Preliminary Experiments on Growth, Survival, Production and Interspecific Interactions of Walleye (*Stizostedion vitreum vitreum*) Fingerlings in Constructed Earthen Ponds in the Canadian Prairies

Li, Sifa and G.B. Ayles

Western Region
Department of Fisheries and Oceans
Winnipeg, Manitoba R3T 2N6

December 1981

Canadian Technical Report of Fisheries & Aquatic Sciences No.1041

Government of Canada
Fisheries and Oceans

Gouvernement du Canada
Pêches et Océans

Canadian Technical Report of Fisheries and Aquatic Sciences

These reports contain scientific and technical information that represents an important contribution to existing knowledge but which for some reason may not be appropriate for primary scientific (i.e. *Journal*) publication. Technical Reports are directed primarily towards a worldwide audience and have an international distribution. No restriction is placed on subject matter and the series reflects the broad interests and policies of the Department of Fisheries and Oceans, namely, fisheries management, technology and development, ocean sciences, and aquatic environments relevant to Canada.

Technical Reports may be cited as full publications. The correct citation appears above the abstract of each report. Each report will be abstracted in *Aquatic Sciences and Fisheries Abstracts* and will be indexed annually in the Department's index to scientific and technical publications.

Numbers 1-456 in this series were issued as Technical Reports of the Fisheries Research Board of Canada. Numbers 457-714 were issued as Department of the Environment, Fisheries and Marine Service, Research and Development Directorate Technical Reports. Numbers 715-924 were issued as Department of Fisheries and the Environment, Fisheries and Marine Service Technical Reports. The current series name was changed with report number 925.

Details on the availability of Technical Reports in hard copy may be obtained from the issuing establishment indicated on the front cover.

Rapport technique canadien des sciences halieutiques et aquatiques

Ces rapports contiennent des renseignements scientifiques et techniques qui constituent une contribution importante aux connaissances actuelles mais qui, pour une raison ou pour une autre, ne semblent pas appropriés pour la publication dans un journal scientifique. Il n'y a aucune restriction quant au sujet, de fait, la série reflète la vaste gamme des intérêts et des politiques du Ministère des Pêches et des Océans, notamment gestion des pêches, techniques et développement, sciences océaniques et environnements aquatiques, au Canada.

Les Rapports techniques peuvent être considérés comme des publications complètes. Le titre exact paraîtra au haut du résumé de chaque rapport, qui sera publié dans la revue *Aquatic Sciences and Fisheries Abstracts* et qui figurera dans l'index annuel des publications scientifiques et techniques du Ministère.

Les numéros 1-456 de cette série ont été publiés à titre de Rapports techniques de l'Office des recherches sur les pêcheries du Canada. Les numéros 457-714, à titre de Rapports techniques de la Direction générale de la recherche et du développement, Service des pêches et de la mer, ministère de l'Environnement. Les numéros 715-924 ont été publiés à titre de Rapports techniques du Service des pêches et de la mer, Ministère des Pêches et de l'Environnement. Le nom de la série a été modifié à partir du numéro 925.

La page couverture porte le nom de l'établissement auteur où l'on peut se procurer les rapports sous couverture cartonnée.

Canadian Technical Report of

Fisheries and Aquatic Sciences 1041

December 1981

PRELIMINARY EXPERIMENTS ON GROWTH, SURVIVAL, PRODUCTION AND INTERSPECIFIC INTERACTIONS OF WALLEYE (*Stizostedion vitreum vitreum*) FINGERLINGS IN CONSTRUCTED EARTHEN PONDS IN THE CANADIAN PRAIRIES

by

Li, Sifa[1] and G.B. Ayles

Western Region

Department of Fisheries and Oceans

Winnipeg, Manitoba R3T 2N6

This is the 139th Technical Report

from the Western Region, Winnipeg

[1] Visiting scholar from Shanghai Fisheries College, China.

© Minister of Supply and Services Canada 1981

Cat. no. Fs 97-6/1041 ISSN 0706-6457

Correct citation for this publication is:

Li, Sifa and G.B. Ayles. 1981. Preliminary experiments on growth, survival, production and interspecific interactions of walleye (Stizostedion vitreum vitreum) fingerlings in constructed earthen ponds in the Canadian Prairies. Can. Tech. Rep. Fish. Aquat. Sci. 1041: iv + 14 p.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

Li, Sifa and G.B. Ayles. 1981. Preliminary experiments on growth, survival, production and interspecific interactions of walleye (Stizostedion vitreum vitreum) fingerlings in constructed earthen ponds in the Canadian Prairies. Can. Tech. Rep. Fish. Aquat. Sci. 1041: iv + 14 p.

Rearing of walleye fry and fingerlings in ponds can decrease the normally very high mortalities in larger water bodies. Subsequent release into natural waters of large fingerlings may ultimately lead to an increase of catchable fish.

An experiment on extensive rearing of walleye was conducted in 4 constructed earthen ponds and 12 farm dugouts in the Canadian prairies. Growth was good: with 112-140 days of growth, walleye attained 102-164 mm with a mean of 134 mm in length and 7.5 - 32.9 g with a mean of 19.6 g in weight. Survival generally was low.

The survival in 11 ponds in which fish were not killed by environmental factors ranged from 1.2 to 18% with a mean of 7.6%, and correspondingly, the production of walleye in the 11 ponds ranged from 0.5 to 36.4 kg/ha with a mean 13.3 kg/ha.

Carp and minnows were also stocked in the ponds but their effects on the walleye were not significant.

Key words: stocking density, growth, survival, mortality, production, critical period.

RESUME

Li, Sifa and G.B. Ayles. 1981. Preliminary experiments on growth, survival, production and interspecific interactions of walleye (Stizostedion vitreum vitreum) fingerlings in constructed earthen ponds in the Canadian Prairies. Can. Tech. Rep. Fish. Aquat. Sci. 1041: iv + 14 p.

L'élevage de jeunes dorés pratiqué dans des étangs peut réduire le taux de mortalité normalement très élevé que l'on constate dans des nappes d'eau plus importantes. Le fait de relâcher dans des eaux naturelles les jeunes dorés qui ont grossi en étang permettra, espère-t-on, d'augmenter le nombre de poissons bons pour la pêche.

