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ATLANTIC SALMON REARING IN MICHIGAN

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SUMMARY

Atlantic salmon, received as small 2.8 inch fingerlings from Quebec, Canada were reared at the Wolf Lake State Fish Hatchery to approximately 6.0 inches from November 1972 to September 1973. The rearing took place in modified, indoor rectangular concrete tanks, equipped with baffles to induce a relatively fast water current along the bottom. Mortalities throughout the entire rearing period were less than one percent. Initial growth rate was very slow, but became as high as one inch per month when exposed to 54^{o} temperatures. Densities were allowed to increase up to 3.3 pounds per square foot of bottom space, but it was learned that density should be limited to 2 pounds per square foot in order to avoid significant reductions in growth rates and fin erosion. Based on what was learned, the Wolf Lake Hatchery appears to be capable of producing 200,000 to 250,000 one year old Atlantic salmon smolts annually.

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INTRODUCTION

After one century, the Atlantic salmon has returned to Michigan.

On April 19, 1873, the Michigan Fisheries Commission was established by Act 124. Their very first fisheries management action was the distribution of 20,000 Atlantic salmon fry to 15 different locations, of which the Au Sable River received 3,000 on May 30, 1873.

A few years after its inception it was discontinued due to a lack of demonstrable success.

Since the time of early fish culture, much has been learned about fish cultural techniques and the optimum utilization of the product in fisheries management. Fry stockings of anadromous fish species, such as the Atlantic salmon, have been replaced with smolt releases. A smolt will immediately start the migration down and out of the river into which it is released. Smoltification is primarily a function of size rather than age, and growth rate is influenced very greatly by water temperature. Hatcheries with very cold water must rear Atlantic salmon for two or even three years (in order to produce smolts). It has now been demonstrated that one year old smolts, or possibly even six month old smolts, can be produced in a hatchery. It only requires sufficient warm water to do so (Peterson, 1971).

After the initial attempts of an Atlantic salmon program by the early Fish Commission, Michigan waited nearly one hundred years for its second trial. A brief chronology of the actions taken thus far follows:

In May of 1972, 19,000 two year old smolts were brought to Michigan from the Domtar Hatchery located on the Madeleine River on the Gaspe peninsula of Quebec, Canada. The trip in Michigan fish planting units lasted 45 hours and the fish were released into the Au Sable and Boyne rivers upon their arrival. Approximately 875 two year old smolts, and 500 three year old Atlantic salmon were transported at the same time and were held at the Wolf Lake Hatchery for future brood stock.

In October of 1972, 20,000 one year old fingerlings were flown from the Gaspe Provincial Atlantic Salmon Hatchery of Quebec to Michigan. These fish have now been reared for one year at the Wolf Lake Hatchery.

In March of 1973, 35,000 Atlantic salmon eggs were flown to Michigan. These, again, originated at the Gaspe Provincial Hatchery. The Wolf Lake Hatchery continues to rear these fish to smolt size and a separate report will cover their hatchery performance.

On April 18, 1973, 10,000 Atlantic salmon eggs were received from Sweden. These are of the freshwater Gullspang strain. They were maintained under strict quarantine at the laboratory of the fish pathology unit at Grayling for six months, recently received a clean bill of health, and have now been transferred to Wolf Lake for further rearing. Here too, a separate report will cover their history in the hatchery.

In May of 1973, another shipment of two year old smolts (15,000) was made from the Domtar Hatchery to Michigan. All of these were directly released into the Boyne River.

The success and potential magnitude of the Atlantic salmon program in Michigan depends, to a large degree, on the capability of the Michigan hatcheries to produce eggs and smolts. The remainder of this report covers the rearing of approximately 20,000 smolts received at the Wolf Lake Hatchery in October of 1972 and includes certain recommendations.

METHODS

The fingerlings were shipped to Michigan by air in plastic bags placed in styrofoam containers. They arrived on October 30, 1972, in 51 boxes, each containing approximately 2.5 gallons of water. They were in transit for 12 hours. Upon their arrival, it was noticed that some fish appeared to be near the surface of the water, and it was suspected that much of the oxygen was consumed. Fortunately the temperature was a low of 38°F. There were no losses. They were transported from the Kalamazoo Airport by station wagon to the Wolf Lake Hatchery, a 15 mile trip. The fish weighed 168 to the pound and averaged 2.8 inches in length.

The Wolf Lake Fish Hatchery, located ten miles west of Kalamazoo, receives its water supply from springs. The main spring located above the facility is covered and produces 1100 gpm at a constant 51°F. The second spring (750 gpm) is situated below the raceway complex and its water is used for the raceway complex only. The second spring is collected in perforated tile flowing to a sump where it is pumped to the aeration chamber above the raceways. These are the basic water sources for the salmonid production facilities of this hatchery. This hatchery also has an extensive series of natural rearing ponds for the production of warmwater fish species.

