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AQUACULTURE:

raising perch for the midwest market

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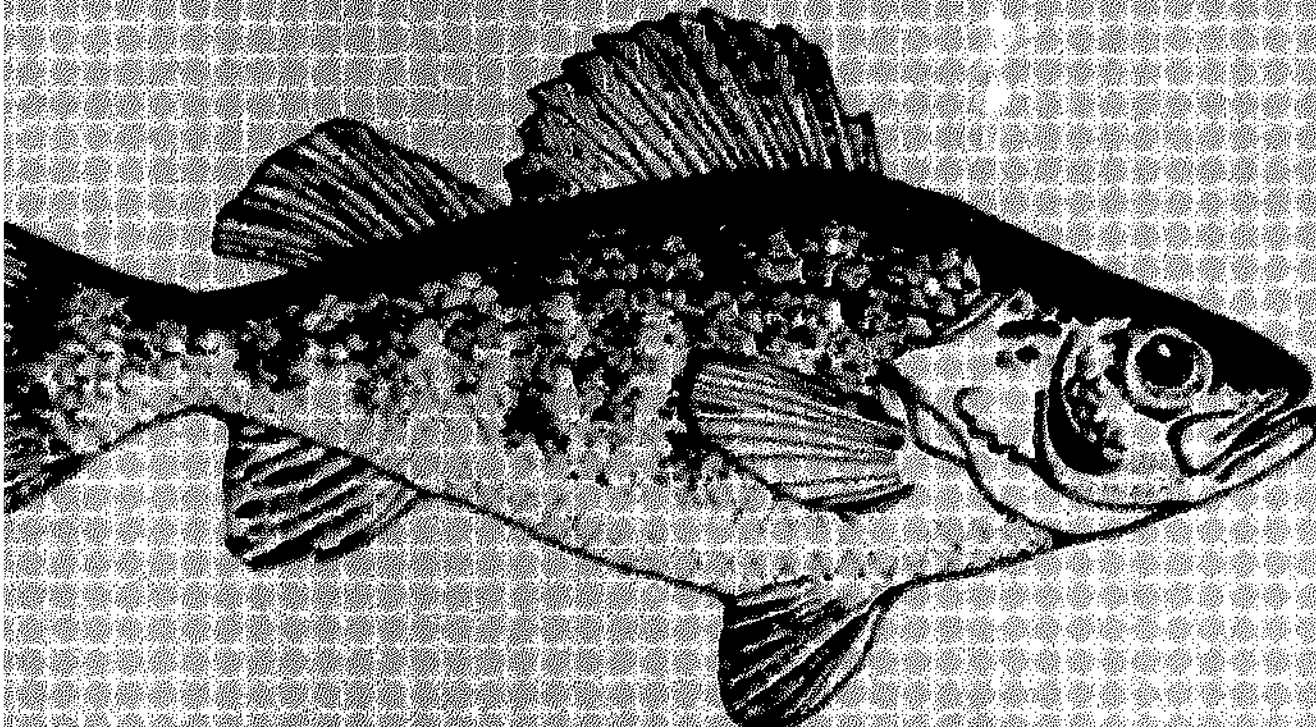

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AQUACULTURE:

RAISING PERCH FOR THE MIDWEST MARKET

Proceedings of a conference sponsored by the University of Wisconsin Sea Grant College Program, the Department of Food Science and the University of Wisconsin-Extension on April 16, 1975.

UNIVERSITY OF WISCONSIN SEA GRANT COLLEGE PROGRAM

Advisory Report #13

June 1975

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FOREWORD

Aquaculture is not a new concept. For centuries, man has been raising fish for food. But the tremendous interest in perch aquaculture which has emerged in Wisconsin recently is very new.

In part, this interest is the result of the condition of the natural perch fishery. Perch is one of the species most in demand in this region, but during the past five years increasing contaminants in the Great Lakes and decreasing catches have suggested that an alternate supply of fish must be found to meet the needs of the commercial market.

Little experience in the commercial raising of perch has been reported and so the University of Wisconsin Sea Grant College Program launched a perch aquaculture research project in 1973. The researchers sought to establish a broad base of nutritional studies, design the physical facilities and develop parameters for tank culture operations.

Research progress during the past two years has been substantial and public interest in the project has continued to grow much faster than anticipated. Harold Calbert, coordinator of the aquaculture research, suggested that a general conference be held to report progress to this interested public. The conference was held April 16, 1975 and the papers delivered at that meeting are included in this volume. Though research work is continuing and much remains to be learned about raising perch for market, these proceedings do represent a broad, if brief, summary of the work to date.

Five hundred people attended the April conference and many, many more expressed keen interest in the subject. Because of this interest and the commitment of Sea Grant investigators, the conference turned out to be a great success. Several people, not directly affiliated with the University of Wisconsin Sea Grant College Program were instrumental in this success. We wish to thank Mr. Marvin Spira, Mr. Robert Follett, Mr. Bert Smith, Mr. John Klingbiel, Mr. Fred Meyer, Mr. James Warren and Mr. Leo Orme for their participation in the conference and their contributions to this proceedings.

We would also like to thank members of the Sea Grant staff and investigators who made the meeting and this proceedings possible — particularly Julie Dolinky who handled registration and helped coordinate the conference.

Finally our thanks to the National Oceanic and Atmospheric Administration, U.S. Department of Commerce, and the state of Wisconsin who have supported this research from the beginning. We also greatly appreciate the research support from the Vita Plus Corporation, Moore's Food Products and the Wisconsin Cold Storage Company. These companies have cooperated to support an aquaculture demonstration facility on the outskirts of Madison where members of the aquaculture research team are trying out their techniques on a semi-commercial scale. The success of this endeavor will provide some indication of the role that perch aquaculture may play in Wisconsin's future.

Gregory D. Hedden, Conference Coordinator
Director — Sea Grant Advisory Services

PURPOSE OF THE CONFERENCE

Professor Harold E. Calbert

Chairman, Department of Food Science
University of Wisconsin-Madison

On behalf of the University of Wisconsin, the Sea Grant Program, the College of Agricultural and Life Sciences and the research personnel concerned with the aquaculture program I would like to welcome you to this conference. None of us realized when planning this conference that the response would be so tremendous. The program coordinator's office has informed me that it was necessary to return as many applications for registration as were accepted. For this, all of us extend our most sincere apologies. However, the facilities that were available mandated the number of conference participants.

This conference will serve several purposes. First, it provides an opportunity for the research workers on the aquaculture project to present progress reports of their studies concerning the raising of yellow perch under controlled environmental conditions. Second, the basic principles that must be followed in establishing an aquaculture system for the raising of these species will be highlighted by the speakers. Third, the marketing of the fish and the market demand for these species will be discussed. Fourth, and probably the most important to those in attendance, the information to be presented will serve as a basis upon which you can made decisions as to whether or not you wish to consider establishing an aquaculture operation and becoming a fish farmer.

The research on this project has been under way a little over three years. There is no intention on the part of any of today's speakers to convey the idea that the answer to every problem that might arise in an aquaculture operation has been found. As today's presentations unfold I believe that each of you will become aware of how much is involved in establishing a system in which yellow perch can be raised profitably for the commercial market. It requires indoor facilities, tanks, and equipment for rearing fish, a reliable water supply and special fish feeds. Depending on size, it can require a considerable capital investment. As yet the supply of fingerlings that are available for fish farming are very limited. Once in operation extreme care must be taken to prevent and control disease. Like any other type of farming venture, to be successful fish farming requires certain skills and knowledge, hard work, investments and considerable luck.

Nevertheless, those of us who have been associated with the aquaculture project are optimistic. We can foresee the time when it will become a new industry in the upper Midwest. To what extent fish farming will progress will depend on the ingenuity and imaginativeness of those engaged in it. We believe that it has a promising future. It is hoped that this conference will serve as the push that will open the door of opportunity for many of you.

Again, I want to welcome you to the meeting. We want to thank you for your interest in what we think will be a very exciting new venture. We hope that today is the beginning of a fine relationship between a potential new industry and the personnel of the university and related agencies that are concerned with aquaculture.

THE RESTAURANT TRADE AND LAKE PERCH AQUACULTURE

Robert Follett
Anchor Fish and Seafood, Appleton, Wisconsin

Due to an increase in demand and a sharp drop in commercial lake perch production, the yellow lake perch may soon disappear from the menus of many fine restaurants throughout midwestern United States. Today the need for lake perch aquaculture is very real and apparent; however, in the future that need will have multiplied many times. In order for processors and distributors to maintain a continuity of supply, it is inevitable that lake perch must be commercially grown on fish farms.

The traditional Friday fish fry has increased restaurant sales volume to a point where Friday has become their most profitable day of the week. Consequently, many restauranteurs are now serving perch on their daily menus. Historically Wisconsin has consumed over 75 percent of the total Great Lakes lake perch production, the remaining 25 percent being consumed along the coastal areas of other Great Lakes states. In years of good commercial fishery production, Wisconsin consumes approximately 20 to 25 million pounds of lake perch a year. The vast majority of these fish are sold to taverns, restaurants and supper clubs. With more and more people eating out every year, the demand for lake perch will increase faster than it ever has before. It has become very evident in the last five years that as people are becoming more cognizant of the dietary and nutritional values of fish, per capita consumption of fish has risen. The 1973 per capita consumption of fish in the U.S. was 12.6 pounds, which has increased over 50 percent in the last 20 years. In contrast to this, in countries where fish are more plentiful, as in the Scandinavian countries, fish consumption per capita averages 54 pounds per year.

In short, I feel that with the help of aquaculture, lake perch consumption could be greatly increased. Lake perch aquaculturists could supply the processors with a considerably fresher and more uniform product than has ever been served in restaurants before. With this fresher, higher quality, better eating product, fish sales in restaurants would increase at a fantastic growth rate. With an abundant supply of lake perch, fish frys could be promoted in other parts of the country, as Wisconsin has promoted them in the past.

The Lake Erie commercial fishery has always been the largest contributing factor to the midwestern lake perch market, supplying it with 80 to 85 percent of its fish. During 1969, the Lake Erie commercial fishery produced 33 million pounds of round lake perch. Since then production has declined to 15 million pounds in 1974. Through research and periodic sampling of fish from Lake Erie, U.S. Fish and Wildlife biologists at Sandusky, Ohio forecast that 1975 production will continue to decrease another one to two million pounds.

No change for the better is anticipated until such a time when there is another successful hatch and year class survival comparable to that of 1965. However, when we do have our next successful hatch it will take three to five years for these perch fry to mature to marketable size. If we were even that fortunate this year for such a hatch, it would be 1978 or 1979 before this class of fish could be marketed. Due to strong demand and extreme shortages, prices of yellow lake perch have climbed sharply. Round lake perch prices in 1969 averaged $.17 per pound, whereas 1974 prices averaged $.55 per pound. It is obvious that if production again declines in 1975, prices will move even higher.

In order to supply restaurants with farm raised lake perch, processors will need round, healthy fish which are disease free, taken from water at the peak of freshness, iced and delivered to processing plants daily on a year-round basis. This would eliminate the need for warehousing huge amounts of fish during months of the year when fish were unavailable. This would be a savings to the processor in warehousing and interest charges. Round lake perch averaging three fish to the pound or nine to ten inches in length are most desirable. When processed these fillets will then average 1-1/4 ounce each or approximately 12 to 13 single fillets per pound. This size of fillet is most commonly used by the restaurant industry. Uniform grading of round lake perch would enable the processor to deliver graded fillets to the restaurant. In this way, the restauranteur will be able to control his food cost and insure himself a reasonable profit.

I feel that aquaculture raised perch should be priced competitively at the outset, with those fish commercially harvested from the Great Lakes. Eventually both fish would seek their own price level.

If the commercial fishery could once again produce lake perch as in the past, I honestly feel that there would be no problem whatsoever marketing the surplus. Several years ago the Canadian fishery exported thousands of pounds of lake perch fillets to western Germany. However, this year we have imported huge amounts of lake perch from Holland to fill the void left by the declining commercial lake perch production. The quality and flavor of Great Lakes lake perch is far superior to any imported lake perch.

All in all, for processors and distributors to supply restaurants with lake perch, it is most imperative that they be commercially raised on fish farms. If you as lake perch aquaculturists can build a successful, profitable industry, then and only then, can we as processors, dealers, fish brokers, and most important restauranteurs, market all the lake perch you can produce. The challenge of this venture is in our hands!

THE INSTITUTIONAL TRADE

Marvin Spira

Moore's Food Products, Inc.
Fort Atkinson, Wisconsin

Moore's Food Products has been in the production and marketing of raw breaded fish products, onion rings, etc., on a national basis for the last 15 years, and on a more regional structure for 30 years. One of the leading items has been raw, breaded lake perch.

When I first came to Moore's in 1970, the sight which greated me was aquariums in every office, test kitchens, laboratories and warehouses. The immediate impression was that Moore's had become very involved in this project, and had come to the conclusion that there was a substantial future to be investigated in the marketing and sales of freshwater fish.

We are all aware, marketing wise, that the shortage of this product has hampered our development into other regions of the country. We have all we can do right now to fill the requirements of the immediate Great Lakes area. We even had to go so far as to repurchase, from one of our distributors, a couple of cases of perch that we could sample to everyone here at the seminar. To put two cases of lake perch into our freezer and hold them for a few weeks until they could be delivered here to the university proved no small security problem. The demand is great enough that we were afraid they would disappear into some long-standing back order.

Of course, initially the large demand for lake perch was not created by its shortage. The regional popularity was due to its wonderful taste and the easy methods of serving — fish fries, lunches, etc. The taste, texture, size, ease of preparation — such as pan fried in butter, french fried in batter and crisp breading — and the fact that it was an easy fish to catch in the Great Lakes and a very popular pan fish for the sport fisherman, created, over the years, an accessibility and taste preference.

Peculiar to the Wisconsin region is the Friday night fish fry at which thousands and thousands of pounds of breaded fish are served. This still exists today and I don't think there are many areas in the country that offer this unique presentation.

It is very frustrating to know that the potential market for lake perch is not only here in the Midwest Great Lakes region, but can be spread to all parts of the country. We have, because of the shortage, frequently been forced to rely on allotment basis of selling to our customers, and for the past six or seven months, having almost all of this supply in poundage sold on standing orders even before they are processed. We have, however, in order to determine the potential marketing and sales picture of this product, introduced it into various regions through our broker representatives. At the present time, we have lake perch being sold in the states of Washington, California, Texas, Colorado, Florida, North and South Carolina, New York, Pennsylvania and even in Maine. While these states account for only two percent of our total sales they were marketed there only to determine the popularity in some small test region of the item, whether they would be a market in which we could, later on, establish some footholds in the institutional or food service area.

We have, of course, established this fact. Lake perch can be sold anywhere in the country and given an adequate supply, our marketing procedures, advertising techniques, end-user work, etc., can be put into effect. It is reasonable to assume that a fish this delightful in taste can be sold as easily in Maine or California, Florida or Washington, as can red snapper, cod, lobster, etc., be sold in the Midwest area, and with the beautiful methods used today in advertising, — full color photographs, counter banners, menu clip-ons — a desire and demand for the product can always be increased.

In the last year, about 31 percent of our total sales were in the state of Wisconsin, 34 percent in Michigan, five percent in Indiana, 15 percent in Illinois, 12 percent in Ohio and one percent in Iowa. The other two percent, as I mentioned before, would be scattered throughout the United States and have been sold, again, only as test for future marketing.

In the past few years, knowing that the northern shore of Lake Erie is closed to fishing during the severe winter months, it has been our procedure to warehouse some inventory to carry over the late winter and early spring period. This year, however, we found that difficulties arose when we were unable to obtain supplies in October and November as easily as in the past years. All the merchandise we could get was sold, even sold on an allotment basis. This, of course, resulted in our being out of stock during the months of January, February, March and, of course, April. If we were to take some advance orders at this time, I'm sure we would go well into the summer before we would be able to catch up with the existing supply.

An interesting note is that during the period of time where lake perch are unavailable, we have made a special effort to use walleye pike, not as a substitute for the lake perch, but as an accompaniment to this type of fish, and have, in fact, established a substantial market for walleye pike. We hope when lake perch become available again, in the next few weeks, that the users of walleye pike will sustain this species also, so that we can create a market for both lake perch and walleye pike.

While the tone of my talk has been to show the demand that is at hand right now, and the potential market, not only in the Midwest, but all parts of the country, we must be cautioned about creating too large a demand too soon for the product. As has been mentioned in progress reports on the aquaculture perch raising experiment here, it will be two to three years before we hope to see any realization of sufficient quantities to relieve the supply situation we now find ourselves in. At best, for the immediate future, what can be raised as a result of this project will really be only a supplement to what is caught in the Lake Erie region. Should the catch and supply in the northern portion of Lake Erie increase, we can proportionately increase our sales efforts. But, of course, natural production and harvesting of fish today is a precarious one in which to project future sales.

We seem to find ourselves in a rather frustrating sales picture. We can sell a lot of perch. We can sell all that is produced at this time. We have potential for substantially increasing our markets and to make lake perch, and for that matter walleye pike, a popular and standard item in the frozen sea food category.

The various means and methods of marketing and selling this type of product for the future are intriguing. There are very few categories in which lake perch will be excluded. Today, we are seeing them served in white tablecloth restaurants on dinner menus, as well as in drive-ins and fast food operations. To expand on these areas and to put full marketing sales and advertising efforts behind this, will be dependent entirely on the future supply of the product. We hope that for the best interests of the economy, the state of Wisconsin and for the people involved in this project who have spent so many months and years in its development, we will come to a successful conclusion of the experiment. We are looking forward to hundreds of thousands of pounds of product being sent from Wisconsin to all parts of the country.

THE DIRECT CONSUMER MARKET

Bert Smith

General Manager, Smith Brothers Fisheries,
Port Washington, Wisconsin.

Since its founding in 1848 on the shores of Lake Michigan north of Port Washington, Smith Brothers Fisheries has enjoyed a challenging 127 years in the fish business. Our family has continually taken great pride in being a part of a unique group of hardy men and families, who for two centuries have fished the Great Lakes.

While considering the significance of a modern fish management project, such as this Sea Grant Aquaculture Program, I would like to provide a brief historical account of commercial fishing on the Great Lakes.

Prior to 1850 very little accurate catch data exists, with the commercial fishing activity generally located in close proximity to the then existing trade markets, transportation and population areas. Historical accounts, however, do show that there were great concentrations of fish available, especially in the lower lakes where most of the activity was then centered. In the ensuing years, until 1900, this great fishery resource was evidently quite stable, due in part to the limited fishery, type of gear and limited markets.

Just prior to 1900 our grandparents witnessed a tremendous growth in the midwest region of our country, particularly in the cities and states bordering the Great Lakes. As transportation and communication improved and expanded, so did the market demand for fresh and processed fish. Quite naturally the commercial fishery expanded and in the past 25 years we have become aware of instances of overexploitation of some species. Our heritage had always dictated that we practice and support good, sound conservation procedures, but in recent years it became evident that other changes have occurred which adversely affected this great food resource.

As population expanded along our shores, so did the man-made problems! With the opening of the St. Lawrence Seaway, the lakes were soon vulnerable to the migration of the parasitic sea lamprey and the prolific alewife. Industrial and agricultural contaminants were allowed to flow into once pure, clean waters, making many species unfit for food. The delicate biological balances of many species have been temporarily harmed by this accelerated "aging" of these great bodies of water. Unlike the unrenewable "fossil fuel" resource coal, the fishery resource is a renewable food resource, and fortunately we are now learning to control and improve these fish populations with new techniques and sounder fisheries management policies.

Unfortunately, though, the production capabilities of the lakes has not kept pace with the increased market demand and we are virtually "out of fish." The per capita consumption of fish and seafoods in the United States has tripled in the last ten years and the industry has done comparatively little other than import more fish from other countries.

The demand for lake perch has similarly expanded, far surpassing the production capabilities of all of the Great Lakes combined. The present marketing area for lake perch in its fresh and frozen processed forms is generally in the states bordering the Great Lakes. Thus, this market is not restricted because of transportation or taste preference, but because of supply. Wholesale and retail organizations have not been able to expand into distant market areas for this reason.

Lake Erie and Lake Michigan produce about 95 percent of the lake perch that are caught for food. The strength of this resource fluctuates from year to year and our marketing procedures have had to adapt to these highs and lows of supply. In recent years, Lake Erie has consistently harvested over 25 million pounds per year, in spite of harvesting as many as three different year classes during their season. A strong market demand has caused the fishing industry to overlook the age-old need for good conservation and serious overcropping of the perch resource is occurring in this lake.

The decline in perch production in Lake Michigan and Green Bay has not been a result of fishing pressure, however, as we find less fishing activity for this species in recent years. Here we must put the entire blame on environmental and biological situations. This data is brought out to show the extreme vulnerability of the perch resource as we now know it.

Some recent studies indicate that 80-85 percent of all the perch production in the lakes enters Wisconsin and Illinois for direct sales, redistribution or further processing. Wisconsin is by far the biggest user. It is estimated that the traditional retail fish stores would require 34,000 pounds of scaled and dressed perch per year if supplies were continually available. It is also estimated that these stores would require 82,000 pounds of perch fillets per year. Grocery stores and supermarkets constitute the largest retail market for these fish, and figures on their requirements — though unavailable — begin to multiply. No factual data is available to me. However, two major chains report 1974 sales of 78,200 pounds of fillets. They, likewise, could not purchase all the product they wanted. It is quite likely that all Wisconsin retail users will soon need 200,000 pounds of fillets per year to meet the market demand.