Une expérience d'élevage intensif a été pratiquée dans 4 étangs artificiels et 12 fosses réservoirs dans les Prairies canadiennes. La croissance des jeunes a été bonne: après 112 à 140 jours de croissance, le jeune doré avait atteint une longueur de 102 à 164 mm, la moyenne étant 134 mm; et un poids variant entre 7.5 et 32.9 g, la moyenne étant 19.6 g. Le taux de survie a été généralement bas.

Le taux de survie dans 11 étangs, dans lesquels la mort des poissons n'est pas due à des facteurs environnementaux, a été de 1.2 à 18%, la moyenne étant 7.6%, et de façon correspondante, la production du doré dans les 11 étangs était de 0.5 à 36.4 kg/ha, la moyenne étant de 13.3 kg/ha.

De la carpe et du fretin furent aussi mis dans les étangs, mais ils ne produisirent aucun effet appréciable sur le doré.

Mots-clés: densité de l'empoissonnement; croissance; survie; mortalité; production; période critique.

INTRODUCTION

The walleye (Stizostedion vitreum vitreum) is probably the most economically valuable commercial and sport fish in Canada's inland waters.

Commercial fisheries statistics show that the total production of walleye has been declining. For example, between 1973 and 1978, the commercial production of walleye in the Province of Manitoba averaged 2.3 million kg per year, which was only 50% of the average annual production between 1945 and 1954 (S. Campbell, Freshwater Institute, personal communication). Similar trends have also appeared in other parts of Canada as well as in the United States. These declines have been caused by an undetermined mixture of such factors as intensive and selective exploitation, habitat degradation, pollution, establishment of exotic species by invasions or introduction and progressive physio-chemical modification of the lake environments by cultural eutrophication.

Fry stocking in waters with established walleye populations has been generally considered ineffective (Forney 1975), and results of stocking fingerlings smaller than 90 mm have also been generally poor (Klingbiel 1971). Survival of walleye stocked at a larger size has been good (Schneider 1969, 1975).

Rearing of walleye fry and fingerlings in ponds presents an opportunity to markedly decrease the normally very high mortalities in natural waters during the critical early period of development. Subsequent release of large fingerlings, into normal waters, should ultimately lead to significant returns of catchable fish.

Some limited studies on walleye rearing have been conducted in the U.S.A. The majority were in ponds or small lakes with intensive or extensive methods (Smith and Moyle 1945; Dobie 1956, 1969; Klingbiel 1971).

In Canada, Cheshire and Steele (1972) reared walleye fingerlings with artificial food and Campbell and Rowes (1980) investigated the growth and survival of walleye stocked in small lakes and for later release into lake Winnipegosis. However, studies of young walleye in constructed rearing ponds in Manitoba are lacking. The objective of this study was to evaluate growth and survival of walleye fry stocked in artificial rearing ponds. Walleye fry were stocked in constructed ponds and farm reservoirs in conjunction with carp (Cyprinus carpio) and fathead minnows (Pimephales promelas).

METHODS

EXPERIMENTAL DESIGN

In two separate experiments (A and B) walleye fry were stocked alone and in conjunction with adult carp and adult fathead minnows. Carp were included because of their considerable effects on aquatic vegetation and the stated concerns of some commercial fishermen that carp may have caused the decline of walleye in Manitoba's Lakes. Minnows were included to assess their suitability as forage for the walleye.

Experiment A was conducted in 4 constructed ponds at the Rockwood Experimental Hatchery located 65 km North of Winnipeg. Walleye and carp were stocked in two of the ponds and walleye alone were stocked in the other two ponds. This experiment was to obtain detailed information on the growth, survival and feeding as well as production of walleye throughout the season. Stocking details are given in Table 1.

Experiment B was carried out in 12 farm reservoirs or dugouts near Erickson, Manitoba (see Sunde and Barica 1975; and Barica 1975 for descriptions of the study area). The experimental design was a randomized block design. The four treatments were: walleye stocked alone; walleye plus carp; walleye plus minnows; and walleye plus carp and minnows. The 3 blocks were high, medium and low densities. Stocking details are given in Table 2. This experiment was to obtain preliminary estimates of growth, survival, and final production. No detailed studies were carried out during the summer.

DESCRIPTION OF PONDS

The 4 ponds in Experiment A at the Rockwood Hatchery were built in 1971 but had not been stocked with fish prior to the present study. With nominal dimensions of 27m x 244m and a maximum depth of 2.4m, ponds 5 and 6 have an effective culture area of 4450 m^2. Ponds 7 and 8 have nominal dimensions of 90m x 244 m with islands in the center (7596 m^2) covered by partially-submerged terrestrial weeds - mainly Typha latifolia, Alopecurus aequalis and Myriophyllum sp. The effective culture area around the islands is 14700 m^2, with a maximum depth of 3.3-3.6 m.

Zooplankton (4 sample sites in large ponds, 2 in small ponds) and benthos (12 samples sites in large ponds, 6 in small ponds) were sampled at two-week intervals with a tube type sampler (improved from Pennak 1962) and an Eckman dredge (0.023 m^2).

Zooplankton were sorted by different size mesh screens (1320, 1180, 1000, 750, 670, 505, 210, 73 u) and then counted separately. Benthos were picked from bottom samples by hand, then counted and weighed according to groups.

Macrophyte density was estimated by collecting all plants within a 0.3m x 0.3m metal frame and measuring dry weight.

Water samples were taken at 1-2 weeks intervals from 0.5 m below the water surface and 0.5 m above the bottom. Chlorophyll a was determined with a Turner Filter Flourometer Model 111. Water chemical samples were analyzed for NH_4-N, NO_2-N, NO_3-N, total P, pH, and conductivity (Stainton et al. 1977).

Temperature was measured and recorded with a recording thermometer. Transparency was measured with a Secchi disc, while light was measured by LI-192S sensors.

The 12 ponds used in Experiment B at Erickson (Table 2) were all located on farms. The ponds were all dug 10-20 years ago as reservoirs for livestock. Their shapes are generally rectangular, and areas range from 729 to 1076 m^2 (except pond 021 which is only 284 m^2 in area). Maximum depths are from 2.9 to 4.7 m.