There are two hatchery buildings which house jar incubators and rectangular concrete rearing tanks. The salmon fingerlings were placed in the rearing tanks of hatchery building No. 1. The water to the hatchery buildings originates at the underground spring. It is aerated to 90 percent saturation at 51°F and enters the buildings by gravity. The water is high quality with a pH of 8.0 and a total alkalinity of 172 ppm. It remains very clear throughout

the year. Initially three tanks were used, designated as tanks no. 1, 2 and 3. The inside tank dimensions are: 25.5 feet by 3.3 feet wide by 2.5 feet deep. Tank no. 1 received 10,616 fish weighing 85.0 pounds, tanks no. 2 and 3 each received 5,010 fish weighing a total of 39.1 and 39.4 pounds respectively. Tanks no. 1 and 2 were modified with plywood baffles, positioned 2.5 feet apart and 0.75 inches off the bottom (Figure 1). Initial depth was maintained at 14 inches and the flow at 50 gpm per tank, providing an exchange rate of nearly 4 per hour. Tank no. 3 was equipped with similar baffles at the end of November. From that time on all salmon were reared only in modified or "baffled" tanks.

On January 5 the depth of the water in tanks no. 2 and 3 was increased to 23 inches and maintained that way during the remaining indoors rearing cycle. The objective was to provide a longer time period of feed suspension to promote better utilization of the food. Tank no. 1 was equipped with an automatic Nielson feeder, 8 feet long, and suspended above the upper part of the tank. It was programmed for feedings at 15 minute intervals day and night. Tanks no. 2 and 3 were hand fed, 8 hours per day. Initially the fish in all tanks were overfed and unused food accumulated daily at the foot of the tanks. By January 15 all three tanks were on automatic feeders. Throughout the rearing period the Oregon moist pellet was fed. The fish were kept in darkness. Shades completely covered the windows and the fluorescent lights were used only during the time the fish culturists worked in the room. At the end of January all fish were graded into two sizes, 93 per pound and 155 per pound.

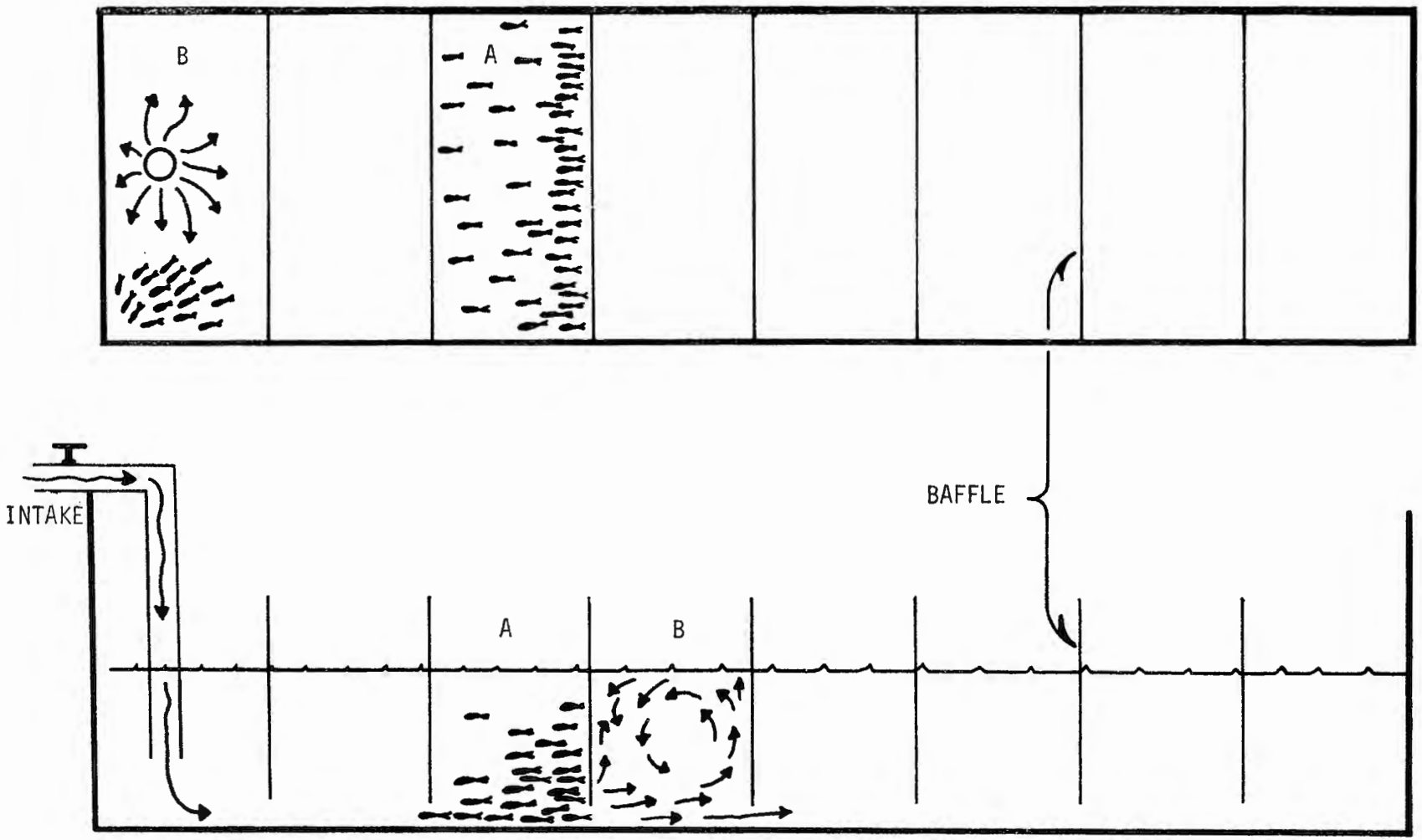
The following distribution was made:

Tank no. 1 - 6,045 fish @ 155/lb. total 39 pounds.
Tank no. 2 - 5,580 fish @ 93/lb. total 60 pounds.
Tank no. 3 - 5,580 fish @ 93/lb. total 60 pounds.
Tank A - 1,395 fish @ 93/lb. total 15 pounds.

