep trough with a series of vertical baffles that alternately shunt the flow up then down through horizontal egg trays (see Figure 1). A drawback to this system would be relative inaccessiblity to individual trays as they are stacked vertically on one another. They

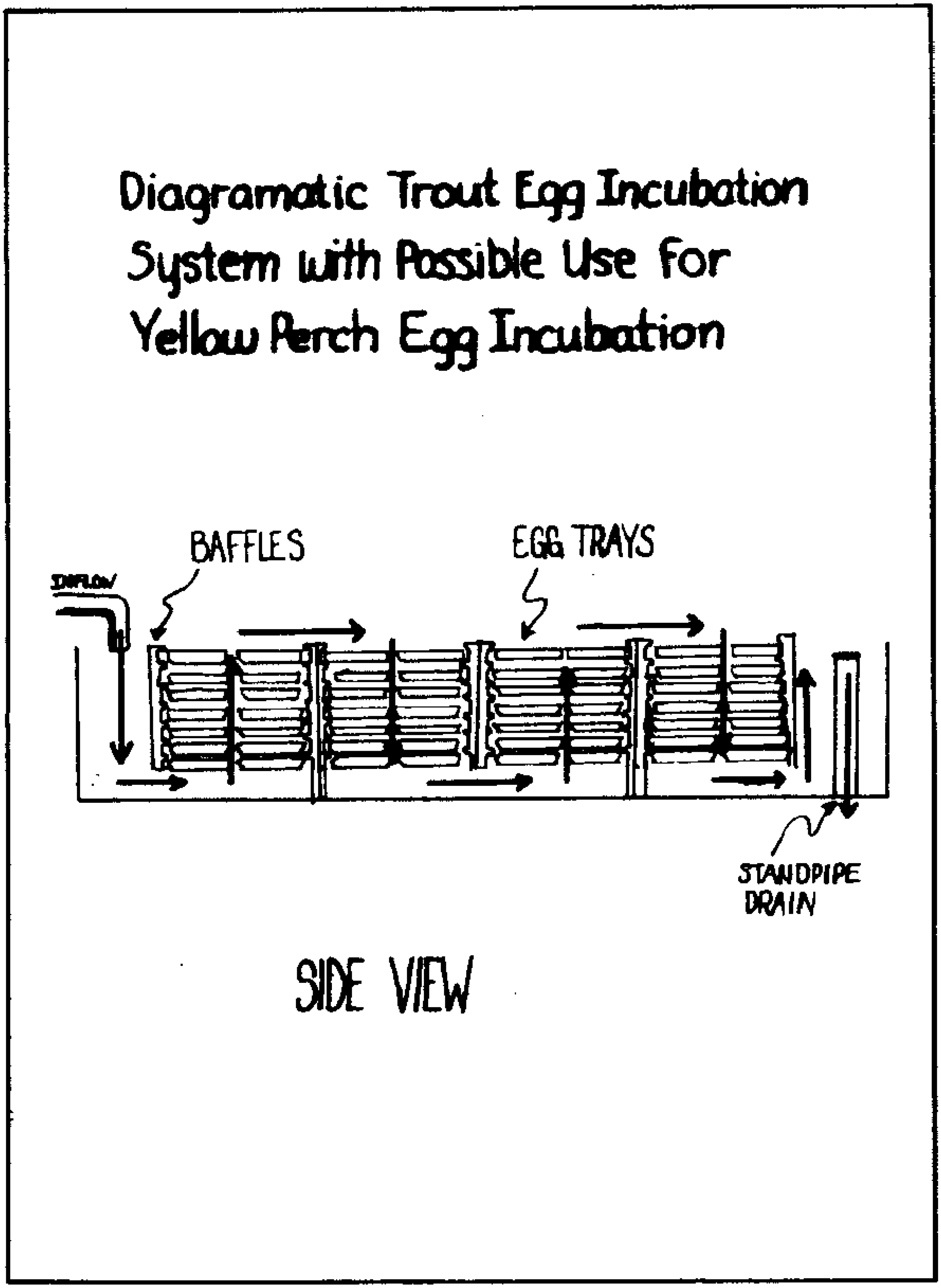
Diagramatic Trout Egg Incubation
System with Possible Use For
Yellow Perch Egg Incubation
BAFFLES
EGG TRAYS
STANDPIPE
DRAIN
SIDE VIEW

Figure 1.

would have to fit tightly so envelopes would not be drawn out the sides of the trays.

Table 2 indicated the temperature units (t.u.) required till eye up and hatching for yellow perch eggs of 1975. Daily cumulative centigrade t.u. are given while only a total is given for Fahrenheit t. units.

A temperature unit has been defined in many ways depending on various uses. In this situation it refers to one degree above 0° C for 24 hours and also one degree Fahrenheit above 32° F for 24 hours[4]. Brown trout eggs have required from 670-770 t.u. at 47-50° F[4]. Our yellow perch eggs of 1973 required 309 t.u. F[5], and averaged 365 t.u. F for 1975. Centigrade t.u. were 172 and 203 respectively for those years.

As the temperature increased fewer units were required for hatching. Our first spawns required 228 t.u. C over an average temperature of 9.9 C. The last spawns experienced 159 t.u. C over an average temperature of 11.3 C. The 1973 average temperature was 11.5 C and 172 units were required.

Hatching dates were decided upon noting several fry that had hatched. A condition such as 50 percent hatch would be more correct, but from a standpoint of return it was felt too many fry would be unrecovered if delayed to a later stage. Hatching could take place on floating screens on the pond anyway.

Date of eye up was difficult to set. Melanin pigmentation in the eye was visible for several days and the date was set when this was easily seen without need for close observation. Eye up dates for four different aged eggs are also noted in Table 2.

There appear to be several conditions closely preceding hatching:

1) Egg envelopes become flaccid with loss of rigidity.

2) Gold iris pigmentation visible surrounding the melanin in the eyes. Best initially seen with aid of a flashlight.

3) Larval movement decreases.

4) Bubbles accumulate in the envelope, giving the mass a tendency to float.

Table 3 indicates chronology of development for some of the spawns, along with early developmental stages not mentioned above.

Larval movement and iris pigmentation can be noted sooner with a dissecting scope. Other stages would be more definitive with scope use, but time demanded only occasional visual checks with the naked eye. Observations on development were late on some spawns and totally missing on others.

Loss of vigor (LLM) appears to be a blockage to hatching, since vigorous movement is needed at this stage to break free of the shell. This may be a natural method to check populations. This phenomenon was also noted by U. of Wisconsin personnel[6].