Zooplankton, benthos and macrophytes were sampled twice during the summer by the methods described above. Water chemistry was sampled once in mid summer and again in early winter. Dissolved oxygen was determined by the Winkler method. Temperature was recorded with a Peabody Ryan continuous recording thermometer.

Throughout the summer, pond 020 was covered with Lemna trisulca and Spirodela polyrhiza. Pond 126, 127, 130 and 013 had Myriophyllum sp., Potamogeton pectinatus, Sagittaria latifolia, and Potamogeton richardsonii. Additional information on the pond environments is given in Appendices 3, 4 and 5.

The experiment A ponds are partially drainable and were supposed to be without native fish, but two rainbow trout in June and two juvenile carp in fall were caught in pond 5 and sticklebacks were found in pond 8. It is likely that these fish entered through the pond drains from a near-by drainage ditch. A few sticklebacks were also found in Experiment B pond 012.

STOCKING OF FISH

Since prior experience was lacking, fry stocking density was difficult to determine. Actual stocking rates were based on recommendations from other biologists, estimates of expected survival and estimates of potential productivity.

Walleye fry about 9 days old were obtained on May 12 and 20, 1980 from the Manitoba Department of Natural Resources, Swan Creek Hatchery on Lake Manitoba. The number stocked in Experiment A was estimated volumetrically, but those stocked in Experiment B were actually counted.

Carp were obtained in mid June from Lake Manitoba. In order to avoid reproduction in ponds, only male carp were chosen. The carp stocked at Erickson were released directly into ponds after transportation while the carp stocked at the hatchery were held in cages for 4 days prior to stocking. All carp were measured, weighed and tagged. They ranged in length from 58.2 to 72.4 cm with a mean of 64.2 cm. Unfortunately, 17 carp escaped into pond 5 which was not supposed to have any.

Mature minnows (mean length 6.7 cm range 5.1-8.0 cm) were caught June 18-19 from lake 200 at Erickson and stocked in the ponds as indicated (Table 2). The sex ratio was 1 female to 2.4 males. Mean fecundity (maturing eggs only) was 477 (n=22, sd=190). The minnows successfully spawned in the ponds and a considerable number of fry appeared in early July.

FISH SAMPLING AND HARVESTING

The walleye in Experiment A were sampled monthly. Despite considerable effort with a plankton net, no walleye fry were caught in the first 30 days. Later, a small mesh trap net and seines were used successfully. Circulating the water in the ponds made it easier to capture the fingerlings.

Fish samples were measured and weighed. Stomach contents from 757 walleye (for an analysis of results see Li and Ayles 1981) and 16 carp were examined.

The harvest of walleye from Experiment A was completed with seines and traps between September 20 and October 22. Walleye from Experiment B were harvested with seines on September 9-11. Because the ponds were not completely drainable the harvests were not complete. It was particularly difficult to catch carp in such conditions and only half of the stocked carp were recaptured. The design of ponds 7 and 8 was especially unsuitable for seining and the standing crop of walleye for the two ponds had to be estimated by mark-recapture methods. Carp production for the ponds where not all of the carp were caught (ponds 5, 7, 014, 126 and 132) was estimated based on the mean stocking weight, mean harvest weight and the assumption that uncaptured carp were still alive.

RESULTS AND DISCUSSION

SURVIVAL

The harvest of walleye from Experiment A ponds ranged from 1.2% to 13.0% with a mean of 6.4% (Table 3), while the harvest of walleye from Experiment B ponds ranged from 0 to 18% with a mean of 4.8% (Table 4). Total fish mortality occurred in 4 ponds (JW, PJ, 013, 014) and almost total fish mortality occurred in one pond (020). The high ammonia levels in two ponds (JW, PJ) and possibly also in pond 014 during the summer sampling period are indicators of summerkill (Barica 1975). Over-population by minnows occurred in two ponds (013 and 014), which had total mortality of walleye. Pond 012 was thickly "carpeted" with duckweeds. The average survival in the remaining ponds was 8.2%. Mortalities could not be attributed to the presence or absence of carp (Table 4).

There was no statistically significant difference in survival of walleye in relation to stocking density ($F=0.26$, $df=2,8$).

GROWTH

In Experiment A the mean harvest weight of walleye ranged from 17.5 to 32.9 g (127-164 mm) with an overall mean of 25.2 g (144 mm). The average standard deviation within a pond was 6.5 g (16 mm). Seasonal growth was greatest in midsummer and stopped in late October when water temperatures dropped to 4°C (Fig. 1). The mean condition factor was 8.4 and ranged from 8.1 to 8.6.

In Experiment B the mean weight of walleye in the ponds ranged from 7.5 to 26.7 g (102-153 mm) with an overall mean of 16.1 g (127 mm)(Table 4). The average standard deviation within a pond was 6.5 g (16 mm). The mean condition factor was 7.3 with a range from 6.5 to 8.1.

The relationship between weight and length, based on the whole summer's data for walleye fry-fingerlings was:

$$\ln W = -11.81 + 3.02 \ln L \; (n=749) \; \text{(Fig. 2)}.$$

There was no statistically significant relationship between the growth of walleye and stocking density ($F=2.22$, $df=2,8$), and also no significant relationship between growth of walleye and fish composition ($F=0.09$, $df=3,7$).

PRODUCTION

The highest production of walleye was 36.4 kg/ha. In Experiment A, the range of walleye production was 0.45-33.3 kg/ha with a mean of 13.8 kg/ha (Table 3). In Experiment B, the range of walleye production was 3.7-36.4 kg/ha (not including the ponds in which environmental factors resulted in total mortality of walleye) with a mean of 13.1 kg/ha (Table 4).

There was a slight but significant negative relationship between the size of walleye and production of walleye in the ponds ($F=2.6$, $n=11$) (Fig. 3) indicating that food supply was limiting growth.

