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Cage Culture Of Salmonids
Type of Study: Primary Production
Fisheries, Acquaculture General
Date of Report: 1989
Author: Saskatchewan Agriculture Dev Fund
Catalogue Number: 3-28-10

TABLE OF CONTENTS

L 1ST OF FIGURES

PAGE

LIST OF TABLES PAGE

ABSTRACT

Production techniques, site selection, survivability, feed conversion and growth rates were examined for rainbow trout (*Salmo gairdneri*), Arctic char (*Salvelinus alpinus*), and brook trout (*Salvelinus fontinalis*) reared in cages in northern Saskatchewan. The project took place at Devil Lake during the period of June 1989 to September 1989.

Out of the 85,784 fish stocked in June and July, only 53.5% (45,923 fish) remained at the end of September. High water temperatures contributed to gill disease, fungal infections and a suspected *Aeromonas* spp. infection. A maximum water temperature of 24.5oC was measured, and no distinct thermocline was found in the lake. Mortalities were estimated at 24.7% (21,200 fish) and unaccountable losses and escapes at 21.7% (18,656 fish).

55.7% of the rainbow trout stock survived the extremely high water temperatures, all the Arctic char died, and 2% of the brook trout stocked survived.

Average fish weight at the beginning of September ranged between 58.1 g to 141.7 g. This is well below the marketable weight of 280 g. Poor growth and feed conversion ratios occurred due to high water temperatures and disease outbreaks.

1. PROJECT OBJECTIVES

To compare and examine cage culture production of Arctic char (*Salvelinus alpinus*) and brook trout (*Salvelinus fontinalis*) with rainbow trout (*Salmo gairdneri*) reared under northern Saskatchewan conditions.

2. INTRODUCTION

Cage culture of rainbow trout has been investigated over the last 5 years in northern Saskatchewan lakes (Ivanochko, 1987, 1989). Progress continues to be made in developing a technology suited for fish culture under northern Saskatchewan environmental conditions.

Very little information is available on the cage culture production of fish species other than rainbow trout in Saskatchewan. 1989 was the first year that certified disease-free stocks of Arctic char and brook trout were available from the nearest hatcheries. Orginally, Atlantic salmon (*Salmo salar*) were to be included in the project, but were later found unavailable. Instead, the cage culture of triploid rainbow trout will be examined when they become available. The general belief of culturing species other than rainbow trout in northern Saskatchewan is that diversification may help reduce the dependence on rainbow trout markets in the case of overproduction and the decline of market prices (Homer, 1989).

During the summer months of 1989, 82,284 rainbcw trout, 1000 Arctic char and 2500 brook trout were obtained from four difference hatcheries and stocke-d into Kames cages at Devil Lake, in northern Saskatchewan.

3. PRODUCTION METHODS

3.1 Site Selection

Devil Lake is part of the northern Churchill river sytem and is situated between two sets of rapids (Little Devil, Murray Rapids and Otter Rapids) (Figure 1). It is located approximately 3 km north from the town of Missinipe, and 80 km north from the town of La Ronge. The lake was chosen in the hope of high saturated dissolved oxygen coming from the rapids. It was also hoped that relatively low water temperatures (below 18°C) would be experienced during the hot season. In addition, water depth was found to be over 20 feet in many areas.

The site is also closer to the processing facility in La Ronge than the previous site at Besnard lake, and power will be available at a later date when the site is further developed.

An initial site was chosen for setting UP the Kames cages and was located 1/2 km from a public dock. Later, this site was found unsuitable because of heavy wind and wave action pushing cages into shallower water and causing nets to drag along the bottom. On July 13, eleven cages (with fish) and a trailer on pontoon5 (Figure 2) were moved to a more suitable site situated in a sheltered area with a water depth between 25 to 30 feet.. Figure 3 illustrates the final arrangement of the cages, and water current readings found near the cages. The water current was found to be significantly higher than at last year's site, Besnard Lake. The trailer on pontoons provided housing for the on-site worker. Before winter, it is proposed to have built on shore, a feed storage facility, insulated housing for staff, and a road cleared from the site to the highway.

3.2 Equipment

Kames cages, imported from a British Columbia supplier, were constructed in La Ronge and used at Besnard Lake last year (Figure 4). Thirteen of the twenty-two cages at Besnard Lake were dismantled and transported to Devil Lake at which time they were reconstructed and arranged for the stocking of the fingerlings. The cages were transported to Devil Lake at various times during the summer months when new shipments of fingerlings were to arrive; or stocking densities needed to be lowered by dividing the fish into more cages. The floating cage system has styrofoam blocks placed under the walkways which provided the flotation. The cages were 4.9 m x 4.9 m (16 x ,16 ft) and consisted of a metal frame and treated lumber. Each individual cage was attached to a steel cable by an eye-bolt clamp. The steel cable stretched across a bay and was anchored to rocks on the shore. Engine blocks were used as additional anchors to reduce cages drifting into shallower areas by wave and wind action.

Various sized nylon-mesh nets were used during the course of the summer months (Table 1). A 1/2 inch mesh net was used initially until the fingerlings reached a length of 5 to 6 inches at which time most of the nets were changed with 3/4 inch mesh. An exception to this was the Arctic char, which were placed in a 1 inch mesh, because they were considerably larger (9 inches) than the other fingerlings. Larger sized mesh allowed for more water movement through the cages thereby providing better water quality for the growing fish. The depths of the nets varied with the size of the mesh and resulted in a wide range of volumes available for the fish. Bleach bottles filled with sand were used as anchors to keep the nets square.

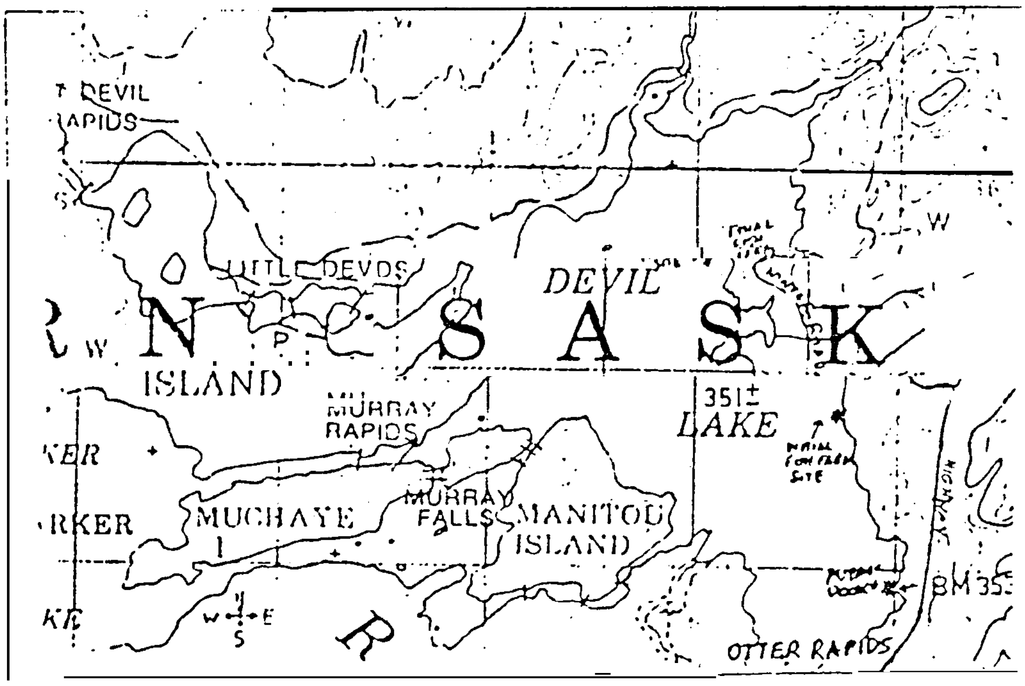


Figure 1. Map of Devil Lake illustrating the location of the cage farm, the public dock, and the access roads.

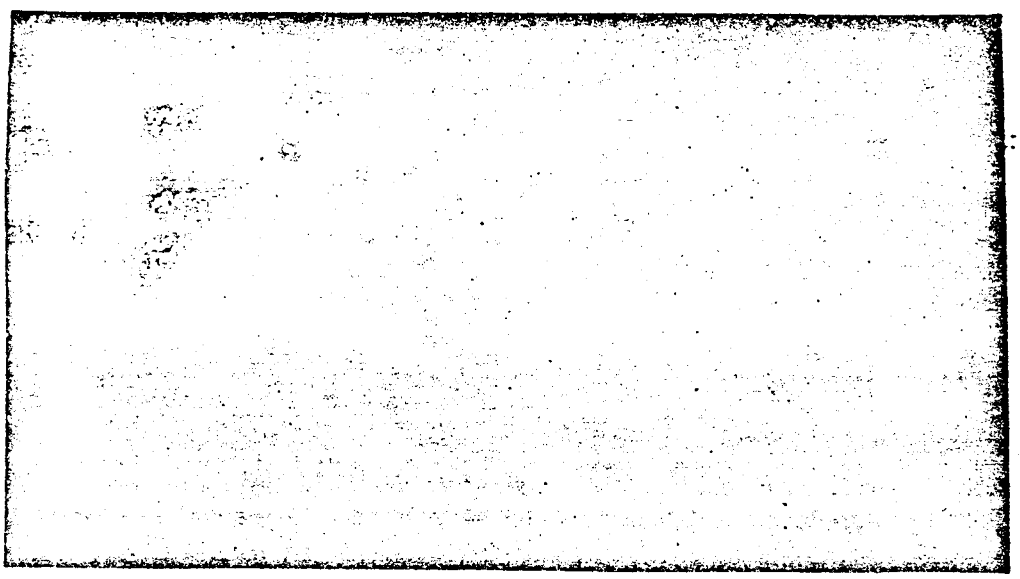


Figure 2. A pictorial representation of the trailer on pontoons and the cages , at the initial site on Devi 1 Lake.