Table 2 - Temperature Units to Eye Up and Hatching for Yellow Perch Eggs

Date	Temperature Cent/Fah	Temp. Units	Date of spawning and cumulative t.u. to eye up and hatch (Centigrade) 19	23	24	25	27
Apr. 19	8.8/47.8	15.8					
20	8.7/47.7	15.7	8.7				
21	8.7/47.7	15.7	17.4				
22	8.9/48.0	16.0	26.3				
23	9.2/48.6	16.6	35.5				
24	9.4/48.9	16.9	44.9	9.4			
25	9.4/48.9	16.9	54.3	18.8	9.4		
26	9.5/49.1	17.1	63.8	28.3	18.9	9.5	
27	9.4/48.9	16.9	73.2	37.7	28.3	18.9	
28	9.4/48.9	16.9	82.6	47.1	37.7	28.3	9.4
29	9.2/48.6	16.6	91.8	56.3	46.9	37.5	18.6
30	9.5/49.1	17.1	101.3	65.8	56.4	47.0	28.1
May 1	9.7/49.5	17.5	111.0	75.5	66.1	56.7	37.8
2	10.0/50.0	18.0	121.0	85.5	76.1	66.7	47.8
3	10.4/50.7	18.7	131.4	95.9	86.5	77.1	58.2
4	10.6/51.1	19.1	142.0	106.5	97.1	87.7	68.8
5	10.6/51.1	19.1	152.6	117.1	107.7	98.3	79.4
6	10.6/51.1	19.1	163.2	127.7	118.3	108.9	90.0
7	10.4/50.7	18.7	173.6	138.1	128.7	119.3	100.4
8	10.5/50.9	18.9	184.1	148.6	139.2	129.8	110.9
9	10.6/51.1	19.1	194.7	159.2	149.8	140.4	121.5
10	11.1/52.0	20.0	205.8	170.3	160.9	151.5	132.6
11	11.3/52.3	20.3	217.1	181.6	172.2	162.8	143.9
12	11.3/52.3	20.3	228.4	192.9	183.5	174.1	155.2
13	11.3/52.3	20.3	(411.2)	204.2	194.8	185.4	166.5
14	11.3/52.3	20.3		215.5	206.1	196.7	177.8
15	11.5/52.7	20.7		(387.8)	(370.9)	208.2	189.3
16	11.7/53.1	21.1				(374.7)	201.0
17	12.2/54.0	22.0					213.2
18	12.2/54.0	22.0					(383.8)
19	12.6/54.7	22.7					

Table 2 (continued) - Temperature Units to Eye Up and Hatching for Yellow Perch Eggs

Date	28	29	30	1	2	3	5	Remarks
Apr. 19								
20								
21								
22								
23								
24								
25								
26								
27								
28								
29	9.2							
30	18.7	9.5						
May 1	28.4	19.2	9.7					
2	38.4	29.2	19.7	9.7				
3	48.8	39.6	30.1	20.1	10.4	- - - -	- -	4/19 eggs
4	59.4	50.2	40.7	30.7	21.0	10.6		well eyed
5	70.0	60.8	51.3	41.3	31.6	21.2		
6	80.6	71.4	61.9	51.9	42.2	31.8	10.6	-4/23 eggs
7	91.0	81.8	72.3	62.3	52.6	42.2	21.0	well eyed
8	101.5	92.3	82.8	72.8	63.1	52.7	31.5	
9	112.1	102.9	93.4	83.4	73.7	63.3	42.1	
10	123.2	114.0	104.5	94.5	84.8	74.4	53.2	-4/27 eggs
11	134.5	125.3	115.8	105.8	96.1	85.7	64.5	well eyed
12	145.8	136.6	127.1	117.1	107.4	97.0	75.8	
13	157.1	147.9	138.4	128.4	118.7	108.3	87.1	
14	168.4	159.2	149.7	139.7	130.0	119.6	98.4	-5/3 eggs
15	179.9	170.7	161.2	151.2	141.5	131.1	109.9	well eyed
16	191.6	182.4	172.9	162.9	153.2	142.8	121.6	
17	203.8	194.6	185.1	175.1	165.4	155.0	133.8	
18	(366.9)	206.8	197.3	187.3	177.6	167.2	146.0	
19		219.4	209.9	199.9	190.2	179.8	158.6	
		(395.0)	(377.9)	(360.4)	(342.4)	(323.7)	(285.5)	

Numbers in parenthesis at the bottom of each column indicate cumulative temp. units Fahrenheit to hatching for that group of eggs. Daily entries are cumulative temp. units Centigrade. Temperature Centigrade is also the temp. units Centigrade for that day.

Table 3—Developmental Stages of Yellow Perch Eggs.

Date	Date spawned on											
	19	23	24	25	27	28	29	30	1	2	3	5
May 1	LM											
2												
3	WE											
4												
5		E LM	LM									
6												
7		WE										
8												
9					E	LM						
10	Sft I				WE		E					
11	LLM	I							E	LM	LM	
12	H		I						WE	E		
13												
14		H	H	LLM							WE	
15				H	I	I	I					
16					LLM	LLM	LLM	LLM	LLM			
17					Sft H	Sft H						
18												
19							H	H	H	H	H	H

Key - LM = Larval movement w/ naked eye
E = Eyed (weak)
WE = Well eyed
I - Gold iris pigmentation
LLM = Little larval movement
Sft = Soft and flaccid
H = Hatching

The method of stocking eggs in our pond could possibly aid fry over this critical period. Wave action lapping against and over the floating screens would agitate the eggs helping the fry break loose from the shell. Handling frees many of the fry. To minimize loss of fry into trough or incubator, it may be better to stock eggs just prior to any hatching, possibly during the inactive embryo stage.

Egg Enumeration

Table 4 gives information on egg enumeration. The smallest female was not used in averaging the number of eggs per spawn, since she was well below the minimum size of adults used in spawning. There appears to be no direct relation between length and number of eggs.

Table 4 - Egg Counts of Three Yellow Perch

Length mm	wt. gm	ovary wt.-gm	no. eggs*	eggs per inch	eggs per mm	eggs per lb.	eggs per gm
107	23	3.15	2031	484	19.0	40,620	88.3**
152	45	10.7	5208	868	34.3	52,080	114.8
170	80	18.0	9150	1366	53.8	50,833	112.0
					Total -	102,913	226.8
					Average -	51,456	113.4

* Estimate as percent of ovary wt. counted and then expanded.

**Not included in averages as below minimum size of adult females used.

The average number of eggs per gram was 113.4. Our brood stock females averaged 38.6 gm each (see Table 5) which gives an average spawn of 4377 eggs.

Table 5 - Yellow Perch Brood Stock Information

	Number	minimum length-mm	maximum length-mm	average length-mm	total wt. gm	average wt. gm
Males	50	97.8	165.1	108.0	681	13.6
Females	50	139.7	190.5	157.5	1930	38.6

Egg fertility was checked on April 28 using a few eggs from spawns of 4/19 and 4/23 (see Table 6). Fertility should have been checked periodically as spawning progressed. Upon stocking the remaining hatching eggs on 5/19, approximately 50 percent were judged dead. This was a very rough visual estimate.

Table 6 - Yellow Perch Egg Fertility

Date spawned	number	number fertile	percent fertile
4/19	11	10	91
4/23	43	41	95
Total	54	51	94

Stocking Pond

The number of eggs stocked in D_1 was estimated by the number of spawns stocked. The number of spawns stocked was less than collected since seven were removed that contained total or nearly total dead eggs.

The following figures show how the stocking rate was estimated:

Eleven spawns stocked from eggs deposited through April 28 at 4,377 eggs per spawn:

$$11(4377) = 48,147 \text{ eggs}$$

Twenty-eight spawns stocked from eggs deposited after April 28 were judged to be 50 percent dead, giving only 14 viable spawns at 4,377 eggs per spawn:

14 (4377) =	61,278 eggs
Add previous stocked eggs	48,147
Total	109,425 eggs

Applying the fertility level of 94 percent:

$$.94\ (109,425) = 102,860 \text{ viable eggs stocked.}$$

Because of the observed low quality of eggs stocked on May 19 it is very possible that percent fertility was down somewhat from earlier eggs. A decrease in quality was also noted by U. of Wisconsin personnel[6]. Often dead eggs were noted inside the folds of the egg envelopes. The envelope is a tube resembling an elongated, thin pickle with transverse accordion-like folds. The eggs inside the folds were dying, probably because of either poor water circulation during incubation to that area, or because initially this area was poorly fertilized. This area should be checked in the future. If the area is fertile, increasing water flow may prevent further recurrence. A one-to-one sex ratio was present during spawning. Two males to each female may be a better ratio. In this instance, two tanks should be used to lessen crowding, which increases battering of the envelopes prior to collection.

A volumetric method of determining envelope size and subsequent number of eggs would be desirable to keep a running total of collected eggs. Physical measurement of envelope dimensions was too inconsistent due to accordion effect.