Generally speaking walleye survived and grew well in "normal" ponds (i.e., no summerkill, no excessive macrophyte growth and no overcrowding from other fish). After 140 growing days in the hatchery ponds and 112-114 days in the farm dugouts the mean weight was 19.6 g (range 7.5 to 27.4 g), and mean production was 9.2 kg/ha (range 0 to 36.4 kg/ha). These results compare favorably with results from other studies (Table 8). In most other studies the walleye were harvested and transferred to other lakes at much smaller size, approximately 1-12 g, after a shorter growing season, approximately 60-126 days (Table 8). Survival of walleye in ponds exhibits extreme variability and in other studies the mean has ranged from 5.2% to 56.5% (Table 8). Production is also very variable but has been as high as 262 kg/ha (Smith and Moyle 1945).

INTERSPECIFIC INTERACTIONS

Minnows grew well in all ponds. The mean weight increased from 4 g on June 4 to 6.2 g on September 9-11 with an absolute growth rate of 22.6 mg/day. Survival of adults in 6 ponds (127, 014, 012, 011, 126, 013) ranged from 20% to 62% with a mean of 29.4%, sd 20.1 (Table 5). The standing crop of minnows decreased in all ponds except the two, 013 and 014, in which walleye did not survive but significant overcrowding of minnows was observed to occur. In contrast with ponds 127, 012, 011 and 126, where the standing crop of minnows consisted mostly of adults the standing crop in 013 and 014 consisted mostly of young minnows (Table 5). Walleye predation may have decreased the young minnow population in the former ponds.

While still tentative, the results do tend to indicate that the addition of minnows, to serve as prey for the walleye, may result in increased production of fingerling walleye (Table 7). Smith and Moyle (1945) reported that stocking bluntnose (Pimephales notatus) or fathead minnow fry several weeks after planting fry was an effective means of promoting yield of walleye. Schneider's (1975) experiment indicated that the addition of minnows as food for 122 mm walleye during their second year's life enhanced walleye growth and survival. In the present experiment, adult minnows were released into ponds 15 days after walleye stocking. The results varied considerably. In many ponds there were very few young minnows presumably because of predation by walleye. In the few ponds where the walleye did not survive there was a significant expansion of the minnow population.

According to Parsons (1971) the average length of forage fish eaten by 150-460 mm walleye was about 30% of the predator length and the maximum ratio was about 40%. Nielsen (1980) found that the maximum length of perch eaten by 250-550 mm walleye is about 40% of the predator. In the present study a 70 mm long minnow was found in a 140 mm long walleye; the ratio was 50%. At stocking the adult minnows and sticklebacks may be strong competitors of the walleye for food but in the fall the forage fish will be consumed by the walleye and the relationship becomes one of predator-prey.

Carp grew well in all ponds except pond JW which had a summerkill. In Experiment A the carp increased in mean weight from 3078 g to 4503 g, and in Experiment B they increased from 3407 g to 4513 g. The condition factor in fall was much higher than in early summer (Table 6). The net increase in biomass ranged from 30 to 62.1 kg/ha with a mean of 46.7 and a sd of 13.2.

Fishermen and some biologists have frequently attributed decreases in commercial walleye production from lakes Winnipeg and Manitoba and elsewhere on predation or degradation of walleye habitat by carp. The results from this study do not support this hypothesis. The carp significantly affected macrophyte biomass. In ponds which contained carp, the density of macrophytes from sampled sites on July 24 was 848, 508 and 40 g/m^2 for ponds 5, 6 and 7, but on August 21 their biomass was 417, 29 and 43 g/m^2 respectively. The macrophyte biomass in two ponds had fallen and in one pond had suppressed. In contrast, in pond 8 which contained no carp, the July 24 estimate of density of macrophytes was 839 g/m^2, while on August 21 it had increased to 1416 g/m^2. However, no other changes could be attributed to the carp. Walleye were not found in carp stomachs. The carp fed on Gammarus (70-90%), Daphnia (5-20%), insects (5-10%), and plants (5-10%).

CRITICAL PERIOD

It is clear, from the present experiments as well as others, that the growth of walleye in ponds is generally acceptable, but that the survival and hence production per ha is highly variable. If an economically viable walleye stocking program is to develop on the Canadian prairies it is necessary that some of the biological uncertainties affecting survival be eliminated. It appears that there are perhaps two critical periods in the development of fry/fingerling walleye.

The first period occurs at about the time of the completion of yolk absorption when the fish shifts from yolk to exogenous food, i.e., during the transition period from the prelarval stage to the post-larval stage. The probability of survival during this period depends on encountering suitable food. Suitable and sufficient food is essential for survival of fry at this time.

This critical period at the time of yolk sac absorption is at a time of major changes in the morphology and physiology of the fry that are essential for feeding (Morris 1956). For example, the first feeding of a post-larval walleye must be accompanied by changes in tooth and jaw structure, visual acuity, muscular condition, and the ability to swallow, digest and absorb food. Failure of any of these functions would mean death. Some experiments have indicated that the poor survival of fry in ponds is often associated with failure of fry to feed even when either natural or artificial foods are abundant. In other words, the critical period happens when old functions are being replaced by new functions inside the body, and the fish are particularly susceptible to environmental variability at this time of high risk.

The second critical stage for the walleye may be during the transition from feeding on invertebrates to feeding on fish and may be related to the actual size of the prey fish. According to Walker and Applegate (1976), walleye longer than 62 mm included minnows in their diets, and walleye longer than 106 mm fed primarily on minnows. This period, however, is not likely to be so critical. Walleye can start to feed on fish when they are as small as 51 mm (Smith and Pycha 1960), or not until they are well over 110 mm (Li and Ayles 1981). It appears that the size and time at which a walleye switches to fish depends on not only its own size but also on the size and availability of prey, both fish and invertebrates.

The finding that there was a correlation between harvest size and production rate but no statistically significant correlation between survival and growth, production or stocking rate suggests that most of the mortality happened in the early culture stages. It is not yet clear when and how the critical period develops in the pond or how to enhance the fish survival during this time. Information concerning the early life history, especially about this critical period, is essential for the effective management, artificial propagation and rearing of walleye.

In general the results of these preliminary experiments on production of walleye in constructed earthen ponds offer considerable promise for the use of this method for enhancing natural fish production but they also indicate that additional research is required in order to promote culture efficiency and achieve maximum production.

CONCLUSIONS

Rearing of walleye fry-fingerlings produces extremely variable results.

Within the range used in this experiment stocking density had no detectable effect on growth or survival.