Using a standard conversion factor of 45 percent yield in filleting, we are then able to project the "round weight" perch requirement of 445,000 pounds per year for Wisconsin alone. Expanding our marketing and processing concepts to new areas would add considerably to this demand.

Sea Grant aquaculture programs in this country are beginning to "show the way" — how our industry can supply the fisheries products needed to meet these increased demands. In closing I would like to quote from a recent article in a trade publication called _Quick Frozen Foods_. The opening paragraph reads:

> Commercial fish farming production in the United States is slated to face a market demand in 1982 nearly seven times that of a year ago, according to a recent report commissioned by Frost and Sullivan, New York market research firm. The market for fish and shellfish raised in controlled environment is predicted to increase from 130.5 million pounds in 1973 to 847.5 million pounds in 1982, a rise of 589.6 percent.

Thank you very much, and a special thank you to the Sea Grant people from the entire fishing industry.

QUESTIONS: Robert Follett, Marvin Spira and Bert Smith

What is the price of the unprocessed fish and the processed fish? Can the waste products be reused?

Robert Follett: An unprocessed fish in the fish industry would be classified as a round perch. We don't really know what the price of round perch is today because there aren't many lake perch available to set the market. But we would estimate that it would be a firm 55¢ to 60¢ a pound; probably closer to 60¢. That's in the round, as it comes out of the water. The price of perch fillets, which would be processed, would probably be over $2.00 per pound.

As for the waste materials, when you fillet the fish or process it, these materials can be reprocessed into what is known as fish meal and this is incorporated back into fish feeds. So it is not wasted if you have processing facilities or access to them. Eventually we could probably advertise like one of the meat packers did many years ago in relation to hogs — "we use everything but the squeal."

How can you get the fish to the processing facility?

Bert Smith: Fish at the harvestable stage would have to be moved to the processing plant in an iced and refrigerated condition. Now conceivably this could be a truck provided by a processor or a group of aquaculture people who could get together and invest in a refrigerated truck —because they must move in a refrigerated, iced state to the processing plant for filleting. That would be in the round state. Iced and refrigereated, these round fish could stand about a two-day period before processing. Then they must be processed or filleted.

One of the speakers mentioned that an average yield of a fish, at marketing size would be about 45 percent. Could you elaborate on that? Also, the price of the fillet was mentioned — is that the price to the distributor, broker, the ultimate consumer; what point along the line are we talking about?

Robert Follett: Yield will vary according to the size of the fish. A larger fish, a ten-inch fish, will yield a better percentage than a smaller fish will, and believe me, we have had a lot of small fish out of Lake Erie, the percentage has dropped down very close to 40 percent. You can take a fish that has really filled out and cut close to 50 percent if conditions are right. So I would think 45 percent would be a good average. When I was talking about the price of processed fillets, this is the price that processed fillet would sell for off the Lake Erie shore right now. It might even be higher than $2.00 per pound. I don't know because there aren't enough fish coming in to really establish a market.

Harold Calbert: I might add that the yields he is talking about are for fish in the natural state, because there haven't been sufficient quantities of aquaculture-raised fish to get figures on them. Because the aquaculture fish were raised under different conditions, they are more what we call a "blocky" type of fish — you might say it's a black angus compared to a range maverick and your yields will probably he higher on these because of the greater amount of meat on them.

What does the term "fish in the round" mean?

Bert Smith: This term is used to describe the fish in the natural state as it comes out of the water, unprocessed, before anything is done with it. We refer to "dressed" perch as perch that have been eviscerated and processed for wholesaling or retailing.

Mr. Spira mentioned the fact that their product was raw, breaded fish fillets. What percent of the market would be in the breaded form as opposed to unbreaded fillets?

Marvin Spira: The restaurant trade for lake perch almost exclusively uses a breaded fish product. The lake perch does not lend itself to broiling, as such, although it is very good pan fried. But I'd say the majority, 80 to 85 percent of the lake perch used in the restaurant trade, would be the breaded fillets.

What kind of fish are you using now and where are they coming from? What will be the price in the future if you have fish produced on farms and from the natural state?

Bert Smith: Because of the shortages, the institutional trade and the retail trade have substituted ocean perch for lake perch. These, of course, come frozen. Very little comes in fresh. We have also substituted other ocean-caught species — flounder fillets, sole fillets, all types of ocean fish. There really has not been a lake fish or a freshwater fish that has been able to fill this gap. Canadian supplies of walleye pike have been very limited, so we have not been able to offer our customers walleye pike instead of lake perch. The preference still seems to be for lake perch.

Marvin Spira: As Bert said, what is being used is really a poor substitute. Nothing really takes the place of a lake perch. We have asked some of our customers to use walleye pike because it is a close cousin of the perch and is also involved in the aquaculture program. We want to create a demand for both species — both the walleye pike and the lake perch. We do market this, not as a substitute for perch, but as a companion freshwater lake fish.

We may experience some decline in the round price of perch to the processor in the future. But this is geared pretty much to the economy of the country. We know the demand is there because we have not completely explored all the available market. However, we do expect some decline in the round price, since the naturally caught fish coming into the market would add to the overall volume that is produced under an aquaculture setup.

Does the industry buy the fish already processed, do they process it or do they expect somebody else to process it?

Robert Follett: At the present time, we attempt to process as much round perch as possible. We bring in fish from Lake Erie when it's available and process it in plants in Appleton and Suamico. We have a fishery at

Suamico where we take in the round perch right off the bay and process it right there. We prefer to process the fish ourselves. But there's a lot of fish dealers in the state that do buy the processed fillets right off of Lake Erie, or wherever they're available.

Marvin Spira: Our particular type of merchandising and sales is concerned with, as I said, a raw, breaded, lake perch fillet. We bring these fish in from Canada in a frozen state, as individually, quick-frozen fillets. We further process them by putting them through a batter, breading and packaging operation. So the fish that we use are frozen fillets and we get them from a processor.

Bert Smith: I could add, in our phase of the business we are not structured to do any filleting. We buy fresh and frozen fillets and then wholesale and retail these fillets. So we rely on a filleting operation, usually located closer to the source of fish.

Harold Calbert: I think you can see that processing the fish is a separate operation from actually growing the fish. It involves different facilities from what the grower has, certain sanitary requirements and many other things.

What has been done with walleyes in relation to this aquaculture project with perch?

Harold Calbert: We've been talking perch because they represent the bulk of the market. But many of the things that are said today, except in terms of size and so forth, apply to the walleye. They're a very closely related species and many of the feed and growing situations can apply equally to perch and walleye. The latter would be marketed a little later, at a little larger size and so on but most of the things we talk about today can be translated directly to the walleye.

Is pollution the main cause for the diminishing supply of the perch or are there other causes?

Bert Smith: It's a combination of factors. Certainly, these environmental problems — the industrial and agricultural contaminants as we would refer to them — have hurt the resource. They prevent, in some areas, a good hatch of perch. But we must undersatnd that the fish in its natural environment is subject to all types of variables — temperatures, weather conditions, etc. In other words, a bad period of stormy weather when the fish are on the spawning grounds can interrupt the natural spawning process. I mentioned previously overcropping of the resource. The demand for perch has caused the industry, particularly over in Lake Erie, to harvest a year class which we think should have been left to grow one more year. They're taking these subyear classes out of the Canadian side of Lake Erie and the whole resource is starting to go down. The American side — Ohio and Pennsylvania — have very strict, good conservation controls to prevent this type of subyear harvesting. So there are many factors which affect the strength of the fishery resource, and environmental problems are certainly part of it, but not the total picture.

Harold Calbert: I might add that there are other projects in the Sea Grant Program that are studying such factors as this. It wasn't included as part of this program because we couldn't get everything in. But, of course, there's also competition from other species now in the lake for a given food supply. It's a very complex problem. All we know is that these populations have fluctuated all through the years and now they seem to peak a lot lower than they used to. Meanwhile, our demand for them is increasing.

Is the lake perch any different from the perch found in our lakes and streams around here? And if there is a difference, is there a demand for the perch in the small lakes and streams?

Harold Calbert: In the trade they keep talking about lake perch because that's what they've always been called — we refer to it as yellow perch, which is essentially the same fish. You'll see them in different sizes, depending upon the food supply and so on, but we're all talking about the same fish. This is different from ocean perch and some other types of fish you see, but we are all talking here about the same fish, the yellow perch.

You spoke about lake perch from Holland. Is that a fish farm product or not? You also mentioned they were of inferior quality — in what way and why?

Robert Follett: I believe these perch are raised via aquaculture on diked land. After the perch are harvested, the land is drained and farmed. Fish are raised during the winter months of the year. They do not have the sweet taste of our Great Lakes perch. They have a stronger taste. I thought at first it was a combination of saltwater perch, but I was informed that they are freshwater perch. We've tried to use some but have had a lot of complaints.

Marvin Spira: The consumer, the restaurant-goer, today likes a fairly pure taste. They don't like a "fishy" fish, and this is what you get in an ocean perch. This is what you get in the Holland perch — it's just plain fishy. The lake perch and the walleye — they are both what we call a good, clean taste, and this is a great assist in marketing. When you sample it out, it is very obvious that this is a preferable fish.

Is there is discernable difference between farm-raised fish in Wisconsin and lake-raised fish? What is the preference there?

Harold Calbert: We have compared the aquaculture-raised perch with perch that we've picked up in many areas of the state. The aquaculture-raised perch have a very white firm meat and a very sweet mild flavor. They always get a good rating when they go through our sensory evaluation panels. We can take perch out of other lakes that will get just as good a rating, but there seems to be more variation in the perch flavor that we get from the wild perch. There's no liver taste or anything like this, which people used to associate with a hatchery raised fish, because they don't get that type of feed. The perch are very uniform, mild and pleasant tasting fish; walleye seem to be the same way.

AQUACULTURE: FACILITIES FOR THE RAISING OF YELLOW PERCH (*Perca flavescens*) IN A CONTROLLED ENVIRONMENT SYSTEM

By

David A. Stuiber

The demand for fishery products in recent years has been increasing. This not only is true in the United States but also on a worldwide scale. In 1973 the U. S. per capita consumption of fishery products reached a high of 12.6 pounds.

Since World War II, the United States has become a fish importing nation importing almost 1.4 billion dollars worth of edible fishery products in 1973. It is becoming difficult to compete with nations, once considered underdeveloped, for some of the available fishery products on the world market. In the past, these products were considered beyond their reach in terms of price.

Also included in the above mentioned import figures are freshwater fish species. Until recently, freshwater fish were harvested from the Great Lakes and inland waters in sufficient amounts to supply the market needs. Due to environmental problems, fishing pressure and changes in the philosophy of the regulatory agencies regarding commercial exploitation of fish stocks, domestic production of freshwater fish species has been greatly curtailed. The future for extensive commercial fishing of the Great Lakes for a number of fish species is uncertain. Even if commercial fishing were allowed to begin again in earnest, most of the fish stocks may never be ample enough to sustain any great amount of fishing pressure.

It is evident that natural supplies of high quality fish species, both saltwater and freshwater, have been fluctuating dramatically. Steps are now being taken to alleviate the pressure on some stocks and still maintain adequate supplies in the marketplace through the increasing use of aquaculture techniques. Catfish, salmon and trout, clams, oysters, crayfish, lobsters, shrimp, as well as other species, are either under intensive investigation or are in actual production.

Approximately five years ago, Wisconsin fishing industry representatives expressed a need for investigations dealing with availability and quality of some of the highly valued freshwater fish species. After discussions, both within industry and the niversity community, a decision was reached that there was merit in investigating the concept of freshwater aquaculture.

The two species selected for aquacultural study, yellow perch (<u>Perca flavescens</u>) and walleye pike (<u>Stizostedion vitreum vitreum</u>), were chosen because of the demand for them and their high market value as food fish.

To establish research priorities for this investigation, objectives were established to determine how such a program would fit into the overall research goals of the Department of Food Science. In the initial stages of the study the objectives were: (a) to determine if yellow perch and walleye would survive in a controlled environmental system, (b) to determine the degree adaptability of both species to accepting pelleted-formulated diets, (c) to determine environmental conditions which would maximize growth rates and flesh quality, and (d) to demonstrate that perch and walleye could be produced in quantity. It was the opinion of the research staff that if a great deal of difficulty was encountered during the first year in meeting objectives (a) and (b), then the effort involved in solving such problems would be of more value if directed toward other endeavors, and the aquaculture project would be terminated at that point. After examination of the first year's data on growth of both species and their adaptation to feeding on formulated diets, it was decided that the project had promise and the investigation should continue.

Observations made on the growth response of both species of fish when temperature and photoperiod were varied produced some significant results. Both perch and walleye were subjected to a combination of 16° and 20°C water temperatures and eight-and sixteen-hour photoperiods. The results of these experiments are presented in Figures 1 and 2. The response of yellow perch (Figure 1) to the lengthening of the photoperiod produced a greater increase in the rate of growth than that observed when the temperature was increased. The response of walleye was the reverse of that observed for yellow perch. In this instance, the effect of temperature (Figure 2) on the rate of growth was more significant than was the effect of increasing photoperiod. In each case the best rate of growth is obtained when both species are held at a water temperature of 20°C and a 16-hour photoperiod. Data of this type formed the basis for the reasoning behind the establishment of the system which will be outlined for use in raising these species.

Fish are cold blooded animals and their basal metabolic rate is regulated by surrounding environmental conditions. The effects on growth rate and thus production of the environmental parameters, photoperiod and temperature, already have been described. The establishment and maintenance of environmental conditions necessary for accelerated growth and production of cool water fish in this geographic region required that a system be developed and operated under cover or "indoors." When growth in a controlled environment system is compared with the growth in nature, a comparable perch can be produced in the controlled situation in eight to eleven months what would take three to four years to produce under natural conditions.

Figure 1

<u>Effect of Temperature and Photoperiod on the Weight Gain of Yellow Perch (Perca flavescens)</u>

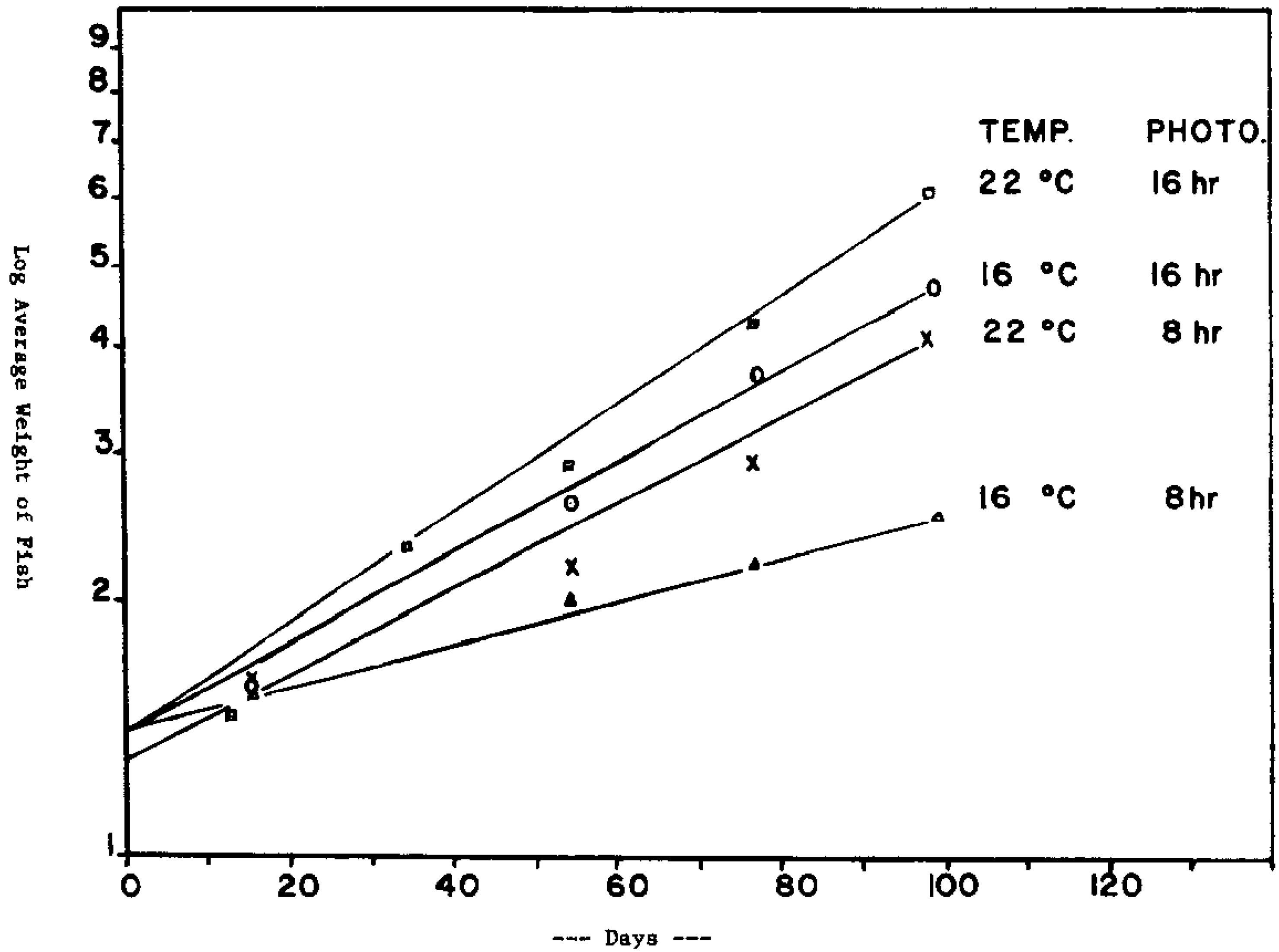
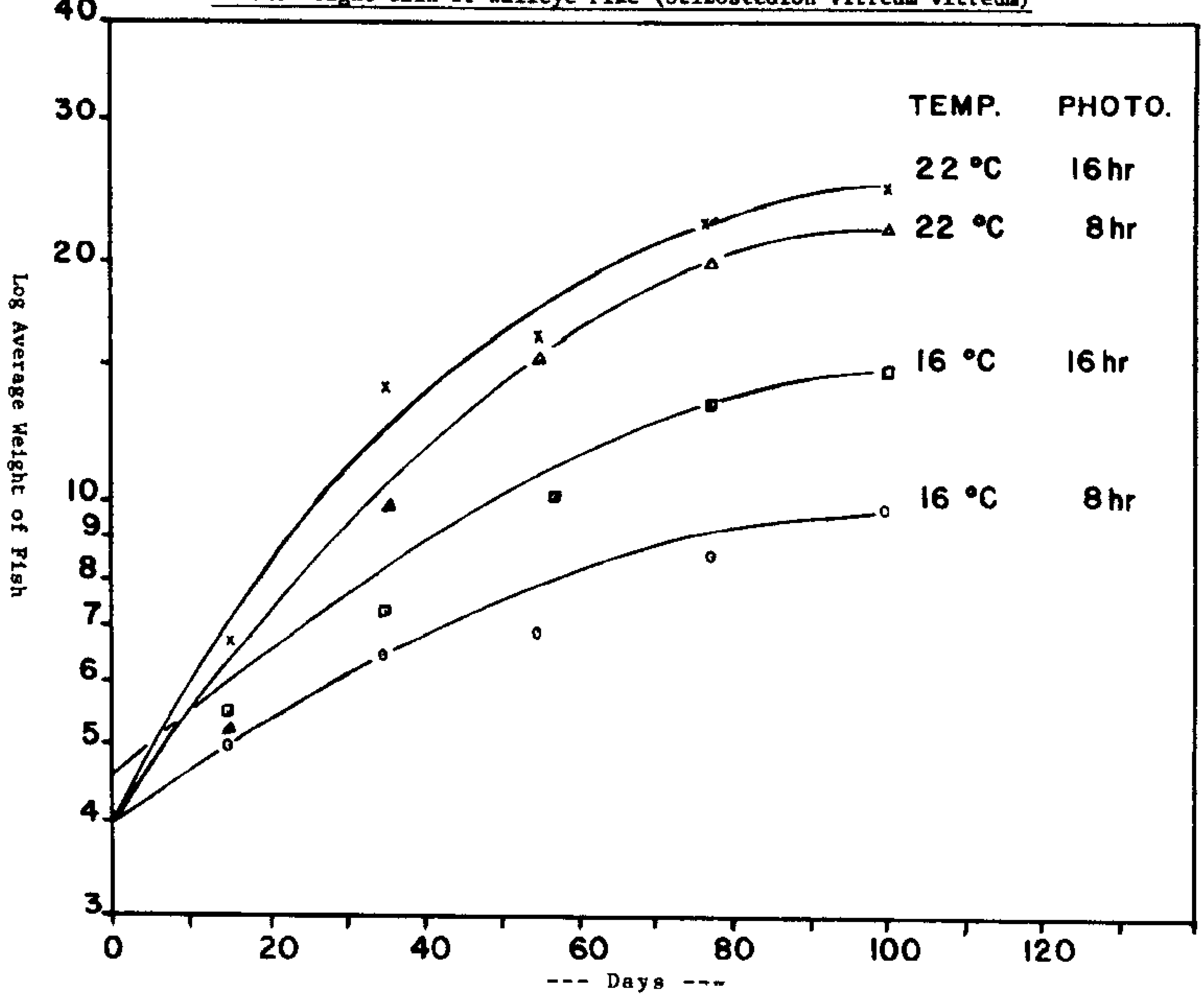


Figure 2. Effect of Temperature and Photoperiod on the Weight Gain of Walleye Pike (*Stizostedion vitreum vitreum*)



Basic components which make up the system are: (a) a building to house the system, (b) a source of water for the system, (c) a unit for producing heated water, (d) a mixing tank or valve for water temperature control, (e) rearing tanks (sized to fit into the structure), (f) settling basin for particulate matter removed from water, and (g) water treatment facility for maintenance of rearing water quality. Additional items including pumps, water softener, pipe, aeration equipment, safety devices, nets, etc. also are required.