The elongate mesh screens used on trout hatching trays fitted to a flotation device with high sides would be ideal for hatching. Wave action may wash out the egg masses if the wall is not high enough. I believe eggs should be exposed to wave action in some form to aid in hatching — possibly a screened cover with low sides. No predation by birds was noted of eggs exposed at the pond surface. This may never be a possibility, but a screened lid would eliminate the problem. We occasionally have problems with grackles robbing fingerlings from our traps, but perch fry do not constitute much of a meal, compared to fingerling bass or walleye.

The pond to be stocked should be filled when the first eggs are produced and fertilized as soon as possible. Stocking was about three weeks after first spawn collection. This will vary with either slowly or rapidly warming water temperatures. Herbicide application should be considered as a preflood or postflood application, depending on the type.

Presently our station uses alfalfa pellets and hay for a general fertilizer. The break in our water supply line kept us from filling our pond until several weeks after fry were stocked. We were therefore late with fertilizer. About 230 kg of hay was placed in the pond from June 6-20. Nothing else was added prior to harvesting the pond July 11.

Fry were first sighted in the pond May 25 at approximately 16mm length. They were observed on June 6 at about 25mm, and there appeared to be very little zooplankton available. Sightings on June 18 showed them to be around 35mm. Assuming a mean stocking date of May 15 and initial length of 6mm, the fry grew 29mm in 34 days to the sighting of June 18 which averages 0.85mm per day. Unfortunately these figures are based only on sightings, not actual measurements, and are probably worth little more than the paragraph used to mention them. Growth in the Red Lakes of Minnesota averaged 0.722mm per day over a 51-day period for several years[3].

Harvest

Paths were cleared in the vegetation to facilitate fingerling removal. Extensive growth of what appeared to be *Najas* sp., *Potamogeton* sp., *Elodea* sp. and *Chara* sp[7] were present due to lack of herbicide application. The pond being shallow for the first few weeks no doubt aided vegetative growth.

The pond was harvested July 11 yielding 29.9 lb. at 1200 fish to the pound for 35,880 fingerlings (12.6 kg at .38 gm each). This was a return of 35 percent from an estimated 102,860 viable eggs and fry stocked. Fingerlings appeared weak although no criteria were used except general body morphology and how stressed the fish became from handling.

The Fish Control Laboratory at La Crosse, Wisconsin received 15,000 of these fingerlings and 160 were sent to the Environmental Protection Agency facility at Monticello, Minnesota. The remaining 20,700 were held in 11.1 C well water in the holding house. We expected to encounter systemic bacterial infection, and holding in cool water slows its progress. We have had problems with this chronic infection in the past with several species, perch being one of them.

Feeding Fingerlings

Feeding was started using our production trout feed of number one granule size (595-841 microns). Some feeding noted after one to two days. It seems best to drop a few particles into small areas initially rather than general broadcasting over the tank surface. This attracts attention to that specific area and when feeding does begin, it may help in teaching others. This applies to training largemouth bass fingerlings and seemed to apply to perch. Bass prefer live, moving food and when a pellet or granule splashes to the surface they rush to inspect it. It doesn't move, other than sinking, so several fish will eye it as it falls to the bottom. With bass, using recently thawed Oregon Moist Pellets which are rolled into small "worms," a gyrating action is often established as the "worm" sinks. This entices fish to sample the object, which leads to eventual acceptance of regular dry production granules.

Time was not available to do the best job of feeding. It requires small amounts at closely spaced regular feedings. Automatic feeders may do the job but I feel a certain personal touch is required. Observation of the fish is helpful.

A switch was made to number two granules (841 microns — 1.19mm) after a few days when a preference was noted for the larger size. The fish were feeding well by the 23rd (after 12 days) and on July 25 they were transferred to a four-foot diameter (1.2 meter) circular tank in the office building on city water at approximately 16°C, where the temperature stayed into September.

The fish probably would have gone on feed sooner at warmer water temperatures, but we were reluctant to do this in view of possible bacterial complications. If the fish had been harvested in good condition, they may have been able to hold in warmer water.

Chronic mortality was experienced through the holding period. Most of the mortality appeared to involve emaciated fish which never went on feed. Of the initial 20,700 fingerlings, 930 were distributed September 3 and the remaining 6,970 were distributed September 9. This amounts to 7,900 fish for a 38 percent survival for the two-month feeding period. Total weight distributed was 23.6 lb. (10.7 kg) and the average size was 334.7 to the pound (1.36 gm each). They entered this period at .38 gm each.

Recommendations

Desirable actions that should be achieved in the future include:

1) Adults should be acclimated to tank culture. Domesticated brood stock in other words and therefore pellet raised fish.

2) Forage should be provided adults if held for substantial periods prior to spawning and for post spawning if they are not accepting dry feed.

3) Periodically sort out spawned out females to lessen crowding in the tanks or use additional tanks with 75 or less per tank.

4) Try two to one male/female sex ratio to lessen chance of infertile eggs.

5) The rearing pond should be well fertilized and herbicide should be considered to alleviate the vegetation problem.

6) Assuming fish are harvested in good condition they should be held in warmer water to facilitate transition to dry feed.

7) Feeding fingerlings should be set aside for future brood stock. This means holding space, preferably tanks.

8) Artificial spawning of adults should be attempted.

Summary

Yellow perch were raised intensively by tank spawning, egg incubation and pond rearing of fry. A return of 35 percent was experienced from fry to fingerling. This may not be very accurate. It would be either side of this figure since it is based on a high fertility rate of 94 percent from early eggs and a rough estimate of 50 percent dead on later stocked eggs. Fingerlings were trained to accept dry feed and grew from .38 to 1.36 gram with a survival of 38 percent to distribution.

Acknowledgements

Thanks go to Kenneth Wolff, fish hatcheryman, for weighing, sorting and measuring the brood stock and to Jeannine Martin for typing the final copy. Thanks also to Robert Balding for providing the adults from his spare time activities.

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TANK SPAWNING OF YELLOW PERCH

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Abstract

Small yellow perch (*Perca flavescens*) averaging 20 grams each (23 to the pound) were held in tanks during the spring of 1973. They had been acquired by hook and line that winter and were excess after stocking the larger ones into a spawning pond.

Synthetic mats were placed in the tank in hopes that spawning might be achieved, but little attention was paid to the fish otherwise. Twenty-seven spawns were obtained and incubated on trout hatching trays. After eye up and near to hatching, half were sent to the La Crosse Fish Control Laboratory and the rest were stocked in the previously mentioned spawning pond. No percent hatch or survival was obtained.

Introduction

Yellow perch are raised by this station for use by various federal agencies, mainly by the Fish Control Lab at La Crosse, Wisconsin. They request fingerlings and eggs for their toxicity tests.

Each spring a pond is allocated for perch spawning and generally is tied up for the rest of the year with that species. Brush and fencing is placed in the ponds for eggs to be draped on in hopes that a mid-depth incubation might be better than bottom incubation. If needs could be met by intensive culture utilizing tanks and troughs, a pond would be free for game or forage fish production.

The spring of 1973 saw us with a few extra perch of questionably mature size but with some obviously gravid females. These fish averaged 20 grams each (23 to the pound) and it is doubtful if any exceeded 15cm (about six inches) and probably 13cm would be an average length. The larger fish were stocked in a spawning pond.

Methods and Procedures

A call was put out the winter of 1972-73 that we needed yellow perch brood stock. With the help of local interested parties, personnel from the station assisted in acquiring these fish by hook and line from Rock Lake, which is the main water source for the station's warm-water program. Approximately 213 perch were acquired by this method. Prior to the spawning season the fish were held in inside concrete tanks on lake water and fed fingerling goldfish (*Carassius auratus*). They were not fed in the spawning tanks.

