Growth of walleye (*Stizostedion vitreum vitreum*, Mitchill) in stormwater retention ponds and overwinter survival of stocked fry and fingerlings in two man-made lakes in Winnipeg, Manitoba.

by

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GROWTH OF WALLEYE(*STIZOSTEDION VITREUM VITREUM,* MITCHILL) IN STORMWATER RETENTION PONDS AND OVERWINTER SURVIVAL OF STOCKED FRY AND FINGERLINGS IN TWO MAN-MADE LAKES IN WINNIPEG, MANITOBA

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GENERAL INTRODUCTION

The walleye Stizostedion vitreum vitreum (Mitchill), is the most economically important of Canada's inland fish species. Canadian commercial fisheries harvest several hundred metric tonnes of walleyes annually (Scott and Crossman 1979). Similarly, an angler survey in Ontario revealed that walleyes were the most commonly sought species and the second most abundant in angler's catches (Scott and Crossman 1979). Exploitation of this resource and habitat deterioration have, however, combined to reduce the quality of both commercial and angling fisheries in Dauphin Lake, Manitoba (Gaboury 1985). Statistics for the Dauphin Lake commercial fishery, available from the Manitoba Department of Natural Resources, Fisheries Branch, indicate a two to three fold drop in walleye catch for the period 1931-1975.

In an attempt to enhance such walleye fisheries, walleye propagation has a history dating back to the late 1800's. Artificially propagated fry have been planted into lakes in Minnesota since 1887 (Smith and Moyle 1945). In Wisconsin, Wistrom (1957) estimates that a fry stocking program began as early as 1910 and that by 1937 over 839 million walleye fry were produced for stocking. These plants were often ineffective, and as a result pond reared fingerling production programs were undertaken in 1940 in both Minnesota (Smith and Moyle 1945) and Wisconsin (Wistrom 1957). Since then cultured fingerling walleyes have been planted into many waters with natural populations. Assessment of both fry and fingerling stocking has revealed varying degrees of success (Carlander et al. 1960; Schneider 1969; Jennings 1970; Klingbeil 1971; Kempinger and Churchill 1972; Forney 1975; Ward and Clayton 1975; Schweigert et al. 1977).

Therefore, due to decreasing walleye stocks and in association with the Prairie Provinces Fishery Enhancement program, young of the year walleye fry were planted in two man-made lakes and two stormwater retention ponds in Winnipeg, Manitoba in 1982. The objectives of the research were: 1. To study the factors controlling growth and production in rearing ponds and, 2. To study the effects of time and size of transfers on subsequent survival in two man-made lakes. The first chapter deals with growth and production in rearing ponds and the second chapter concerns their subsequent survival after transfer into Fort Whyte Lakes 3 and 4.

Chapter 1

CHAPTER 1

ABSTRACT

The two most important factors for optimizing walleye fingerling growth and survival in two Winnipeg, stormwater retention ponds were the availability of food at critical developmental stages and the degree of predatory interactions with larger walleyes. The availability of suitable, small zooplankters as an initial food source in rearing ponds was deemed beneficial in increasing instantaneous growth rates. Following growth and the development of demersal habits, walleye began to eat larger zooplankton and invertebrates in BG 3 pond. This was not the case in Shamrock pond where competition with more efficient planktivores severely affected food availability (type and size).

Bimodality in size frequency distributions and piscivory developed after demersal habits started in both ponds. Growth depensation then further increased the magnitude of bimodality. The presence of a larger size mode "Group 2 walleyes" functioned to decrease survival through a size selective predation on the smallest walleyes present in BG 3 pond. The effect of Group 2 walleyes was less direct in Shamrock pond. No evidence of cannibalism was found, only

fathead minnows were discovered in Group 2 walleye stomachs and functioned to buffer cannibalistic tendencies.

INTRODUCTION

Pond rearing of walleyes is a management technique used to increase year class strength of natural walleye stocks. By rearing fish, from fry to fingerling size, in an environment free of predators, natural mortality during critical periods in the early development of young of the year walleyes, can be decreased (Campbell and Rowes 1981; Li and Ayles 1981b). Stocking large numbers of these pond reared fingerlings should then supplement natural stocks and enhance commercial and sport fishing catches.