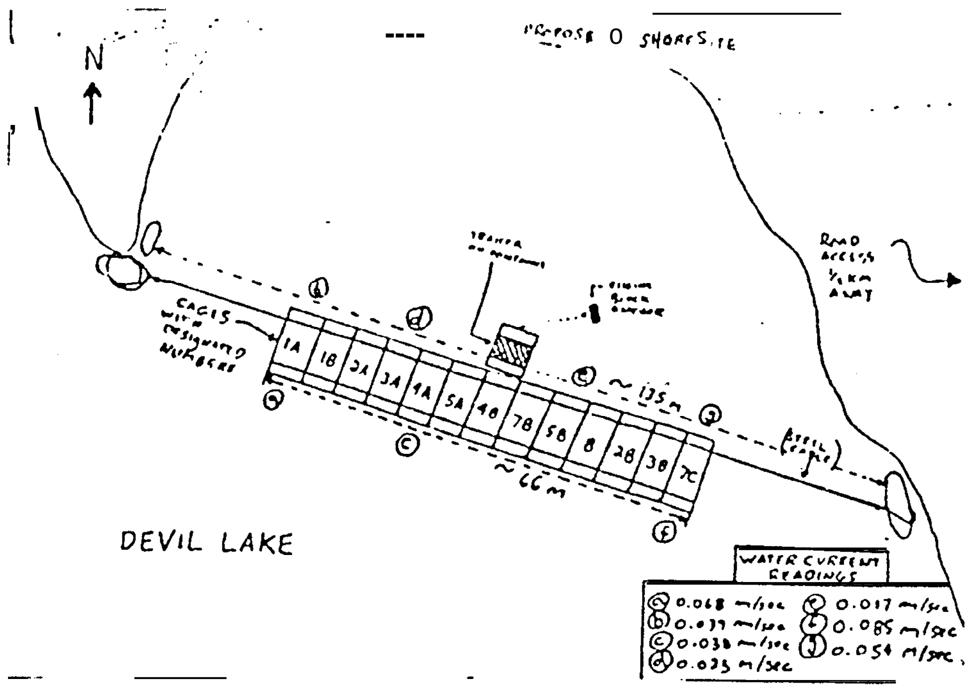


Figure 3. The final arrangement of the fish cages, and the water current readings found at Devil Lake.

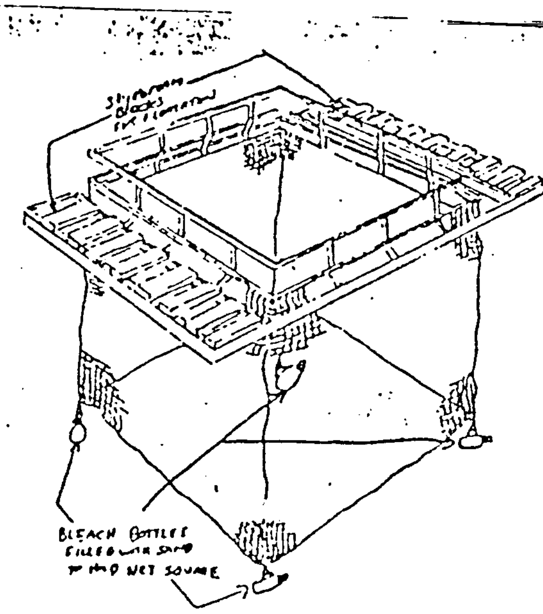


Figure 4. The structure, net, and anchors of a Kames cage (Christensen, 1988).

Table 1. The nets used for the various sized fingerlings stocked at Devil Lake, with resulting volumes and loading densities.

Net Mesh Size (inches)	Fingerling Size (inches)	Depth (m)	Volumes (m^3)	Loading Size Densities (kg/ins)
1/2	< 5	3.1 (lo ft)	56-68	2-4
3/4	5-7	4.6 (15 ft)	71-97	3 - 1 o
1*	> 7	9.2 (30 ft)	182	0.1-0.6

* Used by the Arctic char

Table 2. Hatchery stocking summaries for Devil Lake.

Hatchery	Stocking Date	Cage #	Stocking #	Species
Trout Haven Ranch (Buffalo Gap, South Dakota)	June 14, 1989	1A,1B,2A,	40,000	Rainbow trout
McNabb Trout Farm (Saskatoon, SK)	June 21, 1989	6	1,000	Arctic char
Keet Trout Farm (Saskatoon, SK)	June 21, 1989	8	2,500	Brook trout
F.Q. Aquafarms (Nipawin, SK)	July 1, 1989	4A,4B,5A 5B	22,284	Rainbow trout
McNabb Trout Farm (Saskatoon, SK)	July 8, 1989	7A,7B,7C	20,000	Rainbow trout
TOTAL:		15 cages*	85,784	

* Only 13 cages were actually needed.

Demand feeders were installed midway into the summer for six cages and for the rest of the cages near the end of summer. Hand feeding was mainly relied on during the project in order to observe the fish during the hot spells. Feed was weighed out in buckets using an electronic balance. This balance was also used for fish weigh-ups.

Water quality monitoring used a variety of equipment, a YSI Model 51B Dissolved Oxygen Meter, a Price's Electric Pipe Current Meter, a max-min mercury thermometer, a Secchi disk and a pH Hach kit. Water quality testing was limited to the availability of the equipment, and in some instances was not very reliable.

3.3 Fingerlings

Several fingerling shipments were made for the project from four different hatchery sources (Table 2). The fish were transported by truck in insulated tanks with hinged, vented lids, 12 volt aerators and oxygen were providea. Every effort was made to minimize stress during transport. Densities in the tanks were kept low and temperatures were kept cool while oxygen was supplied. Fingerlings were removed from transport tanks with dip nets and stocked into available cages at Devil Lake. Temperature and dissolved oxygen were monitored in the transport tanks and every effort was made to acclimatize the fish to the lake water temperature ie. stocking fish during the night when the lake temperature was the coolest during a summer hot spell.

On June 14, 40,000 rainbow trout fingerlings (4-5 inches) were transported from Trout Haven Ranch in Buffalo Gap, South Dakota, and stocked into 3 cages in Devil Lake. These fish cost approximately $0.21 each (including transport) . The fish were later divided into 3 more cages during the course of the summer (on July 11, 13, and 15).

On June 21, 1000 Arctic char (9 inches) and 2500 brook trout (4-5 inches) were transported to Devil Lake from McNabb and David Keet Trout Hatcheries (Saskatoon) respectively. The cost (including transport) of each Arctic char and brook trout fingerling was S1.50 and $0.50 respectively. Two cages were used for stocking each species,

On July 1, 22,284 rainbow trout fingerlings (3-4 inches) were transported to Devil Lake from F.Q. Aquafarms, Nipawin, Saskatchewan and initially stocked into 2 cages, The fingerlings cost approximately S0.27 each (including transport). Two other cages were later used to divide the fish into lower densities (on July 30, and August 16).

Therefore, a total of 85,784 fish were stocked into Devil Lake during the early *summer* months and cost approximately $23,960 (including transport).

3.4 Feed Rations

Feed requirements were estimated to a percent body weight fed per day based on fish size and water temperature. Using this as a guide, fish were hand-fed to near satiation daily. Fish were generally starved the day before, the day of and the day after any handling events ie. weigh-ups, cage splitting, etc. to minimize stress and oxygen demand. In addition, less feed was given under other stressful conditions ie. extremely high temperatures and disease. Daily records were kept on the type and amount of feed fed to each cage. Feed was obtained from Martin Feed Mills Ltd. in Elmira, Ontario and stored in Saskatoon. When feed was required for the Devil Lake site, it was picked up from Saskatoon by a marketing and fish delivery van. The feed was in a pelleted form of varying size depending on the size of fish (Appendix 1 & 2), and was packaged in 25 kg plastic bags. At the site, feed was stored outside the trailer covered with a tarp or put in large garbage cans. Demand feeders were later installed for the cages and enabled the fish to self-feed by hitting a descending marked wire attached to a feed hopper. This action released small amounts of feed off of a plastic platform. Past observations have indicated better growth rates, lower feeding conversion ratios, a more even distribution of growth within cages and less labour required when using demand feeders instead of hand feeding (Ivanochko, 1987, Christensen, 1988). Demand feeders were not used initially at Devil Lake in order to observe the fish feeding during the high water temperatures and disease outbreaks. Demand feeders were filled twice per day with 1/2 the daily ration each and hand feeding varied between three to six times per day.