Growth rates of walleye fingerlings in Manitoba ponds are generally good. With 112-140 days of growth, walleye can attain 102-164 mm with a mean of 134 mm in length and 7.5-32.9 g with a mean of 19.6 g in weight among the ponds. Growth is more stable and predictable than survival.

Survival of walleye is highly variable and unpredictable. The survival in this experiment ranged from 0 to 18.0% and clearly follows the trend of other studies.

Since survival of walleye varies, the production also varies. In 11 ponds, it ranged from 0.5 to 36.4 kg/ha with a mean of 13.3. In Manitoba, a production of 40 kg walleye fingerling per hectare appears entirely possible.

Walleye may undergo two critical periods in their early stage of development. Additional information on the critical period for walleye fry-fingerling rearing will be important in improving the rearing of walleye and increasing their survival rate.

ACKNOWLEDGMENTS

We are grateful to K. Rowes and G. Curry who provided technical assistance in the field. We acknowledge with thanks the assistance of S. Campbell and J. Mathias who reviewed the manuscript. Thanks also goes to members of the Rockwood Hatchery and the Water Chemistry Laboratory of Freshwater Institute, and the staff of the Freshwater Institute Graphic Services.

REFERENCES

BARICA, J. 1975. Summerkill risk in prairie ponds and possibilities of its prediction. J. Fish. Res. Board Can. 32: 1283-1288.

CAMPBELL, J.S., and K.R. ROWES. 1980. Growth and survival of walleye, Stizostedion vitreum vitreum (Mitchill) in rearing ponds near Lake Winnipegosis, Manitoba. Can. Tech. Rep. Fish. Aquat. Sci. 949: v + 17 p.

CHESHIRE, W.F., and K.L. STEELE. 1972. Hatchery rearing of walleye using artificial food. Prog. Fish-Cult. 34: 96-99.

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

DOBIE, J. 1956. Walleye pond management in Minnesota. Prog. Fish-Cult. 18: 51-57.

DOBIE, J. 1969. Growth of walleye and sucker fingerlings in Minnesota rearing ponds. Int. Ver. Theor. Angew. Limnol. Verh. 17: 641-649.

FORNEY, J.L. 1975. Contribution of stocked fry to walleye fry populations in New York lakes. Prog. Fish-Cult. 32: 21-24.

HUH, H.T., H.E. CALBERT and D.A. STUIBER. 1976. Effects of temperature and light on growth of yellow perch and walleye using formulated feed. Trans. Am. Fish. Soc. 105: 256-258.

KLINGBIEL, J. 1971. Management of walleye in the upper Midwest, p. 161-163. In Proc. North-Central Warmwater Fish Cult. Mgmt. Workshop, Ames, Iowa.

LI, Sifa and G.B. AYLES. 1981. An investigation of feeding habits of walleye (Stizostedion vitreum vitreum) fingerlings in constructed earthen ponds in the Canadian prairies. Can. Tech. Rep. Fish. Aquat. Sci. 1040: iv + 10 p.

LAARMAN, P.W., and D.E. REYNOLDS. 1974. Methods for propagation of walleye fingerlings in Michigan. Mich. Dep. Nat. Resour. Tech. Rep. 74-5: 14 p.

MILLER, F. 1952. Walleyed pike fingerling production in drainable constructed ponds in Minnesota. Prog. Fish-Cult. 14: 173-176.

MORRIS, R.W. 1956. Some aspects of the problem of rearing marine fishes. Bull. Inst. Oceanog. 1082: 1-61.

NIELSEN, L.A. 1980. Effect of walleye (Stizostedion vitreum vitreum) predation on juvenile mortality and recruitment of yellow perch (Perca flavescens) in Oneida Lake, New York. Can. J. Fish. Aquat. Sci. 37: 11-19.

PARSONS, J.W. 1971. Selective food preferences of walleye of the 1959 year class in Lake Erie. Trans. Am. Fish. Soc. 100: 474-485.

PENNAK, R.W. 1962. Quantitative zooplankton sampling in littoral vegetation areas. Limnol. Oceanogr. 7: 487-489.

SCHNEIDER, J.C. 1969. Results of experimental stocking of walleye fingerlings 1951-1963. Mich. Dep. Nat. Resources. Res. Develop. Rep. 161: 31 p.

SCHNEIDER, J.C. 1975. Survival, growth and food of 4-inch walleyes in ponds with invertebrates, sunfishes or minnows. Mich. Dep. Nat. Res. Fish. Res. Rep. 1833: 18 p.

SMITH, L.L., and J.B. MOYLE. 1945. Factors influencing production of yellow pikeperch, Stizostedion vitreum vitreum, in Minnesota rearing ponds. Trans. Am. Fish. Soc. 73: 243-261.

SMITH, L.L. Jr., and R.L. PYCHA. 1960. First-year growth of the walleye, Stizostedion vitreum vitreum (Mitchill), and associated factors in the Red Lakes, Minnesota. Limnol. Oceanogr. 5: 281-290.

STAINTON, M.P., M.J. CAPEL, and F.A.J. ARMSTRONG. 1977. The chemical analysis of fresh water, 2nd ed. Can. Fish. Mar. Serv. Misc. Spec. Publ. 25: 180 p.

SUNDE, L.A., and J. BARICA. 1975. Geography and lake morphometry of the aquaculture study area in the Erickson-Elphinstone district of southwestern Manitoba. Can. Fish. Mar. Serv. Tech. Rep. 510: 35 p.

WALKER, R.E., and R.L. APPLEGATE. 1976. Growth, food and possible ecological effects of young-of-the-year walleyes in a South Dakota prairie pothole. Prog. Fish-Cult. 38: 217-220.

Table 1. Stocking of walleye fry and carp in constructed ponds. Experiment A.

Pond No.	Area (m^2)	Fish Composition[a]	Walleye Total Number	Walleye Density (No/ha)	Carp Total Number	Carp Mean Weight (g)	Carp Density (No/ha)
5	4,450	W + C	3,000	6,660	17		
6	4,450	W + C	3,000	6,600	12	3,058	27
7	14,700	W + C	12,000	8,000	38	2,992	26
8	14,700	W + S	12,000	8,000			

[a] W - walleye, C - carp, S - stickleback. Carp accidentally escaped into pond 5 and sticklebacks gained access to pond 8 through the drain.