Tank A is a small concrete tank located in hatchery building no. 2. Its inside dimensions are 9.7 feet by 3.0 feet wide and 2.5 feet deep. It was similarly equipped with baffles and supplied with 20 gpm of heated, 54°-55°F water (same spring water). These fish were maintained in the heated water during February and March after which they were returned to a standard tank (no. 9) in the hatchery building no. 1. Again the tank was modified with baffles and maintained at a depth of 14 inches and a flow of 50 gpm.

However, a few times during the rearing cycle the baffles were slightly raised when it was observed that the larger fish turned sideways when they were passing under them. The maximum distance ever attained was approximately 1.25 inches.

SCHEMATIC OF TANK - TOP VIEW - NO SCALE
SHOWS TYPICAL FISH DISTRIBUTION (A) AND INTAKE FLOW (B)



SCHEMATIC OF TANK - SIDE VIEW - NO SCALE
TYPICAL FISH DISTRIBUTION (A) AND WATER FLOW (B)

FIGURE 1. MODIFIED REARING TANK

The velocity immediately behind the baffles is determined with the following equation:

$$V = \frac{GPM}{3.125 \times a_1}$$

V = velocity in feet per second
GPM = gallons per minute flow
a_1 = cross sectional area in square inches
3.125 = GPM per one cubic inch per second

At a baffle distance of 0.75 inches off the bottom the velocity is 0.54 feet per second.

At the end of July, tanks no. 2 and 3 were split since it was felt that their density had built up to an undesirable level.

Mortalities were recorded daily.

Disease inspections were performed on January 10 and August 20. Observations on the general conditions of the fish and their behavior patterns were made throughout the rearing period.

RESULTS

The growth rate started off poor with about an average length increase of slightly over 0.1 inch per month for the first three months (Figures 2, 3 & 4). During this time the fish showed a significant size range and at the end of this period they were therefore graded into two groups. Nearly one third averaged somewhat less than three inches in length while the remaining two thirds averaged almost three and one half inches in length.

It was at this time that 1400 fish were placed in heated water, maintained at 54 to 55°F. All the smaller fish, 6,039, were placed in tank no. 1. Table I summarizes the data on growth rates and conversions, Table II shows total numbers, weights and densities attained throughout the rearing cycle. Early July tanks no. 1, 2 and 3 were thinned by 50 percent since densities became quite high and an increasing problem with fin-erosion was observed. The fish also decreased their growth rate by nearly 50 percent during June which did not occur in the low density tank no. 9, although it did show a small decrease from a 0.84 inch increase in May down to a 0.75 inch increase in June (Table II).

The maximum density reached was 3.3 pounds per square foot resulting in 75, 5.5 inch fish per square foot of bottom space. The growth rate responded favorably after thinning, while it significantly declined in the low density tank no. 9. Yet this low density remained at less than two pounds per square foot in this tank.

Food conversions were particularly unfavorable during the first four months. (Table I and Figures 2, 3 & 4).

TABLE I Conversions And Growth Rates Of Atlantic Salmon At The Wolf Lake Fish Hatchery

	TANK #1			TANK #2			TANK #3			TANK A AND #9		
Date	Conv.	Length * Inch	Monthly Length Gain	Conv.	Length	Monthly Length Gain	Conv.	Length	Monthly Length Gain	Conv.	Length	Monthly Length Gain
End Nov.	4.16	3.09	.17	5.6	3.06	.14	5.4	3.07	.15			
End Dec.	14.3	3.16	.07	7.3	3.22	.16	neg.	3.04	-.03			
End Jan.	7.65	3.29	.13	13.0	3.30	.08	16.25	3.10	0.6			
1st Feb.	-Grading- 2.87			-Grading- 3.41			-Grading- 3.41			Tank-A = Heated Water 3.41 54°-55°F		
End Feb.	6.86	3.10	.23	7.66	3.62	.21	11.88	3.55	.14	7.93	3.61	.20
End Mar.	2.40	3.45	.35	2.59	3.96	.34	3.42	3.83	.28	2.64	4.67	1.06
										Tank #9		
End Apr.	2.42	3.82	.37	2.79	4.30	.34	2.96	4.19	.36	3.26	5.35	.68
End May	1.39	4.42	.60	1.28	5.00	.70	1.07	5.05	.86	1.83	6.19	.84
End Jun.	1.87	4.91	.49	2.23	5.35	.35	2.40	5.42	.37	1.89	6.94	.75
End Jul.	1.80	5.59	.68	2.01	5.78	.43	1.88	6.00	.58	5.19	7.26	.32
End Aug.	1.63	6.40	.81	2.12	6.40	.62	1.64	6.74	.74	3.96	7.71	.45
End Sept.												

