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DESIGN, CONSTRUCTION AND FIELD TESTING OF A MOBILE HATCHERY FOR THIRTY MILLION WALLEYE EGGS

by

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ABSTRACT

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A mobile, self-contained, low technology hatchery for incubating thirty million walleye (Stizostedion vitreum) eggs was designed and constructed at the Freshwater Institute, Winnipeg, Manitoba and field tested in 1985 at a site on the Ochre River, Manitoba. The design criteria, components and construction costs are presented. During the field test 13 million eggs were incubated with 73% surviving to hatch. The operational characteristics with reference to water quality, temperature, duration of embryonic development, disease control and suggested refinements of the hatchery are discussed. Benefit to cost ratios for the unit operated at full capacity ranged from 0.7 if all the output was harvested in a commercial fishery to 1.7 if harvested by a recreational fishery.

Key words: Stizostedion vitreum; eggs; incubation; fish culture; hatcheries.

RÉSUMÉ

Giles, M.A., and M. Foster. 1987. Design, construction and field testing of a mobile hatchery for thirty million walleye eggs. Can. Tech. Rep. Fish. Aquat. Sci. 1533: iv + 28 p.

Un piscifacture mobile, autonome, de technologie simple, permettant l'éclosionde trente millions d'oeufs de dorê (Stizostedion vitreum) a été mise au point et fabriquée à l'Institut des eaux douces à Winnipeg (Manitoba); on en a fait l'essaen 1985 dans la rivière Ochre au Manitoba. Les critères de mise au point, les parties constituantes et les coûts de construction sont présentés. Lors de l'essai dans la rivière, treize millions d'oeufs ont été incubés et le taux de survie à l'éclosion a été de 73%. Les caractéristiques opérationnelles ence qui concerne la qualité de l'eau, la température, la durée du développement del'embryon, la prévention des maladies et les améliorations proposées sont exposées. Les rapports coûts-bénéfices en ce qui concerne le piscifacture, exploité au maximum, vont de 0,7, si tous les sujets produits sont capturés par des pêcheurs commerciaux, à 1,7, si les sujets sont capturés par des pêcheurs sportifs.

Mots-clés: Stizostedion vitreum; oeufs; incubation; piscifactures; pisciculture.

INTRODUCTION

Attempts to establish, maintain, or increase populations of walleye, Stizostedion vitreum, by artificial propagation of eggs collected from natural spawning stocks have been made for almost a century. Although several improvements have been made in the procedures the process still consists of stripping, fertilizing and water hardening eggs of wild walleye stocks, transporting the eggs to large hatcheries where they are incubated through embryonic development to hatching, and transporting the newly-hatched larvae to various sites for stocking. The distribution phase is very limited in time since the larvae must initiate feeding within four to five days of hatch and attempts to feed larvae on artificial food have shown only limited success (Colby et al. 1979).

Survival of walleye eggs spawned in natural habitats may vary widely depending upon spawning substrate, climatic conditions and the impact of human activities upon the spawning areas. Johnson (1961) reported embryonic survival ranging from 0.6% to 36% in walleye eggs spawned on several types of substrate in Lake Winnibigoshish, Minnesota, whereas Fourney (1976) on an eight year study of Oneida Lake, New York, calculated that 0.5-1.0% of naturally spawned eggs survived to hatch. Egg to larvae survival in artificial hatcheries, however, is generally higher with some facilities consistently achieving survival in excess of 65%. Thus the production of larvae from hatcheries, many of which can accommodate more than one hundred million eggs, is substantial. In view of the capacity for production of large numbers of larvae it is surprising that the success of stocking of hatchery-produced walleye has been relatively limited. Laarman (1978) in a survey of published and unpublished data concluded that good success has been obtained in about 48% of walleye plants into water bodies not previously supporting walleye stocks whereas 32.5 and 5.2% success, respectively, occurred in stockings for the purpose of maintaining or supplementing existing walleye populations. Several explanations have been presented to account for the failures including availability of suitable prey, density-dependent mortality resulting from cannabalism or predation and adverse environmental conditions (Fourney 1976) and these factors are undoubtedly of importance after the larvae have been released. Factors operating during the periods of embryonic development in hatcheries and during larval transport, which may influence larval viability after releases, have received less study. Embryonic development and survival is relatively unaffected by dissolved oxygen concentrations at levels exceeding 50% of saturation (Kramer and Smith 1966; Oseid and Smith 1971), although hypoxic conditions may delay hatching (Oseid and Smith 1971). Water temperature, however, strongly affects both the rate of embryonic development and survival to hatch (Colby et al. 1979). Griffiths (1981) reported that optimum temperature for embryonic development of a Lake Ontario population of walleyes was in the range of 10.5 -15.5°C and that daily oscillations in water temperature of 5°C may improve survival. Busch et al. (1975) also reported a positive correlation between the number of young-of-the-year walleye and the rate of increase in mean daily water temperature during embryonic development in a reef-spawning population of walleye in Lake Erie. The investigators suggested that the shorter incubation period occurring at higher temperatures lessened the exposure of the eggs to unfavorable conditions, such as predation, low oxygen, siltation, disease and vulnerability to storms and therefore resulted in an improved hatch. Many hatcheries, however, obtain their incubation water from sources such as wells or deeper levels in lakes which experience relatively small variations in temperature during the period of embryonic development and perhaps lose any positive effects of oscillating and increasing temperatures upon embryonic development. Another consequence of normal hatchery practise is the need to transport the newly-hatched larvae to the various areas in need of stocking. Colesante (1980) demonstrated that netting and transporting larvae in plastic bags at densities of about 4300/L of water resulted in 10-26% mortality with the highest mortalities occurring in tests where the larvae were held for 36 hours in order to acclimate to the receiving water. At densities of 6500-13 000 fish/L three-day-old larvae experienced up to 65% mortality after six hours in plastic transportation bags. In addition to direct mortality handling has been shown to induce numerous sublethal stress responses in various fish species and several days may be required for complete recovery (Pickering et al. 1982; Carmichael et al. 1983). It is probable that such stress would significantly impair the performance and survival of fish in their natural environment.

Walleye represent a valuable resource in both recreational and commercial fisheries (Canadian Fisheries Annual Statistical Review 1983) and account for a substantial portion of the freshwater fish culture activities in central and western Canada. The concept of a small, low-cost mobile hatchery for walleye eggs was considered as an adjunct of the operations of the standard fixed hatcheries normally used to provide walleye larvae for stocking. Several possible advantages could be realized in a mobile facility. Local fish stocks could provide a source of spawn, and eggs reared in the receiving water would avoid the stresses of thermal and chemical acclimation by the resultant larvae. Losses and stress resulting from transportation could be eliminated by releasing the newly-hatched larvae directly into the lake or river. Finally, reduced maintenance costs during the off-season and various socio-economic benefits could be achieved.

After completion of a feasibility study (Underwood McLellan Ltd. 1983) a project was initiated to design, construct and field test a self-contained mobile hatchery capable of incubating approximately thirty million walleye eggs.

HATCHERY DESIGN AND CONSTRUCTION

Design specifications for the mobile walleye hatchery were established using elements

from the feasibility study (Underwood McLellan Ltd. 1983) and input from various provincial hatchery personnel and staff at the Freshwater Insitute (FWI). Initially, the following general objectives were set. The hatchery capacity was to be 30 million walleye eggs with short-term holding capacity for four to eight million larvae. The incubation system consisting of tiered troughs, incubation jars and gravity water flow was to be arranged into four independent units which could be operated in isolation and which could release larvae into separate holding tanks without mixing. The water supply and distribution system was to be sufficiently flexible to permit evaluation of various types of pumps, filtration and temperature control systems. Initially, at least, the physical location of the hatchery was to be limited to maximum horizontal and vertical distances of 90 and 18 m, respectively, from a source of water. The entire hatchery and any support facilities were to be powered by a portable electrical generation system. Finally, the entire facility was to be movable with a minimum of special equipment and to be arranged so that it could be assembled or dismantled within one day. Although many alternatives were considered in meeting the foregoing objectives, certain specifications were set using known requirements for the incubation of walleye eggs. These specifications are presented in Table 1.

In the process of setting and meeting these specifications a general approach employed was to over-design or over-size elements in the system, since it was considered more advantageous to reduce these elements after field-testing the unit than potentially have to upgrade the components during the tests.

The design, component construction and assembly of the hatchery was completed during the period of September, 1984 to March, 1985. With the exception of the electrical wiring, which was done under contract, the unit was assembled by Freshwater Institute personnel at the Rockwood Experimental Fish Hatchery at Gunton, Manitoba. The major systems forming component parts of the hatchery are discussed individually.

PUMPING AND WATER DELIVERY SYSTEMS

The water distribution system was designed in a modular format incorporating three main components; the intake module, the hatchery supply module and the hatchery recirculation module. Each module consisted of a set of pumps and valves and an electrical control panel.

The intake module functioned to deliver water from the source (river or lake) to the hatchery and incorporated five pumps although normally only one was in operation at any time. A 1 HP submersible sump pump (Hydromatic, mod. SP100AH,) enclosed in a triangular screened aluminum stand (P1, Fig. 1) was employed as the main pumping unit. This pump was rated to deliver 270 $L \cdot min^{-1}$ at a head of 18 m of water. The stand was covered with expanded aluminum (mesh, 3x6 mm) oriented so to deflect flowing water away from the stand. The stand could be anchored to the stream bottom with steel rods placed down the hollow frame. Two submersible, 11-stage well pumps (GSW mod. 150K1GP11R, 1.5 HP) connected in parallel (P2, Fig. 1) were used to provide a high pressure water supply (>552 kPa, 80 psi) after a vertical lift of 22 m at a delivery rate of 227 $L \cdot^{-1}$. In addition to the large vertical lift these pumps could be used to operate a sand filter. The pumps were encased in a metal frame covered with perforated plastic sheeting (pore; 3.2 mm) and could be anchored 15 cm above the stream bottom. A nonsubmersible centrifugal pump (Jacuzzi, mod. 7LE, 0.75 HP; P4, Fig. 1) was employed as an electrical backup to the main pumping sytem. A 5 HP gas-driven centrifugal pump (Monarch, mod. ACGF-6; P3, Fig. 1) was used as a further backup in case of loss of electrical power. Both backup pumps were located beside the intake module valving system and could be primed from the main pumps.

The hatchery supply module consisted of a sediment chamber and a paired pumping system (P5, Fig. 1) with a by-pass structure. Water delivered from the intake module was directed to either a sediment settling chamber or a by-pass connected directly to the hatchery. Wire-reinforced, suction-pressure hose (Ju-Flex, diam., 5.1 cm, heavy duty) was used in all pumping connections outside the hatchery. Aluminum couplers were used throughout to connect the various modules to the hose. The sediment chamber (Fig. 1) consisted of an outer shell (2.4 x .9 x .9m; L x W x D) and an inner central compartment (1.8 x .3 x .9 m; L x W x D). Water entered near the bottom of the outer shell and flowed around the inner compartment to reduce velocity. The low velocity water entered the inner compartment through a row of holes (diam., 2.5 cm) near the top of the partition and was pumped via a 0.75 HP centrifugal pump (Jacuzzi, mod. 7-LE) to the main distribution system in the hatchery. Excess flow of water from the intake module was returned to the drainage system via a 15.2 cm outlet located at the top of the outer shell. During normal operation valve V5 (Fig. 1) would be closed and V4 and V6 open. In case of power failure or during cleaning of the settling chamber V5 would be opened, V4 and V6 closed and the hatchery supply pump (P5) turned off. Water would then be delivered to the incubation system directly from the appropriate intake pump (P1 - P4).

The recirculation module was incorporated to provide a potential for heating or cooling of water supplied to one or more incubation batteries and to recirculate water to the incubation jars in cases where the intake water system was disabled. The recirculation system received water from one or both larval tanks or could be arranged to take water from an individual chamber in one larval tank. A 0.5 HP centrifugal pump (Jacuzzi, mod. 5 LE; P6, Fig. 1) was used to deliver this water to a second distribution system in the hatchery where it could supply one or more batteries. Prior to delivery to the batteries the water could be passed through an ultraviolet sterilizer (Trojan Technologies Inc., mod. TS6100) to control disease organisms. The UV sterilizer could be by-passed if necessary. Both the recirculation and the hatchery

supply module incorporated paired pumps which were plumbed as illustrated in Fig. 2. The ball valves and check valves were of the true union design so that in case of failure of one pump the second unit could be turned on and the defective unit removed for servicing.

WATER ALARM SYSTEM

An alarm system was installed to monitor the operation of the water delivery systems. Low pressure indicators were located in both the main hatchery supply and the recirculation manifolds in the hatchery and on the inlet pipe to the sediment settling chamber. Float-controlled microswitches were installed in the top trough of each incubation unit to indicate changes in water level and/or rate of delivery. The pressure and level switches activated a 24 volt DC circuit which controlled an emergency alarm bell.