On March 19 these fish were sorted and 80 of the larger fish were stocked into a spawning pond along with adults from the winter holding pond that we had on hand from previous seasons. The remaining 133 were placed in the upper half of a holding house concrete tank utilizing about 47 cubic feet. Inflow water was from Rock Lake at about three gallons per minute.

No disease was noted in the tank and no prophylactic treatments were given. Two black synthetic mats were placed flat on the tank bottom. Approximate total surface of the mats was 16 sq. ft., with a total tank bottom area of 25 sq. ft.

When egg envelopes were discovered, they were removed and placed on trays in trout hatching troughs. These troughs were used both in the holding house with lake water and in the office basement later with city water. The treatments of formalin at 200ppm constant flow for one hour were given in the holding house troughs when an infestation of Hydra sp. developed.

After eye up all eggs were transferred to office building troughs and then received city water. There was no difference in temperature between the two water supplies at the time. At advanced eyed stage, while initial hatching was commencing for the older eggs, the eggs were transferred to both the La Crosse Fish Control Laboratory for future bioassay work and to our regular spawning pond for hatching.

Results

Eggs were noted in the tanks April 17 at a water temperature of 8.3°C (47°F). Spawning continued through April when the water temperature was 12.2°C (54°F). Approximately 27 spawns were obtained for incubation. Thirteen went to the La Crosse FCL and 14 to our spawning pond. See Table 1 for data on the first eggs spawned.

Table 1 - Temperature Units Required to Hatching for Yellow Perch Eggs.

Date	Ave. temp. F	Ave. temp. C	Cumulative Temp. units Deg. F	Deg. C	Remarks
4/17/73	47	8.3	15	8.3	
4/18	53	11.7	36	20.0	
4/19	53	11.7	57	31.7	
4/20	53	11.7	78	43.4	
4/21	53	11.7	99	55.1	
4/22	53	11.7	120	66.8	
4/23	53	11.7	141	78.5	Embryos well devel-
4/24	53	11.7	162	90.2	oped
4/25	53	11.7	183	101.9	
4/26	53	11.7	204	113.6	
4/27	53	11.7	225	125.3	
4/28	53	11.7	246	137.0	
4/29	53	11.7	267	148.7	
4/30	53	11.7	288	160.4	
5/1	53	11.7	309	172.1	Hatching commencing

A temperature unit has been defined in many ways, depending on various uses. In this situation I have chosen its definition as one degree above 32° for 24 hours on the Fahrenheit scale. I have also used this for the Centigrade scale with 1° above 0° for 24 hours.

For comparison brown trout eggs have required approximately 700 T.U. on the F. scale to hatching and these yellow perch eggs took around 309 T. Units.

Yellow perch can be spawned with an intensive system. The unknown factor at this station, if carried farther , would be training the fry to accept an artificial diet. Fingerling perch of approximately 200 to 400 per lb. (1-2 gram each) have been held and fed for several weeks here in tanks on a dry diet.

Recommendations

A similar trial will be attempted in the spring of 1974 if time and space permit. Smaller metal rearing tanks will be used as trout will occupy available concrete tanks. Procedures will not vary much from 1973 except that more attention will be paid to the trial. Regular production activities generally dominate and little time is available for projects such as this. The following additional information should be compiled for the next trial.

1) Size of the test fish.
2) Sex ratios.
3) Egg enumeration.
4) Percent hatch.
5) Percent survival.

There should be an attempt at culturing any fry produced. Possibly brine shrimp could be acquired for food until fry are large enough to switch to a dry diet. This should be done in replicate with a regular trout starter diet for other fry.

Summary

The initial phase of an intensive culture method for yellow perch was accomplished. The fish spawned successfully in holding tanks on synthetic mats. The eggs were incubated in standard troughs on trout hatching trays and began hatching after two weeks. When the oldest eggs were initially hatching, one half were sent to the La Crosse FCL and the remainder were transferred to a spawning/rearing pond for hatching.

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EXPERIENCE IN PERCH FINGERLING PRODUCTION FROM THE LAKE MILLS NATIONAL FISH HATCHERY

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The Lake Mills National Fish Hatchery is one of about 90 federal fish hatcheries in the United States. We all have our special responsibilities and one of ours is raising perch that are used by other government agencies, particularly the Fish Control Laboratory at La Crosse. Our facility is 88 acres and is comprised of 24 ponds totaling 30 acres and ranging in size from 3/10 to 3-1/2 acres each.

We started raising perch the same way as we raise bass, that is, placing the brood stock in ponds, letting them spawn, then harvesting in June. At this time the fingerlings weighed about two grams, which was the size requested. This worked fine while we only needed 5,000 or 10,000 fingerlings per year, but as our needs increased we found it necessary to intensify our perch fingerling production operation.

We spawn our fish in tanks or ponds and get good fertilization. We found that pieces of brush placed in the ponds help collect the egg ribbons. When we first started this, we ran out of males while we still had ripe females, so now we have three to four times as many males as females.

One of the first things we did was to enumerate the eggs so we knew how many we were stocking. This information is included in Graden R. West's "Intensive Culture of Yellow Perch," which is included in this proceedings. The first year, we stocked approximately 111,000 eggs, had a 93-94 percent hatch and harvested approximately 35,000-36,000 fingerlings from a 1/2-acre pond.

We found that the best incubator was a Heath Techni-Cabinet. We placed four or five egg ribbons on each tray. The eggs don't float out of the trays and we can examine them without disturbing them.

Just prior to hatching, gas bubbles develop in the egg mass and the whole ribbon begins to rise. By this time, the ribbon is difficult to manage and should be in the pond. We needed to know how long it would take the eggs to hatch so we determined the number of temperature units required for incubation. This work is described in Mr. West's paper. Knowing the temperature units required, we found we could slow down or speed up incubation so the eggs hatched at the time the ponds had developed a good crop of food organisms.

Fingerling production requires a fertile pond. Commercial fertilizer or hay can be used to fertilize a pond but we've found that alfalfa meal works the best. It has a high protein content and works faster than hay. With average weather, we get plankton growth in our ponds, suitable for perch production in 10-15 days. We apply about 800 pounds of alfalfa per acre and sometimes have to add more as the season progresses. If hay is used, it should be chopped and applied at a rate of 1,500 lb./acre.

We have found that the best way to stock the eggs is in a small wooden tray with a screen bottom. The eggs are kept off the bottom of the pond and are protected from bird predation because the tray will sink when the bird sits on it. When the eggs hatch, the fry can swim out through the screen.

It is important that the fingerlings be harvested from the pond before vegetation becomes a problem. Perch can be started on dry feed when they are 3/4 to one inch long. In our ponds, they reach this size by about the first of July. If we wait until the middle of July to drain our ponds, submerged vegetation makes harvest of the fingerlings very difficult.

We harvest our fish by drawing the water slowly out of the pond and trapping the fish in the kettle. During harvest, it is very important to stress the fish as little as possible. We have a very serious bacterial problem at Lake Mills and this starts to kill our fish if the water gets warmer than about 60° or if we handle our fish too much.

We have expanded our technology of perch fingerling production significantly since we started. The major achievements have been incubating the eggs indoors and stocking them in ponds on screened trays so the eggs hatch in the pond. I think the next step will come with getting the fish to feed right after they hatch, and the University of Wisconsin Perch Aquaculture Project is working on this. It will also be very important to take the fish that do best in the aquaculture system and spawn them. It takes a long time to produce a hatchery strain of fish, but it improves the fish for cultural purposes.

I'd like also to mention that once the fish are raised, they must be transported. This is an additional stress factor and the best methods of transporting perch fingerlings should be looked into.

QUESTIONS AND ANSWERS

What are the pH limits for spawning perch? I have a cranberry bog with a pH of 4.3

Kayes: Specific pH limits for perch aren't known but the problem with acidic water is that calcium ions aren't present and we know calcium is required for fertilization. There is a real doubt as to whether perch could spawn successfully under acidic conditions. It's better to have water that is excessively alkaline than excessively acidic.