*For length determination the length/weight values for lake trout were used. Fish, upon arrival at end of October were 168/lb. - 2.80 inches.

TABLE II Total Weights In Pounds And Densities In Pounds Per Square Foot Of Rearing Space Of Atlantic Salmon At The Wolf Lake Fish Hatchery

	TANK #1				TANK #2				TANK #3				TANK A AND #9			
End of Month	No. Fish	Total Wt.Lb.	Lbs. per Sq.Ft.	No. per Sq.Ft.	No. Fish	Total Wt.Lb.	Lbs. per Sq.Ft.	No. per Sq.Ft.	No. Fish	Total Wt.Lb.	Lbs. per Sq.Ft.	No. per Sq.Ft.	No. Fish	Total Wt.Lb.	Lbs. per Sq.Ft.	No. per Sq.Ft.
November	10,616	85.0	1.0	126	5,006	39.1	0.5	60	5,005	39.4	0.5	60				
December	10,608	91.5	1.1	126	5,003	45.5	0.5	60	5,003	38.2	0.5	60				
January	10,603	103.0	1.2	126	4,968	49.0	0.6	60	4,991	41.0	0.5	60				
	Grading - Redistribution				Grading - Redistribution				Grading - Redistribution				Tank A 54°-55°-Feb.&March Tank #9 51° Apr.-Sept.			
February	6,039	49.5	0.6	76	5,578	72.4	0.9	66	5,579	68.0	0.8	66	1,394	17.9	0.6	47
March	6,036	67.8	0.8	76	6,432	109.0	1.3	76	6,320	97.2	1.2	75	1,393	38.7	1.3	47
April	6,033	91.4	1.1	76	6,432	139.8	1.7	76	6,317	126.3	1.5	75	1,391	58.0	0.7	17
May	6,030	142	1.7	76	6,422	219.2	2.6	76	6,310	221	2.6	75	1,389	89.6	1.1	17
June	6,013	194	2.3	72	6,412	267.2	3.2	76	6,302	274	3.3	75	1,389	126.2	1.5	17
July*	2,997*	143	1.7	36	3,203*	169.0	2.0	38	3,142*	183	2.2	37	1,270	132.3	1.6	15
August	2,990	213	2.5	36	3,193	228	2.7	38	3,132	261	3.1	37	1,267	158.0	1.9	15
September																
October																

*Thinning - 50 percent.