3.5 Monitoring

i. Fish Inventories

Fish weigh-ups were conducted five times during the summer, on July 5 & 30, August 13 & 29 and September 12, 1989. Approximately 1-2% of the fish in each cage were weighed to give a representative weight for all the cages. The representative weights were used to determine the average weight per fish and the number of fish estimated in a cage. Accumulated mortalities were deducted to estimate the size and number of the standing stock. In addition, weight gains, feed conversion ratios and loading densities were extracted from the information gained. The weigh-up procedure was relatively simple using dip nets, garbage cans and a “touchy” electronic balance. Fish were not weighed at the time of stockings. Initial weights and loading densities were estimated by the use of a length-weight table (Piper, R.G., L-B. McElwain, L.E. Orme, J.P. McCraren, L.G. Fowler, and J.R. Fish, 1982). Fish lengths and the number of fish transported were reported by the hatcheries.

ii. Water Quality

Ongoing monitoring of water quality is a risk management practice which can help predict conditions stressful to salmonids (Robertson, W.D., K.R. Wood & A.J. Sippel, 1987). Temperature was monitored daily at the cage site on Devil Lake and at Besnard Lake (last year's site) using a max-min mercury thermometer. The temperature was recorded at two tines during the day, in the morning and later in the afternoon; at the surface, ten feet below and at the. bottom (between 20 to 30 feet below), Dissolved oxygen was monitored approximately twice per week at Devil Lake using a YSI Model 51B Dissolved Oxygen Meter. This meter was at times not reliable due to poor calibration and battery failure. Turbidity was monitored regularly using a Secchi disk to roughly estimate the algal densities over the summer months. PH was monitored during the course of the summer to determine the alkalinity of Devil Lake. Water current measurements at the Devil Lake site were made using a Price's Electric Pipe Current Meter.

4. RESULTS AND DISCUSSION

4.1 Site Selection and Analysis

The criteria used to evaluate potential cage culture sites, and a comparison between Devil and Besnard Lake sites are shown in Table 3. The site at Besnard Lake is poor for rainbow trout culture in regard to water exchange (Appendix 3 & 4). Water movement is negligible in removing accumulated wastes from the bottom and replenishing fresh, fully saturated oxygenated water. In addition, extremely high water temperatures ie. reaching rainbow trout upper lethal limits have been (and were) experienced during summer months. The dissolved oxygen also fell below 5 ppm in the mornings for several weeks in past summers (Ivanochko, 1987, 1989). Heavy algal growth on nets was promoted by high water temperatures, which further decreased water exchange through the cages. Disease outbreaks were not uncommon during the periods of high temperatures and poor water quality at the Besnard Lake site. Last spring, heavy mortalities were experienced at ice break-up, and were attributed to a presumed production of hydrogen sulphide from the degradation of bottom waste material. Therefore, the site at Besnard Lake was found to be unsuitable for rainbow trout cage farming.

Table 3. Cage culture site analysis criteria and a comparison between Devil Lake and Besnard Lake cage sites.

Cage Culture Parameters	Criteria	Devil Lake Fish Farm	Besnard Lake Fish Farm
Water temp.	R,B.T.: optimum: 15-18°C lethal: 25+oC A.C./B.T. : optimum: 13-17°C lethal: 17+$^\circ$C	15.9-24.50	15-27°C
Water depth	should be at least twice as deep as the nets used	25-30 ft.	18-22 ft.
Water quality:			
i. D.O.	-greater than 5.0 mg/l	>5.0 mg/l	<5.0 mg/l[c]
ii. PH	-suitable: 6.7-8.6	7.8	7.8
iii. Turb.	-low algal density	8-11 ft. (mod)	6-8 ft. (heavy)
iv. H2S	-less than 0.002 mg/l	no Hs found	lethal ?
Water current	-sufficient for waste dispersion, oxygen distribution/exchange & flushing of nets	0.0169-0.0845 m/see	negligible
Shelter	-from severe winds/wave action & ice break-up	sheltered	sheltered
Ice free	-ideally open water year-round if overwintering want mild break-up	ice formation (mild?)	ice formation (heavy)
Security	-avoid sites with Potential vandalism -may require site tender	vandalism potential, site tender	vandalism potential, sitetender
Power	-ideally, hydro electricity directly to site for housing & equipment	accessible to power	no power available
Site access	-close, to reduce costs and stress to fish during transport	close to facilities road access to site under development	relatively close to facilities road access to site
Comparability	-avoid possible conflicts with other users, commercial or recreation	possible conflicts: fishing, tourists	possible conflicts: fishing, tourists

a. Based on Robertson et al. (1987)
b. R.B.T. - Rainbow trout, A.C., Arctic char, and B.T., brook trout
c. Found on hot summer mornings (Ivanochko, 1989).

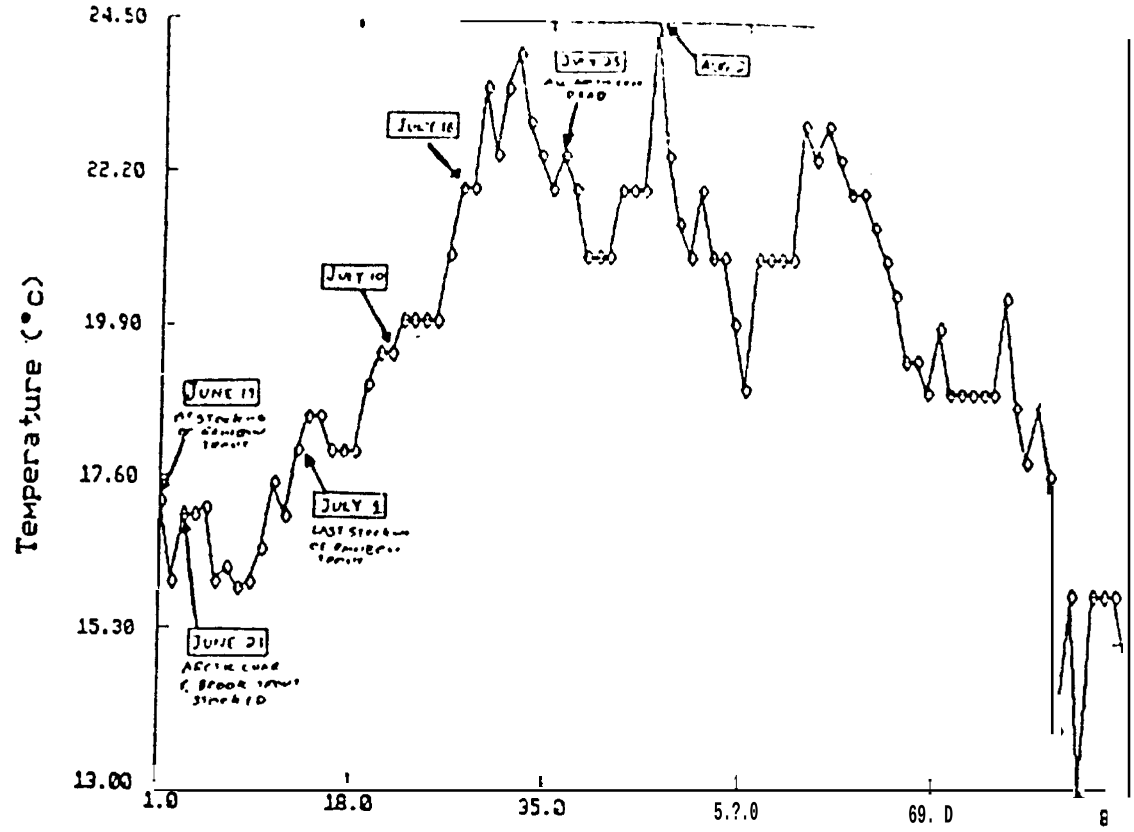


Figure 5. Water temperatures recorded at Devil Lake from June 19 to September 12, 1989.