Several variables affect first year growth of walleyes. Between year variation in natural waters is to be expected, due to the number of factors regulating spawning time, timing of developmental phases, abundance of prey items and potential predators (Serns 1982). As in natural waters, between pond production of walleyes is also extremely variable (Smith and Moyle 1945; Miller 1952; Dobie 1956; Wistrom 1957). The ultimate goal of pond rearing walleyes is to optimize growth and numbers produced however, density has been negatively correlated with growth of pond reared walleyes. This limits the production of significant numbers of large fingerlings (Dobie 1969). Because plants of fingerling walleyes less than 90 mm in length into waters with existing populations have generally been considered unsuccessful (Schneider 1969; Klingbeil 1971) 100 mm is an optimum size for transfer of pond reared walleyes (Li and Ayles 1981a).

Two critical periods in young of the year walleye development have been identified. Li and Mathias (1982) found that the transition from endogenous to exogenous nutrition corresponds to a period of high mortality in post larval walleyes. Presumably this is due to ineffective feeding and subsequent starvation. Li and Ayles (1981b) defined a second critical period for juvenile walleyes, corresponding to a transition to piscivory. Starvation and cannibalism often occur at this time (Dobie 1956; Cheshire and Steele 1963), further depleting fingerling production.

Fry introduced into stormwater retention ponds in Winnipeg, Manitoba were studied to examine the feeding, growth and survival of young of the year walleyes in rearing pond situations. Furthermore, the presence of a forage species in one pond afforded the opportunity to examine the affect of an established minnow population on fingerling walleye production.

METHODS AND MATERIALS

A number of two to four day old walleye fry were obtained from the Manitoba Provincial Fisheries Branch, Swan Creek fish hatchery on May 22 and May 23 1982. Abundance was estimated by a volumetric method where a known number of live fry was added to a known volume of water. The increase in volume per standard number of fry was subsequently used to estimate the abundance of fry to be transported. Transportation to Winnipeg was in a 1000 litre insulated tank, cooled with ice to 15 C, the same temperature as the hatchery water. Inside the tank the fry were in sealed, oxygen injected, water filled plastic bags, supported in water. After temperature acclimation the fry were released along the shore into two stormwater retention ponds located in southern Winnipeg; Bishop Grandin 3 pond (BG 3) and Shamrock pond. Approximately 38,000 fry were released in Shamrock pond at a density of 3.8 $.m^{-2}$ on May 22, 1982. Approximately 17,000 fry (2.5 $.m^{-2}$) were released in BG 3 pond on May 23, 1982.

Shamrock and BG 3 ponds were sampled biweekly for physical and chemical characteristics. Oxygen and temperature profiles were determined using a YSI model 54 Oxygen meter at 0.5 m intervals until July 26, 1982 after which the modified Winkler titration (A.P.H.A. 1965) was used for oxygen profiles at surface, middle and bottom depth intervals. An Austin Inc. model FT3 hydrographic thermometer was used to determine temperature profiles after July 26, 1982. Average temperatures were calculated for comparable sample dates in both ponds. A Radiometer model 29 meter was used to determine the pH of integrated samples. Secchi disc measurements were recorded to the nearest cm. Further chemical analyses were performed on integrated water samples at the Freshwater Institute, Environment Canada, Winnipeg according to the standard procedures outlined in Stainton et al. (1974). The integrated water samples were collected using a tube sampler modified from Pennack (1962). The water column was emptied from the tube sampler into a previously rinsed tub. Analyses were conducted on 1 litre samples.

Zooplankton in the water column were sampled at two stations on BG 3 pond and at one station on Shamrock pond using the tube sampler. The sample was filtered through a 64u screen and organisms were rinsed into sample vials and preserved in 10% formalin. To estimate frequencies of species present, samples from BG 3 and Shamrock ponds were drawn down to 20 ml, using a syringe fitted with a 25u screen to prevent accidental removal of zooplankton. After mixing, a 1 ml subsample was drawn, using a syringe fitted with a glass tube measuring 4 mm inside diameter (Edmondson and Winberg 1971). Adult crustacean zooplankton present were identified to species according to Pennack (1978). Each subsample was then counted and individuals were measured in an etched Sedgewick-Rafter counting cell, using a Wild M5

Stereo-microscope fitted with an ocular micrometer. Frequencies were adjusted according to the volume filtered.