ELECTRICAL SYSTEM

Electrical power for all operations was produced from portable generators. A 12-KW diesel generator (Pritchard Engineering, mod. AD12) supplied power to a main panel in the office. A 4-KW gas generator (Onan, mod. 4CCK-3CE/22000) acted as back-up during periodic servicing or in case of failure of the diesel unit. A 115v, 30-amp service for the residence trailer, 115v, 15-amp circuits for lights and receptacles in the hatchery, and circuits for each of the pumping modules were wired to the main panel. The pump module circuits were wired to twist-lock receptacles located on the steel undercarriage of the trailer. The pump control panels for each module were connected to these receptacles via weatherproof cable. The panel configurations are presented in Fig. 3-5. Ground fault circuit breakers were employed in all exterior circuits.

LARVAE HOLDING TANKS

Two dual-compartment larvae holding tanks (Fig. 6) were constructed from 1/8 in. (3.2 mm,) type 6061T6 aluminum. The overflow troughs were fitted with 6 in (15.2 cm) female NPT flanges at both ends. The flanges accepted a plastic plug or an aluminum MNPT to hose quick-coupler. The paired frame channels inside the tank received frames fabricated from 0.75 in (1.9 cm) square aluminum tubing. Nitex screen (400 or 710 micron mesh) was glued to each frame. Since each end of every compartment was screened the total screened area/compartment was 1.1 m^2 which would produce a mean water velocity of 0.7 mm. sec^{-1} through the screen at the anticipated water flow of 55 $L \cdot min^{-1}$ per compartment. The volume in each compartment was 550 L. A length of Hy-flex discharge hose (diam; 4 in, 10.2 cm) was connected through an aluminum quick-coupler to the drain at the bottom trough of each hatchery battery and led to a compartment in the larvae tank. The coupler on the overflow trough was connected to an appropriate length of lay-flat hose (Blue Devil brand, diam; 6 in, 15.2 cm) draining to the lake or stream. This drain line received water from both larvae tanks and from the overflow of the sediment settling chamber.

HATCHERY TRAILER

The hatchery (Fig. 1) was housed in a 6-wheel Atco trailer (13.2 x 3 m; 42 x 10 ft; L x W) which was partitioned into an office (9.2 x 10 ft; 2.8 x 3 m) and an incubation room (33.5 x 10 ft; 10.2 x 3 m). The original floor of 0.75 in (1.9 cm) plywood was reinforced with a double layer of 0.625 in (1.6 cm) pressure-treated plywood and painted with a non-slip epoxy paint. A row of dimmer-controlled incandescent lights and seven individual 115 volt circuits were installed in the incubation room. A pair of schedule 80 PVC pipelines (diam; 2 in, 5.1 cm) with 1 in (2.5 cm) valved take-offs to each battery were installed on one wall approximately 4 ft (122 cm) above floor level. One pipeline received water from the hatchery supply pump module while the second line received water from the recirculation module. The four incubation batteries were arranged perpendicular to this wall with their drains exiting through holes cut in the floor.

INCUBATION BATTERIES

Four incubation batteries each containing four tiered troughs were constructed from type 304 stainless steel. The troughs and frame were fabricated from 14 and 16 gauge steel, respectively. The upper three troughs (Fig. 7) supplied water to individual incubation jars through 0.5 in (1.3 cm) fittings which were arranged in two patterns, A and B (Fig. 8) to permit staggering on the jar positions in adjacent troughs. The units were arranged from top to bottom in the sequence B:A:B and each trough had seven 0.5 in female NPT flanges of 304 stainless steel. The bottom of each trough (Fig. 9) was sloped from the sides to the centre by 0.5 in over a distance of 6 in (15.2 cm) to facilitate sediment collection and cleaning. The drains were fitted with standpipes (diam.; 3 in; 7.6 cm) which could be adjusted to the desired height to regulate water pressure at the valves. Water flow to each incubation jar was adjusted by a 0.5 in (1.3 cm) plastic gate valve. The bottom trough (Fig. 7) was 8 in (20.3 cm) deeper than the upper three troughs and fitted with four female, NPT flanges (diam., 1.25 in, 3.2 cm) which could be connected to recirculation pumps if necessary. A drain (diam. 4 in, 10.2 cm) was connected to the bottom tank and led through a flexible hose to the larvae holding tanks outside the trailer.

The battery frame was bolted to the floor and the upper section extended to the ceiling and screwed to the joists. This system corrected for any irregularities in the floor or ceiling. The ends of the troughs were supported by cross members of the frame and immobilized with two bolts connecting the cross member to a

flange on the bottom of each tank. The supports were offset from horizontal by 0.5 in (1.3 cm) to provide a slope toward each drain pipe thereby facilitating the cleaning of the system.

Acrylic whitefish/walleye hatchery jars (Midland Plastics Inc., mod. MPC-300) were used because they were lighter, less fragile and cheaper than the standard glass jars. The jars, dimensions, 18.5 x 6 in (47 x 15.2 cm; H x D; volume 7.3 L) were fitted with a top screen to prevent egg loss and attached to stainless steel pedestals (Fig. 7) with rubber straps. Water was delivered to the central standpipe of the jar through a glass tube 7 x 0.5 in, (17.8 x 1.3 cm, L x D) connected to the appropriate valve with a 9 in (23 cm) length of thin-walled Penrose drain latex tubing (diam; 0.5 in, 1.3 cm). This arrangement facilitated the set up and cleaning of the jars without closing the control valve since the glass tube could be removed by pinching the latex tube closed, lifting out the glass tube and allowing it to drain into the trough. For transport and storage the jars could be hung from their supports inside the bottom trough.

Table 2 lists the costs of material, components and services for the construction of the various systems (labour costs for FWI personnel in hatchery assembly are not included).

FIELD TESTS OF MOBILE HATCHERY

Site selection

Field testing of the mobile hatchery was conducted at the Ochre River, Manitoba (Lat. 61° 15'; Long. 41° 17') at a point approximately 1.6 km upstream from its entry into Dauphin Lake. This site was selected after a survey of several sites on the Valley River, Mink Creek, Turtle River, Ochre River, and Crawford drain, all of which are tributaries to Dauphin Lake. These sites were considered since it would allow evaluation of the survival, growth and distribution of hatched larvae as part of the Dauphin Lake Walleye Rehabilitation Program conducted by the Freshwater Institute. The Ochre River site was chosen because it supported a natural spawning run of walleye, exhibited spring hydrological conditions similar to those of other river systems in the area, was being monitored by other research projects and was reasonably close (25 km) to a major town (Dauphin) should parts or service be required. The spring melt waters in this river also transport large quantities of sediment which would permit testing of the system under less than optimum conditions.

The hatchery was moved to the Ochre River in March, 1985. In early April the various external modules were assembled and the systems tested without eggs for approximately three weeks. Subsequently, eggs were incubated for a four week period. Following release of the last group of larvae,additional testing was conducted for a further 10 days. The configuration of the system is presented in Fig. 1. The river bottom at the intake was approximately 2.7 m below ground level and the top of the batteries was 2.7 m above ground. Total pipe lengths from the sump pump to the settling chamber and the hatchery were 24 and 35 m, respectively.

Egg collection

The hatchery received a total of 13 million eggs from five different sources during the period of April 28 to May 14. Approximately 1.3 million eggs originating from Duck Bay and Lake of the Prairies were provided by provincial fisheries personnel and 1.5 million eggs were collected by FWI personnel from the Ochre River and a stream near Toutes Aides. Toutes Aides spawners migrate from Lake Manitoba. An additional 10 million eggs were taken by FWI personnel at Crean Lake in Prince Albert National Park, Saskatchewan.

Each batch of eggs was incubated separately at densities ranging from 0.25 to 2.84 L/jar and water flows of 4 to 6.4 $L \cdot min^{-1}$. Larger groups of eggs, such as those from Crean Lake were incubated in separate batteries. With the exception of the first two batches from Crean Lake, the eggs were incubated at ambient water temperature. Crean Lake eggs originated from cold water (7-8°C) and were transported to Ochre River in 28 L plastic containers completely filled with water. Each container held 180 to 270 thousand eggs. The temperature during transport rose to 14°C for Crean Lake, batch 1 and to 11.8°C for Crean Lake batch 2 which arrived at the hatchery on May 7 and May 11, respectively. Water temperature at the hatchery on May 7-8 was 16-18°C and to avoid additional thermal shock two batteries (A & B, Fig. 1) were put on recirculation, cooled to 14°C by adding well water (7°C) and maintained below ambient by installing two 1/3 HP chillers in larvae tanks TA & TB (Fig. 1). This operation was maintained until May 13 when all batteries were returned to the fresh water system. During the period of recirculation the formalin treatment in batteries A and B was suspended and all recirculated water was routed through the ultraviolet sterilizer.

Upon receipt the eggs were dispensed into an appropriate number of jars and the volume of eggs in each jar was measured to the nearest 50 mL. Duplicate 4 mL samples were extracted and preserved in Bouin's solution or 10% formalin. Thereafter, samples were removed every 1-2 days from specific jars representative of each batch of eggs and the number of dead and live eggs counted under a dissecting microscope. A total of 95 egg samples were examined for mortality and an estimate of relative egg size obtained as number eggs/volume of sample. Dead eggs were not removed from the incubation jars during embryonic development with one exception. One day prior to hatching the eggs in batch 3 from Crean Lake began to associate into large clumps bound with fungus. These eggs were poured into a 45 L tub and agitated by hand to break up the clumps. The dead eggs were then decanted and the viable eggs returned to the incubation jars. After completion of hatching, dead eggs and debris from each batch of eggs were collected

and preserved in formalin for enumeration.

Larvae release

Larvae were washed from the incubation batteries into the holding tanks outside the trailer. A tarpaulin was used to shade the tank. Initially the larvae were allowed to leave the tank at will but aggregations of potential predators were observed in the vicinity of the outlet to the stream and thereafter larvae were retained in the tanks with the screen inserts in place until midnight. At this time the screens were removed and a 40-watt light directed through the overflow aperture. Larvae attracted to the light were carried by the water flow to the river. In addition about 420 000 larvae were retained for 1-1.5 days, removed from the tank with fine mesh netting, and transported to the rearing ponds at Methley Beach.

RESULTS

OPERATIONS

The hatchery was set up and in operation immediately after ice-out and was run continuously from April 8 to May 24 although eggs were incubated only during part of this period. Each battery received 45 $L \cdot min^{-1}$ of water. Estimates of the water output for the 1-HP sump pump, the gas pump, the electric 0.75 HP standby and the two 1.5 HP well pumps were 450, 410, 270-340 and 225 $L \cdot min^{-1}$, respectively. Since the pumping capacity of the intake system far exceeded the 180-230 $L \cdot min^{-1}$ required for the hatchery the flow to the sediment settling chamber was reduced by a valved by-pass (V3, Fig. 1) which returned a portion of the pump output to the stream. Minor adjustments of V3 were performed as required to maintain about 20-40 $L \cdot min^{-1}$ overflow from the settling chamber. Adjustment of V3 was also required to offset major variations in stream depth and the resultant change in back pressure at the pump.

The sump pump operated continuously for seven weeks and the screened pump enclosure was able to exclude debris and functioned throughout the entire period without cleaning. The deflection of water and debris away from the enclosure by the beveled edges of the expanded aluminum screen was probably responsible for the lack of maintenance required. The stand-by gas and electrical centrifugal pumps were fully capable of supporting the water requirements of the hatchery with the sediment system on-line or bypassed. Some difficulties were encountered with clogging of the foot-valve intake screen (3 mm perforations) especially during the later parts of the season when algal growth was prevalent. Maintenance of the screen could be reduced by enlarging both the pore size and the area of the screen and by enclosing it in a box of expanded aluminum. The 1.5 HP well pumps developed water pressures exceeding 5.3 $kg \cdot cm^{-2}$ at V4 (Fig. 1) and were capable of supporting the hatchery. Unfortunately, these pumps tended to clog within a few hours of operation probably from deposition of small stones and debris on their intake screens. This situation increased the electrical drain and tripped the circuit breakers. Inclusion of these pumps in the system was discontinued during egg incubation. The recirculation and hatchery supply modules operated as expected. With all incubation batteries fully operational approximately 39 kPa was pressure developed in the PVC manifolds and the pressure alarms were activated by a 6.9 - 13.7 kPa drop in pressure. No loss in pumping capacity in these systems occurred during the test period.

The alarm system, although rather rudimentary, provided adequate protection against total or partial failure of critical elements. A fall of 13.7-20.6 kPa in the water pressure from the intake system activated a pressure switch on the tee between V4 and V5 (Fig. 1). As noted previously a pressure drop of 13.7 kPa in the recirculation or hatchery supply system activated a pressure switch and alarm bell. The float switches in the upper trough of each incubation battery were activated by a 1 cm drop in water depth and provided a back-up to the pressure alarms. These water level alarms responded within 15 sec to interruptions in water flow.