Will brood stock eat the fry and fingerling if they are in the same pond?

Stairs: Very definitely. That is why we raise perch the way we do, stocking a clean pond with eyed eggs but spawning the fish elsewhere.

If the brood fish have an alternate feed like minnows, will they still feed on the young perch?

Kayes: Perch are not very effective piscivores. They have a hard time catching minnows.

Stairs: I think the big problem is with large perch eating the spawns.

Kayes: At any rate, we can conclude that it is poor pond management to have anything in the pond other than perch fingerlings.

What are the economics of using a high protein fertilizer like dried alfalfa in place of organic fertilizer?

Stairs: I think it is more economical because you get a greater return in pond nutrition per dollar spent. Alfalfa also works very quickly. We finish our pond cycle for perch in four weeks. Using hay for fertilizer, it would probably take four weeks just to get a zooplankton population started. I think everyone would agree that animal manures are very bad because they promote algae and weed growth.

Henry: Also, with animal manure, a great deal is needed and the handling cost is increased.

Do you drain your ponds and let them freeze out every year?

Stairs: Yes, we drain as many as we can.

How do you handle the disease problem in your ponds if you can't drain them?

Stairs: We get parasites in the ponds but we don't have problems with disease until the fish have been removed and handled. Parasites can be controlled with chemicals but the new laws being enforced by the Food and Drug Administration and Environmental Protection Agency make hatchery work very difficult. They haven't registered such chemicals as formaldehyde and copper sulfate which are very important in our fish work.

If it's so important to keep the eggs suspended off the pond bottom, why do perch overpopulate our lakes on their own?

Stairs: I'd guess that the survival rate of eggs laid would be less than one half of one percent in the wild. Perch overpopulate natural waters through sheer numbers. They are very prolific.

Will perch spawn on sand?

Stairs: I think they will spawn anywhere but they prefer gravel.

Do you incubate the eggs until they hatch?

Stairs: No, only until they are eyed. Then we transfer them to the wooden trays with screened bottoms. When the eggs hatch,the fry can swim through the screen and out into the pond.

What do you do to control fungus in the incubators?

Stairs: We use the same procedure as for trout egg incubation. We pour 160-200ppm formaldehyde through the incubator once per day. We only do this until the eggs have eyed because the treatment might kill them after that.

Do you remove dead eggs?

Stairs: That's not practical with perch. It takes too much time.

West: I would like to make a few comments at this point, first on pond flooding dates. In an average year we would flood the ponds when the first eggs are produced. About three weeks after flooding, the fry will need to begin feeding and the zooplankton population should be developed by then. Pond flooding dates should be adjusted according to how warm the spring weather is.

Dr. Hokanson spoke of different stages accompanying the hatch. One of these is when the embryos are heavily pigmented and they become very active. Just before hatching they lose their urge to struggle and become inactive. We believe that this impedes hatching because the fry aren't fighting hard enough to break loose from the shell. We think that these stages are important in determining when the eggs are stocked. If they are placed in the pond during the active period, wave action might break up the ribbons and give a premature hatch. Because of this, we try to stock our eggs during the inactive period just prior to hatching. If you wait too long, the eggs will hatch as they are removed from the incubator so timing is important.

Kayes: I have talked to a lot of people about perch culture and found that there is a different "best way" of doing it for every facility. For instance, at the Lake Mills hatchery, the eggs are stocked when they are well eyed out. If I waited until that long to stock eggs, I would have a great deal of difficulty. The basic reason for this is that Mr. Stairs works with much smaller fish than we do and the ribbons are much smaller and easier to handle. The fish we work with are from Lake Mendota and the ribbons may be five to seven feet long. If I wait until the eggs are well developed, I'll end up with a mess when I try to move them. We move our eggs on day six or seven after fertilization and Mr. West moves his on day eight or nine. One procedure is not more correct than another, just more appropriate for a specific facility.

West: The spawns from six to seven inch fish fit into the Heath trays much easier than the ribbons from a larger fish.

Kayes: With the large ribbons there are more problems with flotation and the larvae escaping from the egg masses, but of course, you get more eggs out of larger females.

Do you need a permit from the DNR to dig a pond even if it will be drained every fall?

Stairs: Definitely. If you raise fish, you have a fish hatchery and you need a fish hatchery license.

FINANCIAL BUDGET FOR A PERCH FINGERLING PRODUCTION OPERATION

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Perch fingerling production will necessarily be a pond operation. Egg taking is best done indoors but fry feeding must be in the natural environment of a fertile pond.

Pond production estimates for coolwater fish range from 50 lbs per acre to 250 lbs per acre, which converts roughly to 11,000-60,000 two-gram fingerlings. The variability of pond production is due to several biological and chemical factors characteristic of each pond environment. It is conceivable that pond production could be raised substantially by supplemental feeding, but for the purposes of this paper it will be assumed that 30,000 fingerlings can be raised per surface acre of water per season. The acreage required to support a 100,000 pound per year production facility would then be about 12 acres, assuming a survival rate of 80 percent from stocking in the production system to harvest.

Fingerling production in ponds requires a high level of management and ponds should be constructed accordingly. A manageable fish pond is one that can be drained and filled easily. Since well water is the most desirable water source for a pond devoted to fingerling production, the soil used for diking must be of a high clay content to minimize pumping requirements to replace water lost through seepage. Pond size is also a factor in management, but small ponds cost more per acre to construct than larger ones. No criteria for sizing perch fingerling ponds have been described but they should probably be limited to around two acres, with a width not to exceed 150 feet.

This prospectus for a 12-acre perch fingerling farm assumes that the land is level; the soil has a high enough clay content to hold water; and adequate groundwater is available at a reasonable depth. Land costs will be minimized if a swampy, but drainable site is chosen or if the area is in some other way unsuitable for other forms of agriculture. It is important that the site not be in a floodplain to eliminate costly diversion canals or higher than necessary dikes.

Figure 1 shows a proposed 12-acre perch fingerling farm containing six two-acre ponds, each with a 150-foot width. The central dike allows truck access to each pond. All dikes have a height of five feet to allow a water depth of four feet at the deep end of each pond. The central dike has a ten-foot crown requiring 4.63 cubic yards of soil per linear foot and the internal dikes have a three-foot crown requiring 3.33 yards of soil per linear foot. Figure 2 shows the cross-sectional dimensions of the dikes.

Each pond has its own water control structure so it can be individually managed. The most practical drainage system for small ponds has been found to be the Canfield drain or turndown pipe. Figure 3 shows the operation of the turndown drain. The standpipe serves as an overflow to regulate the water level of the pond when in the upright position. When turned down, the standpipe becomes a drain. Each turndown drain