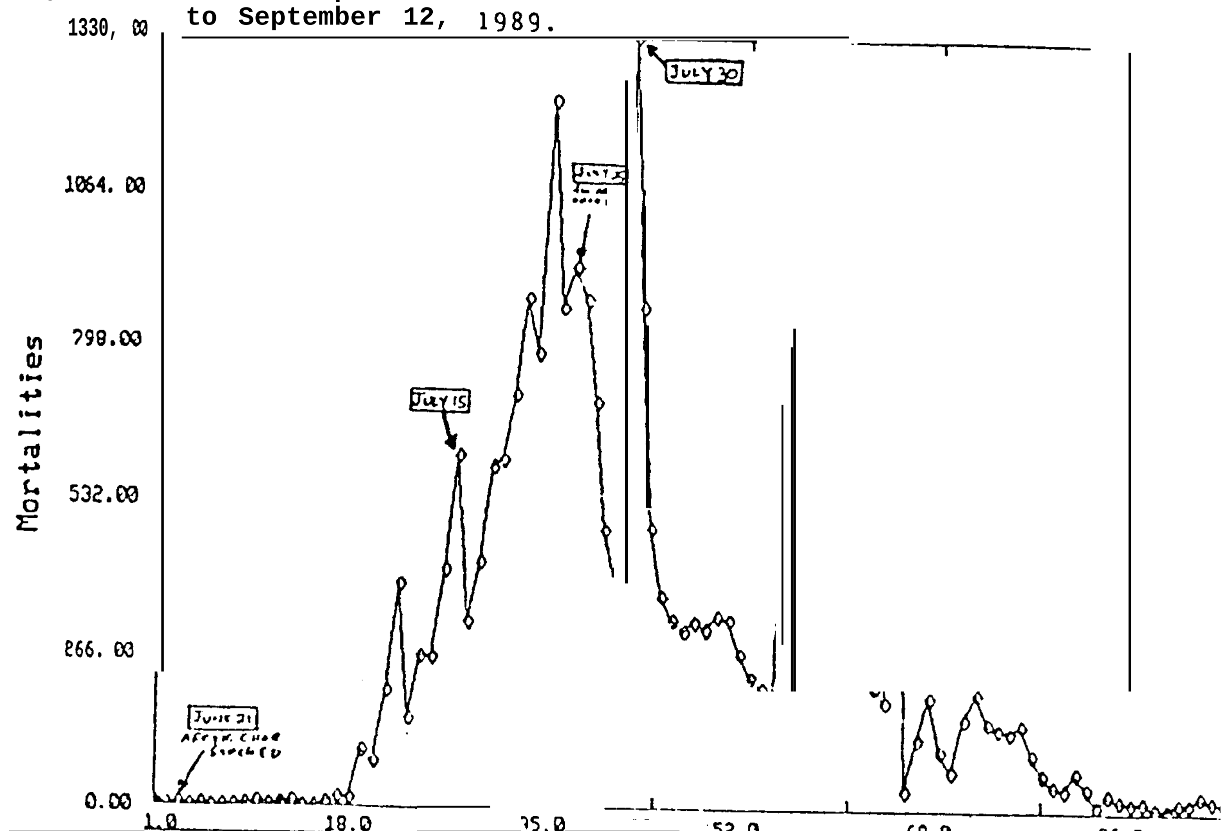
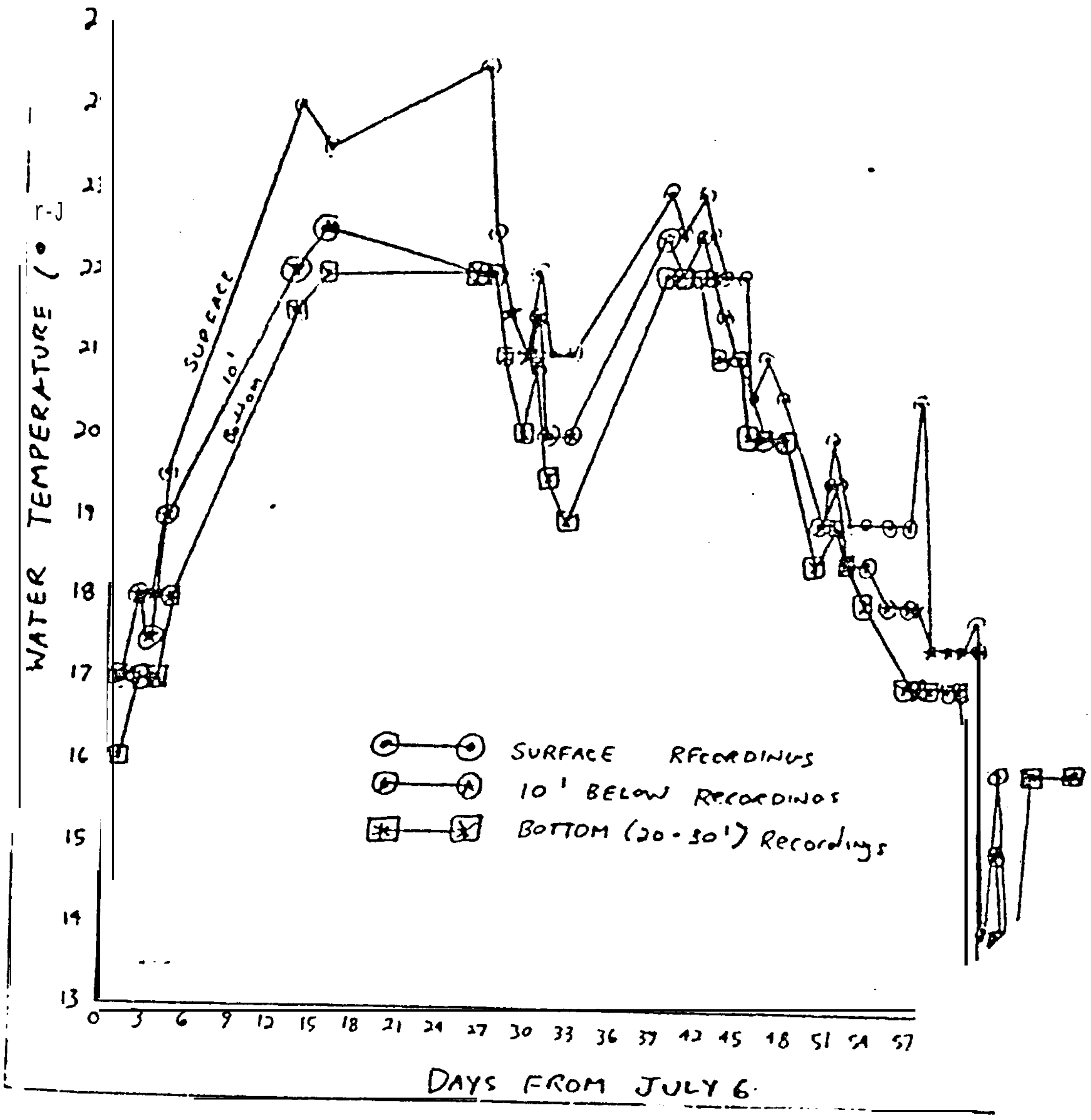


Figure 6. Fish mortalities recorded at Devil Lake from June 6 to September 12, 1989.

Figure 7. Water temperature recordings from the surface, 10 feet below, and from the bottom, monitored from July 6 to September 12, 1989, at Devil Lake.



Devil Lake was chosen in the hope that it would increase growth and survival of the fish stocked, by providing fully saturated dissolved oxygen at all times from the incoming rapids. Hopefully, the site would also have sufficient water current for water exchange to remove accumulated wastes from the bottom, lower water temperatures in the summers, and have no problems with hydrogen sulphide production in the spring.

Devil Lake was found to be fully saturated. with dissolved oxygen throughout. the unusually hot summer. Water temperatures were found to be high (Figure 5) and contributed to the high fish mortalities experienced from June 19 to September 12, 1989 (Figure 6). However, the water temperatures at Devil Lake were found to be generally lower than measured at Besnard Lake (Appendix 5). Besnard lake also experienced heavy mortalities during the summer hot periods (Appendix 6). It should be noted that Besnard Lake had considerably less fish being reared (approximately 40,000) with the majority being much older (Appendix 7). The older fish appeared to handle the thermal stress much better than the fingerlings stocked by having little or no disease outbreaks, higher survival rates and better growth and feed conversions.

Devil Lake was quite deep (25-30 feet), but no distinct thermocline developed over the summer. Bottom water temperatures were generally 1-2°C cooler than surface water temperatures (Figure 7). The generally constant temperature regime throughout the water column was probably due to mixing by the wind and wave action. Water current near the cages was found to be relatively small, but was significantly greater than measured at Besnard Lake. In addition, algal build-ups on nets may be limited by the current and wave action, as less build-ups were observed at Devil Lake than compared to Besnard Lake. pH did not account for the difference, as both lakes were slightly alkaline (7.8) Secchi disk readings indicated slightly less turbidity in Devil Lake than in Besnard Lake.

4.2 Fish Mortalities. Unaccountable Losses and Escapes

A summary of the Devil Lake fish stockings are shown in Table 4. only 45,923 fish (53.5%), out of the 85,784 fish stocked, remained after the long summer of extremely warm water temperatures and disease outbreaks. The fish losses (46.5%) were considerably higher than in past years, with 24.7% being attributed to mortalities, and 21.7% being attributed to unaccountable losses and escapes.

Heavy mortalities (above 500 morts/day) began to increase on the 27th day of stocking (July 16), corresponding to the increasing water temperature (reaching 22+°C). The mortalities continued to surge upwards, peaking at 1330 morts/day on the 42nd day of stocking (July 30), and were associated with the maximum water temperature reached over the summer (24.5°C). The mortalities began to drastically decline as the water temperatures cooled during August and September. However, the thermal stress had done its damage as many of the fish had succumbed to disease. Observations of most of the mortalities revealed damage to the gills; with fusing of gill lamellae, necrosis of the gill tissue, and erosion of the surrounding opercula. In addition, ascites were found in the body cavity and had caused the characteristic "bloating" of the abdomen, observed in moribund fish.

None of the mortalities were sent for a laboratory --- diagnosis; but bacterial gill disease (Myxobacteria spp.) was suspected as to the cause of the gill damage and associated problems. Many of the mortalities also had body damage, most often posterior and dorsal lesions. Some of the lesions may have been caused by predators attacking the fish from above or through the net; but most of the lesions were characteristic of an Aeromonas type infection. In fact, in 1985, rainbow trout mortalities (from cages in northern Saskatchewan) were positively identified for an Aeromonas hydrophila infection brought on by a combination of stressors ie. high temperatures, poor water quality, and excessive handling. (Christensen, 1988).