Discharge and sediment data on the Ochre River were not collected by project personnel in 1985. Discharge records for 1985 and sediment transport and discharge for 1982 were obtained from the Water Resources Branch of Environment Canada and used to estimate the stream sediment load during the period of hatchery operation. The discharge rate for the test period is presented in Fig. 10. Estimates of sediment transport for the pre-incubation (April 10 to 28) and the incubation (April 28 to May 21) periods were 0.48 and 0.06 $kg \cdot m^{-3}$ of discharge, respectively. Since the minimum pumping rate to the sediment chamber from the stream was 0.27 $m^3 \cdot min^{-1}$ the respective inputs of sediment to the chamber were 132 and 16 $g \cdot min^{-1}$. Although the accumulation of sediment in the chamber was not monitored it was observed that in one five day period in mid-April approximately 0.4 m^3 of sediment settled in the chamber. Assuming a specific weight for sediment of 1924 $kg \cdot m^{-3}$ this would represent a retention efficiency of 80% for the sediment chamber. This is undoubtedly an upper limit of efficiency since the size of the sediment particles during this period of peak flood would include the largest fraction which could be carried and the rate of settling of the larger particles would exceed that of the smaller and less dense materials. Sediment was also deposited in the incubation troughs and, to a lesser extent, in the larvae holding tanks. As expected, the coarser materials accumulated in the sediment chamber while lighter fractions were deposited in the troughs. This reflects, in part, the difference in mean water velocity in different parts of the system. Mean velocity in the chamber was 40-50 $cm \cdot min^{-1}$. In the troughs, however, the mean velocity between the inlet and the first pair of jar outlets was 50-60 $cm \cdot min^{-1}$ but decreased to 15-18 $cm \cdot min^{-1}$ in the region of the overflow standpipe. Little or no sediment accumulated in the hatchery jars during normal operation. Each jar received 4-6 $L \cdot min^{-1}$ of water resulting in a mean vertical

water velocity of 22-33 $cm \cdot min^{-1}$. Throughout the test period sediment accumulated to a depth of approximately 4 cm in the larvae tanks for a total of .17 m^3. The larvae tanks were not cleaned during the test period. To clean the battery troughs the hoses to each jar were relocated to the adjacent trough, the standpipes removed sequentially from the upper to the bottom trough and the troughs flushed with a hose in the same sequence. Approximately 18 min were required to clean and return one battery to operation. Since sediment loads were relatively light it was not necessary to clean the batteries during the incubation period.

EGG INCUBATION

The number, survival rate, period of incubation, and thermal units accumulated to hatch for the seven groups of eggs incubated in the mobile hatchery are presented in Table 3. The daily maximum and minimum water temperature and Ochre River discharge rates in relation to the incubation period of each group of eggs is presented in Fig. 10. Discharge rate was relatively constant during the incubation period, ranging between 0.14 and 0.27 $m^3 \cdot sec^{-1}$. Water temperature fluctuated substantially, however, with daily maxima and minima often differing by 3 to 4°C. In addition, a 10°C decline in water temperature occurred in the period of May 9 to 13, followed by an 11°C rise during the next 4 days. This oscillation in temperature did not have an adverse effect on embryonic development, however, since the Crean Lake group 1 eggs which experienced the entire cycle still exhibited a 75% rate of hatch. Water temperature in the hatchery batteries rose approximately 0.1 to 0.2°C over that recorded in the rivers during the days of highest air temperature and were equal to river temperatures on cooler days.

The lowest rate of survival (56%) occurred in eggs spawned at the Ochre River. Eggs which were water hardened in Ochre River water experienced immediate and severe clumping and this effect occurred in water collected from the headwaters or at the hatchery site. Tannic acid treatment (400 $mg \cdot L^{-1}$ for 3 min) or mixing with fine sediment failed to reduce the egg aggregation. Fertilized eggs from Toutes Aides also clumped severely when hardened in Ochre water, but not when hardened in Toutes Aides water. Conversely, Ochre River eggs hardened in Toutes Aides water could be separated by gentle stirring. The chemical factors responsible for the clumping of eggs in Ochre River water have not been identified. Clumping was not observed, however, in any eggs which were completely water hardened prior to exposure to Ochre River water.

The development of fungus in the incubation jars was not generally extensive. In most cases daily treatment with 1:2000 formalin prevented the formation of fungus mats even though the dead eggs were not removed from the jars. In certain cases, especially eggs which had been water hardened in Ochre River water some fungus did develop in the egg clumps. These jars were treated with 1:600 to 1:1000 formalin, once daily for 2-4 days prior to hatch. The eggs in group 3 from Crean Lake also developed a substantial fungal growth and were washed as described previously. In this latter case the extremely high water temperatures experienced in the last days of embryonic development were probably responsible for the increase in the rate of fungal growth. The use of ultraviolet irradiation to control disease organisms during the period of water recirculation for Crean Lake groups 1 and 2 proved highly satisfactory since no enhancement of fungal development was observed during the incubation of these eggs.

Although samples were taken from all jars for estimation of survival, only selected jars from each group were sampled periodically throughout the incubation period to identify trends in mortality over time. Surprisingly, no significant trends in mortality were observed during embryonic development and the coefficients of variation (100 x standard deviation/mean) for the survival estimates of five individual jars were 3.5, 8.2, 9.0, 9.8 and 17.7% based on 5-6 samples/jar collected over the incubation period. These values do not include mortalities experienced by larvae after they swam out of the jars and were collected in the larvae tanks. Very few dead or moribund larvae were seen in the tanks, however, and only a few dead larvae were observed when the tanks were drained just after the bulk of the larvae had been released.

Under the conditions experienced in the hatchery most eggs hatched within 10 to 13 days after accumulating 130 to 160 thermal units. The thermal units were calculated by integrating the water temperatures (°C) recorded several times each day over the period of development. The third group of Crean Lake eggs hatched a little sooner although the uncertain number of thermal units accumulated by Crean L. eggs while they were held at the spawning site prior to transport to the hatchery complicated the estimation of the precise number of units required for their development. In general, however, the degree-days to hatch are within the range commonly observed for walleye (Colby et al. 1979). Very few walleye returned to spawn naturally in the Ochre River in 1985 and significant numbers of larvae were not caught in stream traps so it was not possible to relate the timing of natural hatch in the river to the timing of hatch in the mobile hatchery. The timing of maximum larval drift of walleyes in the Turtle River (8 km east of Ochre River), however was within 24 h of the peak hatch of Toutes Aides and Ochre River eggs which suggests a close relationship between the rates of embryonic development in both situations.

Since the volume of eggs per jar varied from 0.23 to 2.6 L an analysis of the relationship between survival and the relative volume of eggs per jar was performed on groups 1 and 2 from Crean Lake which occupied 22 and 20 jars, respectively. Linear regression analysis yielded the following:

$S = 84.3 - 4.97V$ $r = -0.348$ Crean L. group 1
$S = 85.5 - 2.68V$ $r = -0.258$ Crean L. group 2
where: S = percent survival to hatch
V = volume of eggs per jar in litres

Thus although the relationships were not statistically significant, ($P>.05$), the results suggest that survival may decrease by 3-6% for each liter of eggs incubated in the jar.

Estimates of the mean relative egg size were derived from the counts of eggs in a specific sample volume. Considerable variability was observed in the different groups (Table 4). Estimates of the number of eggs per liter varied from a low of 83 731 to a high of 148 659 in Ochre River and Toutes Aides eggs, respectively. There was also a 40% difference in relative size for eggs collected from Toutes Aides on different days. This difference was not observed, however, in the three groups of eggs from Crean Lake. The significance of egg size in relation to success of hatch and size of larvae at hatch was not examined critically but it can be noted that the highest rates of survival occurred in the groups exhibiting the smallest relative size. This is consistent with the inverse relationship between egg diameter and hatching success reported for chum salmon, Onchorhynchus keta (Beacham and Murray 1985).

LARVAL RELEASE

As soon as hatching was observed in a group of eggs the jar screens were removed and the larvae allowed to leave the incubators. Upon arrival in the larvae tanks which were covered with a tarpaulin, the larvae could exit directly to the river or remain in the tank. No attempts were made to count the larvae. Eggs from Ochre River, Toutes Aides and Lake of the Prairies hatched in the period of May 9 to 13 and were released into larvae tanks TC and TD (Fig. 1) while water from TA and TB was being recirculated through batteries A and B. A sample of 100 larvae were collected from the outlet pipe in the river and held in a plastic pail for 24 h to assess any trauma which may have occurred during release. No mortalities were observed. On May 19 large numbers of larvae left the holding tanks during the daylight period. At that time aggregations of minnows were observed in the region of the drain outlet. Samples of these fish caught by dipnet contained walleye larvae in their stomachs (Table 5) and thereafter the screens were inserted into the holding tanks to prevent larvae from leaving until after 22:00 hours. The outlet pipe was also extended into an area of faster stream flow. This procedure reduced the rate of predation both in terms of the percentage of successful predators and the number of larvae caught by successful predators. A second test of daylight versus darkness release was conducted on May 21-22. Although the predator population as sampled by electrofishing had changed in species composition, there was a reduced percentage of successful predators during the night releases (Table 5). The increase in the number of larvae caught by successful predators probably reflects the large number of walleye larvae released during the night of May 21 (Table 3). These results, although scanty, indicate a need for evaluation of the impact of predation upon larvae released into a stream or lake from a point source.

In addition to the walleye larvae released directly to the Ochre River, approximately 420 000 larvae were dipnetted from the holding tanks and used to stock four one-hectare experimental ponds at Methley Beach and for various feeding behaviour and drift-net calibration studies. The pond studies provided an opportunity to monitor the viability of larvae produced in the mobile hatchery. Minimum estimates of survival to June 26 (five weeks after hatch) ranged from 17 to 35% in the four ponds with a mean of 28.2% for all ponds (J. Mathias, FWI, Winnipeg, Manitoba pers. comm.). None of the seven million Crean Lake walleye larvae released on May 19 to 22 were recovered as fingerlings during their first five months of residence in Dauphin Lake. Estimates of survival of larvae to age 1+ will be made in Dauphin Lake in 1986.

DISASSEMBLY AND PREPARATION FOR TRANSPORT OF HATCHERY

Since one of the original requirements for the mobile hatchery was the ability to operate the unit in two locations per year (Underwood McLellan 1983) a measure of the time to convert from operating mode to transport mode was required. The hatchery remained in operation for approximately one week after completion of the walleye incubation. When all operations and tests were concluded the systems were shut down and the batteries, larvae tanks and sediment chamber cleaned. The incubation jars were stored inside the lower trough of each battery and some of the valves removed from the troughs to avoid breakage when storing the various pump modules and tanks. All the pumps, and electrical services were stored between the batteries while the tanks, hoses, pipes, etc., were stored in the main aisle. Complete disassembly, cleaning, storage and preparation for transport required less than 10 man-hours and was accomplished by two men in half a day, with assistance of a third man for 20 minutes to load the larval and sediment tanks.

OPERATING COSTS

The operating costs for the 1985 field test of the mobile walleye hatchery are presented in Table 6 and include the costs for the entire 10-wk period. The contract costs represent the salaries for an individual with extensive experience in spawn taking and hatchery practise and an assistant with a general background in biology. The residence was a rented 23 ft mobile home which could accommodate four people. Item 4 (Table 6) includes the costs of staff transportation to and from Winnipeg, gas for the residence and other incidental expenses. The relocation costs represent the expenses incurred in moving the hatchery unit from the Rockwood experimental fish hatchery to the Ochre

River but do not include the costs of the return trip. The remaining items are self-explanatory.

BENEFIT:COST ANALYSIS

Various benefit:cost analysis for the operation of a ten million egg walleye hatchery were performed during a feasibiity study by Underwood McLellan Co. Ltd. (1983) and are available in their report. Their analysis suggested that the benefit to cost ratio would range from approximatey 1.0-1.2 if all the benefits were realized by an existing commercial fishery to 2.6 - 3.0 if all the benefits were realized by a recreational fishery. The benefits were calculated using values of $2.50/kg and $6.35/kg for the value of the catch to the commercial and recreational fishery, respectively, and a larvae to age 3+ survival of 0.16%. Estimates of the contribution of the larvae production from a single cycle of operation to the walleye population of Dauphin Lake are presented in Table 7. These estimates are based on estimates of growth, survival and fecundity in this system provided by J. Craig (FWI, Winnipeg, Manitoba pers. comm.) and assume a 1:1 sex ratio. Using an initial capital cost of $60 000 amortized over 10 years at 12% annual interest and an operating cost of $12 000 the benefit: cost ratio to the commercial and recreational fishery would be 0.7 and 1.7, respectively. In addition a total of 109.5 million eggs would be contributed to the spawning potential of the walleye population. These estimates are based on the conservative assumption that 0.05% of the larvae reach catchable size (age 3+).