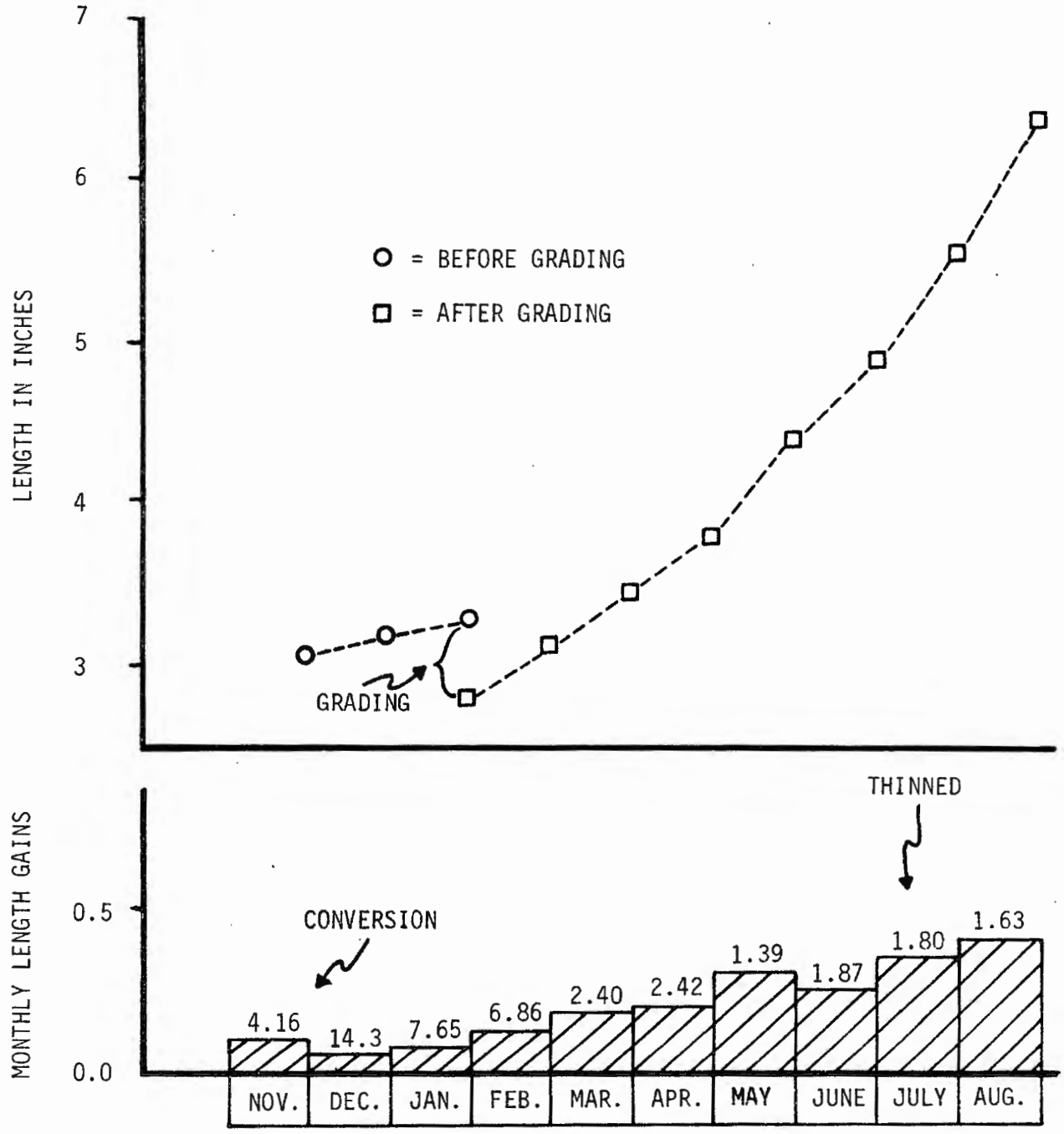


FIGURE 2. GROWTH-RATES; MONTHLY LENGTH GAINS AND CONVERSIONS. TANK NO. 1

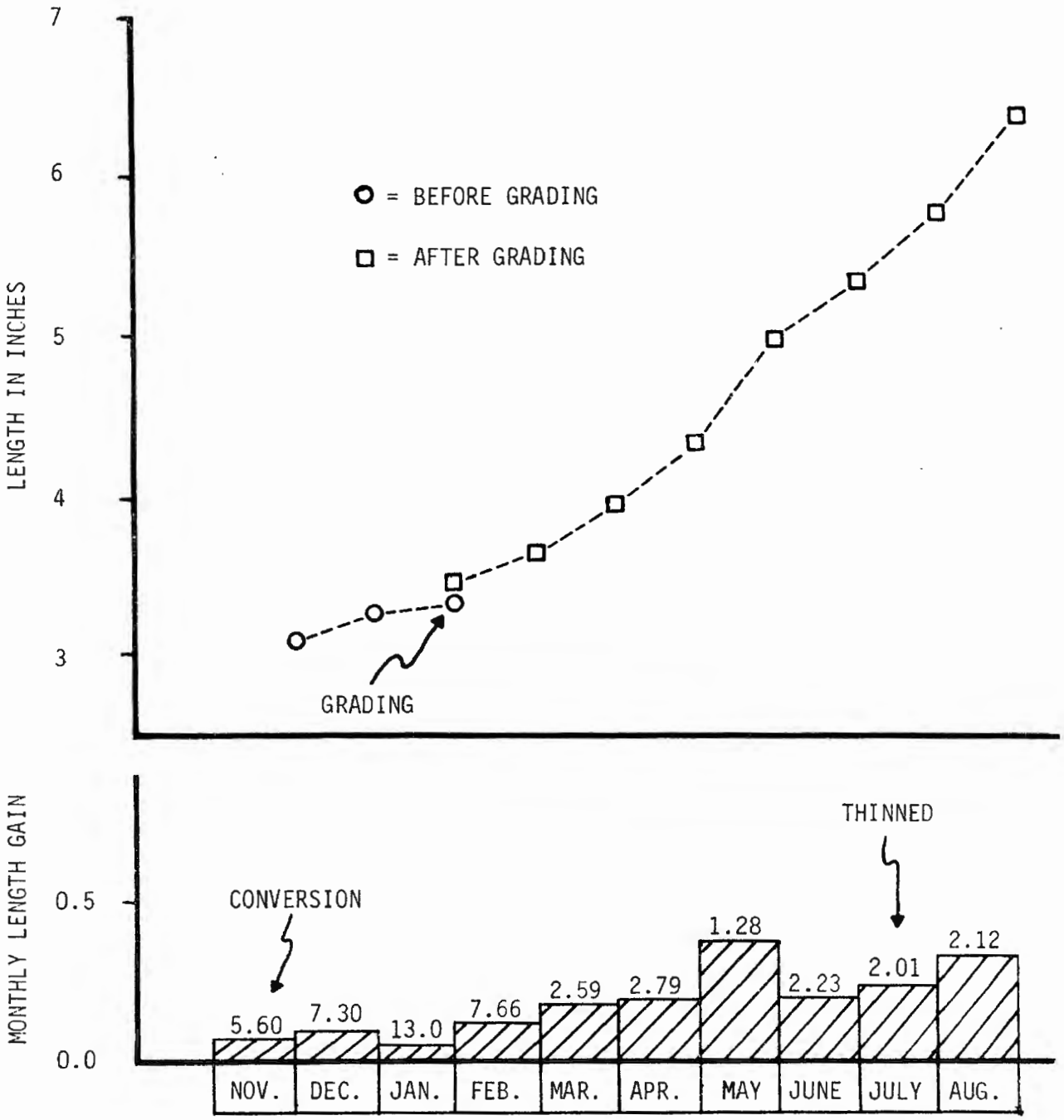


FIGURE 3. GROWTH-RATES; MONTHLY LENGTH GAINS AND CONVERSIONS. TANK NO. 2

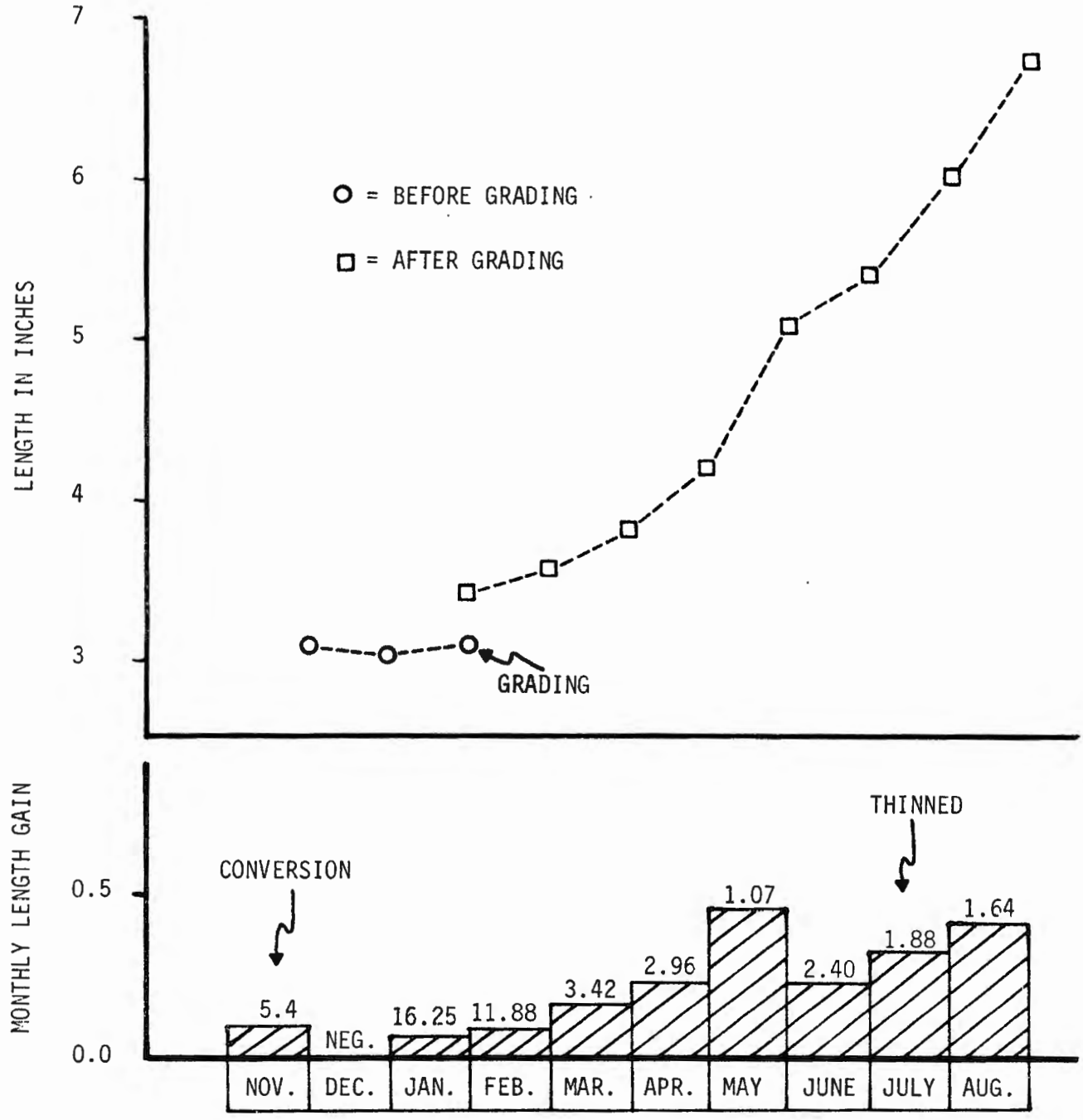


FIGURE 4. GROWTH-RATES; MONTHLY LENGTH GAINS AND CONVERSIONS. TANK NO. 3

The fish were definitely over supplied with feed during that time. They were shy in their feeding behavior but food was made available at frequent intervals. The current created by the baffles moved the unused pellets to the foot of the tank. After a rather long acclimatization period the fish became more at ease and eventually would vigorously break the surface when feeding, and would also feed actively throughout the water depth. Their normal distribution through the tank was quite typical (see Figure 1), with fewer fish in the lower compartments than the upper. However, they did not appear to take up permanent residence in any particular compartment or location within the compartments. Part of the food provided in the upper one third of the tank by an automatic feeder would move along the bottom to the lower end and be picked up by the fish as it came by.