Assessment of the subsampling technique was done using a variance to mean test on 12 replications (Edmondson and Winberg 1971). The variance was found to not differ significantly from the mean for both the most common organism (Diaptomus sanguineus $X^2 = 7.4$, 11 df, P=.0254) and the largest organism (Daphnia pulex $X^2 = 8.76$, 11 df, P=.0431). This indicates that the subsamples were random and that larger individuals were not excluded on the basis of size.

Although BG 3 pond east and west stations displayed significantly different frequencies (Appendix 1), estimates were averaged on each sample date yielding a more representative description of pond zooplankton characteristics.

BG 3 pond was sampled for age 0+ walleyes at approximately weekly intervals by seining close to shore. Initially a seine, 9.1m long with 1.6 mm mesh size bar measure was used to catch walleyes with total length (TL) less than 40 mm. From July 1 to July 23, 1982 an 18.3 m long seine with 3.2 mm oval mesh was used to capture walleyes 40 to 55 mm TL. This net was replaced by an 18.3 m long seine with 6.4 mm oval mesh when walleyes were longer than 55 mm. Shamrock pond was sampled in a similar fashion early in the season. A purse seine technique with the 18.3 m, 6.4 mm oval mesh seine was used late in the season. Samples ranging in number from 9-100 fish were preserved immediately in 10% formalin and then weighed (wet). Fork length and total length were measured to the nearest mm. All measurements were done within four hours of preservation.

Differences in the growth of walleyes were analyzed using the heterogeneity of slopes model, SAS PROC GLM (Sas Institute 1982) for comparable sample dates on both ponds. The Shamrock pond August 13 sample (n=9) was small. It was therefore considered to be unrepresentative and was eliminated from further growth analyses. Consequently, the BG 3 pond August 12 sample was also eliminated to keep sample dates comparable. On October 13 all age 0+ walleyes caught in BG 3 pond were transfered to Fort Whyte Lake 3. Due to handling restraints, only total lengths were measured and weights were calculated from the BG 3 pond length- weight relationship.

Gut contents were studied by removal of the entire gut, from the esophagus to the anus, of walleyes captured on all sample dates. Items were identified as per Pennack (1978), counted and then dried for 20 hours at 150o C for dry weight determination. Prior to drying metasome lengths of copepods (ML), length from the front of the eye to the inflection point of the spine of cladocerans (L), and total lengths of other fooditems were recorded using an ocular micrometer. These units were then converted to millimeters using a 0.01 mm stage micrometer. Unidentified items (portions of various insect larvae, nymphs and pupae) were included in an "insect parts" category.