DISCUSSION

Although the mobile hatchery was operated at only 40% of its design capacity the 1985 field tests demonstrated that the concept was practical. Hatching success equalled or exceeded that experienced in the most successful fixed hatcheries in Manitoba (Corbett 1986) even with minimal treatment of the water from the Ochre River. A relatively simple system for partial control of water temperature also proved practical. The time required to complete embryonic development was generaly 10-13 days which is substantially less than that observed in most fixed hatcheries at this latitude. The thermal units (mean daily water temperature in °C x incubation period in days) accumulated to hatching averaged 141 which is within the range observed in other stocks of walleye (Colby et al. 1979). The shorter development period observed during the field test is a reflection of the higher rate of warming and greater daily temperature fluctuations which occur in riverine versus lacustrine environments during the spring. Since the water temperature warmed by less than 0.2°C during passage through the hatchery the timing of natural hatching should be similar to that observed in the hatchery. In fact, the peak emigration of walleye larvae from the Turtle River, located 8 km east of the Ochre River occurred on May 12 (W. Franzin, FWI, Winnipeg, Manitoba pers. comm.) which is within the hatching period of eggs from Toutes Aides and Ochre River in the mobile hatchery. Natural larvae production from the Ochre River was not comparable since the adult walleye were prevented from migrating upstream by the counting fence operated at the hatchery site.

The use of formalin and ultraviolet irradiation for the control of disease organisms in the flow through and recirculation modes of operation, respectively, was generally satisfactory. Daily treatment with formalin is a common prophylactic procedure in freshwater hatcheries and kept fungus development to a minimum in the present tests. The last group of Crean Lake eggs developed a severe fungal growth within one day after cessation of the formalin treatment and the live egg had to be separated by hand agitation from the fungal mass. Alternatively no fungus developed in the Crean Lake eggs kept on recirculated water for four days without formalin treatment but with ultraviolet sterilization. The UV sterilizer was rated to provide effective sterilization at a flow rate of 400 $L \cdot min^{-1}$. Since the flow through the sterilizer during recirculation was approximately 100 $L \cdot min^{-1}$ and the recirculation time through the system was approximately 20 min it is probable that most disease organisms were killed or inactivated. Sediment and dissolved materials carried in water significantly reduce the penetration of ultraviolet irradiation but apparently the decrease in efficiency was more than offset by the reduction in flow and continual recycling of the water through the sterilizer.

The viability of the larvae from the mobile hatchery appeared to be reasonable since 28% survived for six weeks in the artificial rearing ponds located at Methley Beach. Furthermore, no mortality was observed in samples of larvae recaptured at the outlet of the drain pipe from the larvae tanks and held for 24 hours. Visual observations of fish in the holding tank also indicated a surprisingly strong swimming ability since the larvae could resist being swept away by a velocity of about 2 $cm \cdot sec^{-1}$ for several seconds.

The annual costs of operation for a five week period would be $4 000, plus ten person-weeks salary and cost of hatchery relocation for a total of $11 000 to $12 000. To this must be added the cost of obtaining the eggs. Although the hatchery personnel could assist in the spawning operation, it is unlikely that, unaided, they could obtain sufficient spawn to fill the hatchery. In 1985 the most productive spawning operation in Manitoba yielded less than one million eggs per man-day of effort (Corbett 1986). It is probable, therefore that either a spawn collection crew would be required if local walleye stocks were to be spawned or eggs would have to be obtained from other spawning operations. With the alarm system to monitor the hatchery operation during off hours two persons could easily perform the daily maintenance functions including removal of dead eggs, formalin treatment, water flow adjustments and routine sampling. In most situations the incubation period would span a two to three week period if the eggs were fertilized about the

same time.

Where the purpose of stocking has been to supplement existing walleye populations, stocking rates of 1 000 to 15 000 larvae/hectare have been shown to increase the number of fingerling walleye in various lakes (Fourney 1975; Laarman 1978). At an average density of 12 000 larvae/hectare the output of the mobile hatchery could adequately stock a lake of 1750 hectares (17.5 km^2) if embryonic survival was 70%. For smaller lakes or reservoirs the hatchery could be reduced in size although capital and operating costs would not be reduced proportionally. Alternatively the capacity of the present system could be increased by 50% by adding two more incubation batteries and 42 more jars at a cost of approximately $7 200 (Table 2; 1985 prices).

Although the operational feasibility of a mobile hatchery for walleye eggs has been demonstrated the benefit:cost aspects are far less certain. An analysis of the estimated production of adult walleye from a single cycle of operation at full capacity (Table 7) suggests an estimated cash value of harvestible fish ranging from approximately $15 700 for an exclusively commercial fishery to $39 300 for an exclusively sport fishery. Assuming an initial capital cost of $60 000 amortized over a ten year life span at an interest rate of 12% per annum and an operating cost of $12 000, exclusive of the costs of spawntaking, the benefit to cost ratio would range from 0.69 to 1.74. This ratio could be increased by at least 10% by downsizing the water delivery system or by 42% by increasing the hatchery capacity to 45 million eggs. Although other methods can be employed in such analyses, these analyses would indicate that a reasonable return on investment may be realized. If survival rates of larvae to the yearling stage are more favorable as a result of the benefits derived from incubating the eggs in the receiving waters and not subjecting the larvae to handling stress the benefit to cost relationship could be improved substantially.

Direct, quantitative comparisons of the cost effectiveness between conventional and mobile hatcheries are complicated by differences in scale of operation, location and methods of operation. The estimated annual costs associated with the incubation of walleye eggs, exclusive of spawn collection and larvae distribution of the Swan Creek Hatchery in Manitoba is $10 850 (B. Schaldemose, Fisheries Branch, Manitoba Dept. Natural Resources; pers. comm.). In the past decade an average of 51 million larvae were produced at an average cost for incubation of $212 per million which is approximately one-third of the $570 per million larvae estimated for the mobile hatchery. The Swan Creek Hatchery, however, is the most productive of the hatcheries in Manitoba and has accounted for about 62% of the total walleye larvae output over the past ten year (Corbett 1986). Given the economies of size which could be realized by increasing the capacity of the mobile hatchery and the savings realized by releasing the larvae immediately upon hatch versus transportation from a central hatchery it is probable that a production style mobile hatchery would compare favorably with fixed, conventional hatcheries in terms of cost per larvae. Any benefits resulting from increased larval survival because of reduced handling and acclimation to the receiving waters would further increase the efficiency of the mobile facility. Additional socio-economic benefits may also result from the exposure of the general public to aquaculture activities and employment of local workers during the incubation period. These potential benefits are difficult to quantify but, based on the interest expressed during the 1985 field tests are likely to be significant in terms of program support and development of an understanding of the need for protection, conservation and rehabilitation of heavily stressed walleye populations.

SUMMARY

1. The mobile hatchery was capable of successfully supporting the embryonic development of walleye eggs and achieved survival rates comparable to those from fixed hatcheries.

2. Relatively unsophisticated techniques were required to remove the majority of the sediment from the raw water and provide water of an acceptable quality for the incubation of walleye eggs.

3. Control of disease organisms with daily formalin treatment when the system was operated without recirculation or with continuous ultraviolet irradiation during recirculation was generally successful under a wide range of egg loading rates and incubation temperatures.

4. Some degree of temperature control does appear feasible using the recirculation capability of the hatchery although the present tests only dealt with cooling.

5. Larvae produced in the hatchery appear to be viable, at least to the fingerling stage.

6. The hatchery can be assembled and dismantled in a short period of time and could be relocated within a two day period. The feasibility of operating the unit at two locations per year would depend more on the timing of the two spawning runs than on the time required for relocation of the hatchery. Since timing of walleye sexual development may depend upon several factors, including climatic conditions it is difficult to assess the feasibility of this option.

7. Several modifications to the present system would appear advisable to reduce the initial construction costs and/or improve the operation of the unit. First since the system operates at relatively low pressure <80 kPa most of the piping and plumbing components in the incubation room could use schedule 40 PVC in place of the schedule 80 PVC. The hoses, pipes and valves in the distribution system could easily be reduced to 1.5 in (3.8 cm) diameter. This would reduce the cost of these components by at least 40%. Schedule 80 materials could still be used on components which experience severe stress such

as the couplings. Secondly, the use of multi-stage, high pressure pumps is not recommended unless the water source is much cleaner than the Ochre River. The 1-HP sump pump supplied more than enough water for hatchery operations and was not adversely affected by a wide range of stream conditions. Thirdly, the level of back-up for the various pumping systems could probably be reduced substantially. Duplicate pumps in the hatchery supply and recirculation modules could be eliminated. By using a single size and uniform fittings for all non-submersible, centrifugal pumps, a single pump could be available as a standby replacement for any defective component.It would also be feasible to reduce the external electrical services and have all controls at the main breaker panel in the office. This would reduce the flexibility for setting up the modules in different configurations but could also result in considerable cost reductions. Fourthly, the size of the diesel generator should be reduced to 7.5-8 KW from 12 KW. The 4 KW gas generator could support the hatchery but a diesel unit is considerably less expensive to operate. Fifthly the larvae tanks were not considered adequate, either in terms of design or capacity, to serve their primary purpose of holding larvae for one to three days. Larvae could escape around the edges of the screen frames and possibly incur physical damage. Furthermore the size of the tanks while adequate for one million larvae would be severely over-crowded if the eggs in an entire incubation battery hatched over a short period of time. A possible alternative would be the use of collapsible water tanks (capacity, 6 to 8 m^3) commonly used in fire fighting camps. These tanks could be fitted with removable screens to retain the larvae. The present larvae tanks could be reduced in size by 75 percent and incorporated into the recirculation system and thereby retain the capability of maintaining a degree of temperature control in individual batteries.

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REFERENCES

BEACHAM, T.D., and C.B. MURRAY. 1985. Effect of female size, egg size and water temperature on developmental biology of chum salmon (Oncorhynchus keta) from the Nitinat River, British Columbia. Can. J. Fish. Aquat. Sci. 42: 1755-1765.

BUSCH, W.N., R.L. SCHOLL, and W.L. HARTMAN. 1975. Environmental factors affecting the strength of walleye (Stizostedion vitreum vitreum) year-classes in western Lake Erie, 1960-1970. J. Fish. Res. Board Can. 32: 1735-1743.

BROWN, E.E., and J.B. GRATZEK. 1980. Fish farming handbook. Avi Publishing Co. Int., Westport, CT. 391 p.

CANADIAN FISHERIES ANNUAL STATISTICAL REVIEW. 1983. Vol. 16. Communications Directorate, Department of Fisheries and Oceans, Ottawa, Ontario. 182 p.

CARMICHAEL, G.J., A. WEDEMEYER, P.J. McCRAREN, and J.L. MILLARD. 1983. Physiological effects of handling and hauling stress on smallmouth bass. Prog. Fish-Cult. 45: 110-113.

COLBY, P.J., R.E. McNICOL, and R.A. RYDER. 1979. Synopsis of biological data on the walleye, Stizostedion v. vitreum (Mitchell 1818). FAO Fish. Synop. 119: 139 p.

COLESANTE, R.T. 1980. Walleye fry: Shipping and Stocking Mortality. Prog. Fish-Cult. 42: 238-239.

CORBETT, B. 1986. A review of Manitoba's 1985 walleye spawntaking program. In. Walleye Rehabilitation and Enhancement Newsletter, No. 4, Spring 1986. Deptartment of Fisheries and Oceans, Freshwater Institute, Winnipeg, Manitoba. 26 p.

FOURNEY, J.L. 1975. Contribution of stocked fry to walleye fry populations in New York lakes. Prog. Fish-Cult. 37: 20-24.

FOURNEY, J.L. 1976. Year-class formation in the walleye (Stizostedion vitreum vitreum) population of Oneida Lake, New York, 1966-73. J. Fish. Res. Board Can. 33: 783-792.

GRIFFITHS, J.S. 1981. Potential effects of fluctuating thermal regimes on incubation of walleye eggs. Ontario Hydro Research Division Report No. 81-77-K. 59 p.

JOHNSON, F.H. 1961. Walleye egg survival during incubation on several types of bottom in Lake Winnibigoshish, Minnesota, and connecting waters. Trans. Am. Fish. Soc. 90: 312-322.

KRAMER, R.H., and L.L. SMITH, Jr. 1966. Survival of walleye eggs in suspended wood fibres. Prog. Fish-Cult. 28: 79-82.

LAARMAN, P.W. 1978. Considerations in percid management. Case histories of stocking walleyes in inland lakes, impoundments, and the Great Lakes - 100 years with walleyes. Am. Fish. Soc. Spec. Publ. 11: 254-260.