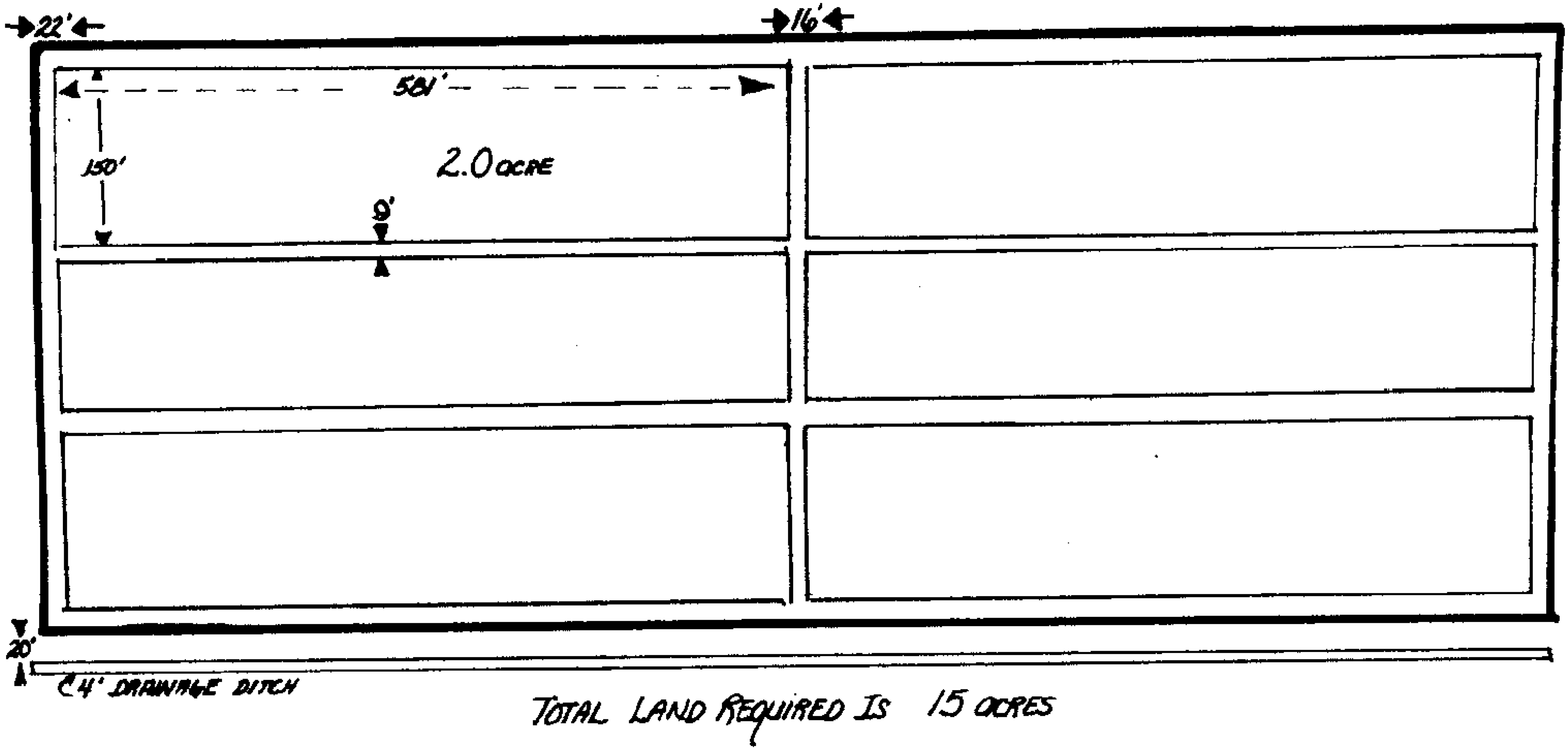

Figure 1. Layout for proposed 12 acre perch fingerling farm. (Scale: 1 cm = 50')

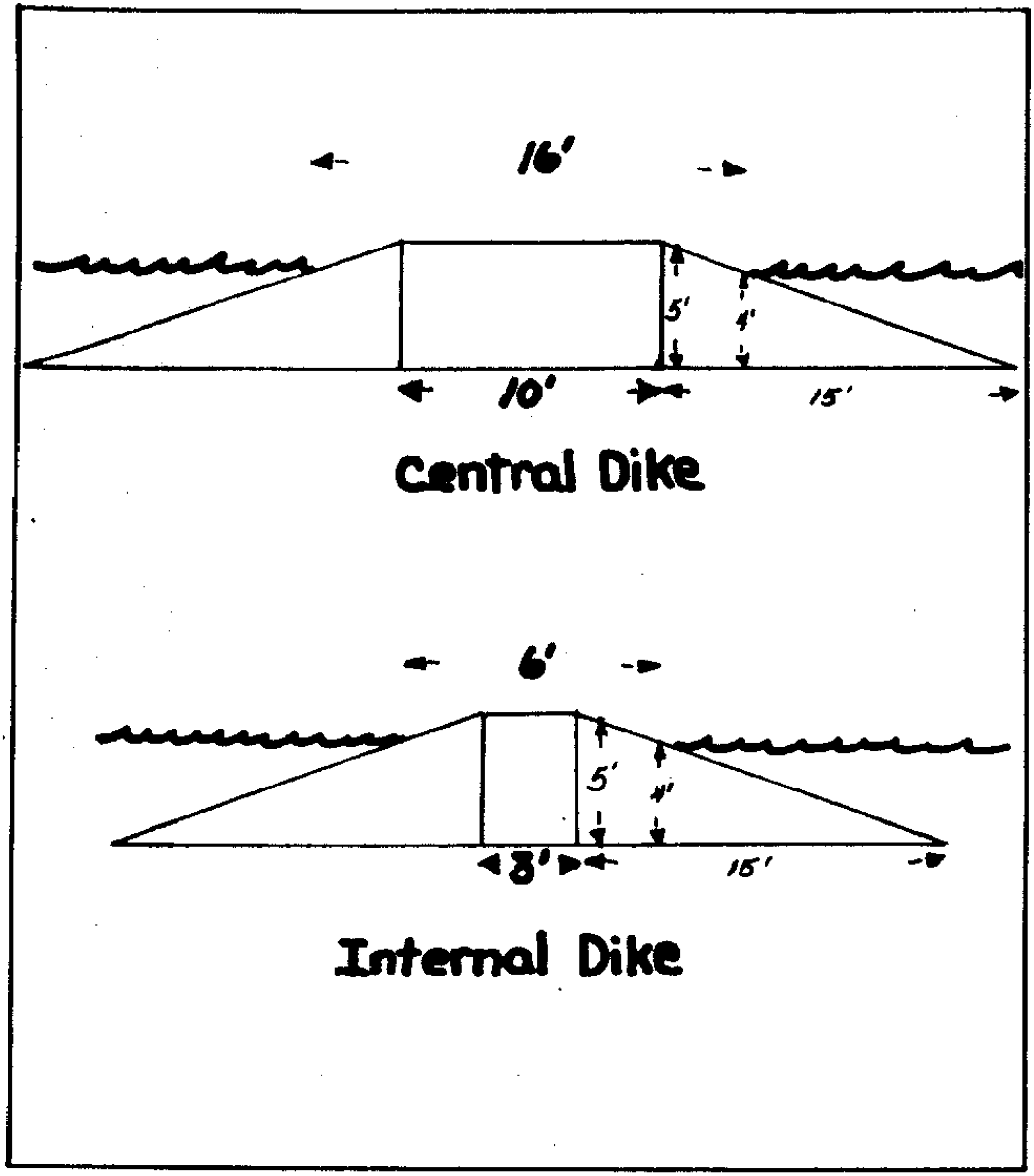

Figure 2. Dimensions of Dikes.
(Scale: 1 cm = 2.5')