Table 2. Stocking of walleye fry, carp and minnows in farm dugouts. Experiment B.

Pond No.	Area (m^2)	Fish Composition[a]	Walleye Total Number	Walleye Density (No/ha)	Minnow Total Number	Minnow Density (No/ha)	Carp Total Number	Carp Mean Weight(g)	Carp Density (No/ha)
PJ	1,059	W	1,589	15,000					
132	958	W + C	1,437	15,000			5	3,333	55
127	730	W + M	1,094	15,000	2,275	31,164			
014	1,076	W + M + C	1,615	15,000	1,796	16,691	5	3,344	46
020	284	W	213	7,500					
129	744	W[b]	558	7,500					
012	887	W + M	665	7,500	1,312	14,791			
011	838	W + M + C	628	7,500	2,279	21,796	4	3,483	48
130	1,014	W	384	3,750					
JW	1,038	W + C	389	3,750			5	3,275	48
126	730	W + M + C	274	3,750	1,984	27,178	4	3,786	55
013	830	W + M + C	311	3,750	2,412	29,060	4	3,142	48

[a] W - walleye, C - carp, M - minnow
[b] Carp were accidentally stocked into 126 instead of 127.

Table 3. Final harvest of walleye and carp from constructed earthen ponds. Experiment A.

	Walleye				Carp		Total	
Pond No.	Mean TL (mm)	Mean W (g)	Survival Rate (%)	Standing Crop (kg/ha)	Standing Crop (kg/ha)	Net Increase (kg/ha)	Standing Crop (kg/ha)	Net Fish Production (kg/ha)
5	164	32.9	1.2	0.5	139.6[a]	+39.9[a]	140.1	40.4
6	127	17.5	9.2	15.7	114.4	+29.9	127.1	45.6
7	147	27.4	2.4	5.7	103.3[a]	+20.1[a]	109.0	35.7
8	139	23.1	13.0	33.3			33.3[b]	33.3[b]

a Estimated (see text).
b Sticklebacks not included.

Table 4. Harvest of walleye, carp and minnows from farm dugouts. Experiment B.

	Walleye				Minnows		Carp		Total	
Pond No.	Mean TL (mm)	Mean W (g)	Survival Rate (%)	Standing Crop (kg/ha)	Standing Crop (kg/ha)	Increase or Decrease of Biomass (kg/ha)	Standing Crop (kg/ha)	Net Increase (kg/ha)	Standing Crop (kg/ha)	Net Fish Production (kg/ha)
PJ	-	-	0	0	-		-	-	0	0
132	102	7.5	18	23	-		231[a]	57	254	80
127	130	19.4	1.5	4	112	-12	-	-	116	- 8
014	-	-	0	0	74	6	197	41	270	47
020	115	11.5	0.5	0.4	-	-	-	-	-	0.4
129	142	23.2	4.5	9	-	-	-	-	9	9
012	118	12.4	11.0	37	31	-29	-	-	67	8
011	123	12.1	5.3	5	57	-51	228	62	290	16
130	131	15.8	11.7	8	-	-	-	-	8	8
JW	-	-	0	0	-	-	0	-	0	0
126	151	26.7	5.8	7	80	-29	269[a]	61	355	39
013	-	-	0	0	157	41	204	53	360	93

a Estimated partly (see text).

Table 5. Survival, growth and production of minnows in farm dugouts. Experiment B.

Pond No.	Adult Survival Rate (%)	Adult Stocking Mean Weight (g)	Adult Harvest Mean Weight (g)	Young Number	Young Weight (g)
127	50.3	4.0	7.2	few	
014	31.8	4.0	5.1	15,235	5,047
012	29.6	4.0	7.0	few	
011	33.5	4.0	6.3	few	
126	61.6	4.0	4.8	few	
013	19.7	4.0	8.5	11,958	8,969
Mean	29.4	4.0	6.2		

Table 6. Growth condition of carp in ponds.

Pond No.	Stocking Mean TL (cm)	Stocking Mean W (g)	Stocking K Factor	Harvesting Mean TL (cm)	Harvesting Mean W (g)	Harvesting K Factor	Fish Number	Instantaneous Growth Rate
6	63.1	3,058	12.2	67.1	4,522	15.0	9	0.408
7	64.5	2,992	11.2	68.0	4,468	14.2	5	0.350
011	66.5	3,483	11.8	68.4	4,785	15.0	4	0.338
014	66.7	3,344	11.3	67.9	4,219	13.5	4	0.271
126	67.0	3,786	12.6	69.0	4,602	14.0	1	0.350

Table 7. Relationship between walleye production and fish composition in constructed earthen ponds (Experiment A) and farm dugouts (Experiment B).

Item	W	W + M or W + S	W + C	W + C + M or W + C + S	Statistical Analysis (F)
Number of ponds	2	2	4	2	
Walleye production (kg/ha)					
Range	7.9-8.5	3.7-36.4	0.5-22.9	5.4-6.6	1.3
Mean	8.2	24.5	11.2	6	
Total mean production (kg/ha)	8.2	72.1	157.5	523.3	14.8
Total net production (kg/ha)	8.2	10.8	50.4	27.7	3.9

W - walleye, C - carp, M - minnows, S - sticklebacks

Table 8. Walleye fry and fingerling pond rearing in experiments in Canada and the U.S.A.