OSEID, D.M., and L.L. SMITH, Jr. 1971. Survival and hatching of walleye eggs at various dissolved oxygen levels. Prog. Fish-Cult. 33: 81-85.

PICKERING, A.D., T.G. POTTINGER, and P. CHRISTIE. 1982. Recovery of the brown trout, Salmo trutta L., from acute handling stress: a time course study. J. Fish Biol. 20: 229-244.

UNDERWOOD McLELLAN LTD. 1983. Feasibility of a mobile walleye hatchery and rearing system. Report to Department of Supply and Services Canada. DSS File No. 01SF-EP430-3-S018: iv + 76 p.

Table 1. Minimum design specifications for the mobile walleye hatchery.

INCUBATION CAPACITY	
total number of eggs	30 million
number of incubation jars	84
number eggs/jar	360 000
HATCHERY CONFIGURATION	
number of tiers/battery	4
number of batteries	4
number of jars/tier	7 (for 3 tiers)
WATER REQUIREMENTS	
per jar	4-6 $L \cdot min^{-1}$
per battery	28-42 $L \cdot min^{-1}$
total for hatchery	112-168 $L \cdot min^{-1}$
DISEASE CONTROL	
daily	1:2000 formaldehyde for 15 minutes/battery
recirculation	continuous ultraviolet sterilization

Table 2. Summary of components of the mobile walleye hatchery and costs (1984/85 prices).

Item	Description*	Number Units	Cost/Unit	Cost (Total)	Supplier†	Address
Battery Incubation (4 troughs/bat. + frame)	30455; frame, 16 ga.; tanks, 14 ga.; 60x16x12 in, LxWxD	4 each	$ 2 263.00	$ 9 053.00	Heli-Fab Ltd.	150 Cree Cres. Winnipeg, Manitoba
Electrical, Supplies & Installation	parts & install. elect. circuits & modules	1 total	$ 6 390.00	$ 6 390.00	Local contractors & suppliers	Winnipeg
Fuel pump (for diesel fuel)	Horn - type hand pump	1 each	$ 65.00	$ 65.00	Princess Auto	475 Planet, Winnipeg, Manitoba
Generator	Pritchard mod. AD12 KW, air cooled & trailer	1 each	$10 258.00	$10 258.00	Pritchard Engineering Co. Ltd.	111 Bannister Ave. P.O. Box 1740, Winnipeg Manitoba R3C 3A1
Generator, Gas (4 KW)	Onan, mod. 4CCK-3CE.22000, 2-cyl. elec.-start	1 each	$ 4 046.00	$ 4 046.00	Pryme Power & Diesels Ltd.	415 Turenne, Winnipeg, Manitoba
Jar, Hatchery	Mod. MPC-300, plastic (6x18 in, DxH)	84 each	$ 55.95	$ 4 700.00	Midland Plastics Inc.	Box 423, 3605-126th St., Brookfield, Wisconsin, U.S.A. 53005
Microswitch, enclosed, waterproof	VARAH, mod. BZV6-2RN4, flange amount, SPDT	4 each	$ 52.85	$ 211.40	L.A. Varah Ltd.	12-1832 King Edward St., Winnipeg, Manitoba
Penrose Drain (latex tubing)	0.5 in diam.	30 pcs.	$ 1.81	$ 54.30	Steven & Son Ltd.	980 Nairn, Winnipeg, Manitoba
Pump Enclosure, (1HP pump)	(30x26x18 ir, HxSxB; 1 in alum. tube) exterior covering, 0.125 x 0.1875 in expand. alum.	1 each	$ 550.00	$ 550.00	Heli-Fab Ltd.	150 Cree Cres. Winnipeg, Manitoba
Pump, gas, (centrifugal)	Monarch, mod. 5ACGF-6, 5HP	1 each	$ 379.00	$ 379.00	Prairie Water Services	89 Fennell, Winnipeg, Manitoba
Pump, nonsubmersible, (centrifugal)	Jacuzzi, mod. 5LE, 115v., 0.5 HP	2 each	$ 182.00	$ 364.00	Prairie Water Services	89 Fennell, Winnipeg, Manitoba
Pump, nonsubmersible, (centrifugal)	Jacuzzi, mod. 7LE, 230v., 1-cycle, 0.75 HP	3 each	$ 192.00	$ 576.00	Prairie Water Services	89 Fennell, Winnipeg, Manitoba
Pump, submersible, (sump)	Hydromatic, mod. SP100AH, 230v., single cycle, 1 HP	1 each	$ 850.00	$ 850.00	Emco Supply	801 Century St., Winnipeg, Manitoba
Pump, submersible, (well)	GSW, mod. 150K10WJ11B, 230v., 1-cycle, 11-stage 1.5 B HP	2 each	$ 715.00	$ 1 430.00	Prairie Water Services	89 Fennell, Winnipeg, Manitoba
Screen, Nitex	8 yd each of 400 & 710 micron mesh	16 yds	$ 14.10	$ 225.60	J.T. Keenan Distributors Ltd.	194 Osborne St. Winnipeg, Manitoba
Sterilizer, Ultraviolet	Trojan mod. TS6100, 100 gpm, 2 in, FNPT ports	1 each	$4,600.00	$ 4,600.00	Trojan Technologies Inc.	Ste. 3120 South Tower, Royal Bank Plaza Toronto, Ontario M5J 2J4
Tanks, Larvae (2 ea., incl. 16 screen frame)	LxWxD; 96x36x32 in; 0.125 in, type 6061T6 aluminum	2 each	$1,475.00	$ 2,950.00	Heli-Fab Ltd.	150 Cree Cres. Winnipeg, Manitoba
		Equipment Total		45 272.30		
PLUMBING COMPONENTS:						
Adapter, hose	Insert x MNPT, 0.5 in	84 each	$ 0.46	$ 38.60	Scepter Manufacturing Co. Ltd.	2081 Logan, Winnipeg, Manitoba
Bushing, reducer	PVC, 2x1 in	12 each	$ 5.25	$ 63.00	Scepter Manufacturing Co. Ltd.	2081 Logan, Winnipeg, Manitoba
Bushing, reducer	PVC, 1 x 0.75 in	12 each	$ 2.45	$ 29.40	Scepter Manufacturing Co. Ltd.	2081 Logan, Winnipeg, Manitoba
Couplers, aluminum (2 in)	1 set hose x hose, remainder hose x male/female	16 pairs	$ 20.00	$ 320.00	Mackay Morton Ltd.	50 Myrtle St. Winnipeg, Manitoba R3E 2R2
Couplers, aluminum (6 in)	Quick-couplers, one type C & one type F/set	3 sets	$ 125.59	$ 375.87	Mackay Morton Ltd.	50 Myrtle St. Winnipeg, Manitoba R3E 2R2
Elbow, 90*, 0.5 in	Schedule 80 PVC, FNPT x FNPT	84 each	$ 3.40	$ 285.60	Sceptor Manufacturing Co. Ltd.	2081 Logan, Winnipeg, Manitoba
Elbow, 90*, 2 in	Schedule 80 PVC, SOC x SOC	14 each	$ 4.40	$ 61.60	Sceptor Manufacturing Co. Ltd.	2081 Logan, Winnipeg, Manitoba
Elbow, 90*, 4 in	Schedule 80 PVC, FNPT x FNPT	4 each	$ 79.60	$ 318.40	Sceptor Manufacturing Co. Ltd.	2081 Logan, Winnipeg, Manitoba
Elbow, 90*, 1 in	Schedule 80 PVC, FNPT x FNPT	16 each	$ 3.25	$ 52.00	Sceptor Manufacturing Co. Ltd.	2081 Logan, Winnipeg, Manitoba
Gauge, pressure	Marsh, mod. #J1448	3 each	$ 11.28	$ 33.84	Mackay Morton Ltd.	50 Myrtle St., Winnipeg, Manitoba R3E 2R2
Hose 2 in (suction)	Ju-flex, heavy duty, yellow-stripe, 150 psi rating	300 feet	$ 2.84	$ 852.00	Mackay Morton Ltd.	50 Myrtle St., Winnipeg, Manitoba R3E 2R2
Hose, 4 in (suction)	Hy-flex, wire-reinforced, rubber	30 ft.	$ 6.72	$ 201.60	Mackay Morton Ltd.	50 Myrtle St., Winnipeg, Manitoba R3E 2R2
Hose, 6 in (lay-flat)	Blue-Devil	300 ft.	$ 1.98	$ 594.00	Mackay Morton Ltd.	50 Myrtle St., Winnipeg, Manitoba R3E 2R2
Nipple, 0.5 in	Schedule 80 PVC	168 each	$ 0.78	$ 131.04	Scepter Manufacturing Co. Ltd.	2081 Logan, Winnipeg, Manitoba
Nipple, 2 in	Schedule 80 PVC	44 each	$ 2.11	$ 92.84	Scepter Manufacturing Co. Ltd.	2081 Logan, Winnipeg, Manitoba
Nipple, 0.75 in	Nylon, NPT x Hose	8 each	$ 0.58	$ 4.64	Scepter Manufacturing Co. Ltd.	2081 Logan, Winnipeg, Manitoba
Nipple, 4 in	Schedule 80 PVC, NPT x Hose	4 each	$ 133.00	$ 532.00	Scepter Manufacturing Co. Ltd.	2081 Logan, Winnipeg, Manitoba
Pipe, 1 in	Schedule 80 PVC	100 ft.	$ 1.35	$ 135.00	Scepter Manufacturing Co. Ltd.	2081 Logan, Winnipeg, Manitoba
Pipe, 2 in	Schedule 80 PVC	100 ft.	$ 2.67	$ 266.80	Scepter Manufacturing Co. Ltd.	2081 Logan, Winnipeg, Manitoba
Tee, 2 in	PVC, Soc x Soc x Soc	22 each	$ 7.45	$ 163.90	Scepter Manufacturing Co. Ltd.	2081 Logan, Winnipeg, Manitoba
Tee, 6 in	Aluminum, 0.125 in wall	2 each	$ 50.00	$ 100.00	Heli-Fab Ltd.	150 Cree Cres. Winnipeg, Manitoba
Union, 2 in	PVC	8 each	$ 22.30	$ 178.40	Scepter Manufacturing Co. Ltd.	2081 Logan, Winnipeg, Manitoba
Valve, ball, 1 in	PVC, True Union	1 each	$ 44.40	$ 44.40	Scepter Manufacturing Co. Ltd.	2081 Logan, Winnipeg, Manitoba
Valve, ball, 2 in	PVC, True Union	12 each	$ 100.20	$ 1 202.40	Scepter Manufacturing Co. Ltd.	2081 Logan, Winnipeg, Manitoba
Valve, check, 2 in	PVC	4 each	$ 18.50	$ 74.00	Scepter Manufacturing Co. Ltd.	2081 Logan, Winnipeg, Manitoba
Valve, gate, 0.5 in	Bagdad, FNPT x FNPT	84 each	$ 3.35	$ 281.40	Scepter Manufacturing Co. Ltd.	2081 Logan, Winnipeg, Manitoba
Valve, ball, 0.75 in	PVC, True Union	10 each	$ 36.40	$ 364.00	Scepter Manufacturing Co. Ltd.	2081 Logan, Winnipeg, Manitoba
SUM OF PLUMBING COMPONENTS				$ 6 796.73		
Trailer	ATCO, 42 x 10 ft, used,	1 each	$ 6 000.00	$ 6 000.00		
TOTAL COST				$58 069.03		

* The units of measure (Imperial or metric) are those provided by the supplier.
† The suppliers of the various items are identified but this does not imply endorsement of specific companies.

Table 3. Summary of sources, survival and rates of development of eggs incubated in the mobile hatchery in 1985.

Source	No. Eggs	No. Jars	No. Larvae	Percent Survival (Mean/Range)	Date Fertilized / Date Hatched	Embryonic Development (Days)	Degree-Days
Manitoba							
Ochre River	759 500	8	428 360	56.4	Apr 28 - May 2 / (May 10 - 12)	12-13	131.3 - 159.7
Lake of the Prairies	268 330	3	164 750	61.4 (57 - 66)	May 2 / (May 12 - 13)	10-11	143.3 - 152.0
Duck Bay	990 230	5	745 130	75.2 (65 - 90)	May 10 / (May 20 - 21)	10-11	129.0 - 144.3
Toutes Aides	815 410	6	561 000	68.8 (57 - 97)	Apr 28 - May 2 / (May 9 - 12)	11-12	129.0 - 146.7
Saskatchewan							
Crean Lake #1	4 007 330	22	3 015 830	73.5 (59 - 85)	May 3 - 6 / (May 19-20)	13-14	*135.0 - 149.3
Crean Lake #2	5 502 760	20	4 164 900	75.7 (66 - 85)	May 7 - 10 / (May 21)	11-13	*130.8
Crean Lake #3	549 140	3	377 810	68.8	May 11 - 13 / (May 22)	8-10	*116.8
TOTAL	12 892 700		9 457 780	73.4			

*8 to 24 degree-days to be added to these values for time held at 7-8°C at Crean Lake.