Fish losses of 21.7% of the fish losses (18,656) were attributed to unaccountable losses and escapes. The 1/2 inch mesh nets, that were used for stocking the less than five inch fingerlings, were made of a very fine material which was prone to tearing from contact with the bottom or attacks from fish predators. The damage resulted in holes large enough for fish to escape. The nets had come in contact with the bottom through wind and wave action at the initial site on Devil Lake, and when the cable broke (July 21) at the the final site. Holes were also caused by the frequent attacks of northern pike (Esox lucius), or walleye (Stizostedion vitreum). Thus, large holes, which were finally detected during inventories, had allowed for an undetermined number of fish to escape. In addition, a miscounting of the mortalities may have occurred, as the counting of mortalities was sometimes estimated due to the sheer volume needed to be counted. This estimation would affect the numbers reported for either mortalities, or unaccountable losses and escapes. Predation may have also contributed to a certain percentage of the unaccountable losses recorded. Bird "ie. gulls and kingfishers and predatory fish attacks may have removed fish from the cages as their prey.

The survival rates varied dramatically between the species. None of the Arctic char survived and 2% (51 fish) of the brook trout survived. The rainbow trout tolerated the higher temperatures much better than the other species with survival rate of 55.7% (45,872 fish).

i. <u>Arctic char</u>

The Arctic char mortalities began to dramatically increase on the 19th day of their stocking (July 10) and continued until the 36th day (July 25) when all the fish had died. The mortalities corresponded to water temperatures rising above 19°C. Every effort was made to save the fish including the use of a 30 ft. net in the hope that the char would take advantage of the slightly cooler water below. In addition, feeding was reduced and then stopped. However, the optimum water temperature for the growth of Arctic char lies between 12-14°C, and temperatures of 180C and above become life threatening (Eriksson, L. & B. Wiklund, 1989). Thus, the water temperatures at Devil Lake had reached lethal limits for the Arctic char. In addition, the Arctic char were not in top form coming from the hatchery. Many of the char, upon initial stocking, had "gaping" jaws ie. jaws extended open at all times, which definitely affected their feed intake and survival. This condition may have developed in the hatchery as the transporting and stocking of the fish was conducted with minimal stress and few mortalities. The Arctic char succumbed to fungal infections which resulted in blindness, tissue deterioration and finally death. Gills were not observed to be damaged, thus bacterial gill disease was not suspected as a cause of death.

ii. <u>Brook trout</u>

The brook trout suffered similar losses as the Arctic char. Heavy mortalities began to occur on the 27th day of their stocking (July 18) and continued until 51 fish remained at the end of August. The mortalities corresponded to water temperatures rising above 22°C. The brook trout suffered fungal infections as well; but bacterial

iii. Rainbow trout

The rainbow trout mortalities began to steadily rise around the 21st day of their stocking (July 10), and peaked on the 42nd day (July 30) when the water temperature reached above 22oC. The mortalities drastically declined once the water temperatures dropped below 22oC in the subsequent weeks. Optimum water temperatures for rainbow trout growth are from 13-18oC. At temperatures between 18-21oC, rainbow trout growth is reduced considerably; above 22oC, the temperatures start to become lethal (Castledine, 1986). Most of the rainbow trout mortalities indicated that the fish had succumbed to bacterial gill disease. In addition, body lesions, characteristic of an Aeromonas type infection, increased dramatically when water temperatures began to drop below 22oC and gill problems were beginning to clear up.

It should be noted that the fingerlings were not in a perfect healthy state upon arrival to Devil Lake from the hatcheries. Many of the fish had fin rot, missing fins and clubbed gills. Necrosis of gill tissue ie. bacterial gill disease, was first observed in moribund fish five days after the first stocking. These fingerlings were the last of the hatchery stock and were obtained at relatively low cost. However, the fish must have been loaded very densely at the' hatcheries, resulting in poor water quality and an unhealthy state. Transporting the fish from the hatcheries to Devil Lake was an additional stress on the less than healthy stocks. In addition, the stockings were in the middle of June and early July when the water temperatures were beginning to be the hottest. Thus, stress related factors were accumulating to hamper the immunity defenses of the fish and contribute to the disease outbreaks. Fish losses among the hatcheries did not significantly differ (Appendix 8).

4.3 Growth

When the water temperatures rose above 22oC, feed rations were reduced or stopped. Feed consumption is shown in Table 4. The growth rates of the fingerlings stocked at Devil Lake were measured from July 5 to September 12, 1989 (Table 5). Growth was experienced during the summer months, but was considerably retarded due to the high water temperatures and disease outbreaks. Average rainbow trout weight estimated at the start of their "stocking ranged from 5.5 g to 11.7 g, and reached the

Table 4. Number of fish remaining, mortalities, feed consumption, weight gains, and feeding conversion ratios during the period from June 19 - September 12, 1989, at Devil Lake.

Cage $$	# Fish Remaining	Morts	Missing Fish	Total Feed Fed (kg)	Wt. Feed /fish (s)	Avg. Wt. Gain/fish (g)	FCR*
1 A	4,676	1,449		426.12	91.13	72.2	1.3
B	3,059	2,095	2,055	607.37	198.55	102.8	1.9
2 A	2,216	1,437	3,945	615.97	277.96	126.9	2.2
B	4,987	748		341.91	68.56	54.4	1.3
3 A	4,910	2,030		621.01	126.48	83.8	1.5
B	5,433	960		392.25	72.20	82.9	0.9
4 A	2,521	2,941		241.65	95.85	52.6	1.8
B	2,480	101		108.39	43.71	40.9	1.1
5 A	3,471	1,924	3,473	283.88	81.'79	52.0	1.6
B	3,140	598		172.76	55.02	43.6	1.3
6 Arctic char	0	1,000		50.00	N/A	N/A	N/A
7 B	4,594	2,790	6,106	249.45	54.30	46.3	1.2
C	4,385	1,261	864	167,61	38.22	34.5	1.1
8 brook trout	51	1,866	583	135.26	2652.16	53.8	49.3
TOTALS:	45,923	21,200	18,656	4,414			

* Feed conversion ratios calculated on basis of weight of feed to average weight gain of fish. Conversion rates take into account mortalities which occurred between weigh-up periods.

weight of 58.1 g to 141.70 g by September. This is well below weights reached in past years (121-245 g), and far below the marketable weight of 280 g. The Arctic char experienced little or no growth as they had all died within 34 days of their stocking. The brook trout experienced little growth, and at an extremely poor feed conversion ratio (F.C.R.).

Table 5. Growth rates of rainbow trout, Arctic char and brook trout from July 5 to September 12, 1989 at Devil Lake (weights expressed in grams) .

Cage #	Initial weight[a]	July 5	July 30	Aug 13	Aug 29	Sept 12
1 A		32.2	46.7	49.4	75.5	104.4
B	11.6	32.2	54.0	61.5	74.0	114.4
2 A	14.8	34.0	66.9	65.9[b]	119.5	141.7
B		34.0	42.2	53.8	80.1	88.4
3 A	11.6	30.5	51.7	54.4	78.5	95.4
B		30.5	56.6	59.4	91.3	113.4
4 A	5.5	7.4	15.9	22.2	37.0	58.1
B				22.2	35.5	63.1
5 A	11.7	12.7	22.5	30.6	48.9	63.8
B			22.5	30.4	45.2	66.1
6 Arctic char	?	112.5		--		
7 A	11.7	-	22.0	27.8		
B	11.7	-	25.1	27.8	41.9	58.0
C				27.8-	42.8	62.4
8 brook trout	11.9	31.7	50.0			65.7

a. Initial weights estimated with a length-weight table (Piper, R.G., L.B. McElwain, L.E. Orme, J.P. McCraren, L.G., Fouler, & J.R. Leonard, 1982).
b. Assumed to be a weigh-up error.

F.C.R. 's ranged between 0.9 to 2.2 for the rainbow trout, and 49 for the brook trout (Table 4). The F.C.R. was not calculated for the Arctic char. The divided rainbow trout cages lowered the densities, which increased the room available for growth, increased water exchange through the cage, and reduced disease transmission. The 0.9 F.C.R. calculated for cage #3B may be due to an error at the time of a weigh-up or errors in consumption measurement, as the F.C.R. was suspiciously lower than the other cages. The extremely high F.C.R. for the brook trout was primarily due to massive overfeeding. Since the brook trout were not always seen feeding at the surface, the on-site worker sometimes overfed the cage, anticipating more fish than were present. Rainbow trout F.C.R.s in the past have ranged between 1.1 to 1.8 (Ivanochko, 1987, 1989). This year, the F.C.R.s were generally poorer; but this may be understandable considering the late stocking dates, stress of site moves, cable breaking, severe thermal stress from unusually high water temperatures, and disease outbreaks. In addition, some cages were overfed due to staff inexperience and poorly adjusted demand feeders, The six cages on demand feeders (cages #1A, 1B, 2A, 3A, 4A, & 5A) generally experienced poorer F.C.R.s, and this may be attributed to the difficulty in adjusting the feeders to handle the various sized feed. Feeders that were not adjusted properly caused feed to pour out of the hopper with most of it being wasted. Demand feeders have been extremely successful in the past fetching lower F.C.R.s than hand feeding; but have been awkward for new workers to adjust.