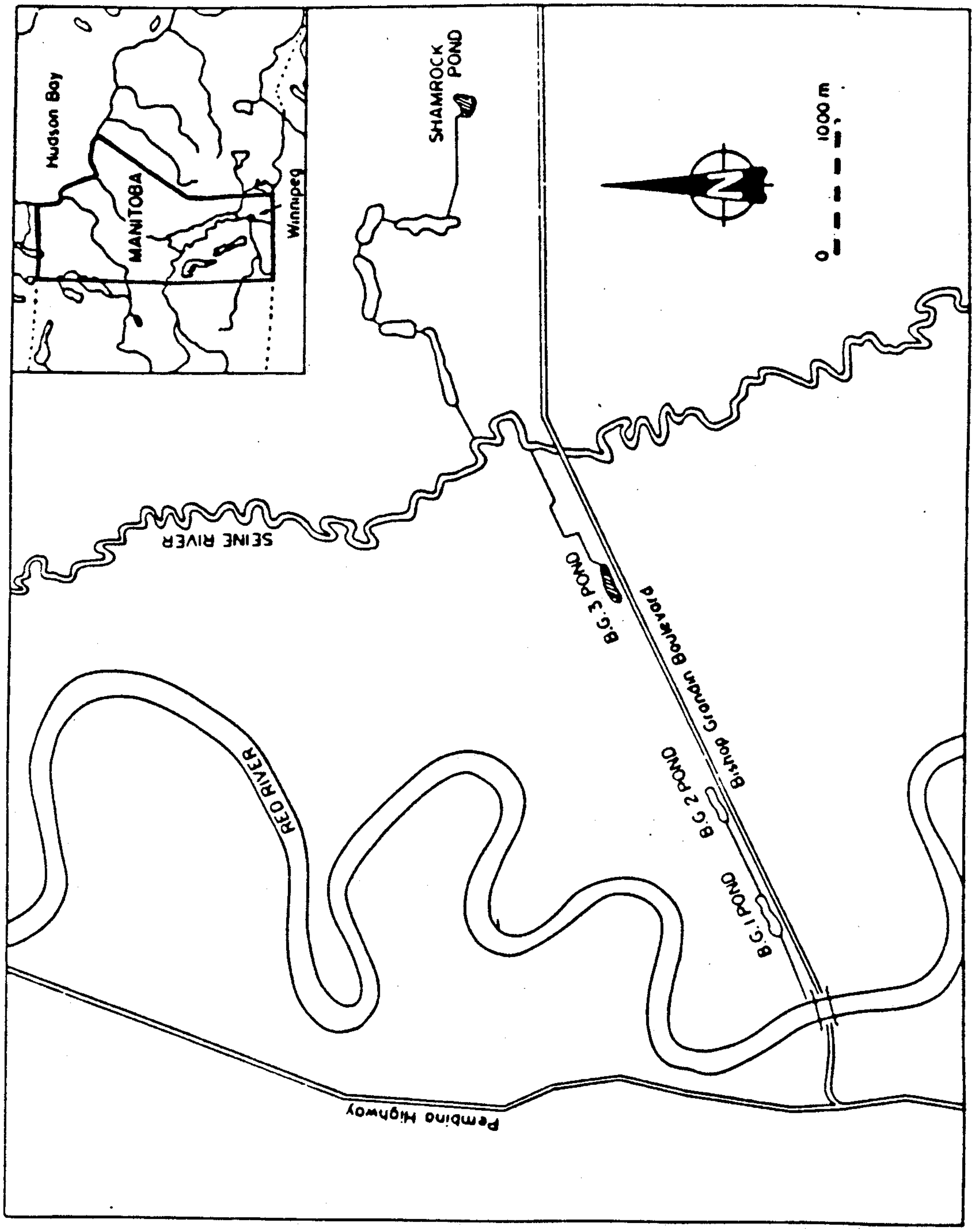
Survival in both ponds was examined "a posteriori" and subjectively based on the relative ease of obtaining the desired number of walleyes for weekly samples and the different transfers to Fort Whyte Lakes 3 and 4.

STUDY AREA

Bishop Grandin 3 pond is located near Bishop Grandin Boulevard in southern Winnipeg (Figure 1). It has a surface area of 0.68 ha and the maximum depth varies between 1.5 to 2.0 m. Shamrock pond is located in southeastern Winnipeg near Shamrock Crescent (Figure 1). It has a maximum depth of 1.5 m in the center with a surface area of 0.98 ha. The ponds were constructed in 1978 and 1975 respectively, to store storm water runoff. During storms the ponds collect runoff from roads, roofs, driveways, etc. and store the water for later release into storm sewers, thus draining down to their normal level.

Prior to the introduction of walleyes, Shamrock pond contained numerous fathead minnows (Pimephales promelas, Rafinesque), some pike (Esox lucius, Linnaeus), and a few yellow perch (Perca flavescens, Mitchill). Apparently, BG 3 pond contained no fish.

Figure 1: Location of the Bishop Grandin (BG) and Shamrock stormwater retention ponds in Winnipeg, Manitoba.



Examination of BG 3 pond zooplankton samples revealed the dominance of the copepod Diaptomus sanguineus and the presence of the cladoceran Daphnia pulex (Table 1). Moina micrura was found infrequently and at low densities. Shamrock pond copepods were dominant and consisted of abundant Diaptomus sanguineus and abundant Cyclops bicuspidatus. Cladocerans were present and were predominantly Bosmina longirostris with few Daphnia pulex (Table 1). Shamrock pond, therefore displayed a greater abundance of small zooplankton than did BG 3 pond.