The building used to house this facility must be insulated and free from external light. Insulation is required to reduce heat losses from, as well as promote ease of temperature control within the system. Overall, this should result in fuel savings, greater operating efficiency and allow for the use of less sophisticated temperature control devices. As for the structure being free from external light, without this feature photoperiod and light intensity control would be impossible. By restricting outside light from entering the growth of photosynthetic organisms in the system are also restricted, which reduces the load on the water treatment system.

Water is basic to the raising of fish and very careful consideration has to be given to its source. It is best not to consider surface water, creek, lake, river or pond as a usable water source. These sources introduce the risk of environmental pollutants into the system. Such waters may contain pesticides, herbicides or other chemical residues considered adulterants in foods by the Food and Drug Administration. If the fish are found to have excessive levels of such residues in their flesh, they would be condemned and destroyed. Another hazard is the possible introduction of disease from these water sources. The safest water source would be that obtained from deep wells. Such water reduces the risk of disease vectors as well as environmental contamination from becoming a problem.

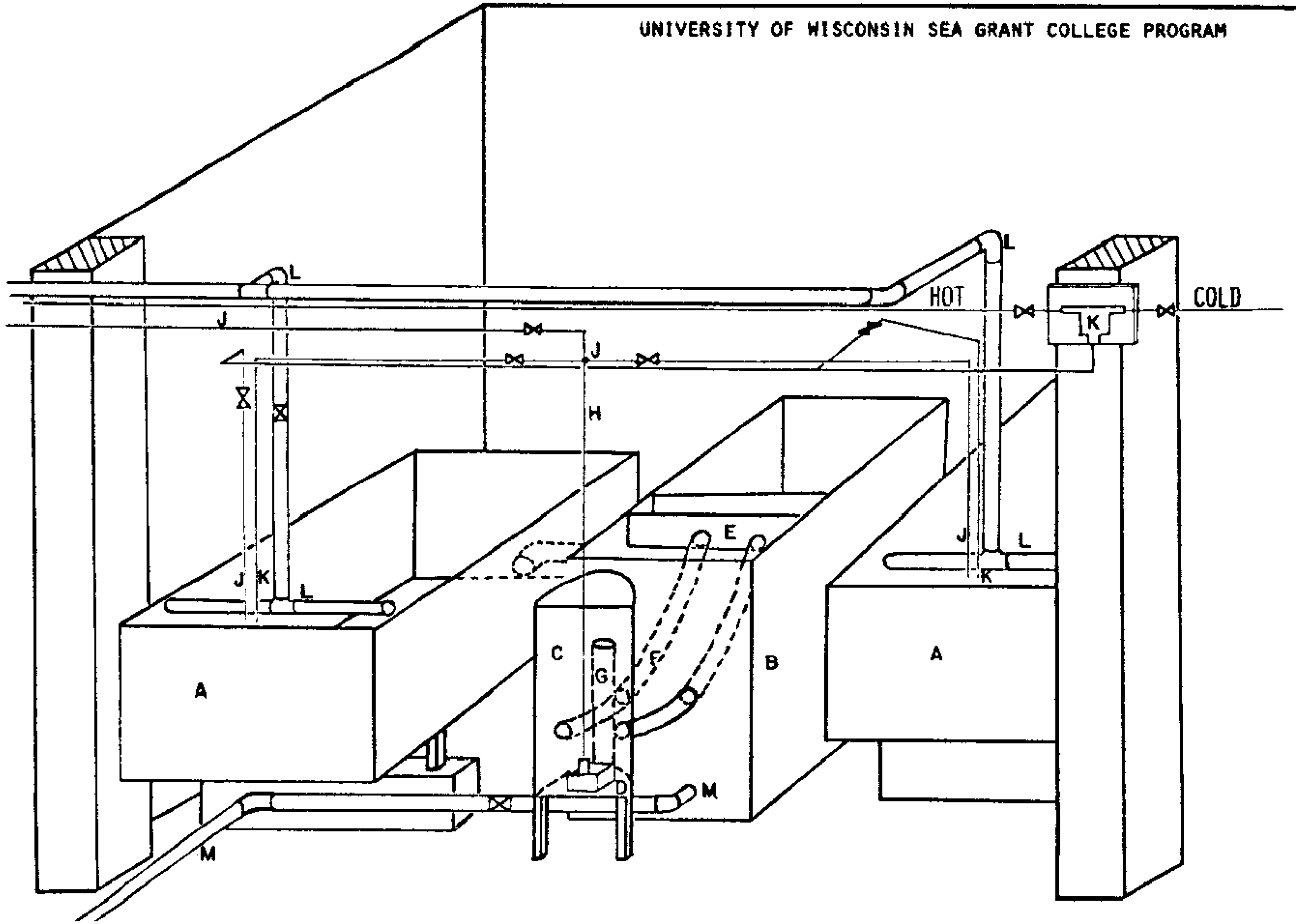
Water, no matter what the source, will have to be heated. The method used will be left up to the individual to determine, since there is a wide variation in installation and operating costs from area to area. Whatever the method — coal, gas or fuel oil, boiler, gas or electric hot water heater, etc. — the unit must be sized to produce adequate amounts of hot water for the system. A check should also be made of the local ordinances and codes governing the installation and operation of such equipment. It also may be necessary to install water filters as well as a water softening system in conjunction with the heating unit. Some well waters may contain excessive amounts of iron and other minerals which would need to be removed. The inclusion of a water softening unit may be mandatory depending upon water hardness.

A diagram, Figure 3, is presented to aid in visualizing flow through and general arrangement of components within the rearing system.

Item (A) represents the rearing tank. The entire system is sized and designed in relationship to this particular component. Consequently certain characteristics of the tank must be carefully considered during design and construction.

FIGURE 3. TANK RECIRCULATORY SYSTEM

UNIVERSITY OF WISCONSIN SEA GRANT COLLEGE PROGRAM



The size of the tank is important from a number of viewpoints. The width and depth of the tank will affect the ease with which an individual is able to work in and around the tank. The depth and width of the water column should be such that visual inspection of the fish can be made but a sense of security is also provided to the fish. The ability to detect changes in the fish population— for example, the beginning of disease, cannibalism, weak or deformed members of the population, etc.— can be detected and remedied. Observations made during experimentation indicated that when water depths exceeded three feet and widths exceeded six feet, an individual had difficulty attempting to retrieve fish or work with them.

When determining the tank length another set of factors come into play. At present the stocking rate of fish, finished weight, has been determined to be approximately one-half pound of fish per gallon of water in the rearing tank. Fish are fed at the rate of three percent of body weight per day. With such stocking and feed rates a large amount of waste material, both unused feed and feces, will be generated in the rearing area. In theory a good portion of this material will have to move through the entire rearing area before it is expelled. Both unconsumed feed and feces represent BOD (biological oxygen demand) which if not quickly removed will help deplete the supply of available oxygen in the water. With the width and depth of the water column as well as the water input rate fixed, the residence time of such material in the rearing tank will be directly related to tank length.

The rearing tank should be constructed with a slope to the bottom of the tank toward the discharge end. This is done to aid in movement of dense particulate matter through the tank. In the experimental tanks a slope of one inch per four feet of length was provided. This proved to work satisfactory.

There have been other rearing tank designed operations for other species which use round tanks and a silo type tank. The use of a silo type tank has some drawbacks compared to the raceway type used in this system. Because of the height of the water column in a silo, large pressures are generated at the bottom of this type tank. This restricts the type of materials which can be used in construction. Another point is that of examination of the stock or having to work in the tank itself. In order to accomplish both feats, the operator will have to physically enter the tank to inspect the stock, as well as make a periodic inspection of the tank itself. The only drawback to the use of a round tank compared to the raceway type is that of space. It is physically possible to get a greater volume of water into a given space leaving adequate area to work around the tanks using a raceway type operation.

Water flows out of the rearing tank through drains situated at the bottom of the discharge end of the tank (not indicated in the diagram) and enters the settling basin (B) at the rear (also not indicated on the diagram). Sludge or dense particulate matter settles to the bottom of the basin and is removed through the drain marked (M). The settling basin represents a quiescent zone in the flow through the system where the dense particulate matter is allowed to settle, thus providing the first step in water quality improvement within the system. Dimensions for the settling basin are not provided because the size of the basin changes with increasing or decreasing rearing tank size.

A knife-edge weir (E) is positioned at the top of the settling basin to retard the movement of scum or floating debris from advancing in the system. Positioning of the weir up or down controls the water level in the rearing tank.

Water overflowing the weir is fed through the lines marked (F) into the sump (C). The water is then pumped from the sump by means of the sump pump (D) into the lines marked (J). In the event of a surge of water to the sump or a pump failure, an overflow drain (G) is provided to prevent flooding.

The water flow in lines (J) is split with a portion of the flow directed to the water treatment system and the remainder going directly back into the rearing tank. Treated water from the water treatment system is returned to the rearing tank through line (L). Fresh tempered 20 °C make-up water is added to the rearing tank through line (K).

Mention has been made of the need for close control of water temperature. Several methods have been employed in attempts at maintaining a constant water temperature in the system with varying degrees of success. The use of a good quality mixing valve provided the best method of control. With the use of such valves any specified water temperature could be obtained directly. Caution is advised when installing such valves that the flow rate required does not fall within the upper or lower operating ranges of that particular valve. When the valve has to operate at either extreme of its tolerance range there is a chance of temperature drift which could result in temperature shock and death to the fish stocks. Household three-way shower mixing valves are definitely unsatisfactory due to the degree of control needed for this type of system. These valves are difficult to adjust and lose adjustment with slight changes in hot or cold waterline pressures or temperatures. Another method used in water temperature control was the use of a mixing tank. A tank is set up with a float valve used to control the water level in the mixing tank through the addition of cold water into the tank. A temperature sensing device is hooked up in conjunction with a solenoid valve on the hot waterline. As water is pumped from the mixing tank to the rearing tank the float is lowered, allowing cold water to enter. As the temperature drops the sensing device triggers the hot water valve open until the set temperature is again reached in the tank and the hot water valve closes. Using this approach, there will be a slight oscillation in the exit water temperature from the mixing tank, but the oscillations are not great enough to cause any undue stress on the fish.

Mention has been made of the presence of particulate matter in the water and its effect on dissolved oxygen in the rearing tank. Sustaining an adequate dissolved oxygen concentration is critical to the raising of fish. Oxygen is added to the system at the point of water input to the rearing tank as well as what is transferred from the air to the water at the air-water interface at the surface of the rearing tank. During peak oxygen demand periods this source of supply will not be adequate. To meet the demand, additional aeration should be provided by air sparging directly in the rearing sections of the system. Preliminary results indicate the dissolved oxygen concentration in the rearing section should not be allowed to drop below 4 ppm and to be on the safe side should be held at 5 ppm. The 4 ppm level should be considered as a danger point to increase the dissolved oxygen concentration.

The portion of the system which is of extreme importance is the water treatment operation. This item will be covered in a later presentation but a brief discussion is in order at this point.

The Environmental Protection Agency (EPA) has been given the task of trying to curb pollution of the environment. Toward this end EPA as well as other federal and state agencies have promulgated regulations governing the effluent discharges from practically all sources. This includes wastes from industrial, farm and municipal sources. To meet effluent guidelines, discharge water will have to be treated. This is one of the reasons for inclusion of this item into the system.

Another and possibly more important reason for inclusion of water treatment within the system is that of conservation of energy. The operation of the system would be simple if it were possible to use a single water pass approach from the standpoint of water quality to raising fish. Unfortunately the high cost of fuel (energy) needed to heat the amounts of water required make such an approach uneconomical. In practice the heated water has to be recycled until it is no longer of suitable quality to obtain maximum benefit from the fuel spent in producing the heat. To obtain this benefit and maintain water quality, toxicants such as the metabolic by-product ammonia are reduced or removed from the water as well as BOD and other contaminants using a biological filter allowing the water to be recycled. At the present time a given volume of water would pass through the system ten times before it is replaced.

The water treatment unit designed for this system is still in the developmental stage but has proved to be effective on a small scale rearing tank.

An area which has not been discussed in any detail at this point is that of light. It has been stated that the system should be kept free from external light. This must be done to establish and maintain a given growth rate response to the most beneficial photoperiod and light intensity. As was indicated in Figure 1, the best growth rate response was obtained using a 16-hour photoperiod. In order to maintain a constant 16-hour photoperiod, artificial light has to be used.

Another factor which is involved is light intensity. Bright light has an unsettling effect on the fish. The fish seem more at ease and feed more readily in dim light. To control both intensity and photoperiod the most effective method would be to use only artificial lighting to the exclusion of external light. Another advantage would be control over the growth of photosynthetic organisms within the system.

It has been observed that dramatic changes in light intensity affects the fish. Switching the lights from off to on has an unsettling effect which may last as long as an hour. During this period the fish are nervous and easily spooked and will not feed. This kind of unnecessary stress can have an effect on weight gain, as well as the overall health of the animal. This situation is easily rectified by installing a motorized diming switch on the electrically timed off and on switch. This allows for a half hour time interval to gradually go from full light intensity to full darkness and vice versa.

Because the response of perch to light is so great, work is continuing in this area. It may be possible to improve on the present growth rates by additional manipulation of the lighting system.

During the design and construction of facilities, thought should be given to problems associated with cleaning and sanitation within the entire system. Any surfaces which are absorbent such as concrete, wood, etc. should be sealed with a nonwetable material. The same holds true for metal surfaces which come in contact with the water in the rearing facility. Sealing surfaces would insure ease of cleaning, retard or eliminate corrosion and make it possible to chemically treat the system if and when problems arise.

The materials which can be used in constructing the rearing facilities will depend upon what is available and the cost. Concrete, plywood, steel, corrugated metal, fiberglass and any other building material having the structural strength can be put to use.

The concept of the use of dairy barns as fish rearing facilities was first conceived as a method for getting started raising fish. Using a barn, with a certain amount of renovation, could provide the shelter needed for a fish rearing system. A second point in favor of barns was that of water. Associated with the barn was a serviceable well which could supply the water needs for a fish rearing operation. A barn would not necessarily be the ultimate structure to house a fish rearing facility, but it could serve as a means of providing a starting point while also providing a supplement to an individual's income from an already idle operation.

For the sake of safety, a backup system must be provided in case of unexpected emergencies. Power failures and other accidental shutdowns should be anticipated and at a minimum, an auxillary oxygen source provided to carry the fish through the crisis. A more complete backup, however, should be included in the system. Emergency power generation equipment, auxillary pumping, as well as compressed air (either from an air compressor on the site or commercially available compressed air bottles), should be serviceable and present on the premises at all times.

To this point, this system sounds complicated when compared to the rearing of fish in outdoor ponds and it is. However, there are advantages to operating a fish rearing system under cover. Problems associated with fish losses due to predators (both natural and human), decreased competition for food from other species and more effective use of food fed can be controlled, as well as prevention and control of disease.

Control and prevention of disease is one of the more important factors in the promotion and use of a closed system for the rearing of fish. By using such an approach, procedures can be incorporated into the everyday operation of the system which would aid in controlling disease vectors and allowing the establishment of good sanitation practices, insuring the maintenance of good, healthy fish stacks. In addition, such a system provides the ability to detect, diagnose and treat diseases before they have a chance to get out of control. Early detection and disease treatment as well as the other advantages, save money through reduced operating costs and stack losses.

QUESTIONS: David A. Stuiber

What is the optimum light condition or photo frequency for raising fish?

We have been working on a straight eight hours off, 16 hours on lighting system. Further work is being done on the possibility of splitting this up, making it eight hours on, four hours off and so on. We don't know whether we will be successful in getting better growth rates out of it, or not but the present system gives us very good results.

There is one other thing I might mention which has to do with light. Not only is the length of the photoperiod very important, so is the intensity of the luminescence that you provide. Strong, bright light is actually taboo. The stronger the light, the more spooky the fish. You want the light dim so they can see the feed and yet not see that much movement around them. They seem to be more content under those conditions and they feed better.

What oxygen content in the water do perch require and how do you propose to arrive at it?

We have found that under experimental conditions, we have no problem raising perch at a dissolved oxygen concentration of four parts per million. However, I would not recommend that you hold a tank for fish or hold your system to that particular level. You should have a system that runs at a little higher concentration because once you get below that level or four ppm, you are running the risk of rapid oxygen depletion and that could kill off or harm your stock.

To put oxygen into this system, we use three pipes. During the feeding periods, you will find that there will be peak demands for oxygen, and in order to supplement the oxygen that's being put into the water, you may have to have an aeration system — for example, air stones placed in the tanks — to carry you over during this period. This system should also be there for safety sake because if you ever get a power outage, you have some way of oxygenating the water until you have the power back on again.

What is the critical time if you should have an outage and what kind of a fail-safe system do you have?

Well, the fail-safe system depends upon how elaborate you want to get. At a minimum, you should have an auxilliary oxygen supply which will take you over the short term. This can be supplied by compressed air tanks that are constantly up at pressure. When something happens, the valves would automatically open and begin to spark air into the system. That's the minimum you'd have to have. Depending upon the lengths of outages in your particular area, you may want to have a generator where you can crank up your own electrical system to keep the operation running. You can't do this for very long though. You have to eventually begin moving water through the system to clean it. If you don't, the level of toxic materials in the water will get so high that no matter how much oxygen you put in the tank, you're still going to kill your fish.

How long does it take for that to happen? Twelve hours?

That depends upon the concentration of fish you put in the system.

If you have a half pound of fish per gallon of water, how long before the fish would suffocate?

At the outside, you've got maybe an hour before you had better have oxygen in those tanks.

What are we talking about in terms of wattage for illuminating the tank?

At the present time, we are using anywhere between 7-½ and 15 watt bulbs. That type of illumination over a tank. And maybe about three bulbs along a 30-foot tank. These are incandescent lights. It's pretty hard to control florescent bulbs.

Have you used air pumps for moving water through this system?

No, we haven't tried that. We do have air stones in the operation which help create a certain amount of agitation. This keeps the particulate matter suspended so it moves easily down the tank and flushes out of the system, but we haven't experimented with air pumps at all at this stage of the game.

How to the fish grow in stainless steel tanks?

They grow very well in stainless steel tanks if you can afford to put in stainless steel tanks. They're pretty expensive.

Why do you have to recycle the water? Why can't you just use fresh water?

If you are going to heat all that water, you've got to figure on some way to conserve energy. I mean, if you've got a lot of money to throw away on fuel oil, fine. If the economics of the system would warrant the use of a pass through system, that would be fine. But unfortunately, with fuel costs the way they are today, you have to reuse that water. Secondly, the Environmental Protection Agency, as well as some other federal and state agencies, will require that the water be treated before it is discharged. I don't think anyone really knows what that treatment will be at the present time, but you're going to have to treat that water in some way. Now, if you have to heat and treat the water, and it is of sufficient quantity and quality to be used again, it would be foolish to throw the water out the door and not pump it back through your operation.

You talked about biological filters and I've read recently about growth inhibiting secretions emitted naturally by fish in a crowded condition. How are these removed?

Biologically. If you recall, water coming out of any sewage treatment operation is really capable of supporting fish growth. During that biological treatment, metabolites are removed. Now, the efficiency of the filter will determine what your stocking rate will be. If I were to give you a set of figures and three people went out and used those figures to establish an operation, one of them would probably do a fine job, another one would do a mediocre job, and the third guy would go broke because his fish would die. It depends upon the adaptability of the individual to carry this system through. It's not an easy system to operate, but it can be done.

Couldn't florescent lights be used?

You could use florescent lights if you wanted to. The only thing is that the amount of luminescence you get off florescent lights is hard to control and in our present system, we've had to mute the light coming from them. We did this by hanging a couple of pieces of plastic bag over the side of the light in order to get dimmer conditions.

What would be the fish poundage per tank?

That depends upon how big a tank you have. I told you before that you have a stocking rate of a half a pound of fish per gallon of water. If you have a thousand gallon tank, you've got 500 pounds of fish. Now, I have to qualify that poundage figure. That figure represents finished weight of fish. That means when the fish are of a size that could be marketed. If we are talking about very small fish, you're not going to stock them at a half a pound per gallon of water. Primarily because the metabolic rate of smaller fish is a lot greater than that of larger fish. Therefore the demands on the system will be greater if you have a large number of fish than it would be per fish for a smaller fish.