On a positive note, the F.C.R.s could have been considerably poorer, considering the severity of the disease outbreaks and the extremely high water temperatures experienced during the summer. Martin's feed appears to be meeting all nutrient requirements for the rainbow trout, and under normal circumstances, F.C.R.s can be expected to be quite adequate (between 1.1 to 1.5). More research is required on the nutrient requirements for Arctic char and brook trout to determine whether rainbow trout feed is meeting their nutritional needs. The Arctic char and brook trout did feed on the trout pellets; but thermal stress and disease caused extremely poor growth and F.C.R.s, as well as, death.

4.4 Loading Densities

Initial loading densities ranged between 3-4 kg/ins for the rainbow trout, and never reached above 1 kg/ins for the Arctic char and brook trout. Thus, every effort was made to minimize hauling and thermal stress by not overcrowding.

Division of cages was implemented when fish began to grow and heavy mortalities started to occur. The densities never reached overcrowded levels as. A loading density of 5000 fish/cage is thought to be ideal for overwintering the fish (Homer, 1989). Past winters have shown that 5000 fish/cage have kept ice from covering the opening of the cage through the continuous movement of the fish. When ice completely covers the cage, the fish can not be observed for mortalities, and the possibility of poor water quality increases ie. lack of oxygen, possible hydrogen sulphide production, etc. In addition, recent research has indicated that the" fish may need access to the "air" to regulate their swim bladders (Robertson , W.D., Wood, K.R., Sippel, A.J., 1987). Observations at Besnard Lake have indicated that 10 kg/m^3 may be the optimum for final densities.

4.5 Predation

Predation plays a significant role in cage culture success. Losses due to predators can be devastating. This year, at Devil Lake, no predator nets were set up on top of cages or around the cage nets. The netting material was-unavailable and predator r ets have been found to be inconvenient in the past. Demand feeders were found to be difficult to move and fill with feed while netting covered the cages. Underwater predator nets restricted water movement by heavy growth of algae. This year, predation was considered to play a minor role in the losses experienced at Devil Lake. However, pike and walleye attacks were observed at Devil Lake, and may have caused a significant number of holes in the nets which allowed fish to escape. Few birds were seen in the area, only the occasionl seagull or kingfisher were spotted; but this could become a problem in the future. Thus, future consideration should be made to reduce predator attacks, which may become more serious once the site has become established a.id the predators have "homed" onto their possible prey.

At Besnard Lake, a considerable amount of the mortalities experienced in 1989 were due to predation. Pike was the main predator, swarming around the cages and attacking the fish through the nets. Fishing was the only method used to try and eliminate the devastating attacks (Figure 3). Bird attacks were also numerous. Seagulls, ospreys, kingfishers and pelicans were frequently seen attacking the cages. Bird attacks were greatly reduced once a light mesh netting was placed over the cages.

5. CONCLUSIONS

5.1 Site Location

It is too early to determine whether Devil Lake is suitable. for fish culture. Heavy mortalities did occur over the summer months, and were attributed to the high water temperatures experienced. However, other factors were associated and contributed to the heavy losses experienced as well. Poor conditon of the fingerlings upon arrival from the hatcheries, disease outbreaks, stress of moving the cages to an alternative site, stress of the cages drifting to shore when the cable broke, handling stress, and predation all contributed to the heavy mortalities at Devil Lake. Thus, accumulated stressors caused the fish to succumb to disease and

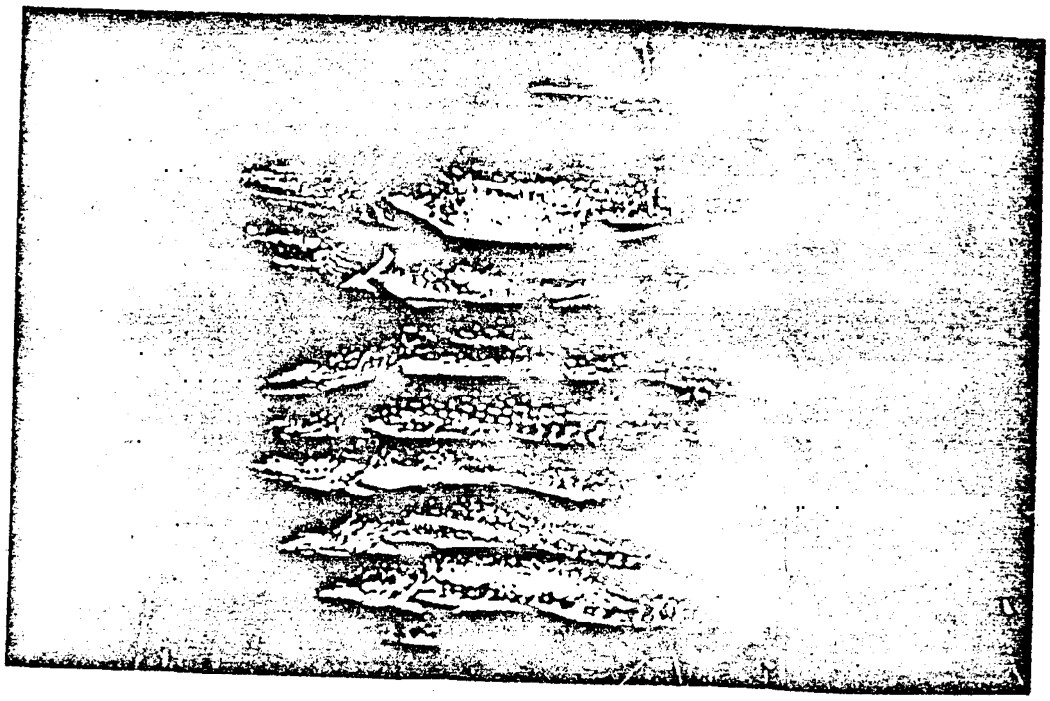


Figure 8. Northern pike (*Esox lucius*) caught off the. fish cages at Besnard Lake within 2 hours.

death. In addition, a large number of fish escaped through holes in the nets, and added to the substantial fish losses. Therefore, more time is needed to assess Devil Lake's performance. The water temperatures did reach high levels, but were generally lower than at Besnard Lake. In addition, fully saturated dissolved oxygen was found to be available at all times. Although no distinct thermocline was found at Devil Lake, the bottom water temperatures were generally cooler than the surface water temperatures. The fish were able to utilize the cooler water (depending on the size of net used) by staying near the bottom of the cage. A distinguishable water current was found near the cages which helped in water exchange. Finally, Devil Lake is closer to the processing facility than Besnard Lake,, more accessible, and power can be installed, which will be big benefits in the future.

5.2 Fish Performance

Mortalities, unaccountable losses and escapes were unacceptably high. Arctic char and brook trout can not survive in the high water temperatures that occur in the northern Saskatchewan lakes where cage culture is permitted. Deeper and cooler lakes are not available due to a Fisheries Aquiculture policy which does not allow cage culture of salmonids in lakes which have lake trout populations. Under the present circumstances, culture of fish should be limited to rainbow trout, which can tolerate much higher water temperatures. Another option may be stock Arctic char, or brook trout, in the fall in the hope that they will reach a marketable size before the following summer. More research is required to investigate Arctic char and brook trout husbandry techniques before large scale operations should be attempted. Rainbow trout husbandry practices must be improved and standardized to meet northern Saskatchewan environmental conditions. All handling events ie. grading, dividing and weigh-up, should be confined to periods of cooler water temperatures. Weigh-ups should not be necessary in the summer as growth and feed conversion ratios can be expected to be poor during the extremely high water temperatures. Hatchery stocks should be improved, and prophylactic medical treatments ie. oxytetracycline medicated feed, should be considered to reduce disease outbreaks in new stockings. Predator nets should be considered to combat an increasing problem.

6. RECOMMENDATIONS

1. A stronger business organization must be set up. More than one person should be expected to run the management of the complete operation. More funding should be obtained for a serious effort to expand into a large scale rainbow trout operation. Expanding into a large scale operation is the only way that cage farming has a chance t-o become profitable in northern Saskatchewan.

2. Production techniques for rainbow trout should be improved and maximized before attempting the culture of other species. It is important to diversify into other species, but currently the market demand for rainbow trout is not being met because of production limitations. Rainbow trout is the best species for culture since it is a hardy fish, able to tolerate harsh environmental conditions and diseases better than other species. In addition, there is more information available to their culturing techniques, since they have been virtually domesticated by some countries. On the other hand, Arctic char and brook trout have been found to be relatively difficult species to rear under northern Saskatchewan condition. Research is still being developed into the culturing of these species, and much more knowledge must be gained before these species will prove to be a reliable source for markets.

3. If Arctic char and brook trout are considered for culture in the future, it should be done on a experimental research basis. This will provide more information into the culturing of these species. These species should be reared separately from the rainbow trout farms to ensure proper sanitation and health requirements, In addition, these species require cooler water temperatures, thus new lakes should be located which meet their water temperature requirements. Research could be conducted on whether a marketable size could be reached for either species, if they are stocked in the fall (after high water temperatures) and harvested before the summer (before high water temperatures). Arctic char can be reared at higher densities (60-120 kg/m^3), and can experience significant growth at very low water temperatures (3-7°C) (Erikson L. & B. Wiklund, 1989). Currently, there is a market demand for "pan size" Arctic char (200-300 g) (Papst, M.H. & G.E., Hopky, 1989).