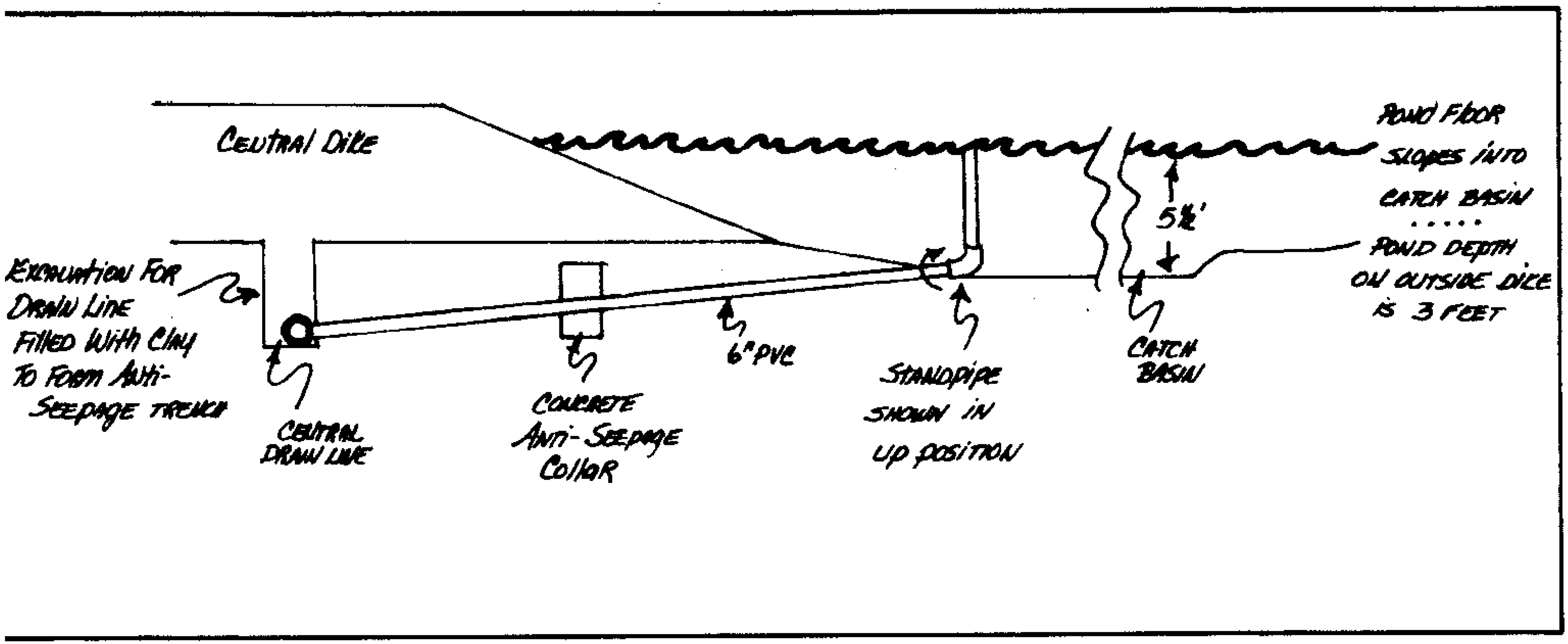

Figure 3. Drainage Diagram

(Scale: 1 cm = 2.5')

is connected to a central drainage line beneath the central dike. Each pond will require about 96 hours to drain completely if the standpipe is six inches in diameter. A circular catch basin should be provided at the drainage end of each pond to facilitate harvest. It should be 1-1/2 feet deep at the center and occupy 10 percent of the pond's area. The catch basin for a two-acre pond would then be 105 feet in diameter.

DISCUSSION

This prospectus presents a reasonable profit projection for a pond fishery operation in Wisconsin. As in other forms of agriculture, the producer is at the mercy of weather conditions and market fluctuations so a feasibility study of this type can be used only as a guide. It is expected that the greatest benefit in an operation on the scale presented here would be in conjunction with a growout facility. The grower would then be producing his own fingerlings at a cost of about four cents each and would have the best opportunity to upgrade his product through genetic control.

COMMENTS ON SEALING POND LEAKS

The best advice on sealing leaky ponds is to avoid digging them on permeable soils. With today's land costs, water regulations and pumping costs, however, it is not always possible to locate the pond operation in an area with ideal soil characteristics.

Many areas in Wisconsin have clay at a reasonable depth so that it can be mined to line the pond. In any case the pond dikes should have clay cores and antiseepage keys. Commercially available clay sealers such as Benonite sometimes solve pond leakage problems but success has been variable and unpredictable.

Carp or hogs are sometimes used to build up an impervious organic layer on the pond bottom and sides but this would take at least a year. A leaky area on a pond dike can be "hogged off" without taking the entire pond out of fish production.

Ten mil plastic sheeting for lining ponds costs about 11 cents per square foot and should be considered an extreme measure because of the cost.

DEVELOPMENT COST SHEET

	Cost
LAND COST	
15 acres @ 500	$7500
EARTH MOVING COSTS	
Drainage system (backhoe) 185 yards @ .75	139
Central dike (caterpillar) 2278 yards @ .50	1139
Internal dikes (caterpillar) 19,021 yards @ .50	9511
Catch basins (caterpillar) 1936 yards @ .50	968
PLUMBING COSTS	
Drainage	
589 ' 6" PVC @ 4.76	2804
6 6" PVC "T"s @ 37.50	225
6 6" PVC male adapters @ 10.63	64
6 6" PVC female adapters @ 15.70	94
6 6" PVC elbows @ 26.79	161
6 yards concrete @ 35.00	210
Supply	
1900' 6" PVC @ 4.76	9044
60' 3" PVC @ 1.68	101
4 6" red "T" @ 37.50	150
2 6" red elbow @ 26.79	54
1 6" elbow @ 26.79	27
2 6" gate valves @ 283.20	567
PUMP AND WELL	
300 gpm submersible turbine pump w/10HP gasoline engine	3035
100' 6" drilling @ 6.00	600
100' 6" casing @ 3.42	342
5 6" couplings @ 10.10	51
OTHER COSTS	
3 acres vegetative cover A 45.00	135
74 yards gravel to surface central dike @ 13.00	962
1 100' sieve, 1/8", 4' deep	225
4 dipnets @ 14.00	56
6 1/3 HP aerators @ 86.00	516
1 lawn mower	125
1-1/2 ton pickup (used)	3000
2 fish hauling tanks @ 1200	2400
1 Oxygen kit	30
TOTAL ESTIMATED INVESTMENT	44,235

COST OF PRODUCTION	Cost
ESTIMATED EXPENSES	
Principal + Interest, 7 years at 9%	8540
Pumping Costs, 4300 gallons @ .52	2236
Aeration costs, 2HP for 30 days	58
Labor, 658 man hours @ 3.50	2303
Taxes, Insurance, Repairs, 4% of 44235	1770
Fish hauling, 300 miles @ .40	120
TOTAL	15,027
ESTIMATED ANNUAL PRODUCTION 360,000 @ .05	18,000
ESTIMATED EARNING	2973
Profit per land acre	198

CONCEPTS IN FISH TANK DESIGN

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Several factors should be considered in selection, configuration and construction materials of any fish culture unit. Configuration of a given culture unit should be determined by the desired water exchange rate, total water volume, depth, shape, drainage system and harvest method. Two of the factors influencing pond size are physical restrictions and economic restrictions, that is, characteristics of the site and development funds available.

Site characteristics and the amount of water available will help determine whether fish are cultured intensively or extensively. Intensive culture can be compared to a feedlot for cattle. Extensive culture is similar to raising cattle on a range.

The water space potential determines which type of culture can be practiced. For intensive culture, the water body must be able to be filled in 30 minutes to four hours. The range for extensive culture is one to seven days.

For instance, if a fish farmer practicing extensive pond culture cannot completely fill his ponds in seven days, he has too much pond space. The water space potential is especially important to a pond operator because during the summer when algae blooms die off and deplete the water of oxygen, the ponds must be flushed. This has to be done within seven days.

An example of an extensive operation would be a water supply of 12,000 gph. With this volume, the operator could have from three to 20,1/10-acre ponds. If he built more than 20 such ponds,his space potential limit of seven days would be exceeded.

An example of how 12,000gph could be used intensively would be with 500 gallon tanks. A 1/2-hour fill time would allow 12 tanks and a four-hour fill time would allow 96 tanks to be operated. If there is excess potential in an intensive culture system due to more water flow than can be managed easily, it can be integrated with an extensive system. One operator I know planned his potential water space and came up with an integrated system having intensive culture in circular tanks coupled with extensive culture in ponds.