Table 4. Summary of relative sizes of walleye eggs incubated in the mobile hatchery in 1985.

Source	N+	Number Eggs·L^{-1}		
		mean	standard deviation	coefficient variation
Ochre River	4	83 731	13 511	16.1
Lake of Prairies	3	87 073	13 107	15.1
Duck Bay	5	145 502	9 730	6.7
Toutes Aides				
Apr. 28	4	106 220	6 929	6.5
May 2	4	148 659	13 815	9.3
Crean Lake #1	22	109 585	6 122	5.6
Crean Lake #2	20	115 366	5 512	4.8
Crean Lake #3	5	115 415	3 635	3.1

+N is the number of jars of eggs from each source.

Table 5. Summary of predation upon walleye larvae in the vicinity of the release site of the mobile hatchery by various species of minnows.

Sample Date	Species	Number	Fork Length+ (mm)	Weight+ (g)	Successful Predators (Percent)	Larvae/Predator*
May 19 (18:00 h)	Emerald Shiner *Notropis antherinoides*	44	27.9 (4.1)	0.257 (.172)	61.4	6.7
May 20 (23:00 h)	" "	12	34.2 (7.0)	0.392 (.232)	16.7	2
May 21 (10:30 h)	Spottail Shiner *N. hudsonius*	16	72.4 (8.2)	5.459 1.438	25	3.8
	River Darter *Percina shumardi*	12	56.2 (2.5)	1.733 (0.24)	0	0
	Common shiner *N. cornutus*	5	56.4 (21.8)	3.94 (4.35)	60	13.3
	Longnose Dace *Rhinichthys cataractae*	1	40.6	0.78	0	0
	Johnny Darter *Etheostoma nigrum*	3	43.2 (1.0)	0.633 (.01)	0	0
	Blackchin shiner *N. heterodon*	1	49.9	1.74	0	0
	Logperch *Percina caprodes*	1	74.7	4.94	0	0
May 22 (00:30 h)	Spottail shiner	64	68.5 (16.9)	5.24 (3.52)	14.1	29.2
	Johnny Darter	2	57.4	1.86	0	0

*Successful predators only
+mean (1 standard deviation)

Table 6. Summary of operating costs for 1985 field testing of mobile hatchery.

1.	Fuel and Maintenance for Diesel Generator	$ 1 531.78
2.	Relocation	$ 650.00
3.	Contracts (20 person-weeks)	$13 564.72
4.	Travel and Incidental Expenses	$ 1 322.31
5.	Repairs and Sundry Expenses for Hatchery	$ 400.00
6.	Residence	$ 3 260.00
7.	Food	$ 1 376.04
	TOTAL	$22 104.85

The costs incurred during the actual period of egg incubation and release would be apprroximately half of this total.

Table 7. Estimate of production from one cycle of operation of the mobile hatchery at full capacity.

Age	N	Survival (Percent)	Natural Mortality (Percent)	Fishing Mortality N (%)	kg	Potential Spawning (millions of eggs)
Fert. Eggs	30 000 000					
		70				
Larvae	21 000 000					
		0.7	99.3			
1 yr	147 000					
		27	73			
1 - 2 yr	39 690					
		46	54			
2 - 3 yr	10 716					
		46	27	(27)		
3 - 4 yr	4 930			2 893	1 800	
		46	27	(27)		
4 - 5 yr	2 268			1 331	1 370	29.5
		55	18	(27)		
5 - 6 yr	1 247			612	1 040	47.5
		55	18	(27)		
6 - 7 yr	685			337	674	32.5
		0	18	(82)		
7 - 8 yr	0			560	1 404	
				Total wt to fishery	6 288 kg	

Value: a. commercial fishery ($2.50/kg) = $15 720

b. sports fishery ($6.25/kg) = $39 300

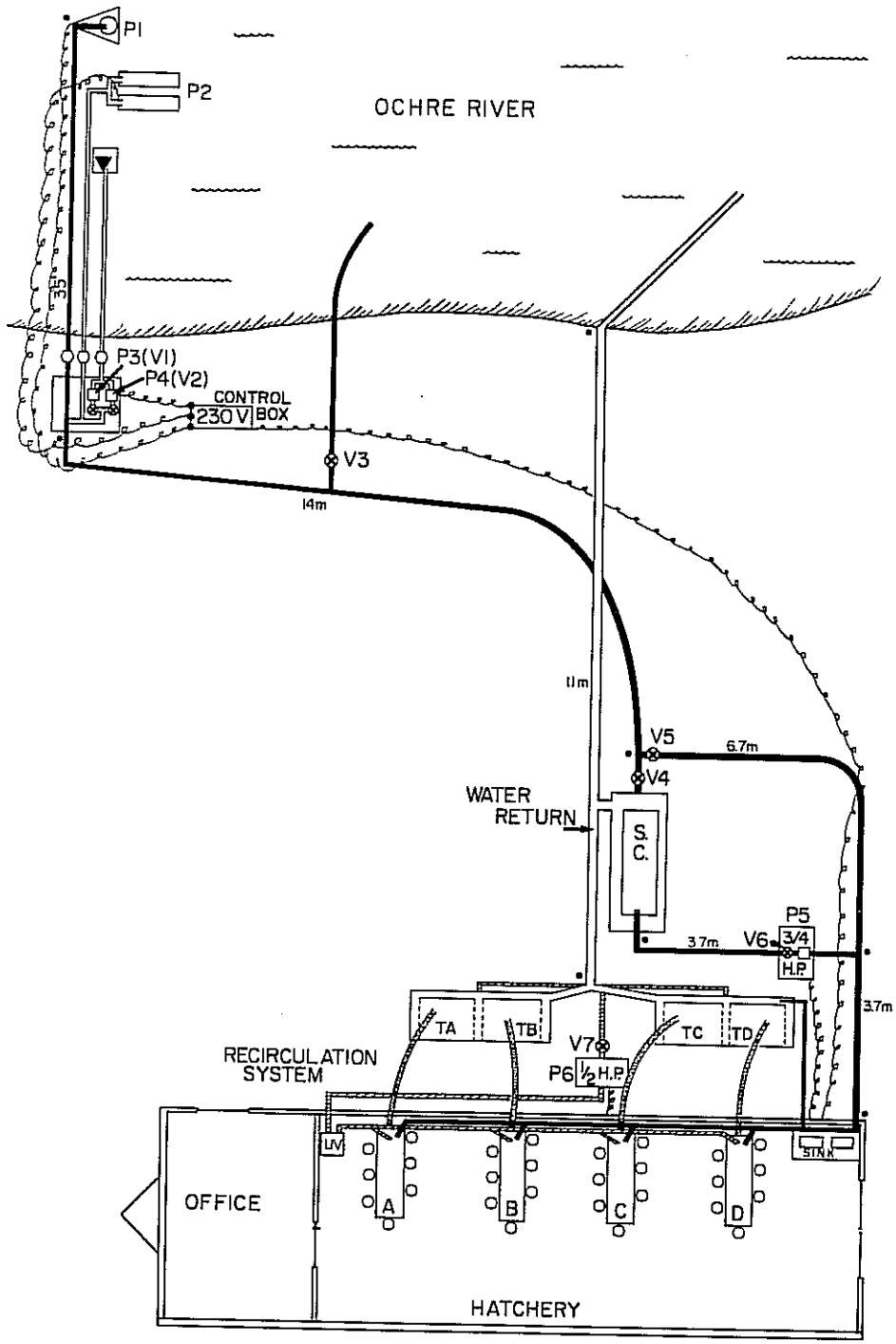

Fig. 1. Schematic of the arrangement of the pumping modules and configuration of the mobile walleye hatchery during the 1985 field test at the Ochre River, Manitoba. P1-P4, intake pumps; P5, hatchery supply module; P6, recirculation module; S.C.; sediment chamber; A-D, hatchery batteries A to D; TA-TD, larval holding tank compartments; UV, ultraviolet sterilizer; V1-V7, water distribution control valves.

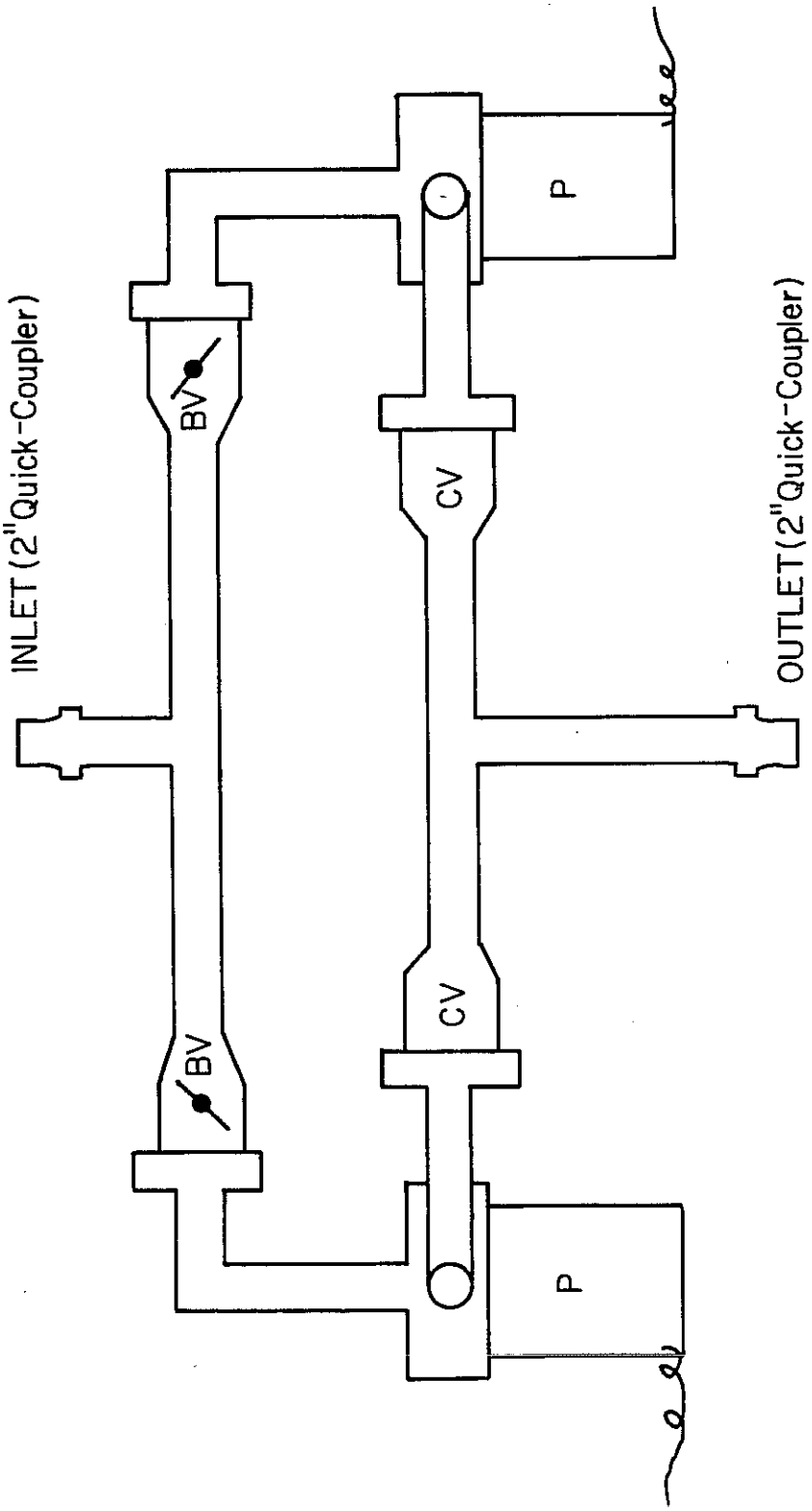

Fig. 2. Schematic of the pumping and valving system for the hatchery supply and recirculation systems. BV, 2-inch true union ball valve; CV, 2-inch true union check valve.