4. More technical support is needed in Saskatchewan and should be provided by the provincial and federal governments. Department of Fisheries and Oceans aquiculture progams are virtually non-existent in Saskatchewan. Research and development is definitely needed in Saskatchewan, which has considerable aquiculture potential with over 1000 clean,. fresh lakes. Saskatchewan has the potential to be a world leader in freshwater aquiculture, especially in trout farming. More support is needed in the following areas: site selection analysis, production techniques, fish health, and educational training for workers. Support from the Industrial Research Assistance Program, the Saskatchewan Indian Agricultural Program, NEDSA, and the Agricultural Development Fund have definitely helped; but more funding and technical aid are needed to make cage farming in Saskatchewan viable.

5. More research is needed to determine whether Devil Lake is suitable for culturing fish. More water quality analyses and site surveys should be conducted before one particular site is fully developed. Development should only proceed once Devil Lake is found to be suitable for a large scale production of rainbow trout.

6. Fingerling stockings must be conducted much earlier in the year than this year. An ideal stocking month would be May when the ice begins to break up and the water temperatures are cool. Definitely no stockings should be made during July when the highest water temperatures occur every year.

7. Hatchery stocks must be improved by better husbandry techniques which will help in the survival of the fingerlings when they are stocked into the lakes.

Prophylactic treatments with medicated feed (oxytetracycline or other equivalent antiobiotics) should be experimented before the fish are transported; and/or at the lake when the fingerlings arrive. These treatments should greatly reduce the severity of bacterial gill disease and fungus outbreaks, as well as provide some protective immunity against other diseases while the fish acclimatize to their new environment. Treating fingerlings with antibiotics should not be feared by the consumers ie. from the build up residues in the tissues, especially if the treatments are stopped after the initial summer. Treatments should only be needed for newly stocked fingerlings to help protect them from disease caused by accumulated stressors in the summers. Treatments should not be necessary for older fish which are more tolerant to stress than the fingerlings. Thus, the older fish will have been off the medicated feed for at least a year before they are harvested, leaving no residues remaining in the tissues.

8. A site manager is needed at Devil Lake to organize all fish farm events. The manager should ensure that correct sized nets, optimum loading densities, fully operational equipment, correct feed size, feed deliveries and the organization of the staff are all planned well in advance of the fingerling deliveries. Once the fingerlings “ arrive, better husbandry techniques must be implemented and followed until the fish are harvested”.

9. Current demand feeders should be modified or replaced to become more convenient for all staff, old or new. Solar powered automatic feeders may be ideal” and should be experimented. The automatic feeders would still save labour required, but may be easier for adjustment and more convenient for filling feed “than the demand feeders. In addition, the demand feeder’s descending marked wire may cause injury to the fish by constant contact during feeding; or if the marked device at the end of the wire is removed, it becomes a “spearing” weapon. Furthermore, wastage of feed may be reduced by an easier operation.

10. Perhaps the most important recommendation, no handling events should be conducted in the hot summer months. Research information regarding growth and feed conversion ratios are important, but should not be conducted at the expense of the fish. The past five years have shown that growth can be experienced during the summer, and F.C.R.s range between 1.1 to 2.2 for rainbow trout. Under high water temperatures, growth and F.C.R.s are going to be quite poor, thus sample weigh-ups are providing little new information and are causing considerable stress to the suffering fish. Thus, handling events should not be conducted during the summer, especially in July when the

water temperatures rise above 18°C. A weigh-up should be conducted upon arrival of the fingerlings, and then when the water temperatures begin to cool (usually August). Grading of the fish should be done to maximize an even growth distribution within a cage, and should be conducted before the ice forms on the lake. Division of cages is extremely stressful and every effort should be made to stock fingerlings in cages that will not have to be divided in the summer.

11. More research is needed on loading densities, but initial results indicate that fingerling densities should be between 2-4 kg/m³; and final densities should not be much more than 10 kg/ins , under northern Saskatchewan conditions. Robertson, W.D., K.R. Wood & A.J. Sippel. 1987, have developed a loading density experiment that could be adopted to help determine optimum densities.

12. Nets should be changed at least once a month in the summer to remove algal buildups and provide good sanitation. Pressure washing definitely removes the algae; but stresses the fish while cleaning, and increases the chance of transmitting disease to all the cages.

13. Predator nets, above and below the cages should be used to protect the fingerlings from birds and pike attacks. In addition, nets will be protected from being torn, and thus reduce the number of fish escaping. The benefits of installing predator nets out-weigh the disadvantages.

14. Water quality monitoring should be conducted on a regular basis, and well kept fish farm records (up-to-date) must be maintained.

15. Feed should be stored properly ie. in a cool, dry area, and regularly inspected for quality.

ACKNOWLEDGEMENTS

1 am extremely grateful for the help provided by the staff of the Saskatchewan Indian Agriculture Program, and the Industrial Research Assistance Program, in particular, Bernie Zuk and Warren Negata (I.R.A.P. supervisors). In addition, Gerald Ivanochko (Government Extension Agrologist), Murdock McKay (SIAP Administration), Tom Charles, Duane Rediron, Dennis Rediron, Ricky Merasty, Joe Halkett, Georgie Bradford, Jimmy Hryniuk, Jeff Morin, and Mark Morin, who all made this project possible. Finally, but not least, my deepest appreciation for the support, enthusiasm, friendship, and dedication offered by Doug Homer (SIAP Extension Agrologist).

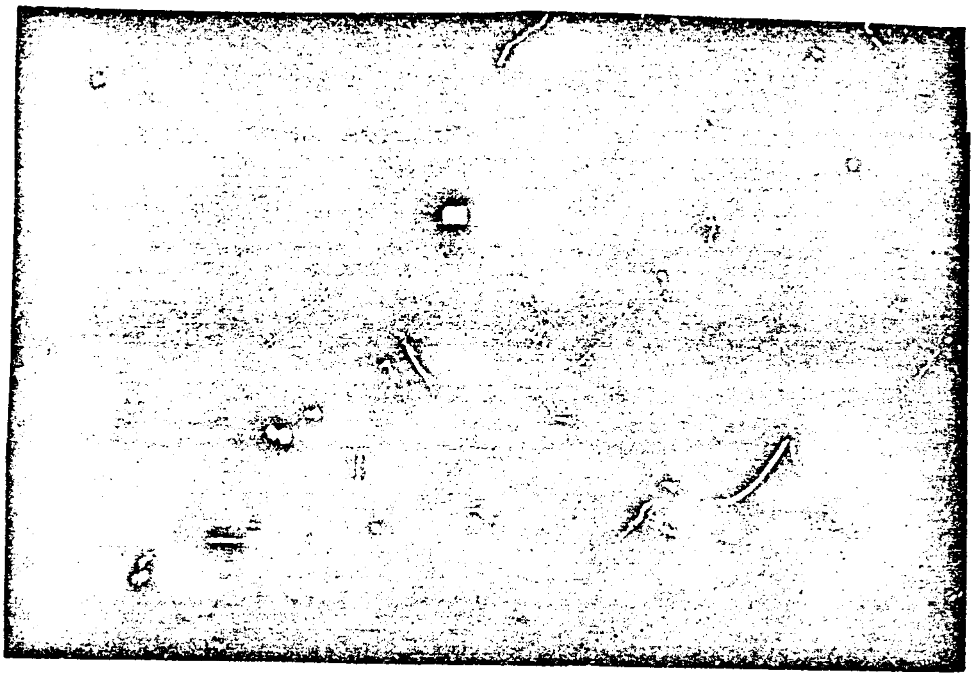
APPENDICES

Appendix 1. The proximate analysis of Martin fish feed ration (Ivanochko, 1987).