Neither pond was deep enough to stratify thermally. Average temperatures for the water column for both ponds are presented in Figure 2 with BG 3 pond tending to be warmer than Shamrock pond until September 8-10. Unlike BG 3 pond Shamrock pond ammonia levels reached a peak on July 27 (Figure 3) corresponding with a marked depletion of oxygen near the bottom on July 13 and July 27 (Figure 3). This indicates aerobic decomposition of organic matter, subsequent oxygen loss and the release of NH4+ from the sediments (Wetzel 1975). This accounts for the larger mean ammonia level in Shamrock pond (Table 2). Nitrate peaks followed ammonia peaks, due to nitrification, as oxygen levels increased (Wetzel 1975). Because no oxygen loss and subsequent release of NH4+ was observed in BG 3 pond mean nitrate values were similar but slightly higher. Overall, exluding N-NH4+, mean nutrient levels tended to be greater in BG 3

Table 1. Relative abundance of zooplankton in BG 3 and Shamrock ponds' zooplankton samples, June to October 1982.

	Pond	
Fooditem	BG 3	Shamrock
O. Copepoda	80.3%	87.5%
Diaptomas sanguineus	80.3%	45.7%
Cyclops bicuspidatus	-	41.8%
O. Cladocera	19.7%	12.5%
Daphnia pulex	18.8%	0.6%
Bosmina longirostris	-	11.9%
Moina micrura	0.9%	-

pond due to initial peaks, which dropped to levels similar to Shamrock pond as the season progressed. A greater mean concentration of chlorophyll-a was observed in Shamrock pond corresponding to greater algal growth. Conductivity was consistently greater in BG 3 pond than in Shamrock pond, however, both ponds fall into Barica's (1975) moderately saline category, a modification of Rawson and Moore's (1944) "saline eutrophic" grouping.

These factors indicate that the older Shamrock pond was more productive, probably because it had richer bottom sediments. In addition, because Shamrock pond was circular, with less fetch, was located in more of a depression and was more or less surrounded by houses, it was not subjected to as much wind produced mixing as was BG 3 pond. Inhibition of mixing thus facilitated oxygen depletion associated with the richer bottom sediments of Shamrock pond.