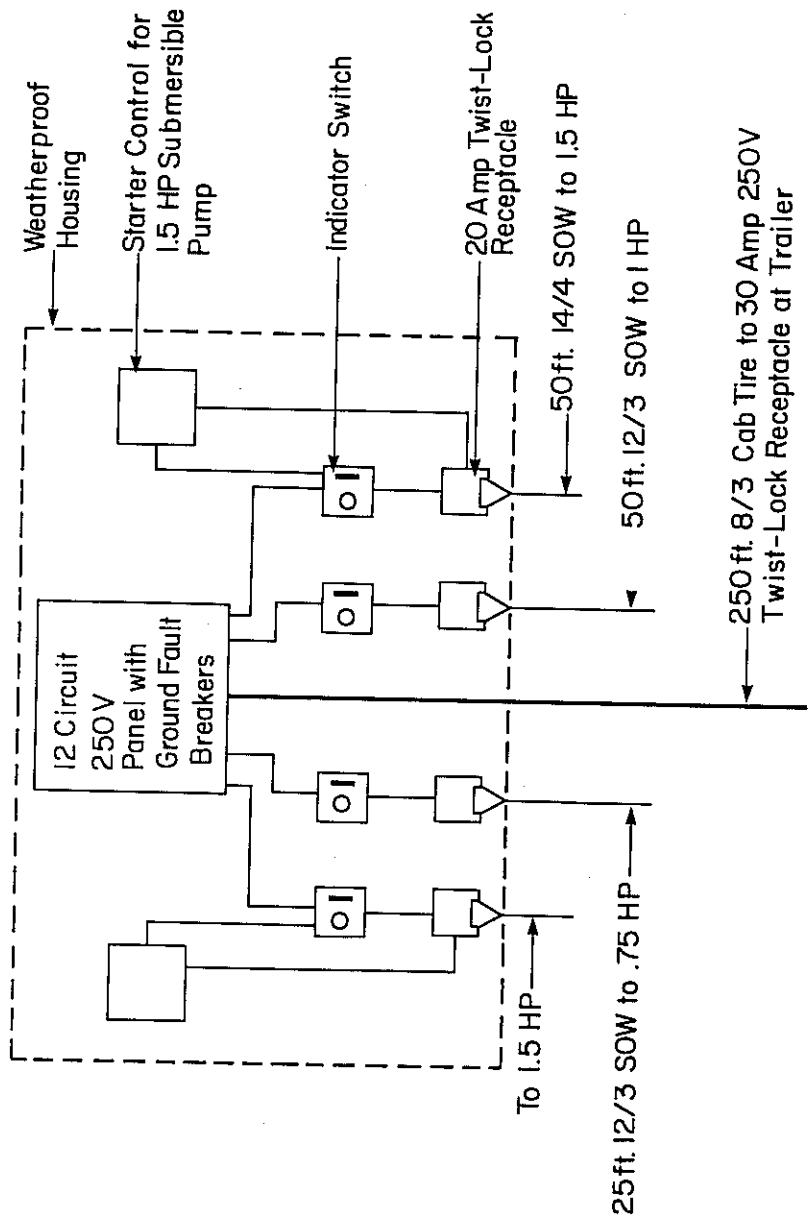

Fig. 3. Schematic of intake module electrical supply.

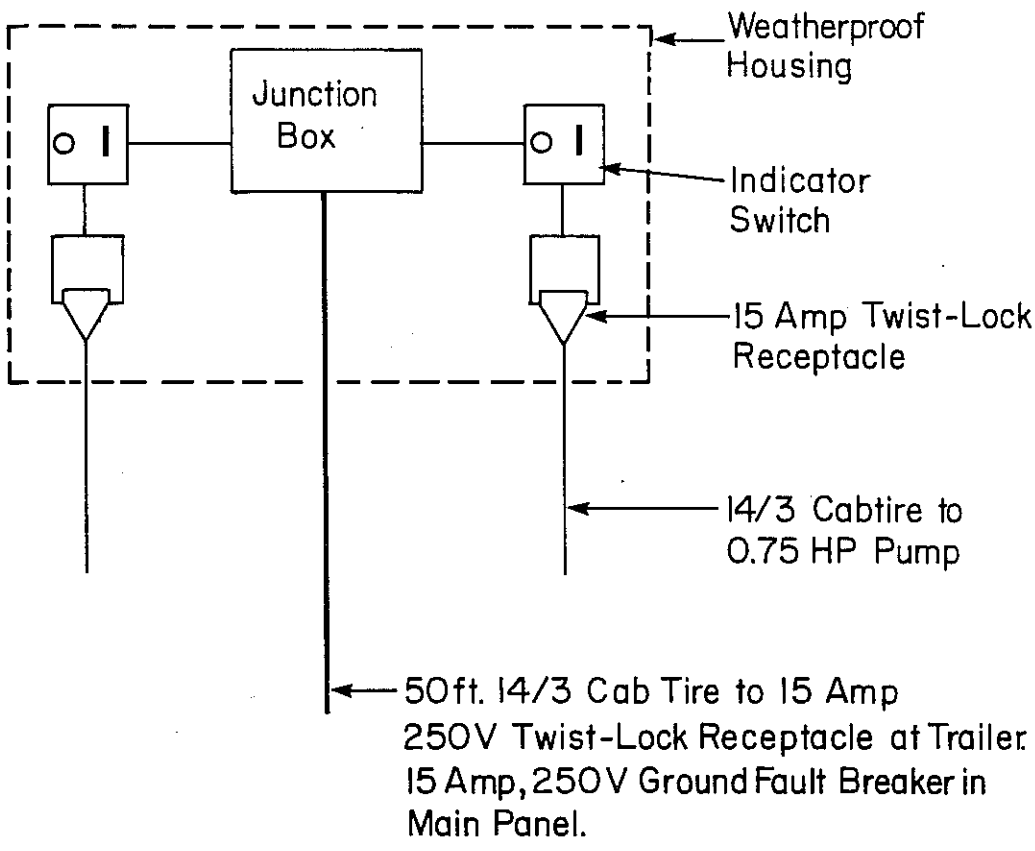

Fig. 4. Schematic of hatchery supply module electrical panel.

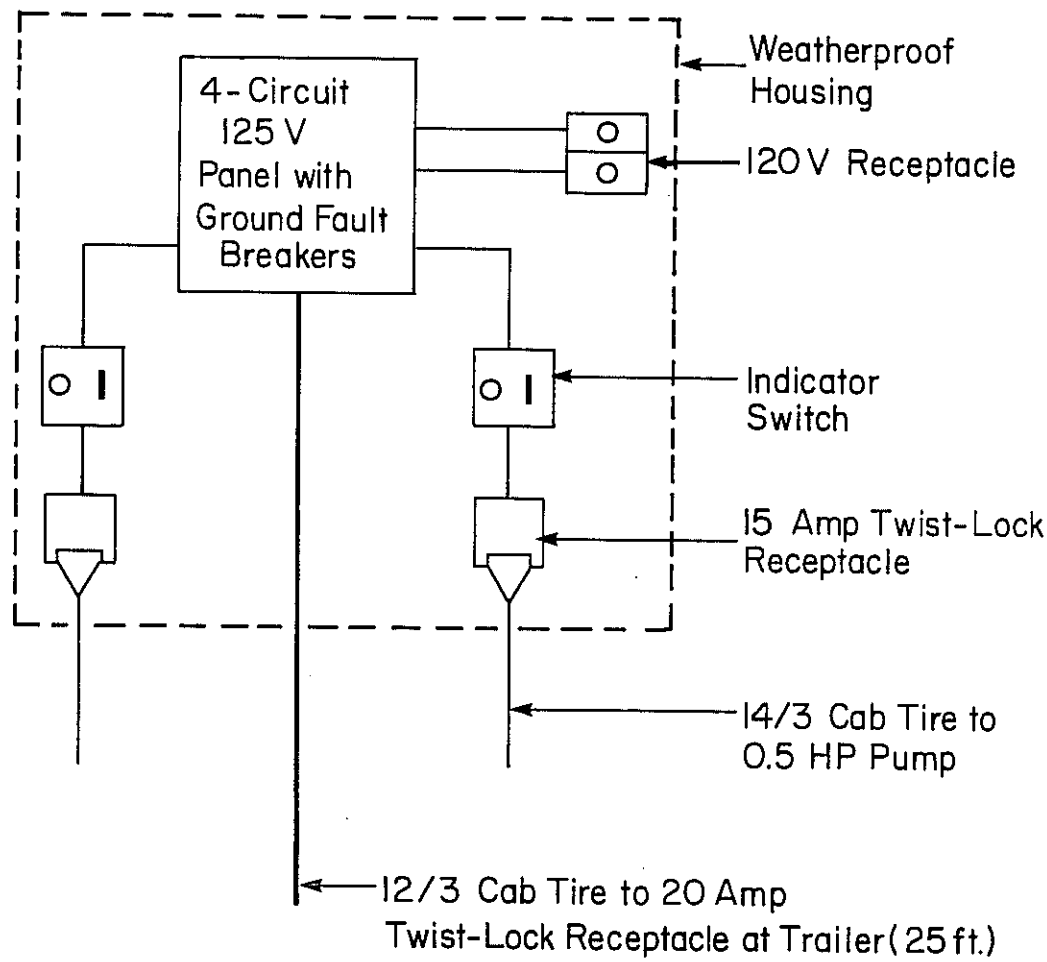

Fig. 5. Schematic of recirculation module electrical panel.

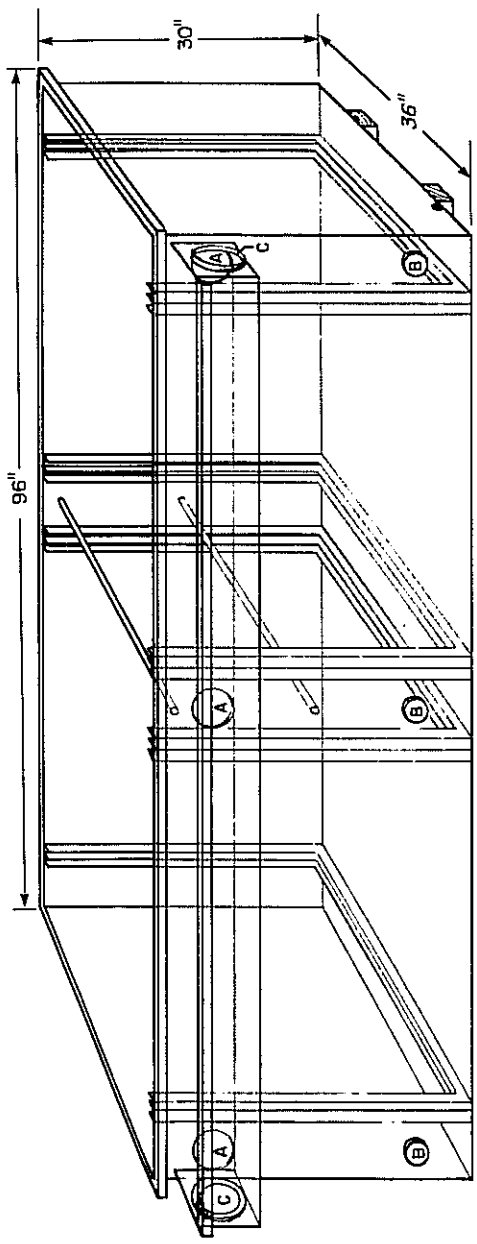

Fig. 6. Schematic of larvae holding tank. Letter A designates 4 in diameter exit port, B, 2 in diameter quick-coupler and C, 6 in diameter quick-coupler.