As the density approached two pounds per square foot of bottom space, signs of fin erosion appeared. Conversion and growth did not seem to become affected until the density approached three pounds per square foot (Tables I and II). Throughout the rearing period the mortalities were insignificant. The January 10 disease inspection report A. liquefaciens, the August 20 inspection reported the presence of IPN, A. Liquefaciens and enteric organisms. Disease problems were not encountered however.

By July some smoltification occurred. Interestingly, there appeared to be fewer to smoltify (5 percent) in the low density tank no. 9 which contained the largest fish. Smoltification in the other tanks was estimated at 10 percent. The conditions factor, as observed by eye, appeared to be greater in tank no. 9.

DISCUSSION

One year of rearing Atlantic salmon fingerlings in the spring water at Wolf Lake Fish Hatchery has provided some interesting information.

The poor growth rate during the first four months was probably the result of a rather long adjustment period, coupled with the fact that it coincided with a normal, seasonal growth reduction.

However, Peterson does not feel that the Atlantic salmon need a "rest period" during the cold season (Peterson, et. al 1972).

The poor conversions during these four months reflect primarily wasted food, rather than the inefficient utilization of the food by the fish.

It is possible, however, that more of the food would have been used (better growth) if it had been made available through very frequent feedings under conditions of light. This technique was used in Sweden to grow one year old smolts. In this Swedish experiment feeding was done over a 24 hour period every 15 minutes for a duration of 15 minutes with automatic feeders under constant light. No detrimental

effects were encountered and the author felt that the increased growth rate was a deterrent against parasites and other diseases. This accelerated feeding schedule was only applied during the first few months, after which the fish had to be transferred to the outdoor facilities supplied by river water. During this time the temperature was elevated up to 54°F but gradually reduced again to about 48°F in order to acclimatize the fish to the prevailing river water temperature. (Peterson, 1972).

The fish at Wolf Lake finally underwent an adjustment and their feeding behavior changed from one of "secrecy" to one of almost unrestrained activity, which included breaking the surface when food was administered.

Based on the information thus far it is our opinion that one year old smolts can be produced at the Wolf Lake Hatchery with little difficulty. This is in agreement with Peterson (1972) who states "In hatcheries with a good supply of well water with a temperature of about 50°F, the production of still larger one year old smolts must be an easy task."

In his attempts to produce one year old smolts, only four percent of the fish reached more than 140 millimeters (5.5 inches) in length, yet the returns were very encouraging. However, a fantastic return of over 40 percent was experienced from fish which were larger than 140 millimeters. Although just a trend, it is of great interest and, according to Peterson, further experiments with real large one year old smolts should be performed.

To meet the challenge of one year old smolts at Wolf Lake, one of the following conditions must be met:

First, if eyed eggs are imported from Quebec, a slight temperature elevation from 51°F to 55°F for several months during the early rearing should be provided. The accelerated growth rate this triggers appears to continue for a few months after the fish have been returned to the 51°F water (Table I, Figure 5).

Secondly, if Michigan develops its own egg source, incubation can start on 51°F water and be completed in about one month. Feeding of fry can then start in February rather than May or June allowing a three month head start. Possibly large one year old smolts can then be produced without heating any of the water.

Based on the observations we have made, we recommend a maximum rearing density of up to 2.0 pounds per square foot of bottom space, for fish five inches and larger.

This is somewhat higher than Peterson's recommendation of 1.5 pounds (Peterson, et. al 1972) and significantly higher than Piggins' who suggested a density of less than .75 pounds per square foot (Piggins, 1971).