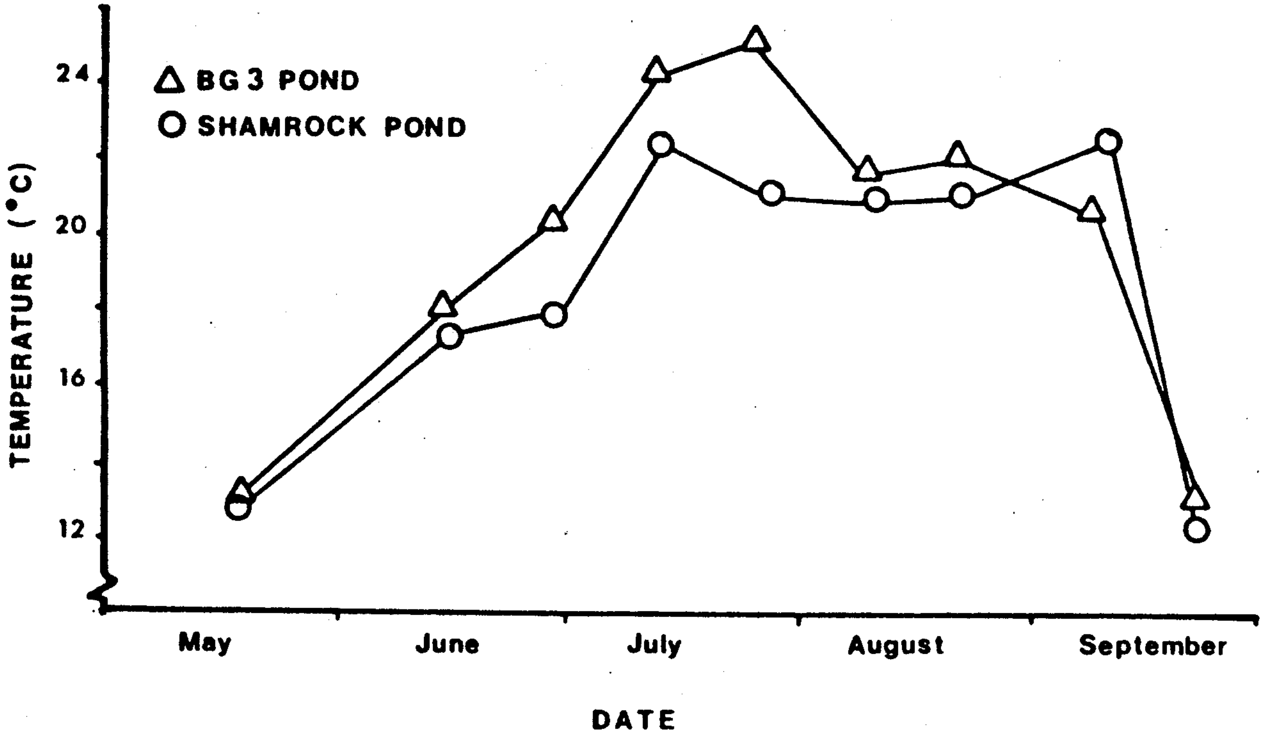


Figure 2: Mean sample date water column temperatures in BG 3 and Shamrock ponds, 1982.

Figure 3: Ammonia levels and surface minus bottom oxygen level differences for Shamrock (A) and BG 3 (B) ponds, 1982.

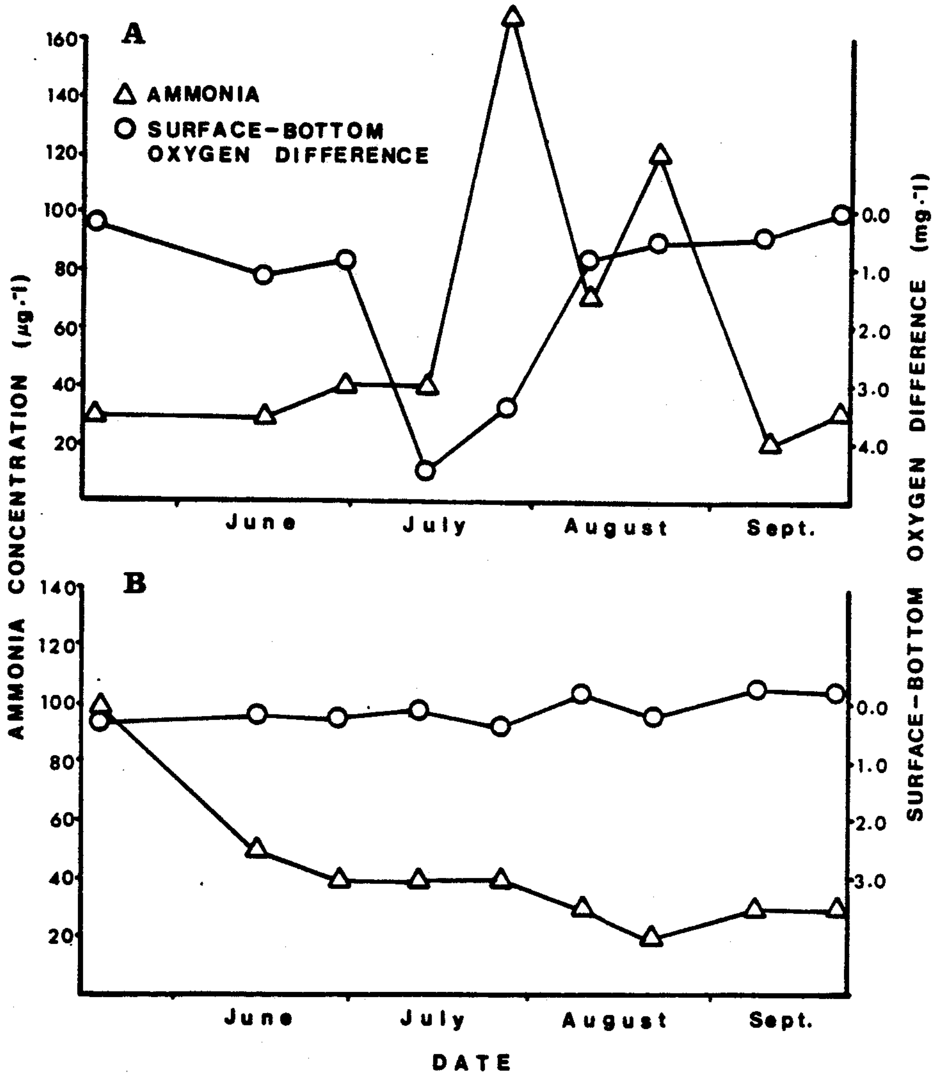


Table 2. Morphometric parameters and mean June to October (1982) values for some environmental factors for BG 3 and Shamrock ponds.