What would you envision as being necessary in converting the building facility, as far as the surrounding buildings, for sanitary conditions and such? What amount of work would be required on the structure itself so conditions would be proper for an aquaculture operation?

Well, it depends upon the condition of the structure to begin with. First of all, you have to insulate the building. You want to cut down as much as you can on the heat loss. It should be cleaned up, kept dust free and all the area around there should be sealed. You put sealer over the concrete so you can easily keep it clean. You might end up having to paint the inside of the system with some type of epoxy or washable paint. You have to remember you are handling a lot of water in this particular area and the materials that you use in converting the building should be such that they're going to take a lot of dampness and splashing. I thing a lot of this is going to be left up to the individual who wants to put this thing into operation and his ingenuity.

WATER RECONDITIONING FOR FISH PRODUCTION

By John T. Quigley, Ph.D., P.E.
Assistant Professor of Engineering
Sea Grant Advisory Services

Introduction To Design Considerations

The proper place to start might be with the waste metabolites produced by the fish and any excess feed. These wastes can be characterized as oxygen demanding materials, nitrogen loads as ammonia, phosphates, suspended and other dissolved solids.

The removal or satisfaction of oxygen demand is not a specific objective of treatment in this system. However, as noted elsewhere, ammonia-nitrogen (NH_3-N) gas is a specific toxicant. The fish are much more tolerant of the ammonium ion-nitrogen (NH_4^+ -N) form. Ammonia loadings* vary through the life cycle, being high on a per unit body weight basis for the smaller, younger fish. Ammonia release rates are also higher during and shortly after feeding periods. Additional ammonia is leached from long-standing solids and, especially, from excess feed. Other nitrogen gas problems and floating solids may result if solids are not promptly removed from the recirculating system.

One usual biological treatment option for treating the nitrogen load is nitrification, meaning to convert ammonia as ammonium ion (NH_4^+) to nitrate (NO_3^-). The fish are relatively tolerant of this mineralized form. In a completely enclosed rearing system, a follow-on stage for denitrification could be required as well (Meade, 1974). Here, the microbes would convert the nitrate to free nitrogen gas (N_2). These overall reactions are illustrated below:

$$NH_4^+ + 2\ O_2 \xrightarrow{\text{organisms}} 2H^+ + H_2O + \underline{NO_3^-}$$

$$6\ NO_3^- + 5\ CH_3OH \xrightarrow{\text{organisms}} 5CO_2 + 7H_2O + 6OH^- + \underline{3N_2} \uparrow$$

The usual wastewater treatment options include trickling and submerged filters and suspended growth systems. For various reasons, the latter systems have not found application here. Some of these processes are illustrated schematically in Figure 1.

*In this report, quantity refers to the total ammonia-ammonium nitrogen present.

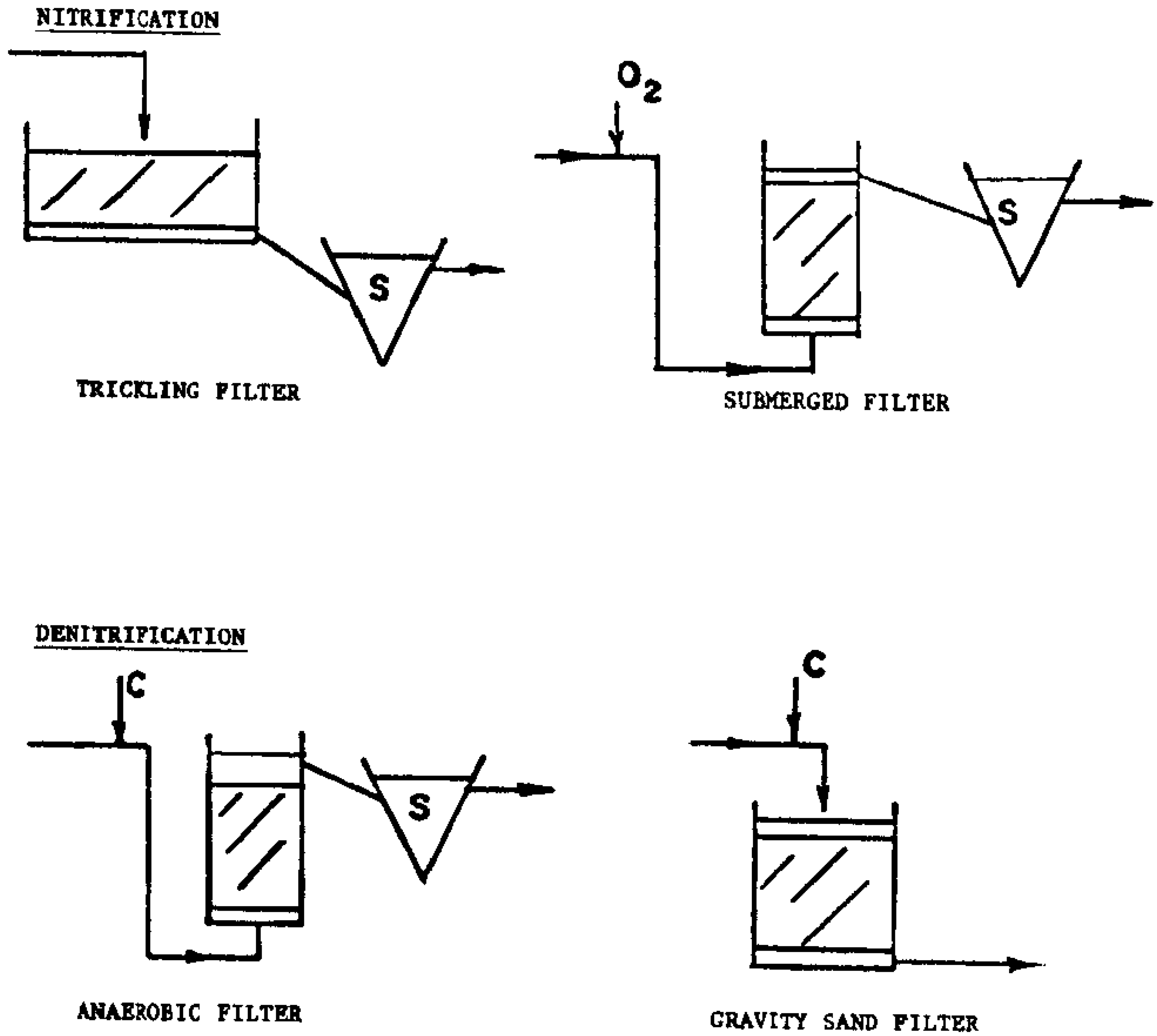

NITRIFICATION
O_2
S
S
TRICKLING FILTER
SUBMERGED FILTER
DENITRIFICATION
C
C
S
ANAEROBIC FILTER
GRAVITY SAND FILTER

Figure 1.

Demonstration Facility Design

Among the usual control parameters are temperature, acidity or pH, compounds of nitrogen, including ammonia (NH_3) and nitrite (NO_2^-), concentrations of biochemical oxygen demand (BOD), dissolved oxygen (DO) and solids, including both suspended and dissolved materials. As has been noted earlier, temperature is an important factor in the fish rearing unit. It is also important to water reconditioning in several ways, including its effect on rate of nitrification. Similarly, pH must be controlled for many reasons, including its effect on the relative distribution of (NH_3) gas $\rightleftharpoons NH_4^+$ ion equilibria (Kramer, et al., 1972). Actually, the nitrification process is doubly affected by pH in that the level of microbial activity is sensitive to it as well as to the tolerable reactant concentration. This acid-base equilibria requires constant adjustment because the biological treatment processes tend to consume alkalinity and to generate acids (e.g., $C \rightarrow CO_2$, $N \rightarrow NO_3^-$, etc.). By promoting the dissolution of calcium carbonate or limestone to maintain system alkalinity, pH may be controlled to the range 7.0 to 7.5. BOD loading has been considered in design only in so far as it influences nitrification in the filter. Dissolved oxygen concentrations suitable for fish rearing of five milligrams per liter (mg/l) or more are generally satisfactory for introduction to the treatment units. At production loadings, supplemental aeration will be required in submerged and trickling filters. On the basis of preliminary studies, biological treatments sufficient to treat the ammonia loading also control other metabolic by-products.

Time Phased Capacity

Of necessity, the water reconditioning facility is designed to respond to varying loads and to produce variable quality outputs as the fish grow to final size. Initially, a sedimentation unit trickling filter system will produce a very high quality effluent. As total ammonia loadings and water throughput rates increase, the upflow clarifier may be converted to a submerged filter with some reduction in return water quality. This latter step will require that the last few feet of the rearing tank be screened off to serve as a settling tank. At this point, a fraction of the recirculated stream may be treated for denitrification to maintain acceptable levels of nitrate on the higher end of the one to five day detention times anticipated for this water in the facility. For a larger, multiple tank rearing facility, this aspect of design will be less important as steady state conditions in specialized facilities should prevail for most activities.

Throughput Requirements

The hydraulic load on the water reconditioning system is determined by production tank throughput requirements. Among the factors that determine throughput are waste feed and metabolite removal, which may be thought of as suspended and dissolved solids. Simple experiments have confirmed that for stocking densities of about 0.1 pound per gallon, turbulence induced by the fish themselves materially aids in moving suspended solids along to the outlet end of the tank. Solids were seen to move readily at a water flow velocity of

0.1 feet per minute for this stocking rate. Turbulence from supplemental aeration will further aid solids movement, as well as a modestly sloping bottom in the production tanks.

Owing to the high stocking rate anticipated for the production rearing of perch, on the order of 0.5 pounds per gallon, substantial ammonia loadings must be anticipated. These have been estimated for the present design at about 0.04 pounds NH_3 -N per hour for 1,000 pounds of fish in the tank at about two percent daily feed rate (Kramer et al., 1972). A linear flow through velocity of 0.1 feet per minute (fpm) would lead to a build-up of around 4.5 mg/l NH_3 -N in the 2,250-gallon tank. From the foregoing discussion one can immediately appreciate the limits placed on detention time of water in the production tank. Therefore, in order to provide some flexibility in the control of ammonia level in the tank, the design will permit linear velocities up to about 0.5 fpm corresponding to an anticipated per pass build-up of less than 1.0 mg/l. The general flow system is schematically illustrated in Figure 2.

Other features of the flow through system include bottom opening connections between rearing tanks and clarifiers for the removal of solids. Experiments have shown that a screen, with openings sized to deter the fish, will suffice to protect a small settling area around the tank outlet. The outlet arrangement should minimize turbulence.

Launders can be sized with linear overflow rates consistent with usual sanitary engineering practice up to 30,000 gallons per day per lineal foot. In general, system interconnections were patterned after facilities observed at the National Environmental Research Center and are illustrated schematically in Figure 3. Water levels are controlled in successive vessels through the use of adjustable weirs and with a minimum of lifts.

Summary of Treatment Concerns

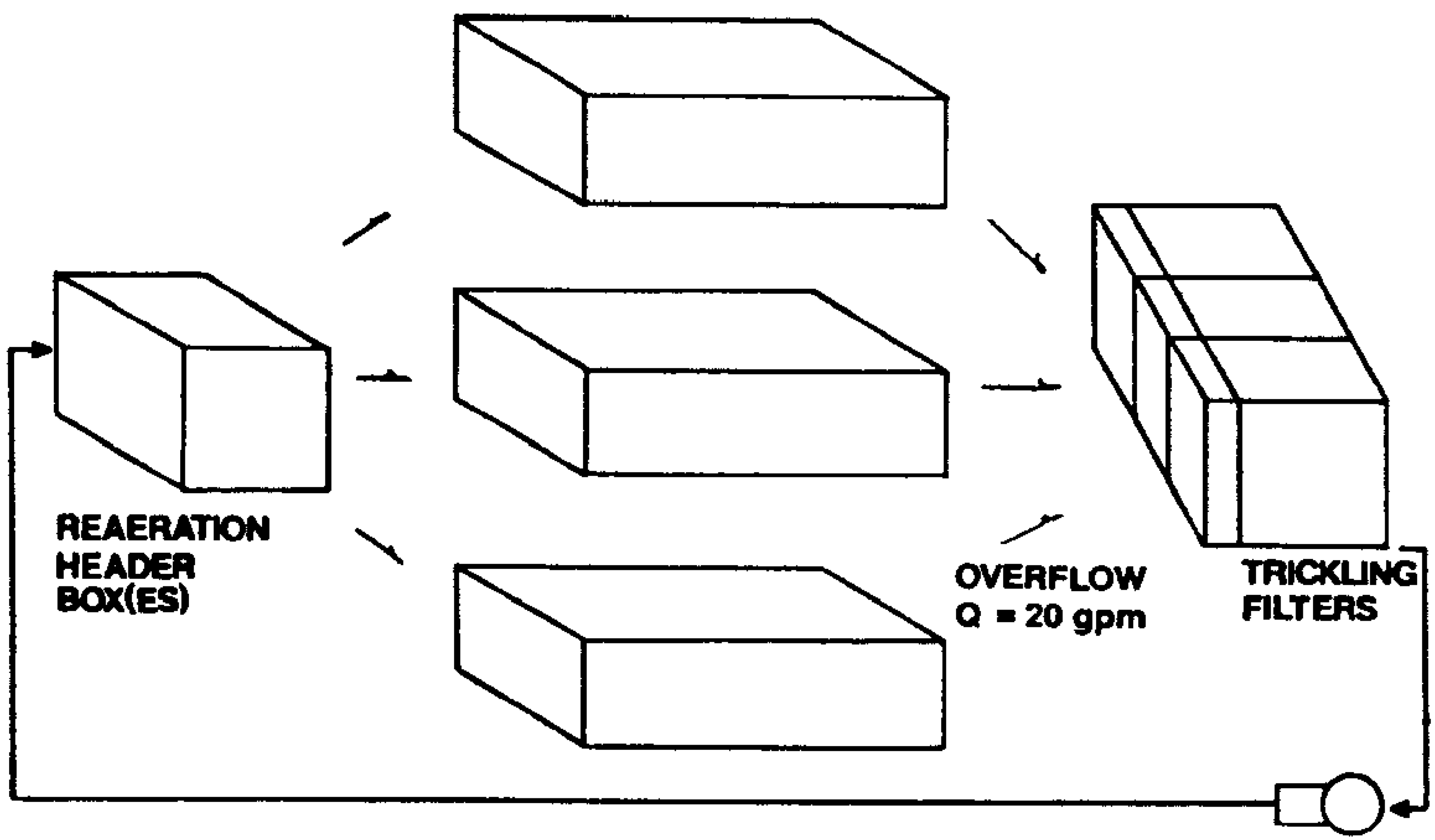
Suspended solids removal can be accomplished most simply by sedimentation. Flow rates up to 5,000 gallons per day per square foot (gpd/ft^2) have been reported (Kramer, et al., 1972). Preliminary studies here have tended to confirm these findings, with detention times of 15-30 minutes. A rectangular settler to facilitate solids removal is shown in Figure 4. Partial removal of suspended solids may be accomplished also with screens (Meade, 1974). Additional study will be required to select a suitable screening approach or application for this system with the objective of increasing potential recirculation rate while decreasing settler surface area.

Dissolved solids are removed for the most part in two ways: (1) Through dilution with make-up water and continually wasting of conservative materials; (2) Through microbial uptake where the materials are actually metabolized and may become part of a cell mass for removal as a suspended solid. These latter processes are effected in the various filter units. For example, in a trickling filter, an active bio-mass is maintained on the surface of media. The well aerated media is then irrigated with a water containing ammonia, other metabolites and BOD. The microbes may sorb and consume the BOD materials as a carbon source while converting the NH_3 NO_3^-. An active population of microbes with these capabilities must be grown on the filter media as one would raise

FIGURE 2.

UPFLOW SEDIMENTATION UNIT

TRICKLING FILTER
(UPFLOW ALTERNATIVE)



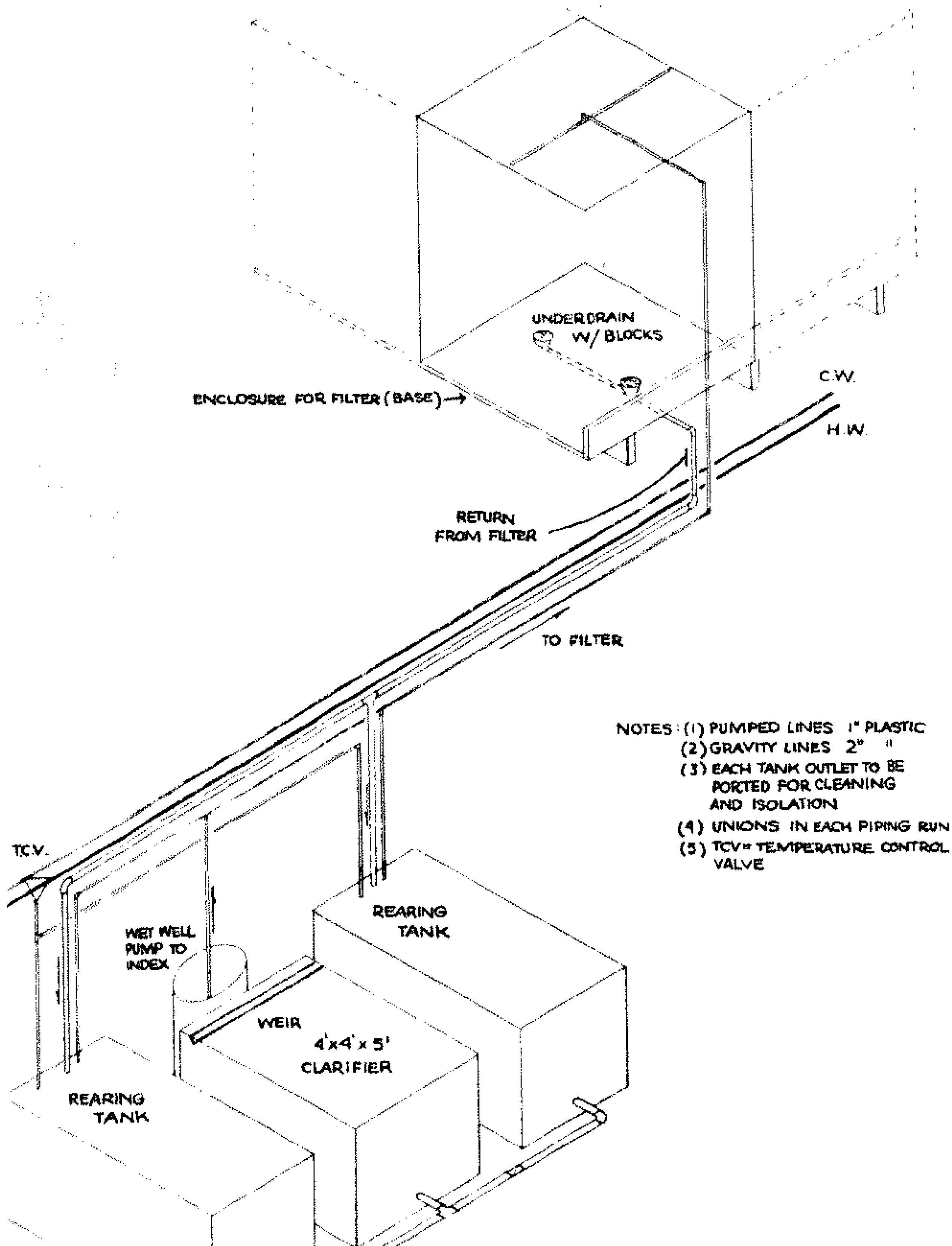


Figure 3. Piping Schematic for Aquacultural Demonstration Facility
UW Sea Grant Program

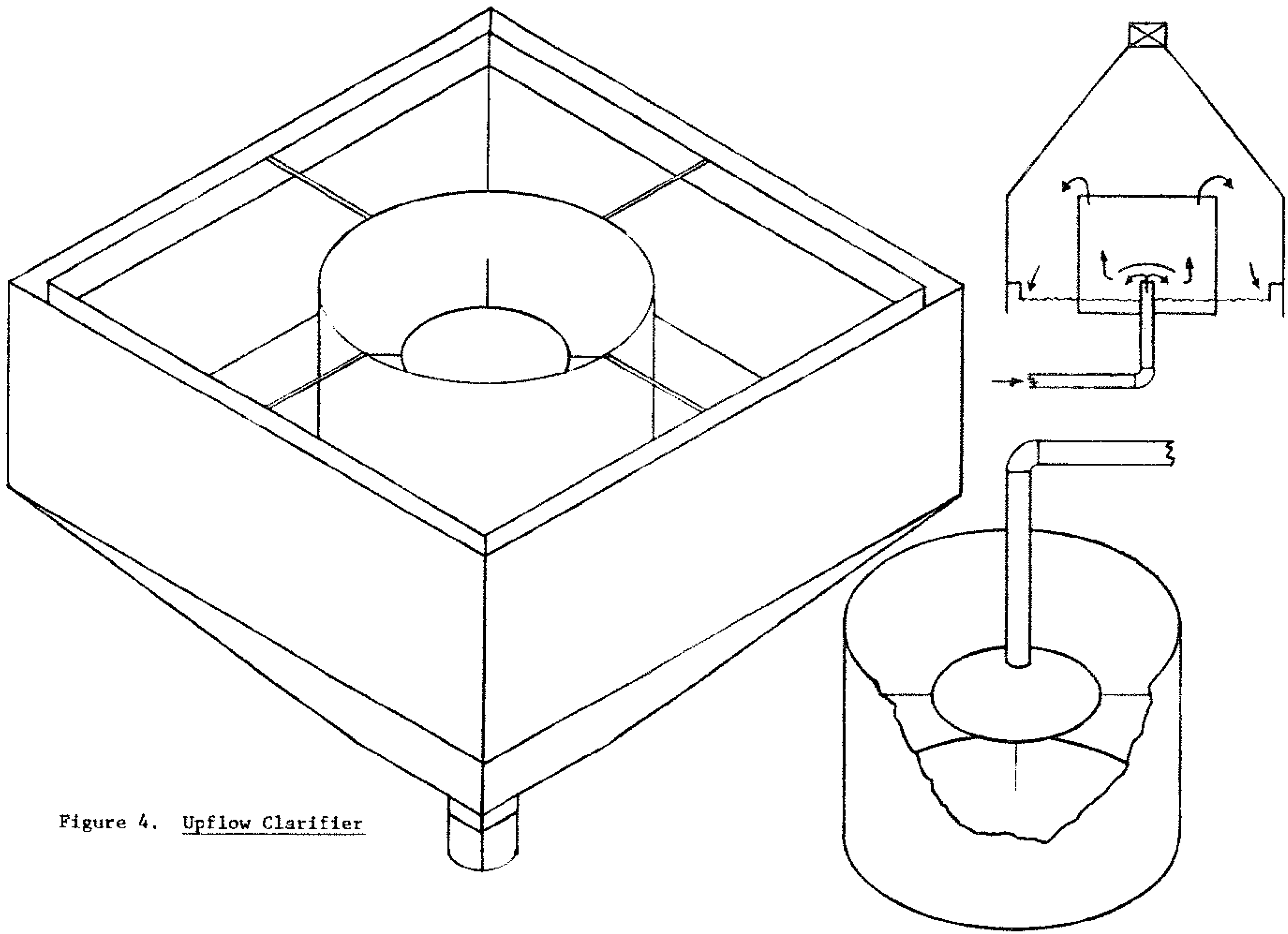


Figure 4. Upflow Clarifier

any crop. Neglect could destroy the activity and require its regrowth. A usual hyraulic loading rate for the plastic media is 900 gpd/ft^2. Temperatures of about 70°F have provided exceptional nitrification rates in small-scale studies.