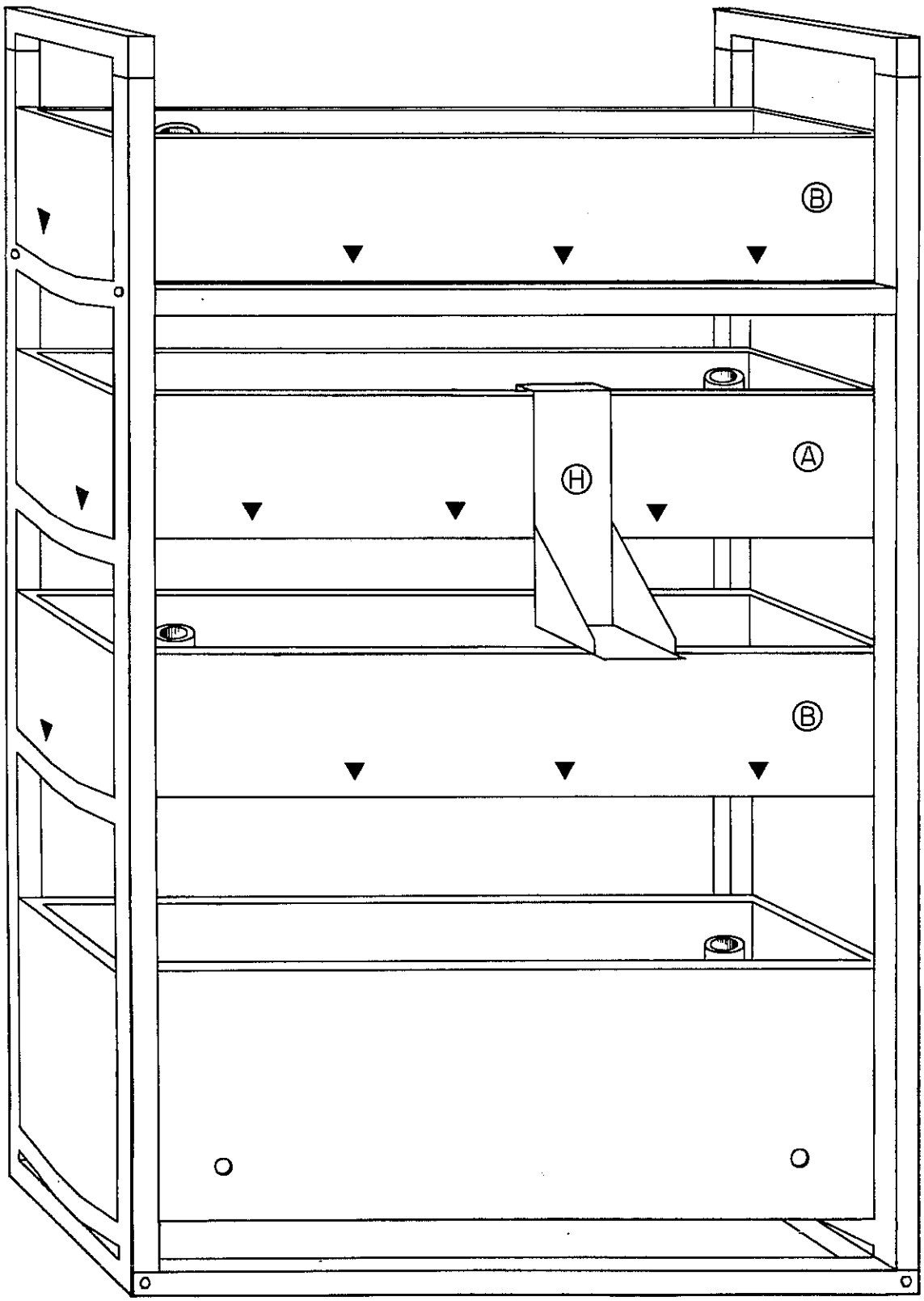

Fig. 7. Schematic of a single egg incubation battery. A and B designate the two trough configurations shown in detail in Figure 8 and H is an incubation jar holder.

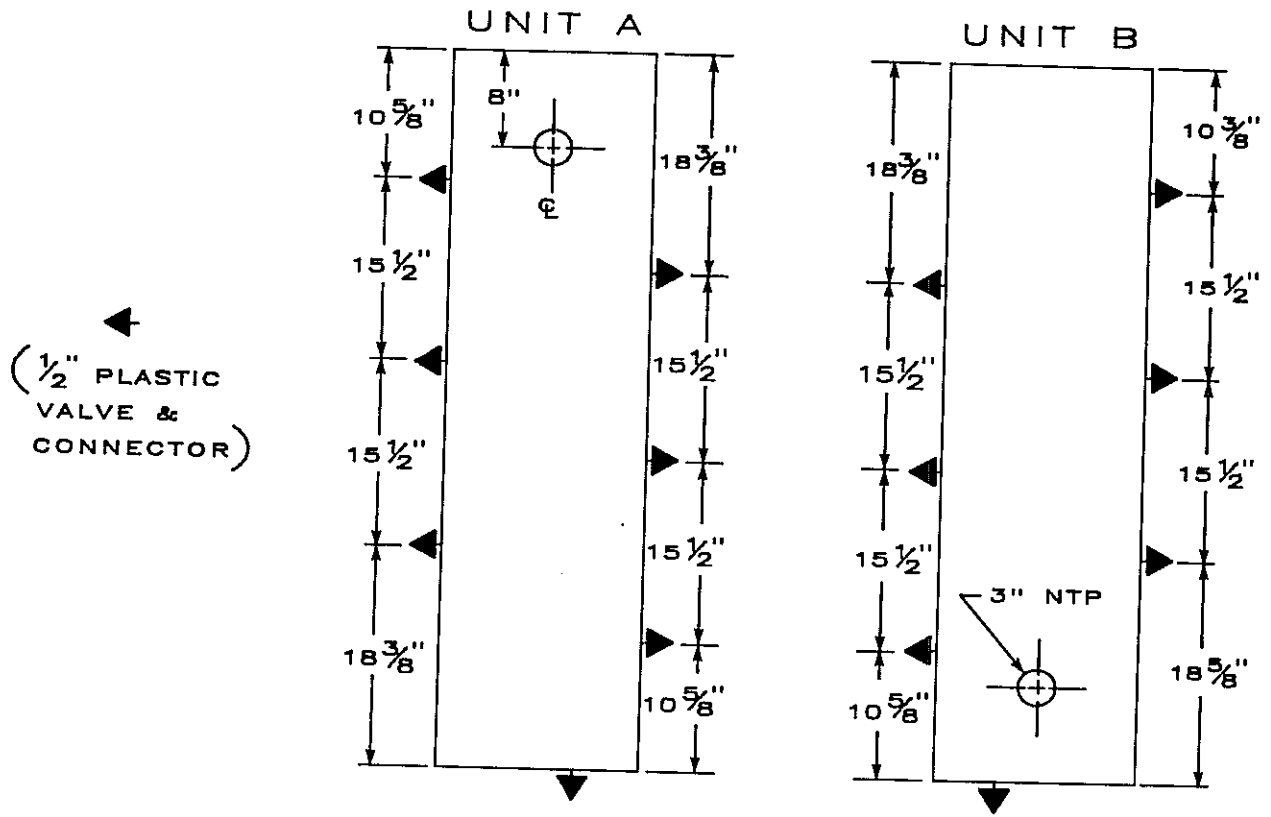

Fig. 8. Detailed top view of battery troughs showing configuration of valves. Each battery contained one unit A and two of unit B.

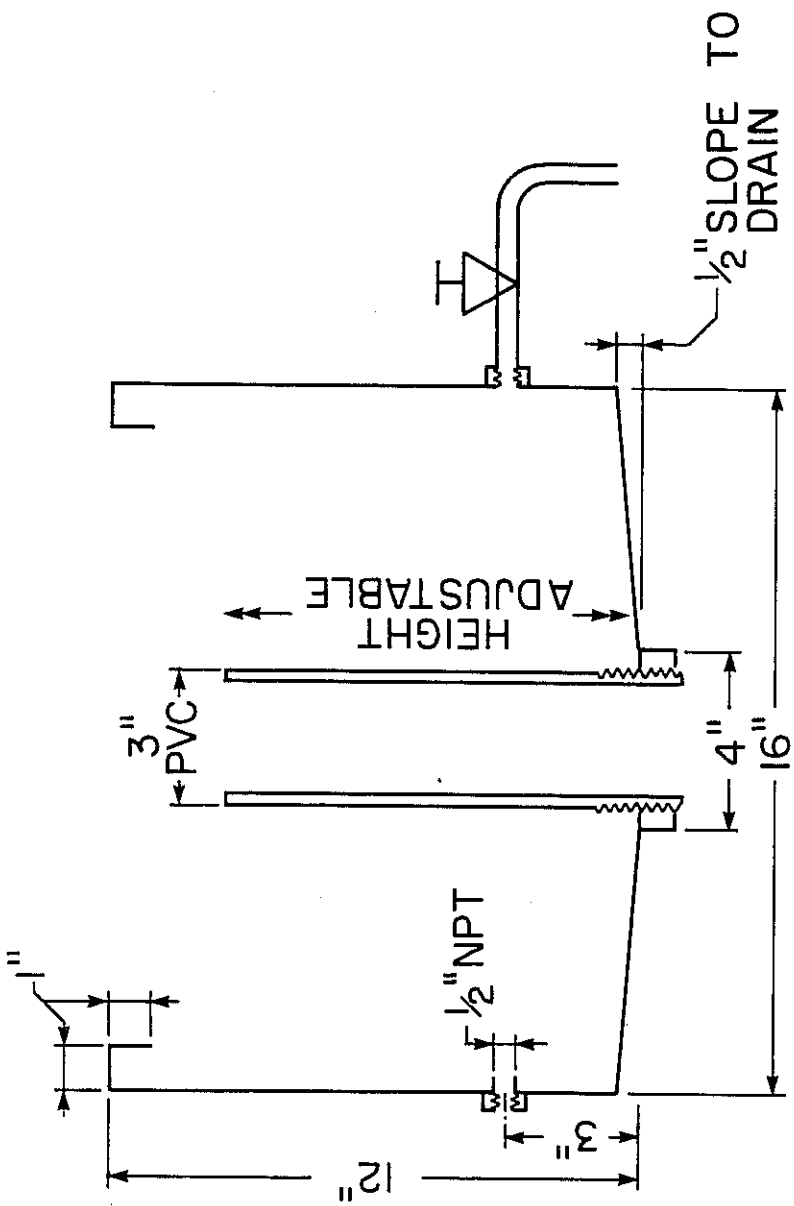

Fig. 9. Cross-sectional view of incubation troughs showing elevations of valves.

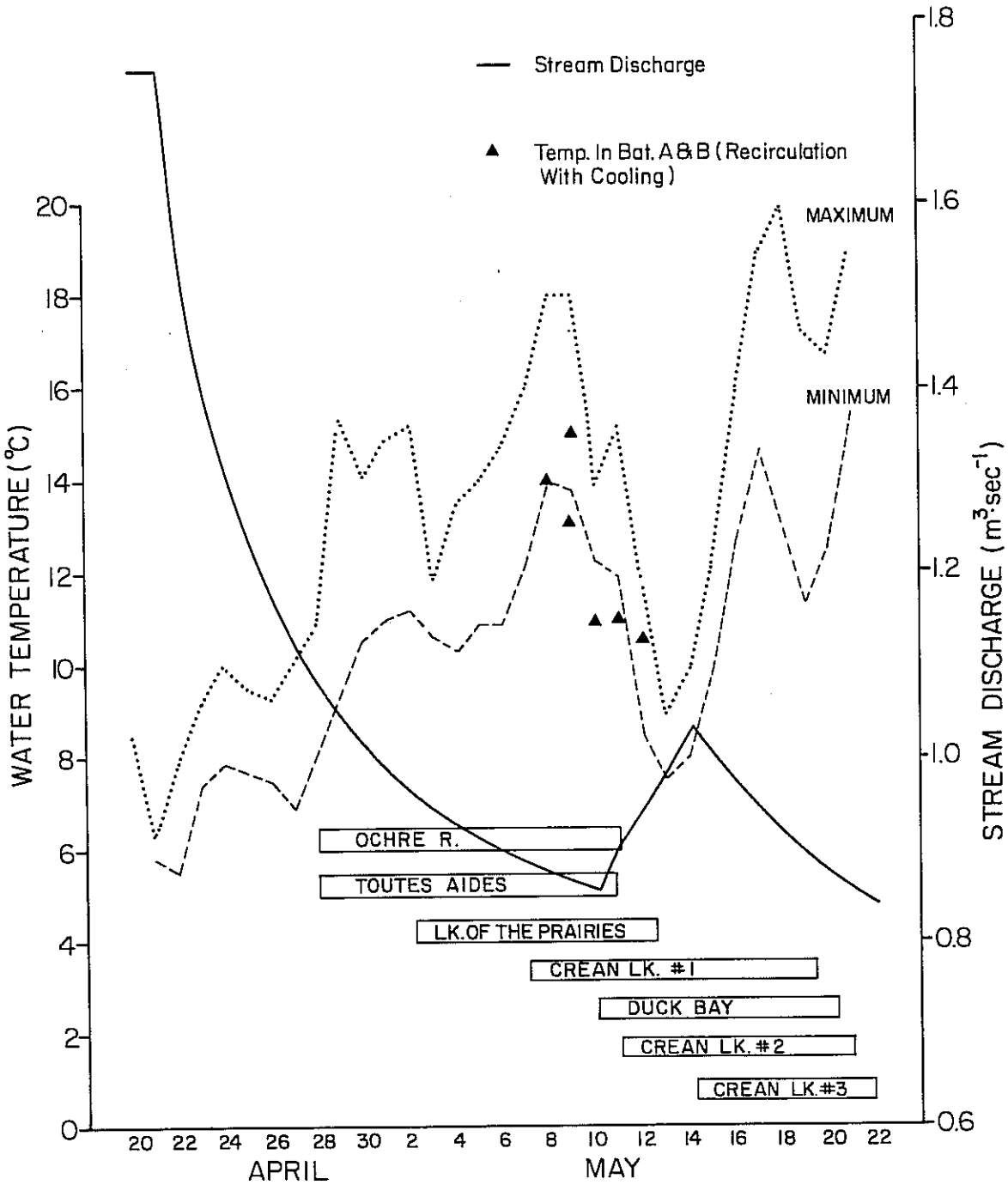

Fig. 10. Summary of water discharge, daily minimum and maximum water temperatures and incubation period for the seven groups of eggs during the 1985 field tests of the mobile walleye hatchery. The solid triangles represent the water temperature in batteries A and B during the period of recirculation and operation of the two 0.3 HP chillers.