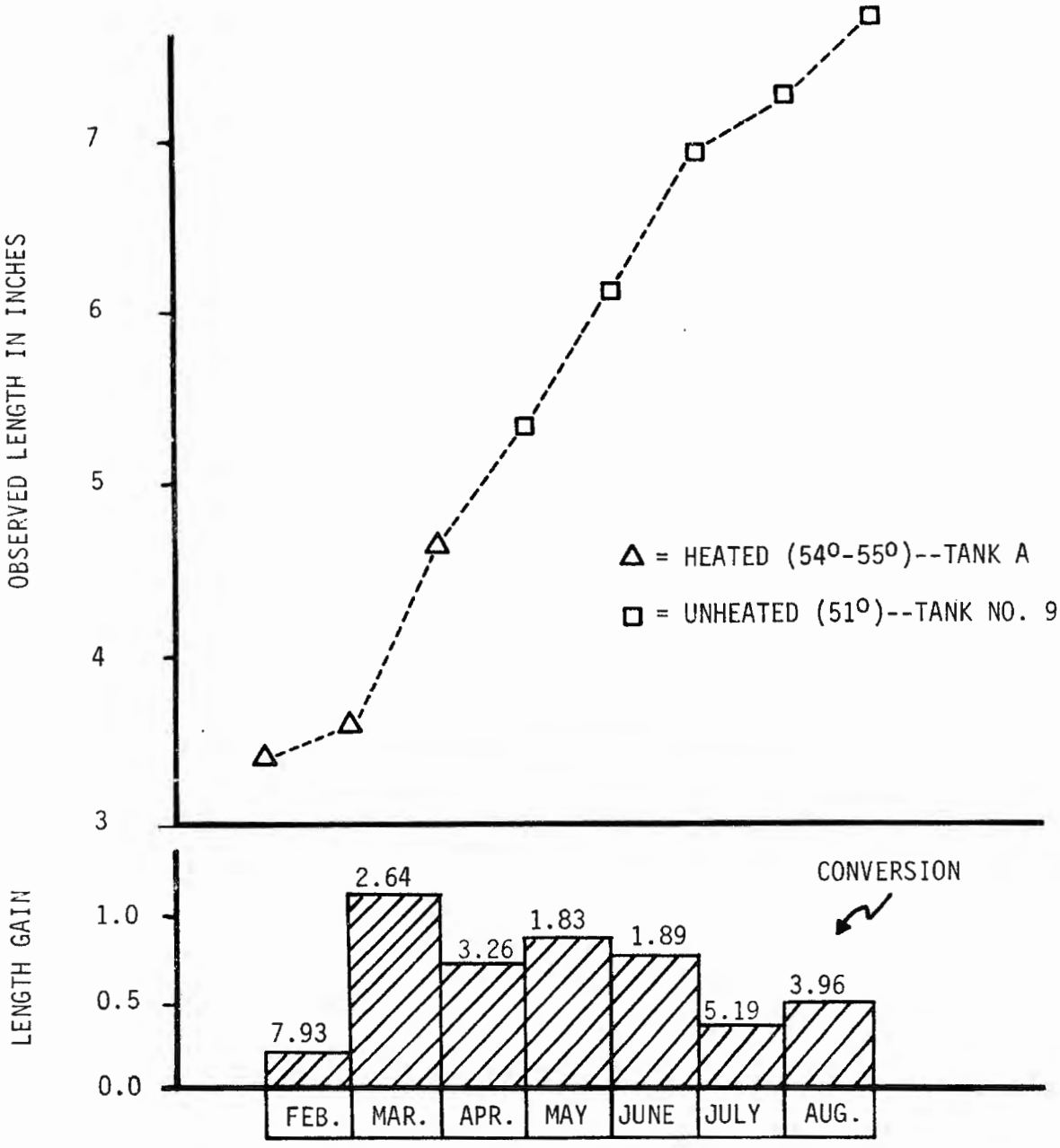


FIGURE 5. GROWTH-RATES; MONTHLY LENGTH GAINS AND CONVERSIONS.

The fact that these relatively high densities of 2.0 pounds per square foot are possible could be the result of the baffles in the rectangular tanks. The salmon in "baffled" tanks occupy vertical space as well as bottom space, in particular just in front of each baffle (Figure 1).

The induced velocities along the bottom result in a more or less perpendicular upward current in front of each baffle. This, we suspect, induces the fish to occupy vertical space. If this is an advantage the baffles provide, it appears to be not the only one. The tanks also become fully self-cleaning, constantly and rapidly removing any solids to the foot of the tank. The current also gives direction to the fish, makes them exercise and keeps the food moving. However, this modification works properly only if relatively large volumes of water pass through the tank.

The flow should be great enough to create, at least, a slight movement of water on the surface. This movement is indicative of a continuous and complete water change between the baffles which avoids areas of stagnation. Additional studies to determine the full merits of the baffles, their proper positions relative to each other and the bottom etc. are needed, and will be conducted.

If baffles are considered in hatchery design, it will be important to consider them along with efficient water utilization. At the Wolf Lake Hatchery the production of the Atlantic salmon was very poor in terms of flow and were at best only five pounds per gallon per minute. However, the quality of the used water, it is assumed, was still sufficiently good for at least an additional five pounds of production, which would result in a total production of ten pounds per gallon per minute.

It is our projection that the Wolf Lake Hatchery can produce approximately 250,000 one year old smolts annually or a total of 25,000 pounds of Atlantic salmon smolts.

The quality of the fish reared at Wolf Lake appears to be high, but the real test, as Peterson has stressed, will be their survival and return after release (Peterson, et. al 1972). Mortalities have been as low as one percent throughout the nearly one year of rearing.

Fin erosion was the most noticeable adverse condition when densities approached 2.0 pounds per square foot of space. This condition worsened as densities were allowed to increase to as high as 3.3 pounds per square foot in tank no. 3 (Table II). However, before these densities were reached the growth rates started to decrease. They picked up again immediately after thinning, which was done in the beginning of July (Table I and figures 2, 3 & 4).

CONCLUSION AND RECOMMENDATIONS

1. The Wolf Lake Fish Hatchery, as it appears to us now, would be capable of producing approximately 250,000 high quality one year old Atlantic salmon smolts (10/lb.).

2. The modified, or baffled rectangular, longitudinal rearing tank appears to be very suitable for the rearing of Atlantic salmon smolts.

3. The Oregon moist pellet is capable of producing quality hatchery Atlantic salmon smolts, based on observed growth rates, mortalities and diseases.

4. Tentatively the rearing densities are recommended to be 2.0 pounds per square foot of bottom space for fish five inches and larger.

5. We recommend that further studies be conducted with the modified tanks, with the Atlantic salmon which originated from eyed eggs shipped to Wolf Lake and, as soon as possible, with the production of one year old smolts from Michigan's own sources.

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