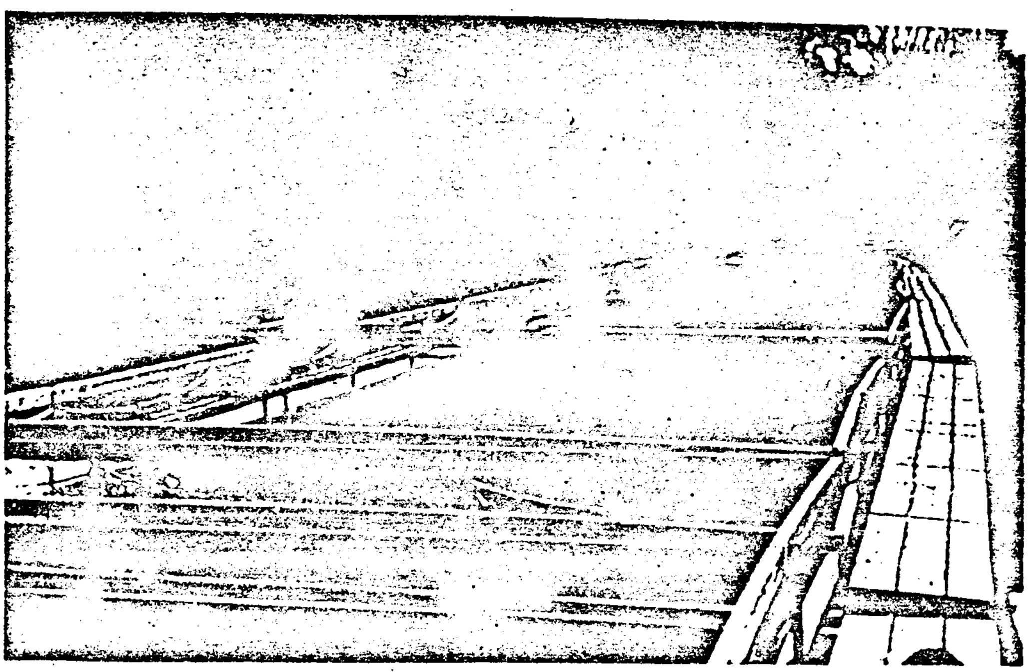
	Martins Feed
Moisture (%)	8.0
Protein (%)	38.9
Fat (%)	15.2
Fibre (%)	4.8
Ash (%)	5.3
Iodine Value (%)	115.0
Calcium (%)	1.1
Phosphorous (%)	0.8

Appendix 2. The feed sizes used for the different sized fingerlings stocked at Devil Lake.

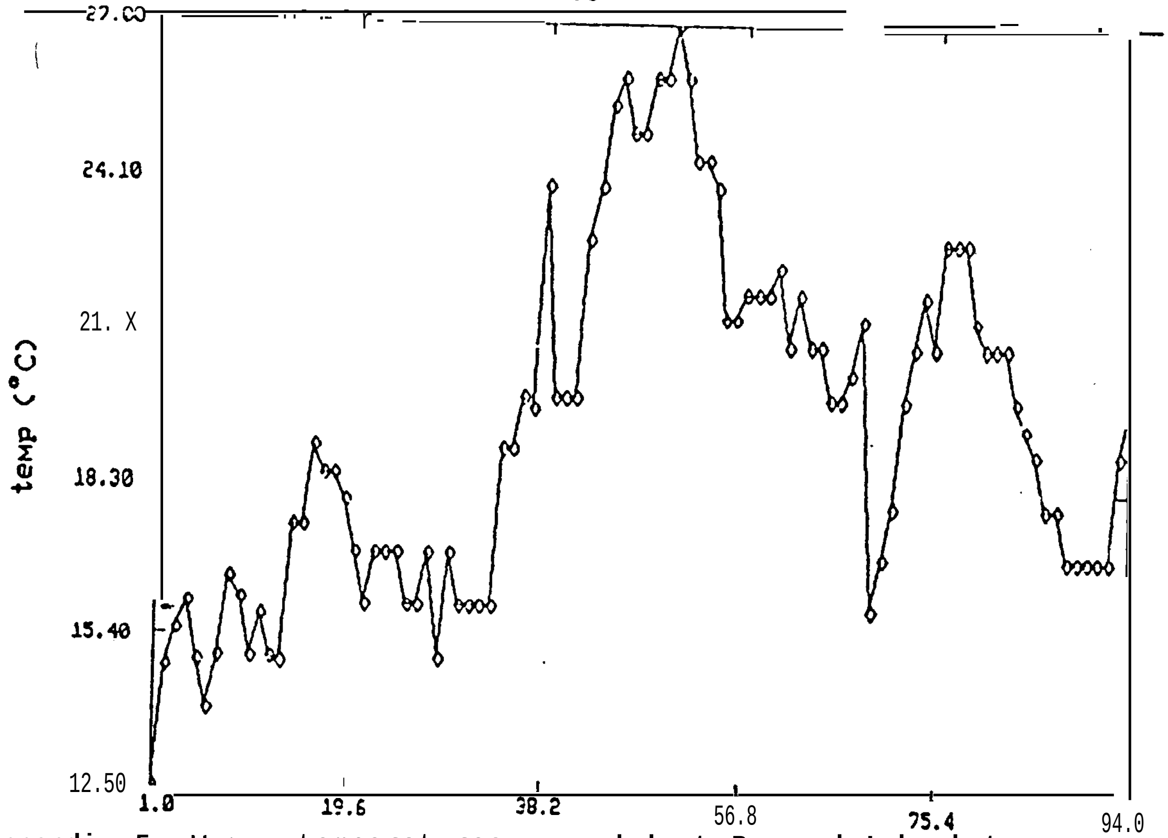
Feed Size	Fingerling Size
2 GR	2.7 - 4.0 inches (7.6 - 10.6 cm)
3 GR	4.0 - 5.0 inches (10.6 - 12.7 cm)
3 PT	5.0 - 6.0 inches (12.7 - 15.2 cm)
4 PT	6.0 - 7.0 inches (15.2 - 17.8 cm)
5 PT	6.0 - 10.0 inches (15.0 - 20.0 cm)



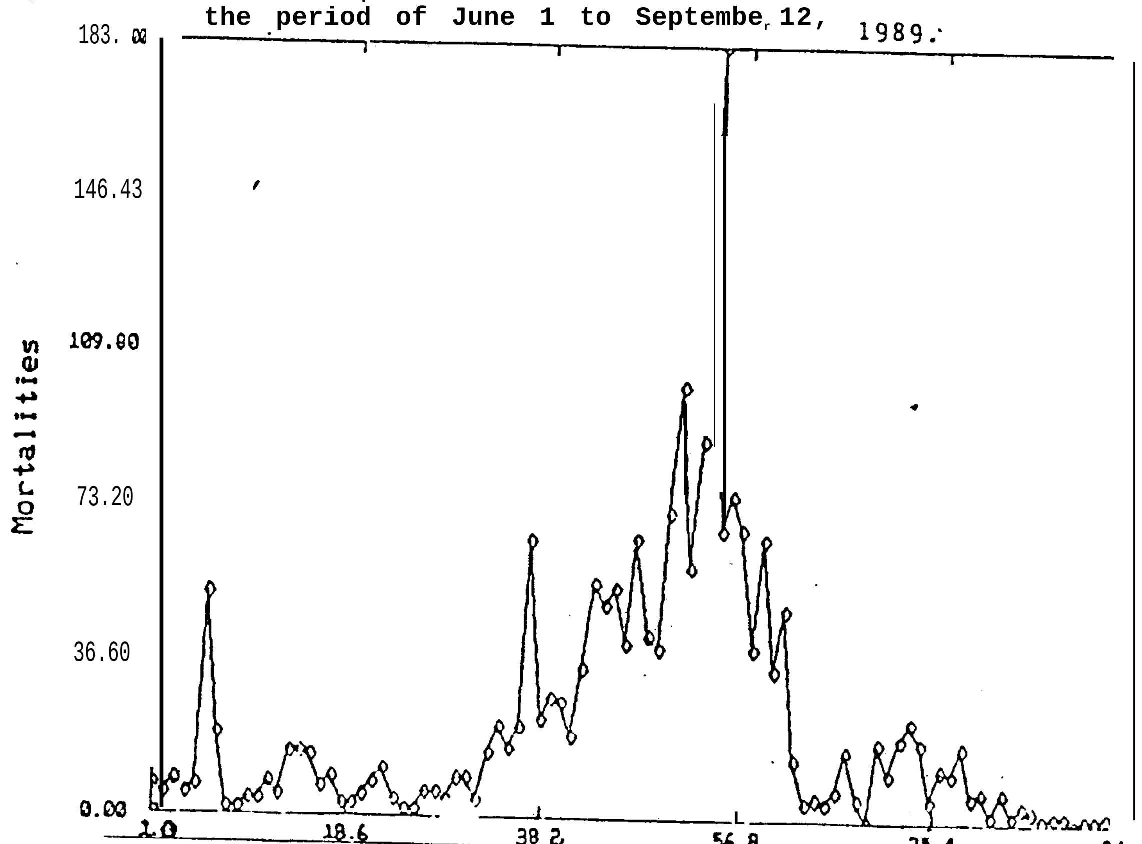
Appendix 3. A pictorial representation of the rainbow trout cages at Besnard Lake.



Appendix 4. An eastern shot picture of the cages, staff housing, and the feed storage building at Besnard Lake.



Appendix 5. Water temperatures recorded at Besnard Lake between the period of June 1 to September 12, 1989.



Appendix 6. Fish mortalities recorded at Besnard Lake between the period of June 1 to September 12, 1989.

Appendix 7. A picture of 1-3 pound rainbow trout (between the ages of 1 to 3 years old) harvested from Besnard Lake.

Appendix 8. Mortalities and other losses of rainbow trout from the different hatcheries.

Hatchery	Stocking Number	% Morts	% Other Losses	Remaining Fish	% Total Losses	Total cost
Trout Haven (S.Dakota)	40,000	21.8	15.0	25,281	36.8	$ 8,400
F.Q. Aquafarms (Nipawin)	22,284	25.0	22.9	11,612	47.9	$ 6,106
McNabb's Trout (Saskatoon)	20,000	20.3	34.9	8,979	55.2	$ 6,704
TOTAL:	82,284	22.3	22.0	45,872	44.3	$21,210

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