Parameter	Pond	
	BG 3	Shamrock
maximum depth (m)	1.5-2.0	1.5
surface area (ha)	0.68	0.98
age (years)	4	7
pH	7.8	8.1
NH_4-N (ug/l)	42	61
NO_3-N (ug/l)	10.5	7.7
SRP (ug/l)	9.8	4.0
TDP (ug/l)	29.0	28.5
Chlorophyll-A (ug/l)	1.8	20.8
Conductivity (uS/cm)	817	560
Secchi disc (cm)	120.6	47.4

RESULTS

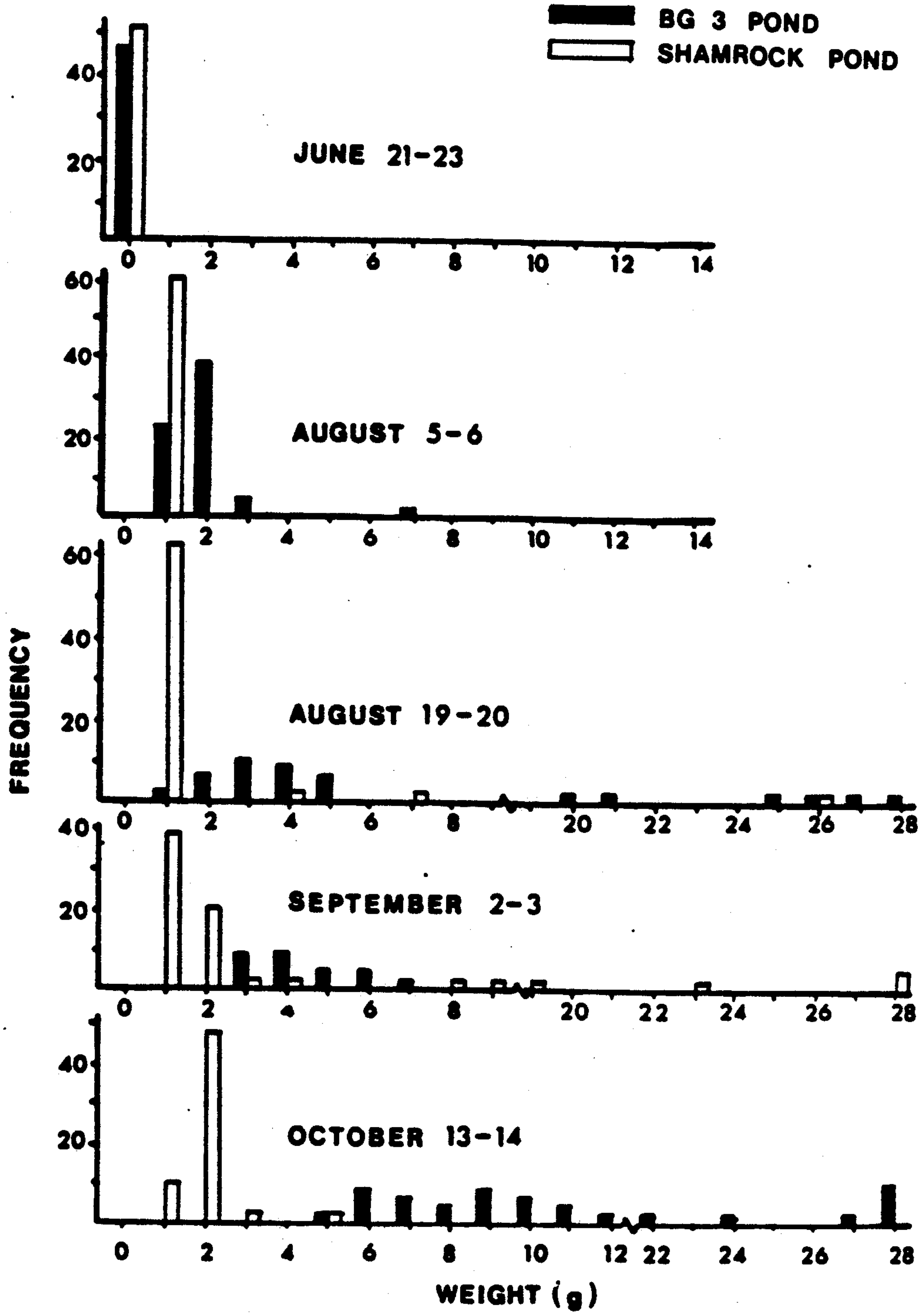
Growth

Walleye fry were planted into BG 3 and Shamrock ponds at a mean total length of 7.0 mm and a mean wet weight of 0.002 g. Initial growth, in length and weight, was rapid. A single peak of juvenile walleyes less than 0.5 g was found in both ponds in the June 21-23 samples (Figure 4). On August 5 the range was still restricted in Shamrock pond (0.5 to 1.5 g) but one larger fish was present in Bg 3 pond extending the range to 0.5 to 7.0 g.

The August 19 sample, in BG 3 pond, was composed of one group of walleyes ranging from 0.5 to 5.5 g and a larger group weighing 19.5 to 30.5 g. The comparable sample in Shamrock pond (August 20) indicated the presence of two groups, one with a modal weight of 1 gram with larger fish of 4.0, 7.0, and 26.0 g also present.

Bimodality was again observed in Shamrock pond on September 3 with an increase in the range of the smaller group (0.5 to 4.5 g) The range of weights noted on September 2 in BG 3 pond was 2.5 to 7.5 g with no large individuals sampled. In comparison to the September 3 Shamrock pond sample, the September 2 BG 3 pond sample revealed a different distribution of fish weights. Fewer of the smallest walleyes were present in BG 3 pond and the range of the small group was greater than in Shamrock pond.

Figure 4: Selected weight: frequency histograms for BG 3 and Shamrock ponds walleye, 1982.



On October 13 BG 3 pond walleyes ranging from 4.5 to 12.5 g and 21.5 to 49.0 g were sampled (Figure 4). Again the distribution of weights of the smaller group in BG 3 pond was spread out compared to the Shamrock pond October 4 sample distribution. The range of sizes of this smaller group was greater in BG 3 pond and the peak of smaller walleyes present in Shamrock pond throughout the season was not evident in BG 3 pond weight:frequency and length:frequency distributions (Appendix 2).