Upflow filter rates as high as 30,000 gpd/ft^2 have been reported for hatchery service and were considered in design. Other studies (Young, et al, 1973) indicate that this hydraulic loading rate may be optimistic. Actual operating requirements will determine acceptable limits on ammonia concentration in the system and allowable hydraulic loadings at these temperatures. Detention time is critical also to high levels of nitrification per pass and recycle, if provided. Moreover, practical production facilities may utilize much lower cost media as, for example, broken stone. In fact, a limestone media may serve both as a filter media and a source of buffer and has been recommended for comparable applications (private communication, 1974). Brief experiments conducted on a 30-gallon aquarium scale system suggest that sustained operations of this type should be possible given adequate controls and these practices are to be demonstrated now in this facility.

Summary of Practical Aspects

In piping layout, frequent access points should be provided for cleaning, dewatering and/or later modification. The number of valves can often be reduced in these low head systems by using simple stops at basin outlet drains. Also, basin inlet and outlet arrangements should be designed to resist clogging due to biological growths on the material and in the fluids to be transported. Multiple launder arrangements may be required to remove scum and froth that occur with dissolved solids buildup at high stocking rates and low dilution.

In conclusion, it is appropriate to emphasize that facilities should be selected for flexibility, ease of maintenance and economy of operation. That is to say, try to avoid building needless limitations into your system!

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QUESTIONS: John T. Quigley and Harold Calbert

If you took some given weight of feed, say 100 pounds, and fed it to the fish, how much of this would be solid wastes that you would have to dispose of?

John Quigley: Could you tell me how much of that excess would be used as feed, first of all?

Harold Calbert: Of course, it's going to depend upon your conversion rate. If we take a conversion rate of about 1.5 pounds of feed to a pound of fish, we find that the perch are converting or utilizing about 80 percent. This is an average that we worked out based on a number of experiments. So if you put in 100 pounds of feed, 80 pounds of that would be taken up by the fish. The rest probably would not be; the fish would put out some feces and so forth. This would be a rough way you could calculate utilization.

John Quigley: I saw data some time ago for a somewhat different kind of facility — the suspended solids production was about double the waste feed. So everything else was contributing about the same amount as the excess feed. If that represented about 20 pounds, other solids would represent a little less than that. It might be well to mention that a good amount of material does turn up as dissolved solids. So there are suspended materials which can be taken out by settling and there are also some dissolved materials.

Harold Calbert: One thing we might point out is the husbandry of this. This has nothing to do with the sanitary engineer, but with the fish. If you were going to give a certain amount of feed a day and just dumped that all in at one time, you'd be wasting a lot of it because the fish will only eat so much at one time. So the ideal way of feeding — and this again depends upon their stage of growth and all — is to give them only what they can consume over a period of time. Rather than dumping the whole lot in at once, you feed them either continuously or on schedules.

Could you talk about diatomaceous earth filters — how they might fit into this system?

John Quigley: They'll work fine from the standpoint of removing the suspended materials but they will probably work out to be much too expensive. Any kind of a body feed filter like that is going to work you out of house and home. We are trying to provide a buffer in this system by dissolution of natural limestones that you've used in the filter medium to avoid the addition of lime. The filter would obviously do the job from the standpoint of removing suspended solids, but I think it would be just too costly to operate.

Have you tried centrifugation as a means of removing the solids?

John Quigley: I haven't myself, but I've read of studies that indicate it will work. You're dealing with particles that are very little different in gravity from the water, but you do get separation. As I was trying to class some of the ammonia removal processes, I think it would just be a very costly way to do it.

Would the waste water that you put in your holding area be suitable for raising other fish, such as bass?

John Quigley: We think it would. I would reject it in a pond situation because it would run up to the point where the fish couldn't live with the nitrate levels any more, probably, in addition to other metabolites. What you're trying to do in the pond, then, is to rely on the algae, or whatever is growing in there, to strip it back down to more reasonable levels. You may wish to remove those algae now and then if you're going to protect the fish out there from the problems of a very rich, that is a very eutrophic, pond.

How do you recommend disposal of solids in the systems — land disposal or what?

John Quigley: Basically, I'm thinking in terms of facilities analogous to manure handling — surface spreading.

Presuming that you feed continually, what would be the range of rates of new water introduced into the system based upon a half pound per gallon density of stocking and what would be the range of rates for recirculating water? At what point would you not have to filter it out if you had a warm water source to continually introduce new water?

John Quigley: Depending on the flow through rates in the tanks — whether we're limited by solids removal or ammonia generation — this has to do with the stocking rate. You've given us a stocking rate of a half pound per gallon, so we're up at our peak load. I was thinking in terms of detention times in the tanks of about an hour. In other words, we're going to move the water through at about 0.5 feet per minute, so in a 30-foot tank the water is going to be present for about an hour. So I am going to want to turn the tank volume over every hour during the day and recycle it. We anticipate that when it comes out of the tank it will contain on the order of 1-½ to 2 mg per liter of ammonia in some form, mostly ammonium ion because of the way we are controlling the pH. We feel that we have data that indicate that this can be done. Then we're going to put the water through the filter and convert it, basically, to nitrate. We're going to continue recirculating water until the nitrate levels build up to levels which I believe will be in excess of 500 mg per liter. So I would guess that you're going to get about 20 cycles out of it, which means in effect that you will have been able to recirculate it all day. You'll have recirculated it 24 hours, or maybe more, so then you'll have to replace your water in the facility about once a day.

You'll have to add the water once per day and you have to recirculate it how often?

John Quigley: Now, you specified the peak stocking rate, and this is only during the last period of the grow-out that you achieve these peak concentrations. At this point you're going to be doing all that the system can do. I suggest that you plan to be turning the water over on the order of once per hour.

And if you add more new water or change the water over more often, do you have to recirculate less?

John Quigley: If you put more fresh water in, then you could recirculate less, yes.

Harold Calbert: If I get your question, it is: at this peak loading, what would be the amount of water intake per day equivalent to your tank capacity, and you'd be discharging that. Now you wouldn't be drawing your tank out empty and then filling it. This is what goes on all day and you had the equivalent of 20 uses per day of your other water. Now, if you want to put in more fresh water, you naturally don't have to cycle so much because you'll have to let it out somewhere — your system will only hold so much. But the theory we're working on here is to recycle as much as possible to keep your costs down.

Would the number of times the same water could be used make a difference at the fingerling stage or the full-growth stage?

Harold Calbert: As was pointed out by Professor Stuiber, your metabolism and your growth rates in your fingerlings are much higher than in larger fish. You're producing more waste products per fish and so forth on a weight basis. So, yes, you would have to have more fresh water or more treatment at the smaller fish stage than at the larger stage.

LICENSING REQUIREMENTS FOR AQUACULTURE

John Klingbiel
Fish Management,
Wisconsin Department of Natural Resources

In Wisconsin, a number of regulations must be considered in the development and operation of aquaculture facilities. Developments in other states are operated under different regulations. Therefore, appropriate state agencies must be contacted to ensure compliance with state law.

Wisconsin requires that private aquaculture facilities be licensed as private fish hatcheries. The license covers the physical facility and allows its operation in a certain manner. Only those species listed on the license can be propagated.

There are four different types of private fish hatchery licenses, three of which are commercial and one which is basically noncommercial. Currently there are about 250 commercial type licenses issued, but only 14 of these are for warmwater fish species. None of these 14 raise fish for food. There are also about 1,550 noncommercial type licenses in effect. These are basically hobby type operations.

All types of licenses allow the operator to stock fish in the facility, rear them and remove them at any time by any method. A Class A license also allows the operator to incubate fish eggs and sell both the eggs and fish which he produces. A Class B license is similar to Class A, except that eggs cannot be incubated or sold. A Class D license allows the holders of Class A or B licenses to use facilities in other locations as part of their operation. A Class C license is noncommercial and is used mainly by hobby type operators. It allows both the incubation of eggs and rearing of fish, but does not allow the sale of fish or eggs, except for consumption on the premises or for sale to Class A licensees. General sale of minnows is allowed, however.

Fees for these licenses are as follows:

Class A - \$50; Class B - \$25; Class D - \$5.00; Class C - \$5.00

The license applicant must also pay any expenses incurred in the required inspection of the facility by the Department of Natural Resources. These costs exclude the salary of the inspector.

Private fish hatchery licenses are issued on a calendar year basis and must be renewed each year. Applications can be obtained from the Fish Management Section of the Department of Natural Resources.

Another legal consideration in aquaculture is the possible requirement of a discharge permit in accordance with the Wisconsin pollution discharge elimination system. Facilities discharging waste water into surface waters must have a permit if their annual fish production is 20,000 pounds or more. It has not yet been determined whether facilities producing less than 20,000 pounds will need a permit for land discharge of their waste water. All discharge permits specify special conditions of operation. Usually monitoring requirements and daily effluent limitations on total suspended solids and ammonia nitrogen are specified. Applications for a permit can be obtained from the Industrial Wastewater Section of the Department of Natural Resources.

If a facility is using more than 69 gallons per minute of well water, a high capacity well permit is needed. The 69 gallon per minute stipulation includes all wells on the property, both pumped or artesian. Applications for this type of permit can be obtained from the Private Water Supply Section of the Department of Natural Resources.

Outside facilities, especially those involving navigable waters or streams, may need special types of approval. Permits are necessary for pond construction if they are located within 500 feet of a navigable waterway. The design of dams must be approved on all streams. Applications for permits and approvals of these types can be obtained from the Water Regulation Section of the Department of Natural Resources.

If fish are viscerated or processed in other ways, a food processing license is needed. The requirements for a license include impermeable walls, floor and ceilings in the processing plant and also require the availability of potable hot and cold water. Licenses cost $15 to $50, depending upon the volume. Applications can be obtained from the state Department of Agriculture.

QUESTIONS: John Klingbiel

Would you please repeat what you said about requirements for wells?

If at any time there is over 69 gallons of water per minute coming out of the well — that is a pumping well or an artesian well — a high capacity well permit is needed.

If you're producing 20,000 pounds of fingerlings versus 20,000 pounds of rough fish, are the discharge permits the same?

A discharge permit is necessary for both, though the requirements may be different. The actual requirements are pending, as Dr. Quigley mentioned. There will be specific EPA (Environmetnal Protection Agency) requirements and there will be specific state requirements. The state requirements have to be at least as restrictive as the EPA's, according to our understanding, and can be stricter. The hearings are in the process of being held, so this hasn't been established as yet but you're going to have to have a permit.

If you take the wastes from your fish growing operation and put them on your own land so they don't go into any navigable stream, do you still need a permit?

People in our Environmental Protection Division don't know yet. This is one thing just hanging, that needs some legal interpretation. I'm sure that as soon as the hearings are over, they'll get a legal interpretation to clarify this.

POTENTIAL — SOME ECONOMICS OF FISH PRODUCTION*

Richard Vilstrup, Professor
Agricultural Economics and
Meat and Animal Science, UW-Madison

Historically, people in Wisconsin have considered natural production of fish the best source of fish protein. Many have asked: Why should we develop aquaculture?

The meat industry was forced early in our history, from a dependability on hunting for animal meat supplies, to obtain meat from agriculture or domestic feedlot production. Today, the commercial fishing industry also faces critical problems in pollution, environment, regulation and competition with sport fishing. Industry leaders are currently focusing renewed attention on aquaculture as a source of commercial fish for consumers.

It is encouraging this morning to hear the major fish processors and distributors articulating the current need for expanded supplies of yellow perch and walleye pike. Commercial aquaculture systems will require strong markets to provide adequate economic returns to encourage the development of domestic production systems.

The world food situation and the accelerated growth in population has amplified the concern for new sources of human food and protein. Conservative projections indicate that we will have a world population of over 6 billion people by the year 2000. Many areas of the world, with critical food problems, have utilized aquaculture to feed their people. References to fish farming are documented in early Chinese history, in biblical times and more recently in the middle east countries. Some countries have developed fantastic yields by using several species of fish simultaneously in the same pond; some fish that eat on the water's surface, some at middle depth, and some on the bottom—efficiently utilizing water and feed.

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*This study was completed by a team consisting of Professor Dick Vilstrup, UW-Madison; Pat Cantlon, Graduate Student, Agricultural Economics; and Max Kummerow, Meat and Animal Science Department.

Currently, there is a growing demand for fish in the United States. Per capita, fish consumption has increased from 10.6 pounds in 1967 to 12.1 pounds in 1975, or a 14 percent increase in the past eight years. The United States now imports over two-thirds of the fish consumed from world markets and Canada. The concern for fish as a diet food and a variety item in the menu has increased demand. Fish consumption is projected to expand further in new studies published by federal agencies and industry leaders.

The natural supply of fish has continued to decline with increased fishing pressure and environmental problems. The natural supply of yellow perch comes from Lake Erie and with the bulk imported from Canada. Commercial catches from Lake Erie have dwindled from a high of 33 million pounds in 1969 to 15 million pounds in 1974. It has been estimated that nearly 75 percent of the yellow perch are consumed in Wisconsin, and leading processors and distributors have documented the need for replacing the loss of the natural landings of yellow perch from Lake Erir. The current prospects for an increased natural harvest appear limited.

Several significant economic factors are also limiting fish from natural sources. The costs of energy, labor, equipment, boats, regulations, permits and docking facilities have made fishing less profitable. The heavy investment costs have reduced fishing profits. The cost of obtaining a good catch is about the same as experiencing a poor catch.

In summary, it appears that there is a strong demand for yellow perch in the institutional market. Wisconsin is ideally located to supply this market, if high quality fish can be produced economically, near processors and distributors in the state.

Some Economics

The future development of an aquaculture system for perch depends on our ability to make production profitable. Several key factors will determine profitability, including cost of fingerlings, feed, facilities, labor and the market price of fish. An analysis was made by Cantlon, Vilstrup and Kummerow, using the current state of knowledge and assumptions provided by the Departments of Food Science, Engineering and Limnology, and a review of Sea Grant literature available.

Costs and Returns

The following study is based on a fish production building 40 feet wide and 100 feet long. An aquaculture perch production system producing 150,000 fish or 50,000 pounds of fish was selected as an example. Fish would be marketed in five lots of 10,000 pounds throughout the year to maximize the use of the building and facilities — to establish an estimate of costs and returns.

It was necessary to make several basic assumptions. It is important that these assumptions are carefully studied to accurately interpret the costs and returns schedule.

Table A

A facility producing 50,000 pounds of yellow perch annually. The fish are marketed in five lots of 10,000 pounds each at approximately ten-week intervals.

Qualifying Assumptions (for new or old facility)

1. Two gram fingerlings could be purchased as needed from a hatchery at 5¢ each.

2. Feed costs would average 17¢ per lb. through the production period (1 yr.).

3. Mature fish would be marketed at 65¢ per lb.

4. Feed conversion would be 1.4 to 20 grams (live weight), and 1.5 thereafter to the market weight of 150 grams (3 fish per lb.).

5. Labor demand would be nearly constant through the year (3 to 4 hours daily).

6. Density of fish in tanks would meet biological requirements, and is 1 lb. of fish to 10 gallons of water early in the growing period increasing to 1 lb. of fish to 2 gallons of water at market weight.

7. No specific charge would be made for land.

8. Death loss of fingerlings would average approximately 10% distributed through the growing period as indicated.

9. Water Treatment and Handling System:

   a) The entire volume of water would be moved through the tanks and filtered every 3 hours. (Turnover time is 3 hours.)

   b) 2-1/2% fresh (make up) water would be heated and added each turnover.

   c) An adequate water treatment and handling system could be installed for approximately $10,000.

10. Investment required for a new facility would be approximately $53,000.

Table B

Yellow perch production in a new facility producing 50,000 lbs. of fish annually. April 1975

			Estimate Your Costs
Receipts	(50,000 lbs. @ 65¢/lb.)	$32,500	______
Fingerling Cost	(167,500 @ 5¢/lb.)	8,375	______
Feed Costs	(75,000 lbs. @ 17¢/lb.)	12,750	______
Operating Costs			
Electricity	(4KW per hr. continuous @ 3¢/KWH)	1,050	______
Heating Make Up Water	(20% Daily MU)	1,200	______
Heating Growing Facility to 55° - 60° F.		900	______
Ownership Costs			
Depreciation on Building	$\frac{26,000}{20}$	$ 1,300	______
Depreciation on Equipment & Water Treatment	$\frac{27,000}{10}$	2,700	______
Taxes, Insurance, Repairs: Building & Equipment	[53,000 x .03]	1,600	______
Returns			
Receipts		32,500	______
Fingerlings		8,375	______
Feed		12,750	______
Operating Costs		3,150	______
Ownership Costs		5,600	______
Returns to Labor, Management & Investment		$ 2,625	______

Table C

Investment Schedule. April 1975

		Estimate Your Costs
Building: 40' x 100', insulated, cement floor, wired for 100A. service, ventilating fans [$5.50 square feet]	$22,000	______
Well: 1,000 gph capacity	2,000	______
Heating system to maintain 55° - 60° F.	2,000	______
	$26,000	
Equipment and Water System:		
10 Fiberglass Production Tanks 30' x 6' x 4' @ $1,500	$15,000	______
1 Fiberglass Fingerling Tank 2,000 gal. @ $1,000	1,000	______
Miscellaneous Equipment	1,000	______
Water Treatment and Handling System	10,000	______
	$27,000	______
Total Investment:	$53,000	______
Labor Demand: 3-4 hrs. daily (3 x 365 x $3.00/hr.)	3,285	______
Interest on Investment (53,000 x .08)	4,240	______

Table D	New Facility	April 1975

Change in Returns to Labor, Management & Investment as the price of 1) Feed, 2) Fingerlings, 3) Fish Changes--all other prices are held constant as each factor is analyzed

1. **Feed Change:**

	Feed Cost: ¢/lb.	Returns to L. M. & I.*
	22	(-$1,125.)
	21	(- 375.)
	20	375.
	19	1,125.
	18	1,875.
Planning Price	17	2,625.
	16	3,375.
	15	4,125.
	14	4,875.
	13	5,625.
	12	6,375.

2. **Fingerlings Change:**

	Cost: ¢ each	Returns to L. M. & I.
	8	(-$2,400.)
	7	(- 725.)
	6	950.
Planning Price	5	2,625.
	4	4,300.
	3	5,975.
	2	7,650.

3. **Change in Market Price of Fish**

	Price per lb.	Returns to L. M. & I.
	90¢	$15,125.
	85¢	12,625.
	80¢	10,125.
	75¢	7,625.
	70¢	5,125.
Planning Price	65¢	2,625.
	60¢	125.
	55¢	(-$ 2,375.)
	50¢	(- 4,875.)

*Labor, Management and Investment

Recent experience has taught us that feed costs can vary widely. New technology and production facilities could reduce costs of fingerlings. Market prices have changed historically with supply and demand.