Reference	No.of Ponds	Stocking Density (No/ha)	Growing Days	Survival Rate (%)	Harvest Size	Production (kg/ha)	Comments
Smith and Moyle 1945	66	108680 (4940 -1976000)[a]	100	6.0	11.4 g	54.2 (9.9-262)	Minnesota, some ponds with minnows or sucker fry
Miller 1952	8	(74100 -130490	74-123	16.7 (0.9-34.4)	2.2-6.1 g	14.8-108.4	Minnesota, drainable, thinning 5 times
	11	(81325 -148200)	60-126	5.2 (0.9-20.1)	1.1-8.3 g	0.8-121.5	Minnesota, drainable, fertilized
Klingbiel 1971	34			7.8 (0-40.5)		47.2 (0-241)	Wisconsin, drainable
Laarman and Reynolds 1974	13	21366 (4631 -123500)		9.8 (0-24.4)	65.5 mm	49.9[b]	Minnesota
Schneider 1975	10	247		45 (11-77)	234-348 mm	25 (5.6-48.2)	Michigan, drainable stocking materials were 81-152 mm fingerlings. For 8 ponds stocked 48 mm minnows or 46 mm sunfish, with stocking rate 11.2 kg/ha
Campbell and Rowes 1980	1	1709	81	56.5	105 mm	7.1	Manitoba, Lake Coleman, 117 ha
Present study	4	(6600-8000)	140	6.5 (1.2-13.0)	25.2 (17.5-32.4)	13.8 (.5-33.3)	Hatchery ponds
Present study	12	(3750-15,000)	112	4.9 (0-18.0)	16.1 (7.5-26.7)	7.6 (0-36.4)	Farm dugouts

[a] Figures in table in parentheses indicate ranges.
[b] 2170 fish/ha converted to kg/ha assuming a 65.6 mm walleye weighs 2.3 g.

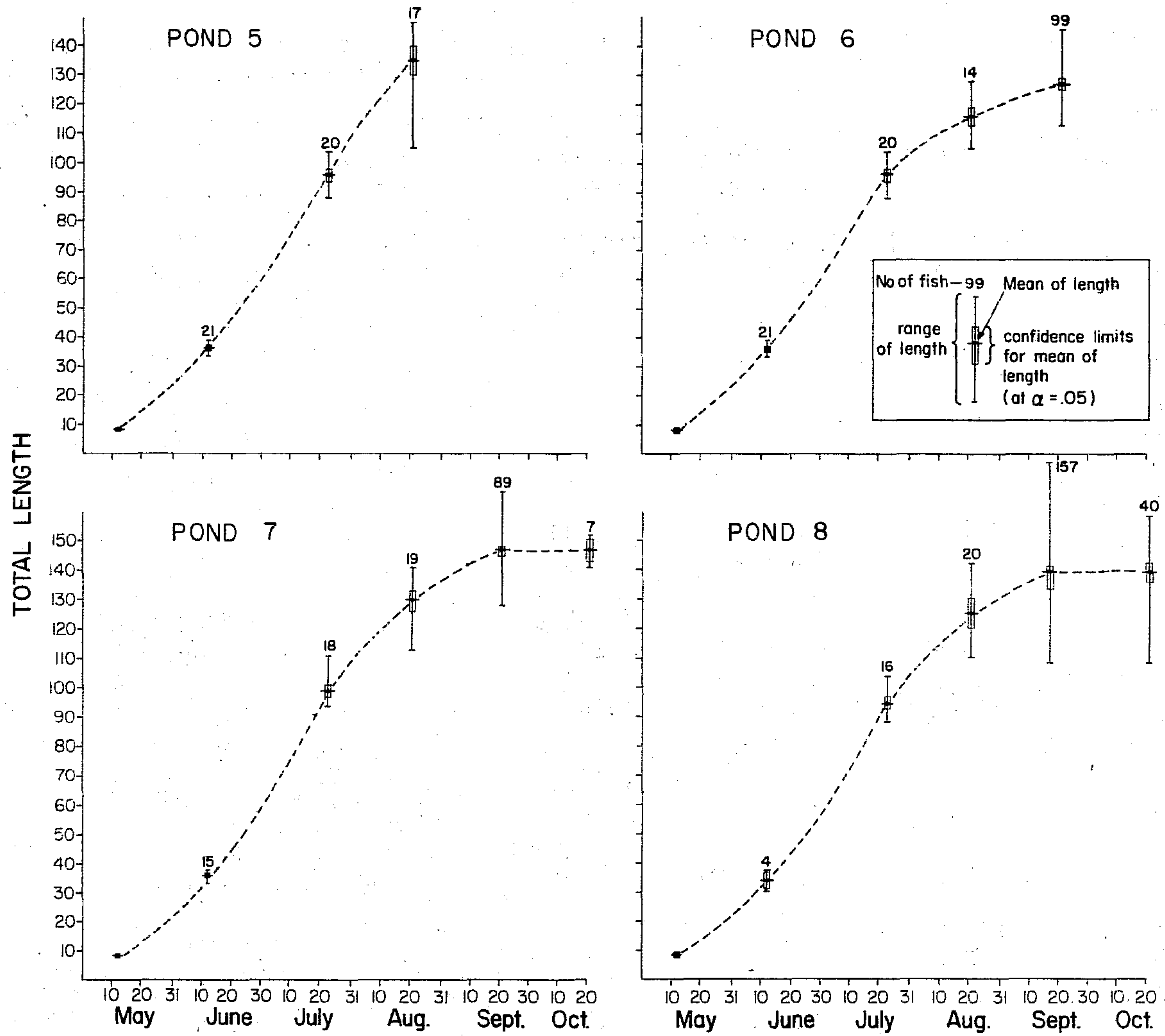

Figure 1. Seasonal growth of walleye fry and fingerlings in Experiment A.