Different construction materials and methods are available for different economic situations. At one end of the scale is fish culture in rivers, lakes or the sea. These water bodies cannot be drained so cage culture is practiced. A cage can be any shape, be made from netting or wire and have a lock space and flotation collar around it. The flotation used is often Styrofoam or 55-gallon drums.

An exciting application of cage culture is floating raceways. The netting is replaced with vinyl and the raceway is pumped full of water. The advantage is that the water can be taken from any depth, so the best quality of water is used throughout the year. The upper limits of the water column, where cage culture is confined, is not always the best water for fish culture.

Another type of fish culture vessel is a canal or raceway. The simplest type of construction is earthen. The sides can be improved with concrete, wood or vinyl. The most expensive type of construction is all concrete. I design my concrete raceways in 10 cubic meter sections to facilitate calculations when treating the fish for disease.

There are two basic types of pond construction. In pit construction, the pond is dug down into the ground and in dike construction the levees are built up above the orginal ground level. Dike construction is the more desirable because it allows drainage. Some ponds have wood or concrete sides, but most are earthen.

Silos are sometimes used for trout culture and can be built above or below the ground. They are usually made of concrete, fiberglass reinforced cement, metal or fiberglass.

Tanks are usually made of poured concrete but there are several disadvantages to this type of construction. If the fish culturist decides that his facility isn't designed correctly, he can't move his tanks if they're made of concrete. Also, concrete is porous so the walls can harbor disease organisms. They can be painted but the paint falls off in a short time. Tanks can also be made of fiberglass or metal. The best tank we've used is a double walled fiberglass tank with internal wood reinforcement and foam insulation between the walls. It is functional, movable and easy to keep clean.

The next thing I'd like to discuss is the shape of tanks for extensive fish culture. In a pond operation the lay of the land or shape of the site might determine what shape the ponds are. Rectangular ponds should be 1/10 acre or larger. Small ponds have a greater amount of shoreline, which is the productive area of the pond, than larger ponds but cost more, per acre, to build. The amount of time that fish will remain in the pond helps determine how deep it should be. A short-term pond need only be deep enough to keep birds from wading the edge. This is about three feet. If fish are going to be kept in the pond longer than eight weeks or so, it should be deeper so that as the fish grow they have enough space. Also, deeper ponds are slower to be choked with weeds than shallow ones. From a pond management standpoint, the fish must be out of the pond before weeds become a problem.

The next consideration I'd like to address is harvesting. The first fish ponds built in this country had channels leading toward the drain to funnel the fish down. The next step in the evolution of fish ponds was to slope the entire pond bottom into a kettle or catching basin from where the fish could easily be harvested. A further refinement to this is a concrete kettle with gates so the fish can be more easily confined. The best ponds have a concrete slip down the center so that when the pond is drained, the fish slide down into the kettle and harvest themselves.

There are several types of drainage mechanisms. The standpipe drain is common but there are some faults in it. Once the pipe is turned down, you can't always get it back up. The collar can come loose and leak. It's difficult to screen a standpipe because it quickly gets clogged with weeds and it's hard to clean because the drain is under water. One simple type of drain is a sluice with dam boards. The number of boards in place determines the water level. Also, this type of drain is easy to screen.

In summary, tanks can be rectangular or round. The depth can be 1/4 to 1-1/2 feet for a very short term, 1-1/2 to three feet deep for an intermediate term and deeper for a long term. The pond should drain to a central collection point for the fish. A little planning by designing tanks right and letting them do the work will pay off in dividends.

I would suggest the following publications for anyone interested in getting into fish farming.

Fish Farming International
Arthur J. Heighway Publication, Ltd.,
110 Fleet St.
London, England EC4A 2JL
Subscription U.S. $25.00

Second Report to the Fish Farmers
Resource Publication 113
Bureau of Sport Fisheries and Wildlife
Washington, D.C. June 1973 $2.10

The Commercial Fish Farmer and Aquaculture News
620 E. Sixth
Little Rock, AR Subscription $10.00

GROUP DISCUSSION

Why are you raising perch? It's considered a trash fish in our area.

Soderberg: It may be a trash fish for sporting purposes but it's the most valuable finfish for food in this area. Fresh perch fillets are now retailing for $4.69 per pound.

Stairs: My comment on that is that in years to come there may be no fish considered trash. We might be utilizing all fish for food. The Food Science Department here has shown that all kinds of fish can be made palatable.

Calbert: The reason that we have been primarily interested in perch aquaculture is that there is a demand for this product that is not being supplied. In most new food industries, a product is developed and then a market is developed. In the case of perch, we already have a market. Admittedly, this is a luxury market. I don't know why people would pay over $4.00 a pound for perch when they can get top grade steak for half that price, but they do. In the future, if food supplies become critical, we might consider a species of fish less costly to raise but for now, we're trying to work out perch aquaculture so that it is fairly feasible and somewhat economical. Perch will never be a cheap fish, but we'd like to see it get to the point where a farmer raising it could make a profit.

Kayes: Beauty is in the eye of the beholder. One of the most commonly cultured fish in the world is carp, but its value as a food fish is very low in this country. Carp is not a native fish; it was introduced by your ancestors because, to them, it was an important food.

Would you say that hormonal control of brood stock is a feasible thing to do at this time?

Kayes: The hormonal control of spawning is feasible but it takes a certain amount of skill. Whether or not it is a worthwhile technique will depend upon the individual fish culturist. It is a very commonly used technique for other kinds of cultured fish. The endocrine or hormonal control of maturation in perch is not feasible at this time and I don't think it will be in the near future.

On temperature suppression of the adults, is it important to put the males, as well as the females, through a cold period?

Hokanson: The female is the most critical, but it would be desirable for the timing of maturation of both sexes that it be under the same condition.

Kayes: We have people in our project working with sperm preservation. Most of the technology for this has already been developed, so I think that in the foreseeable future we will have sperm available when we need it and only the females will have to be controlled.

Hokanson: I think one of the effects of a cold period on males is that it prolongs the period of time when spermatazoa are available, but the female cycle is much more precise and limiting.

Is food availability the major constraint on fingerling production in ponds?

Staire: Yes, I would say that food is the major limiting factor, but the amount of food available can be influenced.

Henry: Another thing is rain. A heavy rain can eliminate a good crop of food organisms in the pond. Weather is a very important factor at that time of year.

Soderberg: A given pond will have a certain carrying capacity, and once this is reached, additional feed and fertilizer won't have an effect. There is a whole host of chemical and biological factors that affect what the carrying capacity of a pond is.

West: It can be harmful to overfertilize or overfeed a pond because the BOD rises and there might be a possiblity of oxygen depletion.

Is the aquaculture program still interested in the culture of walleye?

Calbert: The walleye program is still viable. Up until this year we've concentrated on perch because of space limitations, but now that we have a new facility we'll be doing more work with walleye.

Hokanson: I would like to make a few comments that I failed to mention in my talk. On holding back brood stock or embryos, it depends upon the water supply. Brood stock could be held back a week or two on spawning in water at a temperature of 4°C. Well water is not cold enough for this. I would also like to bring out the importance of the fattening period in the yellow perch's reproductive cycle. This will be especially significant for those interested in brood stock production. If anything interferes with the normal processes that occur within the fattening period, the fish won't mature the next year. It is also important that the brood fish spawn each year. The reabsorption of the gametes will interfere with the development of next year's crop of eggs and no spawning will occur.

Kayes: In conclusion, I would like to make a point on the positive side. We've heard about all the factors that contribute to successful fingerling production: increasing photoperiods, certain temperatures being required, certain conditions necessary in the ponds and so forth. In reality, the normal average temperatures and conditions outdoors are the best conditions for culture. If this weren't true, perch wouldn't be successful in the lakes. The point is to take advantage of the natural system as much as possible. Learn what the requirements are and find ways of adjusting, manipulating or making slight modifications on the natural system to obtain the maximum yield.

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