It is interesting to examine the impact of change in the cost of feed as all other factors are held constant (Tables D & G). The costs of fingerlings and fish price changes were also analyzed, holding all other factors constant.

Table E

New Facility

Effect of Price Changes on Returns

1. A 1¢/lb. change in feed price changes returns by	$ 750
2. A 1¢ change in fingerling price changes returns by	$ 1,675
3. A 1¢/lb. change in market price changes returns by	$ 500

Price changes are critical in determining future profitability. A one cent change in each factor can drastically boost or decrease returns.

Table F

New Facility

Density of Fish per Gallon of Water

Density is also an important factor. Currently fish are grown at an average density of 1/2 pound of fish per cubic foot of water. A 50% increase in acceptable density to 3/4 lb. of fish per gallon of water would affect net returns approximately as follows:

Increased receipts	$16,250.00
less feed costs	6,375.00
less fingerlings	4,200.00
Increase in returns	$ 5,675.00

Table G

Yellow perch production in an existing facility—producing 50,000 lbs. of fish annually.

			Estimate Your Costs
Receipts	(50,000 lbs. @ 65¢/lb.)	$32,500	________
Fingerling Cost	(167,000 @ 5¢/lb.)	8,375	________
Feed Cost	(75,000 lbs. @ 17¢/lb.)	12,750	________
Operating Costs			
Electricity	(4 KW per hr. continuous @ 3¢/KWH)	$ 1,050	________
Heating make up water	(20% daily MU)	1,200	________
Heating growing facility to 55° - 60° F.		900	________
Ownership Costs			
Depreciation on Building	13,000 / 20	$ 650	________
Depreciation on Equipment & Water System	27,000 / 10	2,700	________
Taxes, Insurance, Repairs: Building & Equipment	[$40,000 x .03]	1,200	________
Returns			
Receipts		$32,500	________
Fingerlings		8,375	________
Feed		12,750	________
Operating Costs		3,150	________
Ownership Costs		4,550	________
Returns to Labor, Management & Investment		$ 3,675	________

Table H

Remodeled Facility

Change in returns to labor, management and investment as the price of 1) Feed, 2) Fingerlings, 3) Fish Changes; all other prices held constant.

1. Feed Price Changes:

	Feed Cost: ¢/lb.	Returns to L. M. & I.
	22	(-$ 75.)
	21	675.
	20	1,425.
	19	2,175.
	18	2,925.
Planning Price	17	3,675.
	16	4,425.
	15	5,175.
	14	5,925
	13	6,675.
	12	7,425.

2. Fingerling Price Changes:

	Cost: ¢ each	Returns to L. M. & I.
	8	(-$ 1,350.)
	7	325.
	6	2,000.
Planning Price	5	3,675.
	4	5,350.
	3	7,025.
	2	8,700.

3. Market Price of Fish Changes:

	¢ per lb.	Returns to L. M. & I.
	85	$13,675.
	80	11,175.
	75	8,675.
	70	6,175.
Planning Price	65	3,675.
	60	1,175.
	55	(-$1,325.)
	50	(-$3,825.)

Table I
Remodeled Facility
Effect of Price Changes on Returns

1. A 1¢/lb. change in feed price changes returns by $ 750
2. A 1¢ change in fingerling price changes returns by $ 1,675
3. A 1¢/lb. change in market price changes returns by 500

Table J
New Facility
Density of Fish per Gallon of Water

Density is also an important factor. A 50% increase in acceptable density to 3/4 lb. of fish per gallon of water would affect net returns approximately as follows:

Increased receipts	$16,250.00
less feed costs	6,375.00
less fingerlings	4,200.00
Increase in returns	$ 5,675.00

<u>In Summary—Some Considerations</u>

Basic economic data and experience in producing yellow perch is limited. More precise budgets can be prepared as cost data becomes available.

Caution must be used in interpretations of cost and return schedules. It is essential that you use similar assumptions to compare costs. It should be noted that start-up and working capital costs are not brought into the projections. Also an emergency back-up power system would be desirable in case of a power failure.

Disease prevention and control is imperative. Currently there is a scarcity of skilled diagnostic and treatment personnel. Some drugs used to treat disease are not yet approved by FDA for use on fish that will be processed and sold at retail.

Alternative tanks that may be suitable is a need. Right now fiberglass, concrete or the poly-lined wooden tanks appear most promising. However, acceptable steel framed, poly-lined tanks similar to the backyard swimming pools might be feasible, and would reduce tank investment substantially.

Water treatment and handling system costs, and the effectiveness of the treatment process remain to be demonstrated. If, for example, more make-up water has to be added each turnover, then the 2-1/2% projected operating costs will increase quite rapidly. A lower make-up rate would decrease operating costs.

It is essential that a market outlet be developed before a production unit is established. A marketing agreement stipulating approximate delivery dates, pricing methods and fish specifications would be desirable. Assistance in location of established processors and updated cost data will be available from the project team.

In Conclusion:

Aquaculture, including yellow perch production, appears to have a viable potential. Under current price and marketing conditions, it is imperative that any aquaculture system include excellent management, cost control and marketing agreements. The level of knowledge in aquaculture is currently limited. We would encourage you to obtain new methods of fish production and technology from the University of Wisconsin as the project develops.

QUESTIONS: Richard Vilstrup, Patrick Cantlon, Max Kummerow and Harold Calbert

Where does the government stand at this time in relation to financing and supporting this effort — can we look for help there?

Our honest answer would be that I'm sure we would be considered like any other enterprise by FHA and other government agencies and the banking system. We've had a lot of interest by government agencies but most financing agencies will be looking for data on sound planning, reliable markets and evidence of good production practices and management.

Professor Calbert, didn't you mention something about a bill before Congress?

This may not have anything to do with the actual financing of the operation, but there is a bill before Congress, I think it's HR370, in committee, it concerns aquaculture. If this bill passes, it will put up some money to get aquaculture going, to do research, to help people get into the business. It's based on using some of the import taxes that they collect on some of the imported fish to help pay for this financing. It hasn't been reported out of the committee but it's under consideration.

Would you review the density and the size of the tank that you used in the example that you costed?

The maximum density at which fish were concentrated was a half pound per gallon and this was when they were close to market weight. We scheduled the fish to be produced in five lots of 10,000 pounds each in order to get a higher utilization out of the total water capacity of the system, which is about 46,000 or 47,000 gallons. That includes ten production tanks of about 4,500 gallons each and one fingerling tank of about 2,000 gallons. As the fish become larger, the density increases.

What is the density on the first month, second month, third month?

We start out with a rule of thumb of a pound of fish per ten gallons of water. That's for the smallest fish and then it slowly grades up to a pound of fish per two gallons of water at market weight.

The fact that you need two gallons of water per pound of fish doesn't mean that you have to have total capacity in your system of that amount, because the fish are not all at the maximum size at the same time, so actually it's less than a gallon per pound of annual production capacity.

Is this a one-man operation you're talking about?

On this 40 by 100 building, we are using a labor requirement of three to four hours per day once it is operating and functioning. That would indicate that if you worked an eight hour day, seven days a week, you could handle two of these units.

Regarding the location of the processing plants, is there a map available that would show their location in northwest Wisconsin?

We are surveying the industry now, and intend to produce a brochure showing the location of processors in the state. From what I recall you could go to Bayfield or to Superior in northwestern Wisconsin.

Is it at all economically feasible to raise perch in open water ponds?

Yes, you can raise them in open ponds, but you can't compete with this enclosed system because as soon as the water temperature drops in those ponds, the fish's metabolism slows down. As you go into the winter period all they do is stand still and shiver. They eat about enough to maintain themselves and to build up for reproduction in the spring. You are not going to put on any growth. What you do is essentially end up with what is going on out there in nature. It's going to take you two or three years to raise a marketable fish. On the other hand, you won't have a big facility or investment or anything like that. But you're going to take all the chances that there are in nature with disease, predators, poachers, contaminants and so on.

You showed how much your profit would increase if the price of fingerlings went down a cent. What leads you to believe that it wouldn't go the other way?

That table indicated that you would lose money if the price of fingerlings went up. It now seems feasible to raise fingerlings in ponds, and we hope to reduce the cost this way. We probably won't grow the fingerlings under the conditions you'll see this afternoon.

Currently there is no commercial production of fingerlings, or an assured supply throughout the year at the size that we want. If you want to buy fingerlings, the best you can do is about ten or 15 cents for a fish that's three to four inches long. From the biological standpoint, it seems reasonable to assume that fingerlings of the size that we would want — two grams or an inch and a quarter long — could be produced for a nickel and perhaps for considerably less. Now, the cost could be greater so we presented a table showing higher and lower costs of fingerlings.

Can you force the brood stock at any time during the year?

That part of the program is still under research. We have been able to get the female perch to spawn early by the use of drugs and controlling the temperature and light conditions. In the future we hope to have our own brood stock and have perch spawning throughout the year. At the present time we do take fingerlings in at the beginning of the season, and by keeping them in cold water and giving them a maintenance diet, we can hold them up to a year at the small size. You don't at that time have a large amount of money invested in those fish. You can take them from that holding tank, put them into the system, raise the temperature gradually, put them on a forced ration, and under controlled environmental conditions obtain the same growth rate out of those fish that you originally got when they came into the system.

What if you get to 45 weeks and the market wasn't quite where you wanted it, and you decide to hold?

An aquaculturist has an advantage here. When a fisherman comes in he has to sell his catch and get the boat unloaded. Here we've got these fish alive in water, and we don't have to move them. You could hold these fish and play the market a little bit. The question is would we have more death loss and what happens to feed efficiency.

We assume that the death loss would occur primarily during the first 15 weeks that the fingerling is on the forced diet. About seven of the total of ten percent fish loss occurs then. We experience relatively little death loss during the later stages that the fish are fed. The feed conversion rate seems to drop off some from the biological data that I've seen, but it does not appear to be terribly significant.

What is the risk inherent in holding the fingerlings over this long period of time? Do they become more susceptible to temperature change when you shift them into the growing stage?

To date we haven't observed any problems in shifting these small fish from the cold water environment into the controlled environment. It's one of those situations where you can't change the environment over night; going from ten to 20 degrees centigrade takes about a week to acclimate the fish. After that they don't seem to have any problems. There's no difference exhibited between the held fish than those that immediately went into the system.

What is the average time from the fingerling to the processing plant?

The time that we assume in the operation scheduled is 45 weeks on the average, from a two gram fingerling to a fish that weighs 150 grams and that would be three fish to a pound. Now, there's going to be variation around that figure. As the industry develops, we would expect that breeding and selection will occur so that we will get a more uniformly producing fish.

Did you raise your own fingerlings or did you buy them?

We haven't bought fingerlings although we have checked on prices. When we first started, we were able to get some very small fingerlings from the DNR. We also hatched some out on an experimental basis. This year for the first time, we are set up to hatch out eggs in quantity. We will not be on the market for selling fish. I do know, from conversations with people in this room, that they will be in the business of selling fingerlings this year. This can be done outside very well because you can get the fingerlings to the size you want if you have a normal season by the first part of July.

Considering an annual gallon capacity for the tanks that's somewhat less than one gallon per every pound of fish you raise annually, how did you calculate the heating costs and what degree temperature rise did you consider from the water source to the 70 degrees?

We assume a 20 percent daily water makeup and that the water temperature from a well is about 50 degrees Fahrenheit on the average throughout the year. This is supported with data that is available, at least for southwestern Wisconsin. I assumed that we were using an energy source to heat water that cost the same per 100,000 BTUs as coal. So I used the coal cost, which comes in at about ten cents per 100,000 BTUs. Fuel oil is about 2.5 times the cost of coal and LP gas or natural gas is considerably more than that.

What about the death rate?

The figure we used here was about ten percent with most of the death loss occurring during the first 15 weeks of the growing period.

How do you market them in five times when basically you will probably buy them all at one time?

We have a holding tank for fingerlings and then gradually we bring them out and start to feed them at different times. So there are progressive groups coming out. They don't all start at the same time. Some of them are in a holding stage; some of them are in a push stage.

FISH NUTRITION

Leo E. Orme
U.S. Fish and Wildlife Service
Diet Testing Development Center
Spearfish, South Dakota

I would like to express my appreciation for being invited to participate in today's program. I feel that there is great potential in the commercial production of cool water fish. The development of the cultural methods and feeding programs for these fish is in its infancy. But, I am sure with the interest in this area, which is exemplified by the response to this workshop, that great strides will be made to bring these developments about in the next few years.

In my presentation, I would first like to briefly comment on fish nutrition and fish feeds in general and then present some of the findings from the projects carried out through the Cooperative Cool Water Fish Diet Testing Program.

In the past, the production of fish for both commercial and recreational purposes has been insignificant when compared to the livestock and poultry industries. Even today, fish feeds make up less than one percent of the total animal feeds manufactured in the United States. For these reasons, there has been little incentive for feed companies, equipment manufacturers and others to support research for the development of cultural methods or nutritional programs for fish. The limited research and development work in fish culture and nutrition has been supported primarily through state and federal programs.

The nutritional requirements for fish are rather ill defined. Most of the work for establishing requirements has been done with trout and salmon. In recent years, certain basic requirements for catfish have been worked out. As for cool water fishes, we are just beginning to determine their basic nutrient requirements. Many of the basic nutrient levels are determined by trial and error feeding trials, which usually is a slow process.

A balanced ration must contain protein, energy, fat, vitamins and minerals in the proper proportions. The optimal protein level for trout and salmon feeds varies with the fish's stage of growth. The feed for young fry contains 45-55 percent high quality protein, fingerling feeds 40-45 percent and production feeds 35-40 percent protein. The essential amino acids required by trout and salmon are the same ten required by other animals, only in slightly different proportions.

Oils are the major source of energy in the diets of cool and cold water fish. Here again, the energy or oil content of the different feeds varies. A high energy content in the feed is required by the rapidly growing fry. Fry feeds contain 15-18 percent oil, fingerling feeds ten to 15 percent and production feeds seven to ten percent.

Trout and salmon require at least one percent linolenic acid in their feed to maintain optimal growth and health, whereas other animals require linoleic acid. The difference in the fatty acid requirement between fish and other animals was not determined until 1972.[1]

Since cool and cold water fish are carnivorous (meat eaters), it is easily understood that they do not efficiently utilize carbohydrates. Carbohydrates are the primary source of energy in animal rations. In fish feeds, oils and a portion of the protein serve as the major source of energy. Only 15 to 20 percent of the energy in conventional trout production feeds is derived from carbohydrates.

Vitamin requirements are difficult to establish since the composition of the ration, physiological activity and interactions between vitamins all influence the requirement for each vitamin. A requirement has been demonstrated for several vitamins. For some, a quantitative requirement has also been determined. Presently, a shotgun approach is used in formulating vitamin premixes for fortifying fish feeds.

Minerals are usually the last nutrients to be considered when formulating a balanced ration. Custom mix mineral supplements make it easy to balance the mineral content of feeds. The mineral requirements for fish have not been determined. Research findings have shown that iodine, iron, calcium, cobalt and phosphorus serve the same physiological functions in fish as in other animals. Therefore, it is prudent to assume that the requirements for fish would be similar to that of other animals. Even though fish have the unique ability to absorb minerals from the water, a trace mineralized salt is added to the ration to assure an adequate supply of the essential trace minerals to maintain the health of the fish. The known requirements and recommendations for trout, salmon and catfish are published in the National Research Council, Nutrient Requirements of Domestic Animals, No. 11.[2]

As you can see, the nutritional requirements for fish are lacking in several areas. This makes it quite difficult to formulate balanced rations with any confidence that they will adequately meet the fish's needs. Through trial and error feeding trials, many feed ingredients have been evaluated in fish feeds. The information obtained from this testing, in addition to the requirements that have been determined, serve as the guidelines for formulating the feeds.

There are several conditions, other than supplying the nutrients that need to be considered when formulating the feeds and setting up a feeding program for fish.

The feed is fed in water; therefore it must be in a form that will hold together until the fish consume it. Fish are not able to feed on meals or from feed troughs as other animals. Also, the fine feed particles readily dissolve, fouling the water. Not only is this a waste of feed, but in excess can cause disease and other problems. For these reasons, fish feeds are manufactured as pellets or granules. The pellets must be durable enough to hold together during handling, storage and feeding. But the pellet must break up rapidly after the fish ingest it. This is important for maximum digestibility since fish have short, simple digestive tracts and do not chew their food. For maximum feed efficiency, the size of the feed particles should be matched to the size of the fish. Only a few pellets or granules are fed to a fish at a feeding. Therefore, each pellet must contain all the feed ingredients in the proportion formulated in the feed to provide the fish with all the required nutrients.

An adequate feeding schedule greatly affects the success of a fish feeding program. Fish also become accustomed to routines. Once you start feeding fish at a certain time, it is a good practice to maintain the time schedule. First feeding fry should be fed hourly. As the fish grows, the frequency of feedings can be reduced. Fish five inches and larger are normally fed at least twice daily.

I am sure you will find, if you haven't already, that fish feeds are expensive compared to other animal feeds. Livestock concentrate feeds cost between $6.00 to $10.00 per hundred pounds. Fish feeds are priced between $15.00 and $30.00 per hundred pounds. There is good reason for these price differences. Fish feeds are very rich in protein, fat and vitamins. They also contain a high percentage of animal protein supplied primarily from fish meal.

A comparison between nutrient levels would be:

	Livestock and Poultry Feeds	Fish Feeds
Protein Percent	12-22	25-55
Fat Percent	2-5	7-18
Vitamins	1 X Level	3 X Level

The ingredients used in fish feeds to obtain the high level of nutrients are costly and also very susceptible to deterioration.

Not only do fish feeds contain a high level of oil, but the type of oils used is easily oxidized. Oxidation of the oil during storage produces rancid feed, toxic agents, foul odors and destroys several vitamins.

Care must be taken to preserve the freshness of the feed and retain the nutritional value. The feeds should be stored in a cool, dry place. The recommended storage time for most fish feeds is 90 days. This is a relatively short time compared to livestock feeds.

The developments in cool water fish culture are following a similar pattern to those in trout culture, and for the same reasons. The fish were originally propagated under intensive culture to supply the increased demands of the sport fishery.

The pure biologist first raised the fish on all natural feeds in ponds. The production was limited by the amount of natural feed that could be provided and often the quantity was unpredictable. An increased and reliable production was needed to meet the growing demands for sport fish. About this time, a market for live and dressed fish began to develop that could only be supplied by private or commercial fish producers.

The natural feeds were supplemented with meat by-products and eventually the total diet was comprised of meat products. Then limited supplies and increased prices forced the fish producer to look for new feeds for his fish. Cereal products were blended with the meat as extenders. This proved satisfactory, but required a lot of labor and large freezer facilities. In the early 1950s, advancements in basic fish nutrition made it possible to formulate a complete dry pelleted trout feed. These feeds produced good growth and maintained the health of the trout.

Cool water fish culture is in the phase of transition from pond culture with natural feeds to intensive culture with dry formulated feeds.

It may be well to note that the advancements in fish breeding, cultural techniques and disease control must also advance abreast with nutrition for the total program to move forward.

Many of the developments in the intensive culture of other fish may be applied to cool water fish. But there are several striking differences that need to be worked out before they can be raised in a similar manner as trout and catfish.

What has been done in the area of developing formulated dry feeds and feeding programs for the cool water fish?

In 1970 the Diet Testing Development Center became involved in a token effort with two federal hatcheries to test trout feeds as fry and fingerling feeds for walleye and northern pike. The few fish that did accept the feed were not healthy, indicating that trout feeds do not meet their nutritional requirements.

A more formal program was initiated in 1971. Several state and federal hatcheries participated in the cool water diet testing program. Three experimental diets, W-1, W-2 and W-3 (Table 1) were formulated for testing that year. These diets contained about 55 percent protein and 13 percent oil. The variations were in the type of ingredients used in the rations. The W-3 feed containing the highest level of fish meal showed some promise as a satisfactory feed. Disease outbreaks detracted from the results of several feeding trials.

In the second year of the program, we became better organized and established a set of guidelines for conducting the feeding trials, plus a system for collecting the test results in a uniform manner. The Oregon Moist Pellet, a salmon feed made with some raw fish and the W-3 dry feed were evaluated. The attempts to start fry on the test feeds were virtually unsuccessful. A few tiger muskie, northern pike and largemouth bass fry were observed taking the feed. But in all cases a heavy mortality occurred which was attributed to starvation, cannibalism and disease. The results from the fingerling trials showed the greatest promise. Tiger muskie and largemouth bass offered the best potential for a dry feed program.

Table 1

Diet Formulations

Ingredients	W-1	W-2	W-3
Herring Fish Meal	30	30	50
Skim Milk	5	-	-
Delactosed Whey	10	5	7
Wheat Middlings	10.5	8	-
Soybean Flour	10	5	5
Fish Solubles	10	10	10
Brewer's Yeast	5	5	5
Gelatin	3	-	-
Blood Flour	-	25	10
Trace Mineral Salt	1.5	-	-
Vitamin Premix No. 25	4	4	4
Water	5	-	-
Fish Oil	3	4	-
Soybean Oil	3	4	9

In 1973 several more hatcheries joined the program. Dr. Harold Calbert, University of Wisconsin, also joined the group. Up to this time, only state and federal hatcheries had been in the program.