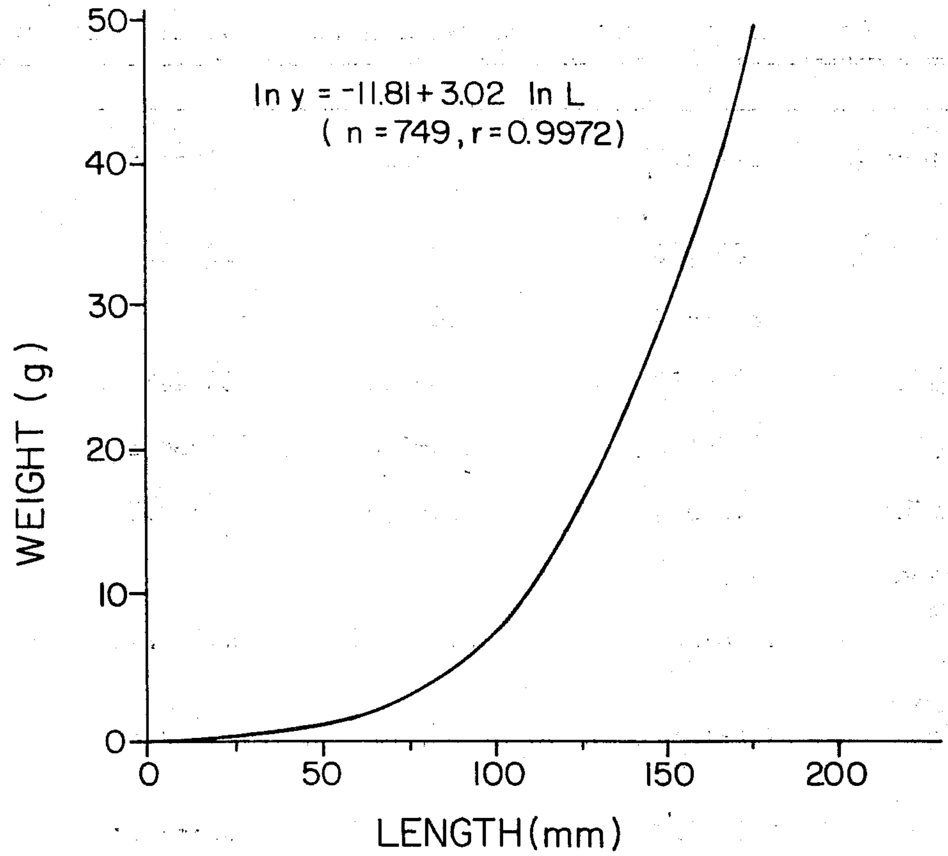

Figure 2. The relationship between length and weight of fry fingerling walleye stocked in constructed ponds (749 fish).

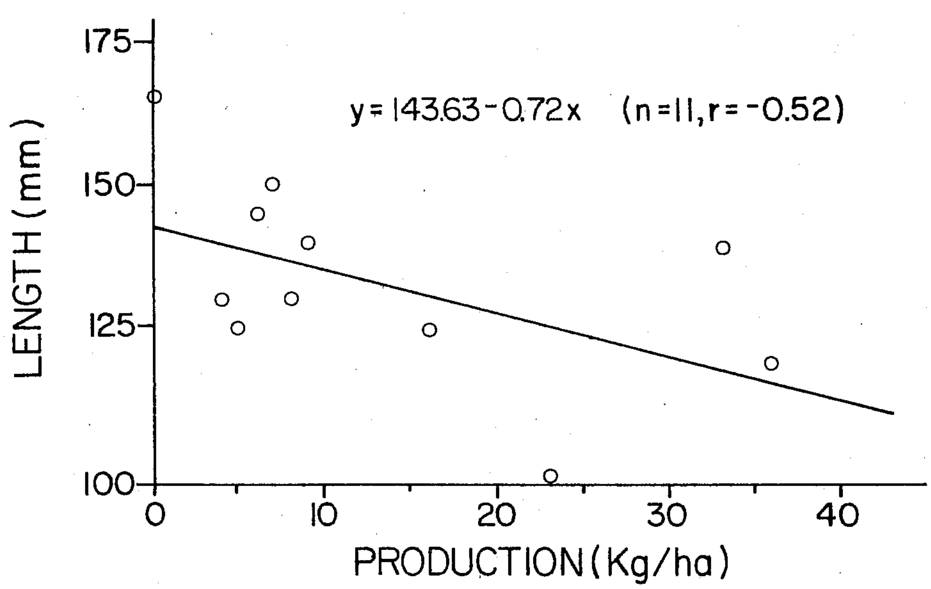

Figure 3. The relationship between size and production of fingerling walleye stocked in constructed ponds.

Appendix I. Physical and chemical characteristics of ponds used for Experiment A.

Pond No.	5	6	7	8
Transparency (m)	1.7-2.5	.3-2.5	.15-1.9	.45-2.5
Light ($\mu E.m^{-2}.S^{-1}$)	60-1050	102-810	20-780	162-780
pH	8.2-8.8	8.2-8.9	8.2 -8.6	8.3-8.9
NH_4-N (µg/L)	20-190	40-240	50-443	30-190
NO_2-n (µg/L)	1.0-4.0	1.0-6.0	1.0-38.3	1.0-6.5
NO_3-N (µg/L)	1.5-9.0	2.0-9.0	1 -22.3	1.5-13
Total dissolved phosphorus (µg/L)	13.5-26	17.5-36.5	29.3-92.5	24-58
Conductivity (25°C,µg/cm)	905-1250	1875-2250	1715-2150	979-1285
Chlorophyll a (µg/L)	0.2-40.3	0.1-13.7	0.3-41.4	0.3-28.4

Appendix II. Physical and chemical characteristics of farm dugouts used for Experiment B (July 29, 1980).

Pond No.	011	012	013	014	020	126	127	129	180	132	JW
pH	7.8	7.7	8.1	8.4	7.7	8.6	8.0	8.0	8.1	8.2	7.9
NH_4-N (µg/L)	30	100	170	860	40	210	100	840	620	220	50
NO_2-N (µg/L)	1	8	3	40	2	5	6	7	27	5	4
NO_3-N (µg/L)	12	126	31	95	12	5	10	43	82	4	2
Total dissolved phosphorus (µg/L)	231	91	123	56	117	104	164	263	254	51	
Conductivity (25°C, US/cm)	650	460	440	1210	310	550	710	460	1510	1030	460
Chlorophyll *a* (µg/L)	44	44	14	21	47	126	48	104	149	22	405

Appendix III. Mean food biomass, throughout the summer, in ponds used for Experiment A.

Pond No.	5	6	7	8
Total (No, 10^8/ha)	13.6	12.3	12.9	7.6
(Wet wt.,kg/ha)	188.6	303.7	403.2	197.9
Crustaceans				
(No./L)	55	56	66	37
(Wet Wt.,mg/L)	7.4	8.8	9.5	2.5
Gammarus				
in water (No./L)		71	438	160
(g/L)		1.4	6.8	3.2
on bottom(no./m^2)	1177	579	207	742
(g/m^2)	7.5	4.8	2.9	5.8
Chironomids(No./m^2)	440	95	511	21
(g/m^2)	2.9	0.4	3.0	0.2
Chaoborus (No./m^2)		11	43	4
(g/m^2)		0.02	0.35	0.0036