A new set of diets were formulated for testing along with the Oregon Moist Pellet. They were labeled W-4, W-5 and W-6 and varied in the protein and energy levels (Table 2).

Walleye pike, northern pike, tiger muskie, largemouth bass, muskellunge and yellow perch were the species included in this year's program. Fry feeding trials were generally unsuccessful, resulting in no more than four to seven percent survival.

Varying degrees of success were achieved with the different diets. The W-4 and OMP feeds appeared to be adequate for smallmouth bass fingerlings. The walleye, northern and muskie fingerlings showed some promise of feeding on the W-5 feed. The muskie/northern pike hybrid was successfully fed all three dry feeds. The fingerlings were 1.5 to 2.0 inches when started on the dry feeds. All the feeding trials were heavily plagued with disease problems, cannibalism and a lack of knowledge as to the optimal rearing conditions for intense culture.

Overall, the results indicated that the W-5 diet performed best and that these fish require a high protein, high energy feed.

Dr. Calbert found that perch fingerlings adjusted quickly to the W-3 feed and began to feed within a week. The walleye were somewhat more reluctant, but after mixing daphnia with pellets for the first feedings, the walleye fingerlings also accepted the dry feed. The optimal water temperature for both species was determined to be 72 degrees F. The perch grew twice as fast with a 16-hour photoperiod as opposed to an eight-hour photoperiod. Light had far less effect upon walleye and they seemed to prefer a dimmer light. Feeding rates of three, five and seven percent of the body weight per day were also evaluated. The three percent level produced the fastest growth for both species.

Gross feed conversions for walleye during the 42-week period went from 1.16 to 4.35. A reversed trend was indicated for yellow perch, with conversions going from 31.9 to 1.45.[3]

The results of the 1973 test program were reviewed and analyzed to set up guidelines for 1974.

In 1974 the cool water diet testing program really took hold. Four federal hatcheries — Valley City, North Dakota; New London, Minnesota; Senecaville, Ohio; and Gavins Point, South Dakota; three states — New York, Michigan and Pennsylvania, with a total of nine hatcheries for all three and the University of Wisconsin — participated in the Cool Water Diet Testing program.

Species used in the feeding trials were walleye, sauger, northern pike, muskellunge, muskellunge/northern pike hybrid, largemouth bass, smallmouth bass and yellow perch.

Table 2

Diet Formulations

Ingredients	W-4	W-5	W-6	W-7
Herring Fish Meal	45	45	30	50
Wheat Middlings	-	2	14	-
Soybean Flour	-	10	10	10
Delactosed Whey	7	10	10	5
Brewer's Yeast	5	5	5	5
Fish Solubles	10	10	15	10
Blood Flour	20	-	-	5
Corn Gluten Meal	-	5	5	-
Fish Oil	9	9	7	9
Vitamin Premix	4	4	4	6

The W-7 diet (Table 2), which is a high protein, high energy feed similar to W-5 but with an increased vitamin fortification, was tested at all stations.

None of the attempts of starting fry on dry feed were successful. Starvation, disease and cannibalism were the major factors responsible for the high mortality. The fry were often started on brine shrimp or a natural feed, but failed to convert to the dry feed.

The results from the fingerling feeding trials were more promising. Pond reared walleye fingerlings ranging from 1.5 to 2.5 inches were used in the feeding trials. Valley City NFH in a short feeding trial produced a fourfold increase in a test lot of walleye fingerlings with approximately 75 percent survival. In a Pennsylvania state hatchery, walleye fingerlings were fed the W-7 feed and grew from 1.5 to four and five inches with a survival of 32.8 percent.

Northern pike fingerlings were reared successfully by Pennsylvania on the W-7 feed from a 1.1 inch size to six inches. Survival was only 15 percent.

Limited testing was conducted with muskellunge. Valley City NFH and Pennsylvania state reared small 1.5 inch fingerlings to about six inches on W-7 feed. Survival was in the area of ten percent.

The results of the full-scale production program by the state of Pennsylvania has shown that muskellunge/northern pike hybrids can be produced in large numbers on the W-7 feed. One hundred thousand one to four inch fingerlings were fed the W-7 feed. The ending size of the fish was 5.5 to eight inches. The average survival was 68 percent.

New York State was also quite successful in rearing the hybrid muskellunge. Fry were started on zooplankton and brind shrimp, then converted to dry feed.

The trials conducted with largemouth bass and smallmouth bass fingerlings produced varying degrees of success. The growth rates were acceptable with survival of 70 percent or better.

Dr. Calbert's work here at the University of Wisconsin included the evaluation of three diets with 50, 40 and 27 percent protein. Preliminary results showed that the perch grew about as well on the 40 percent protein diet as on the 50 percent protein. The energy levels of the two feeds were similar. This is an ongoing program, so I do not have the final results.

The accomplishments in 1974 pave the way for dramatic changes in the whole concept of producing these species at the production level. One has only to think about the broad range of species reviewed in this paper to grasp the interest and potential of this program. It has developed from a casual sideline to a formal program of significant magnitude.

The program for 1975 is already under way. The W-7 diet will again be the test feed. Fry as well as fingerling feeding trials will be conducted on all species. Work will be done in the areas of nutrition, disease control, environmental factors, cultural practices and development of broodstock.

We have learned a lot since the start, but we still have a long way to go before we can consistently have reliable and predictable results.

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QUESTIONS: Harold Calbert (in place of Leo E. Orme)

Could you talk about the hourly feeding of the fingerlings?

Let's talk about this in terms of size. As the fish hatch from the eggs they have an egg sack attached to them. And for a period of three to four days that extremely small fish — not much larger than the head of a pin — lives off his egg sack. After that time, the sack is consumed and there's a period of four to six days when the fish has to have a feed that we cannot formulate as yet — it's mouth hasn't even developed yet. In nature, the fish would be eating rotifers, zooplankton and things like that. We are doing some experimental work on this and will be able to tell you after our fish hatch out, what's best to feed them at that stage. As the fish get up to about half an inch or an inch, they are called fry. At this time they have to be fed quite frequently, during the hours when the light is on. The next stage in the fish's development is the fingerling stage — as they get up to about an inch or an inch-and a-half. By ten weeks, they are past the fingerling stage, but there isn't any set date or size where they go from being, say, a child to an adult. This period where you have to feed them every hour is a relatively short one. I might add that if they do have sufficient feed in these early stages of life, they will usually double in size about every 24 hours.

You have spoken of the diet for these fish. What is the availability of these foods and who is processing them?

All of the items listed for the diets are normal ingredients which most feed manufacturers would have on hand. These are commonly used in other types of animal feeds, although probably in different proportions. There is a local commercial feed manufacturer here in town, the Vita Plus Corporation, which has been producing feed for us. The Ralston Purina Company has been producing feed for quite some time. Glencoe Mills is producing fish feeds and so are several other companies.

Has anyone had any luck using cheese whey material?

Yes. Whey is one of the ingredients in this formula. We do not raise the fish completely on whey because you have a high lactose content and some other problems.

Have you experimented with any natural foods such as worms?

When we got our first bunch of fingerlings in, through the graces of the state Department of Natural Resources, some mud minnows and a few other odds and ends were mixed in with them. We separated out the perch but kept the minnows and others around, kind of as pets. The fellow on the research project at that time just couldn't stand to see a fish die, so I couldn't get rid of them. So whenever he was out of the room, I would take one of these minnows and throw it into the tank with the perch and the walleyes. As soon as I threw the minnow in with the walleyes, it was gone. But the perch, while they love minnows, are not fast enough to catch them. The minnow could live in the perch tank and do quite well.

This year, as we hatch these fish out, we are using some of the natural feeds. But we have not made it a practice of using worms.

It was stated that the carbohydrates in the ration make up 15 to 20 percent. Is there a certain process to that?

We have turned to such things as oat flour as the carbohydrate source, and we find that with the smaller fish, this has to be pretty fine. They don't like it particularly well, and if you don't have it mixed in fine, when they ingest the pellet they'll work it around their mouth and spit it out. As the fish get larger and the pellets get larger, this is not so much of a problem.

When you dilute your diet to reduce your protein from 40 or 50 percent down to 27 percent, what has been your major diluent? And have you checked the digestibility of various diluents?

We have been using what was available and what we knew would work. The major diluents, in order to keep the diet essentially isocaloric, have been the oils. We have used oat flour in ours, although there are other types of carbohydrate sources that could be used. As I mentioned earlier these fish to not depend on the carbohydrates as their major source of energy, so you have to keep it to a minimum. We have to be careful with the oils so we are sure we have the essential fatty acids. This has been one of the limiting factors. We can't get the oil too high or they can't metabolize it. There's quite a bit of information on this subject in relation to other fish species and from everything we have tested to date, the data seem to bear out with the perch, too.

If the discharge from a 50,000 pound-a-year fish operation ran into a ditch where it didn't drain off too much, how smelly would it be on a warm day in the summertime?

I really can't give you a specific answer to that, but by treating the wastes with filters, we have removed a good bit of the organic matter, which is basically what causes it to smell. I'm not saying there wouldn't be any smell, but the major content of this waste would be more of a mineral nature if it has been treated properly before discharge.

Have you done anything further on using the fish carcasses?

These go into meal which could be reincorporated back into the fish feed. We do not have a fish meal operation here. There is, to my knowledge, one commercial operation in Wisconsin. The University of Washington, in their food science department, has a small setup where they do take the carcasses and produce a meal out of it. To do this, you need a system for drying the material, heating it, grinding it and powdering it. So carcasses can be reused in meal, but you have to have enough of this stuff for the processing to be economical. On a farm producing 50,000 pounds of fish, where you probably wouldn't be cleaning them anyhow, I doubt that you would have enough.

How economically feasible is this fish raising project? Is it correct that it costs 58 cents a pound to raise fish?

I think you have to recognize that all the figures that were presented here were based on assumptions and a lot of the technology is not yet worked out well enough to know. For example, what's the most efficient size operation? I don't think we really know that yet and I think that anyone that is going to go into this business ought to do this own feasibility study and figure out what his costs are going to be on his own specific operation.

A lot of these costs have to be projected. We have had to arrive at some kind of a realistic estimate of the price that one would probably be able to get for these fish. The feed prices have changed since we started this project; fish prices will probably go up. I am sure that when we estimate certain costs, no two people will have those same costs. The cost of a tank alone can vary. You may build your own tank and do it for a quarter of the cost of a new one. We can't guarantee anyone a profit; it could be an economical operation for some people but not for others.

Is it possible to take some of the stunted fish in lakes around the state and grow them in controlled conditions?

It depends upon at what stage of growth they are. If they are adult and have been adult for a few years, I don't think they are going to show too much remarkable growth, in tank culture. Also the legality of taking these fish is something else that would have to be considered.

When you projected these costs, did you include the cost of interest on the money invested and so forth?

We used interest on the working capital of eight percent and we also had an interest or an opportunity cost factored in. The one cost we did not have in here was land cost. If you are going to pay all of these costs in any kind of an operation, as you know, you'll probably get down to a fairly level line, but then, of course, you are taking your profit in another way.

DISEASE PREVENTION AND CONTROL IN CLOSED SYSTEMS

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and

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Disease in fish culture is usually a reflection of the overall environmental conditions under which the fish are held. Prevention and disease control must therefore be considered as an integral part of the overall program of any fish husbandry. Disease control must be included in planning of the system design, waste removal units, backup systems, nutritional considerations and selection of fish stocks. Use of drugs and chemicals should be considered only when all other efforts to prevent or control disease have failed.

Any deficiencies in design, equipment capability, waste removal or diet will result in poor growth, increased susceptibility to disease or losses. Well nourished fish under optimal environmental conditions are usually highly resistant to disease. When things go wrong in the environment, disease will follow.

Someone once coined a set of statements which have come to be known as Murphy's laws. Paraphrased, these laws are as follows:

1. Don't worry — nothing will be all right.
2. If anything can go wrong, it will.
3. If anything goes wrong, it is sure to do so at the least opportune time, when least expected, and when it will cause the greatest damage.

Anyone considering intensive culture of fish would do well to commit Murphy's laws to memory.

In considering disease control, one must realize that disease is actually any state of "dis-ease," i.e., any condition in which the fish is not at ease.

Fish are similar to other domestic animals, especially chickens, in the types of disease they contract. There are many parallels between the intensive culture of poultry and that of fish. Fish are susceptible to viral, bacterial and parasitic infections. They also develop tumors, have congenital defects and are subject to a great variety of environmental injuries, such as nitrite poisoning, chemical toxicosis, excessive temperature and sunburn. Nutritional imbalances cause disorders such as cataracts, reduced fertility, skeletal deformities, poor growth and death.

Death from any cause is merely a sign, an indication that the fish were unable to survive the conditions which prevailed. Since our definition of disease includes any condition which weakens or kills the fish, attention should first be directed toward the environment in which the fish are held.

In closed systems, no water, oxygen or food enters unless it is specifically provided by the fish culturist. No wastes leave unless provision is made to remove them. Any deterioration of water quality in a closed system will immediately cause stress which will be reflected in poorer fish growth, reduced resistance to infection and death.

Nutritional Disease

Diets provided to the fish must include the energy and protein sources needed and must also have adequate levels of vitamins and trace elements. Fish producers who attempted to rear channel catfish in cages or raceways using rations developed for pond culture experienced severe financial losses due to broken-back syndrome. In the catfish, broken-back syndrome was traced to a deficiency of vitamin C (Lovell, 1974). Culturists attempting to use closed systems should expect similar problems since the dietary requirements of predator fishes, such as the yellow perch and walleye, have yet to be adequately determined.

Environmentally-Induced Disease

What goes into a culture system as food comes out, either as fish flesh or as wastes. Normal metabolism produces waste products that will ultimately prove toxic to the fish if not removed. Ammonia, carbon dioxide, urinary and fecal wastes and decomposing organic matter such as uneaten food, all contribute to a deterioration of the water quality. A system capable of sustaining a population of small fish may be totally inadequate when the fish have doubled or tripled in size. The reader is referred to Piper (1970) or Speece (1973) for information on how to avoid overloading and losses associated therewith.

Biological waste removal processes require oxygen — over and above the amount required for fish respiration and metabolism. In a closed system for trout culture at 55 degrees F, fish respiration used 3.8 ppm of oxygen. Nitrifying bacteria required another 3.4 ppm (Speece, 1973). The effect on aeration costs is readily apparent. Ironically, as ammonia and carbon dioxide concentrations rise, oxygen levels are usually dropping. As oxygen decreases, the toxicity of ammonia and of carbon dioxide increases so a double threat develops to fish survival.

The removal of metabolic wastes must be efficient and continuous. Any decline in efficiency will be reflected in stress and declining fish health. The importance of continuous operation cannot be overemphasized. A half-hour shutdown can prove fatal to all fish in a heavily loaded system.

Relation of Environment to Infectious Diseases

Having considered environmental factors as potential sources of disease, attention should be directed toward infectious and parasitic agents. Certain organisms survive only in live fish, and transmission of the diseases they cause is from fish to fish. Such disease-producing agents are true pathogens. Others are extremely adaptable organisms and can survive outside of fish, causing infections whenever fish are weakened or otherwise predisposed to disease. Most fish disease agents are of this type. Still other microbes rarely cause infection, doing so only in marginal environments. Wild fishes frequently carry low numbers of these organisms in their bodies, i.e., they may be "carriers."

The most common fish disease agents are ubiquitous inhabitants of natural waters. Whether or not outbreaks occur is the result of complex interactions between the host, the environment and the pathogens (Snieszko, 1974). Three basic factors must be co-existent if disease is to occur. These are: the host must be susceptible, the disease agent must be infective and the environmental factors must be working to the disadvantage of the host. This may be graphically demonstrated by Figure 1.

Environmental elements are usually the triggering factor in disease outbreaks. As long as the host, the pathogenic agent and the environment are in balance, no disease occurs. However, a disturbance in any one of them disrupts this balance, and a disease outbreak will appear and spread.

In natural waters, the incidence of disease is seasonal, usually in response to temperature, environmental stresses or changes in the developmental stage of the fish (Meyer, 1970). Environmental conditions in functioning closed systems should be relatively static. This means that only those parasites that thrive at the ambient temperature will flourish. All others will disappear or never be a problem. Those parasites whose survival is enhanced will cause problems far in excess of their importance in the wild and will show no seasonality in incidence. Once introduced into a closed system, such organisms will cause continuous threats to the fish stocks. Although the number of species of problem organisms in artificial culture systems may decline, the severity of their effects will increase manyfold (Dogiel et al., 1961).

Management as a Control of Disease

Fish culturists try to maintain a highly favorable environment for the fish and, in doing so, work to the disfavor of disease agents. Success in fish culture is limited, not by the best conditions available, but by the worst conditions that develop during a rearing cycle. According to Wedemeyer (1974), "Fish in intensive culture are continuously affected by environmental fluctuations," such as changing temperatures and water chemistry (especially during stocking operations) and by "management practices such as handling, crowding, hauling and drug treatments." These stresses require adjustment by the host. Any time the stress exceeds the host's capability to adjust, disease will result. Wedemeyer (1970) has shown that even moderate stress can predispose fish to physiological disorders or to infectious diseases. In closed systems, even though a mechanical breakdown might not result in direct losses, it could lead to other diseases due to the stresses to which the fish had been subjected.

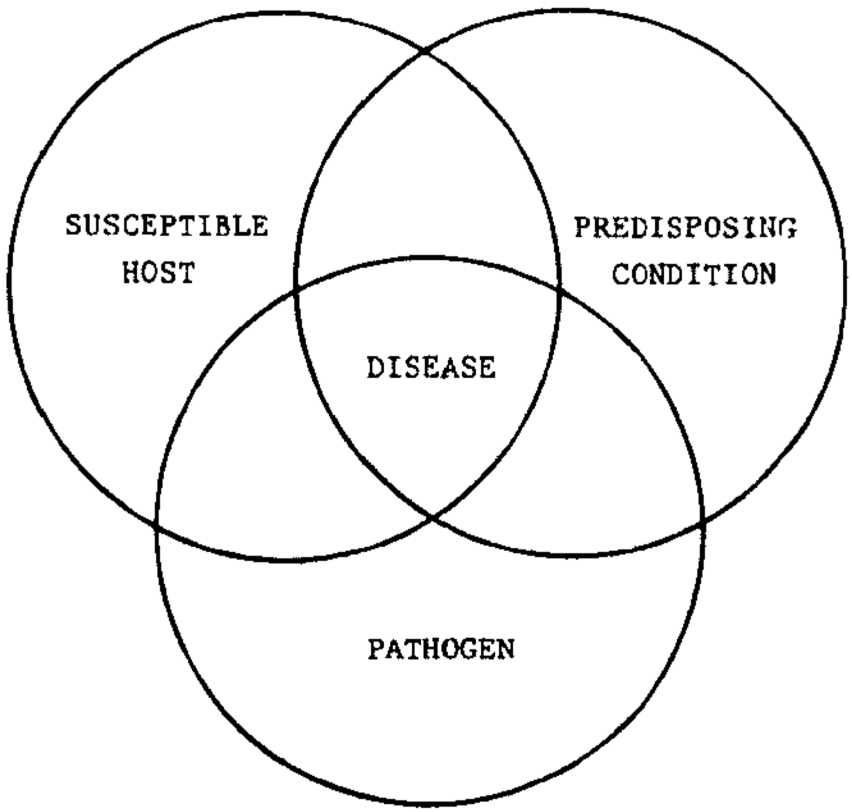

Fig. 1--Interrelationships of factors involved in outbreaks of disease (After Snieszko 1973).

Mayer (1970) reported a high incidence of hemorrhagic septicemia in channel catfish that survived low oxygen stresses on commercial fish farms.

Disease-Free Stock

The selection of healthy fish stocks is equally important to developing an adequate environment. It is imperative that all fish placed in the system be as free of infectious diseases and parasites as possible. Wild fish should be avoided since all can be carriers of disease which cannot be removed by prophylactic treatments.

If possible, start with eggs which have been effectively disinfected prior to introduction into the system. If fish are introduced, these should be from a source where the health of the stocks has been monitored and the fish are known to be free of major infectious agents.

Complete rearing of a fish stock in intensive culture from egg to adulthood is very important if a closed system fish culture is to succeed. Brood stocks of known history must be developed which are free of infectious agents found in wild stocks.

Disease agents enter systems usually on fish or with water in which infected fish were held. This means that organisms can be introduced by the fish culturist unless every effort is made to prevent doing so. New lots of fish should be given prophylactic treatments and held in quarantine until they are determined to be healthy. New fish should never be stocked directly into an operating system. The danger of contaminating the rest of the stock constitutes a risk the owner cannot afford. Once a disease is introduced or develops in any part of the system, the entire stock is vulnerable and will develop the infection. The effects are similar to a forest fire — when one begins it will spread to the entire forest unless it is stopped by some outside force. In the case of fish diseases, when prevention has failed the only recourse is to use chemical treatments or to close down the system.

Careful stock selection will help reduce problems, but there is no way to anticipate everything that will arise.

Indicators of Disease

Awareness is the key to success. Awareness of mechanical problems, of the health of the fish stocks, of water quality and of what to do to solve the myriad problems that might occur is what preventive medicine in fish culture is all about.

A daily log of losses must be kept. Such information provides valuable insight to problems which exist in the system. The culturist must always know exactly how many fish are present in each tank. The concept of being "nickeled and dimed to death" certainly applies in fish culture. The number of animals present affects feeding rates, flow rates and treatments for disease.

Rates of loss may also provide information as to the source of existing problems (Figure 2). Failures of the pumps, aerating equipment, biological

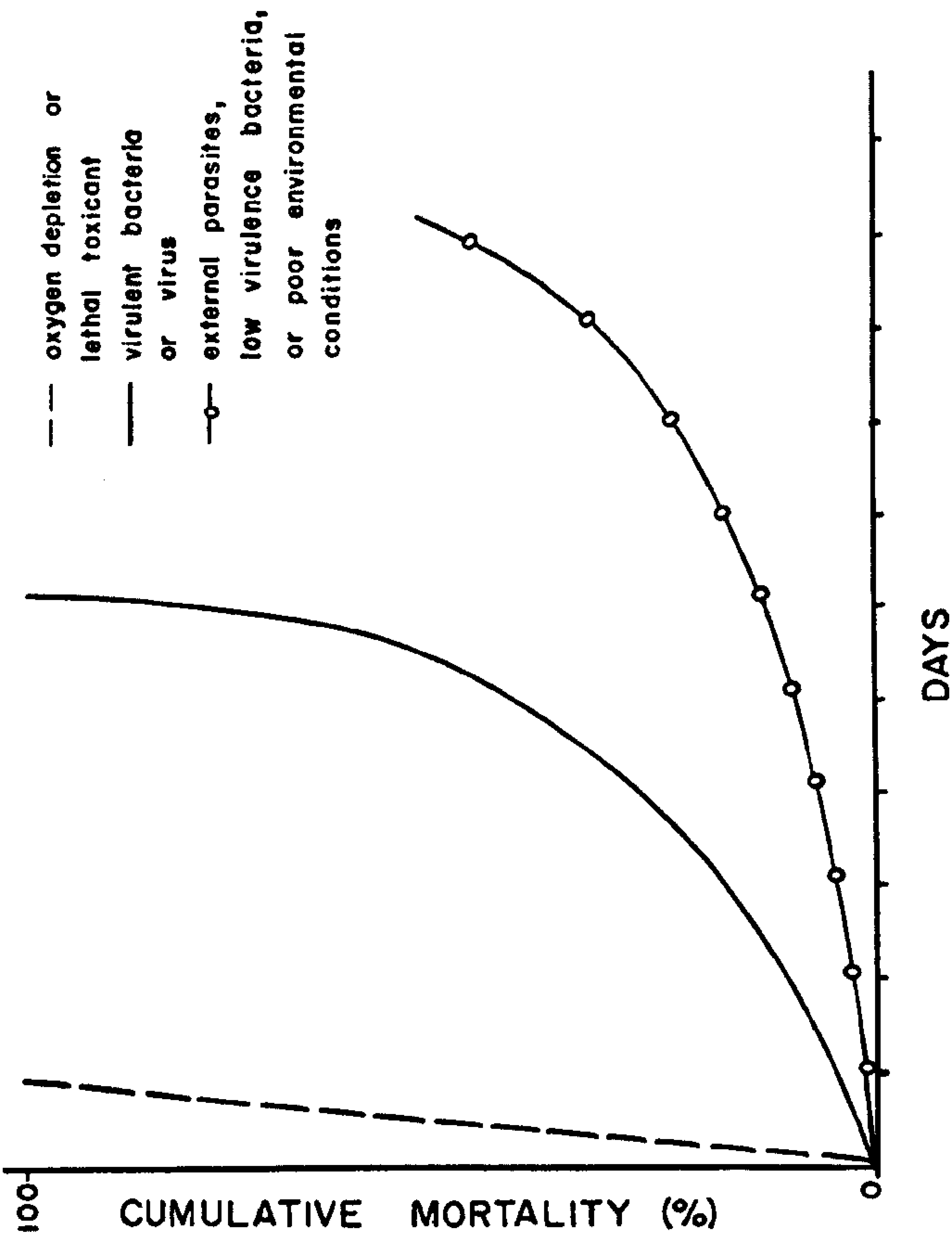

Figure 2. Curves of mortality rates associated with various etiological agents.

filters or backup equipment represent environmental catastrophes which cause all of the fish in the system to die within a short period of time. Highly virulent bacterial or viral infections begin with a slow loss rate that rapidly accelerates to high proportions. External parasites, bacteria of low virulence and marginal environmental conditions are evidenced by low but persistent mortality rates.

Treatment of Infectious Diseases

Even under the best of environmental conditions, disease outbreaks occasionally occur. Failures to use parasite-free stocks, the stocking of carrier fish or the use of contaminated water supplies will introduce infections to otherwise "clean" systems. Every fish culturist dreams of being able to raise disease free stock — a dream that has yet to be achieved in fish culture. As a result, the need for treating fish should be expected.

Viral diseases do not respond to any type of treatment. When such infections occur, the best course of action is to destroy the infected lot and sterilize the entire facility. Since viruses are true pathogens (transmitted by infected fish or the water), the source of infection must be identified and eliminated before a second culture attempt is made.

Drugs that might control most of the common bacterial infections are known. Unfortunately, few of these are economically feasible and even fewer have been approved by the Food and Drug Administration for use on fish intended for human consumption. The paucity of approved drugs places additional restrictions on their use. While a culturist might wish to use drugs on a preventive basis by routinely treating at periodic intervals, doing so could actually work against his goal. When drugs are used improperly, susceptible bacteria may develop a resistance to treatment. More and more drug is then required to achieve the same level of control until, ultimately, the bacteria are totally resistant.

Parasitic diseases of an external nature can be treated. However, chemicals approved for use on food fishes are also few in number. Drug resistance may occur with these organisms as well.

Many of the chemicals used to treat diseases adversely affect biological filters, so provision must be made to prevent such compounds from circulating. Bypasses can be used to operate a closed system during treatment, but the culturist must realize that bypasses require the addition of substantial amounts of makeup water since treated water must be discarded to protect the filter. If bypass systems are provided with their own pumps and plumbing, they can also be used to operate the facility during emergency repairs of the regular equipment.

Four key factors must be considered whenever a chemical application is contemplated. Briefly stated, these are the water, the fish, the causative agent and the chemical. Knowledge about each must be in hand before any application is made.

Knowledge of the water includes such information as knowing the volume in each tank and in the total system, whether or not a bypass system is available and how much makeup water is available. Also, what is the rate of turnover in each unit? What is the water chemistry (pH, total hardness, alkalinity, dissolved oxygen level, etc.)? What is the temperature?

Knowledge concerning the fish includes the species under culture, the number of fish present, specific requirements for temperature and dissolved oxygen and any unusual sensitivities to chemicals. A given compound may be many times more toxic to one species than another. As an example, young bass are very sensitive to malachite green whereas channel catfish and rainbow trout are fairly tolerant. Eggs are especially susceptible to chemical damage close to the time of hatching. Sac fry and larval stages are usually more sensitive than fingerlings and adults. Another aspect to be considered concerns the condition of the fish. Questions such as —are the fish too sick to take food, and are they too weak to tolerate treatment — must be considered.

Information on the causative agent should include, first of all, a correct diagnosis. This knowledge should then make it possible to determine the vulnerable portions of the organism's life cycle, what type of compound will be needed, and how best to apply it. Systemic bacterial infections require antibiotic drugs administered in the diet since drugs added to the water would never reach the site of infection.

When all of the foregoing data are in hand, one may then begin to consider which drug or chemical to use. Selection of the compound must be based on the following information: Is it effective against the causative agent? Is it available in a formulation that will reach the site of infection? Is it effective under the existing water chemistry? Will it have adverse effects on the biological filter? Is it known to be toxic to the species of fish or life stages involved? Can I afford to use it? Is the compound approved by the Food and Drug Administration for the use I am planning? Failure to observe the latter could result in the production of fish which cannot be marketed due to illegal chemical residues in the flesh.

It should be immediately evident that the successful treatment of fish goes far beyond diagnosis of the problem. Beginners should seek technical assistance and obtain informational guides such as Treatment Tips: How to Determine Quantities for Chemical Treatments Used in Fish Farming (Meyer, 1965), and Cost of Disease Treatment (Piper and Wolf, 1959). Proper forethought avoids most of the complications which might develop, yields more efficient and effective treatments and results in improved fish health.

While disease is frequently blamed for the failure of many experimental systems, it is our opinion that diseases are merely an indication of more basic problems. Careful analysis of the many projects which attempted to grow channel catfish in closed systems reveals that nearly all systems were inadequate, overloaded, lacked backup facilities or were based on incomplete scientific knowledge of diets and water quality requirements.

Sources of Technical Advice and Assistance on Fish Diseases and Their Control

Eastern Fish Disease Laboratory, U.S. Fish and Wildlife Service, R.F.D. 1, Box 17, Kearneysville, WV 25430

Fish Farming Experimental Station, U.S. Fish and Wildlife Service, P.O. Box 860, Stuttgart, AR 72160

Hatchery Biology Laboratory, U.S. Fish and Wildlife Service, P.O. Box 252, Genoa, WI 54632

National Fish and Wildlife Disease Laboartory, U.S. Fish and Wildlife Service, University of Wisconsin-Madison, c/o Department of Veterinary Medicine, Madison, WI 53706

Sources of Information on Fish Diseases

Bullock, G.L., D. A. Conroy and S.F. Snieszko. 1971. Diseases of Fishes. Book 2A: Bacterial Diseases of Fishes. T.F.H. Publications, Inc., 211 West Sylvania Avenue, P.O. Box 27, Neptune City, NJ 07753. Cost: about ten dollars.

Conroy, D.A. and R.L. Herman. 1970. E. Amlacher's Handbook of Fish Diseases. T.F.H. Publications, Inc., 211 West Sylvania Avenue, P.O. Box 27, Neptune City, NJ 07753. Cost: about $15.00

Hoffman, G.L. and F.P. Meyer. 1974. Parasites of Freshwater Fishes: A Review of Their Control and Treatment. T.F.H. Publications, Inc., 211 West Sylvania Avenue, P.O. Box 27, Neptune City, NJ 07753. Cost: about $15.00.

Meyer, F.P., K.E. Sneed and P.T. Eschmeyer. 1973. Second Report to the Fish Farmers. Resource Publication 113, Fish and Wildlife Service, U.S. Department of the Interior, Washington, D.C. 20240. Cost: about $2.50.

Meyer, F.P. 1965. Treatment Tips: How to Determine Quantities for Chemical Treatments Used in Fish Farming. Fish Farming Experimental Station, P.O. Box 860, Stuttgart, AR 72160. Cost: free.

Piper, R.G. 1970. Know the Proper Carrying Capacities of Your Farm. New Method at Bozeman Center Should Help Fish Farmers Cut Losses Caused by Overloading. American Fishes and U.S. Trout News, Vol. 15(1):4-6 and 30.

Spotte, S.H. 1970. Fish and Invertebrate Culture: Water Management in Closed Systems. John Wiley and Sons, 605 Third Avenue, New York, NY 10016. Cost: $8.95.

The Progressive Fish-Culturist. This is a quarterly journal which contains many articles related to fish disease control and closed culture systems. It is available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 at the cost of $3.05 per year.

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Lovell, R.T. 1973. Essentiality of Vitamin C in Feeds for Intensively-fed Caged Channel Catfish. Journal of Nutrition 103(1):134-138.

Meyer, F.P. 1965. Treatment Tips: How to Determine Quantities for Chemical Treatments Used in Fish Farming. U.S. Fish and Wildlife Service, Washington, D.C. Resource Publication 66. 17 pages.

Meyer, F.P. 1970. Seasonal Fluctuations in the Incidence of Disease on Fish Farms. Pages 21-29 in A Symposium on Diseases of Fishes and Shellfishes. Special Publication No. 5, The American Fisheries Society, Washington, D.C.

Piper, R.G. 1970. Know the Proper Carrying Capacity of Your Farm. New Method at Bozeman Center Should Help Fish Farmers Cut Losses Caused by Overloading. American Fishes and U.S. Trout News 15(1):4-6 and 30.

Piper, R.G. and K. Wolf. 1959. Cost of Disease Treatment. The Progressive Fish-Culturist 21(3):135-137.

Snieszko, S.F. 1974. The Effects of Environmental Stress on Outbreaks of Infectious Diseases in Fishes. Journal of Fish Biology 6(2):197-208.

Speece, R.E. 1973. Trout Metabolism Characteristics and the Rational Design of Nitrification Facilities for Water Reuse in Hatcheries. Transactions of the American Fisheries Society 102(2):323-334.

Wedemeyer, G.A. 1970. The Role of Stress in the Disease Resistance of Fishes. Pages 30-35 in A Symposium on Diseases of Fishes and Shellfishes. Special Publication No. 5, The American Fisheries Society, Washington, D.C.

Wedemeyer, G.A. and J.W. Wood. Stress as a Predisposing Factor in Fish Diseases. U.S. Fish and Wildlife Service, Washington, D.C. Fish Disease Leaflet 38. 4 pages

QUESTIONS: James Warren and Fred Meyer

How would you know whether you have a potentially lethal chemical or mineral element in your water supply?

You can do two things. First, you can have your water analyzed. This is a rather expensive proposition. Even more meaningful would be to try your water out on a few fish. You don't need an elaborate system, just a system that could be used to test a small population, even a few hundred fish, for a 30-day period or longer. These smaller pilot trials are essential before you get into a large-scale investment and operation.

If you are using an old dairy facility where certain insecticides are used, how would you control these insecticides' residues to prevent them from getting into your present system?

Talk to your state board of health and find out what is allowed in a food-producing facility. Find out whether or not there are likely to be residues and if so, what are the hazards. There are so many different compounds that you could use that it would be difficult to pinpoint any one. The best bet is to talk to your state board of health.

Are you working on any immunization treatments that would help prevent some of these diseases in fish?

This is probably one of the busiest areas of fish disease research at the present time. On the West Coast, for example, they have developed a commercially-marketed vaccine for immunizing young coho salmon against vibrio — a bacterial infection — prior to their stocking in saltwater rearing impoundments.

Keep in mind that the salmonids — the rainbow trout and the salmon — have been raised for something like 75 years and we still don't have a vaccine for them. We haven't even really begun to raise yellow perch yet, so we're just scratching the surface as far as perch are concerned.

Could you use PVC piping in your system and not worry about ending up with PCBs or any other chlorinated hydrocarbons in your fish?

There's a slim possibility. There is a problem in confusing PVC and PCBs. For those of you not familiar with these two terms, PVC is polyvinyl chloride, which is a compound they use to make plastic piping and PCBs, polychlorinated biphenyls, which are also found in plastics as plasticizing agents. PCBs may be a problem. With proper cleansing, preparations and rinsing, the residual amounts of plasticizers in most fish culture systems are quickly washed away. After all, we're talking about a system that is being continually rinsed. Perhaps at first there may be some residues on new material, but this is generally flushed out quickly. During a period of time the soluble materials will be leached out and removed from the system.

How do you detect fish that have parasites?

I didn't really discuss how to tell when a fish is sick. The very first indication is when the fish quits feeding. That's the first indication that something's wrong. Secondly, look for changes in behavior. Fish with parasites will sometimes scratch and rub themselves against the bottom of the tank. Other times they might actually spin in circles and have convulsions. Fish, like the yellow perch, generally swim with the dorsal fin — that's the one on the back — erect. If that's drooping and folded, the fish is not feeling well. Listlessness, lack of energy, sores on the side, little white pimples, color change — these all are indications of disease.

How do you pick out the sick ones when you have 150,000 head?

If you had 150 head of cattle in a pasture, you wouldn't have any trouble picking out the sick one. Same with the fish. Sick ones generally segregate themselves from the rest. The healthy ones either come to you, if they are accustomed to you, or they flee. The sick one is the one left behind. They are the ones that collect at the screen where the water goes out. They are the weak ones.

SUMMARY

Robert A. Ragotzkie

Director, Sea Grant College Program
University of Wisconsin

We have heard today about a system to raise yellow perch rapidly, efficiently and economically. We have heard about some of the problems you will encounter and we have heard some of the solutions. We have had the moment of truth with Professor Vilstrup, who led us through the cost analysis to the bottom line.

We learned something about the legal aspects of 20th century fish farming — about the licenses and permits needed — a situation I hope can be simplified as soon as fish farming becomes a reality.

From the food industry people we learned that yellow perch are in demand and that existing and potential markets will grow if the supply can be increased.

All of these factors are and will be the subject of our continuing Sea Grant research and advisory service program. This conference is the first exposure of the results of our aquaculture research program. Through this and future conferences and workshops we are inviting you to be partners with us in this exciting enterprise.

All of what we have heard today relates to perch and the Great Lakes. I think it might be useful to spend a few brief moments to place this perch aquaculture project in a larger perspective — a perspective beyond today and beyond the Great Lakes.

First of all, fish farming is not a new idea. Nearly 2,500 years ago in the year 475 B.C. a Chinese scholar, Fan Li, wrote the first treatise on fish culture. About 1,000 years ago Hawaiians were practicing fish farming to provide a private and reliable source of fish for their chiefs. They did this by building large enclosures at the edge of the sea, using large rocks to construct the dikes. The virtue of this system was that the sea water containing plankton and small organisms moved through the interstices of the rock dikes, but the larger crop fish were kept in while predators like barracuda and sharks were kept out. Thus the Hawaiians had a pretty efficient system.

Of course the Hawaiian system did not produce as much fish per gallon as Dr. Calbert, nor was the product as easily harvested. But it worked, and since the cost of labor was not a major consideration for Hawaiian chiefs, economics was not a serious problem.

So fish farming is an old idea, but until very recently it has not been widely practiced outside the orient and Indonesia. Large-scale, commercial fish farming was not developed for several reasons.

Probably the most important reason is that until recently it was believed that the wild fish resources of the sea were inexhaustible. Only in the past ten years has this belief been proved wrong. Even in the 1960s suggestions by fishery scientists that the capacity of the sea to produce was limited and that this limit was being approached fell on deaf ears.

Of course the concept of the sea as an inexhaustible supply of food was a part of the larger concept that the world could produce enough food to feed its people for the foreseeable future. No one at that time took seriously the idea that there might be a worldwide food shortage within 20 years — yet here we are. Wheat and corn surpluses are a problem no more, grain exports are today more a political issue than an economic one.

In 1972 the largest fishery in the world, the anchoveta fishery off Peru, suffered a major collapse — due partly to a severe occurrence of El Nino, which is a disastrous incursion of warm tropical water into the cold upwelling area off the Peruvian coast, and partly to overfishing. The anchoveta catch decreased from ten million tons per year to less than two million tons. The result of this collapse was a shortage of fish protein concentrate, which is used for poultry feed. This in turn put added pressure on soybeans as a source of protein, and so we see how the limits of the sea directly affected land-based food production.

Many other marine fisheries are showing serious signs of overexploitation. The whale fishery is essentially destroyed. Cod, plaice, haddock and other ground fish are becoming scarcer. Production of shellfish and crabs is decreasing because of deterioration in the water quality of coastal estuaries. International competition for migratory fish such as tuna and salmon has become intense — to the detriment of the fish stocks themselves.

Another reason that fish farming developed so slowly was the lack of economic incentive. It was cheaper to catch wild fish out of the sea and fish prices were not high enough to attract private capital into new and risky ventures.

Today these factors are changing and changing rapidly. The capacity of the sea to produce usable protein is being approached much faster than anyone expected and at the same time demand continues to increase. Food costs, and especially protein costs, are rising and will continue to do so as the real cost of energy and fertilizer is accounted for. So the economic incentive has developed.

With these changes has come a recent research emphasis on aquaculture. In the last several years the number of successful or promising aquaculture projects has grown from a few undersupported and undermanned projects to raise shrimp or oysters or even an abortive experiment in the late 1940s to raise clams for Campbell Soup Company, to a whole spectrum of scientifically sound and well supported projects. Several trout and salmon farms are on the verge of making money on the west coast, pompano and shrimp are being raised in Miami, closed-system oyster and clam production is being developed in Delaware and even the delicate and finicky Maine lobster is succumbing to culture methods being developed on both east and west coasts. In fresh water, catfish farming in the south central states has become a major source of income for farmers.

So we return to an old idea whose time has come. Although the response we received from Washington when Harold Calbert proposed four years ago to try to raise perch in Wisconsin was somewhat less than enthusiastic, all the signs pointed toward success. First, Professor Calbert had a pretty impressive track record raising chickens; second, the Lake Michigan perch fishery had essentially disappeared and the Lake Erie supply looked none too good; and finally the entire food picture — both land and sea — had begun to change from a surplus situation to a long-term shortage situation.

As you all learned today Professor Calbert and his group are on the way to success. He has shown that it is possible to raise marketable and tasty perch fast and cheaply in the laboratory. He now is ready to give his system a trial on a modest pilot plant scale. This pilot project will give him and his group an opportunity to solve the problems that will inevitably arise at the operational scale. The system will be refined and adapted to production methods — then we can think about perch farming as a viable and profitable business.

I know you are all anxious to see this pilot-demonstration project. So let me say thank you all for coming and I hope you found the day worthwhile.

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