Overall, the largest mean sample sizes were 117.9 mm TL (5.1 g) on October 13 in BG 3 pond and 70.8 mm TL (4.5 g) on September 3 in Shamrock pond.

Within-pond variability in walleye growth resulted in the distinct group of larger walleyes being approximately twice the weight of the largest member of the more abundant smaller group (eg. BG 3 pond, August 5 Figure 4A). To facilitate future consideration, the smaller segment of the population are referred to as Group 1 walleyes and the larger, as Group 2 walleyes.

Group 2 walleyes were first evident on August 5 in BG 3 pond samples and on August 20 in Shamrock pond (Figure 4). These fish were initially, and remained throughout the summer, distinct from Group 1 walleyes. Means with 95% confidence limits were calculated for log weights of both groups (Table 3). The limits did not overlap for dates when both groups were sampled, supporting this manipulation. In total, Group 2 walleyes accounted for 3.4% of the total BG 3 pond walleyes sampled and 2.9% of the total Shamrock pond sample. Group 2 walleyes were similar in abundance relative to Group 1 walleyes in both ponds (Table 4).

Increasing mean wet weight in Group 1 walleyes was accompanied by increases in the range of weights as the season progressed. As a result, sample variances increased as a function of the sample means. To stabilize variances and compare growth, Taylor's power law was applied to the data. A log-normal transformation was appropriate (Elliott 1975).

Shamrock pond Group 1 walleyes growth, in log weight, exhibited in contrast to BG 3 pond, a "stanza" pattern where growth was reduced after mid July (Figure 5). Growth in fish length followed a similar pattern (Swanson and Ward 1985). The average lengths of Group 1 walleyes in mid October were 101 mm (BG 3) and 63 mm (Shamrock pond).

The predicted log weight on time regression lines do not entirely explain the relationship of weight to time, however, to quantify differences in growth between BG 3 and Shamrock ponds, the linear component of the log weight vs. time relationship for equivalent time periods and comparable sample dates was used. Instantaneous growth rates (Ricker 1975) for BG 3 and Shamrock pond were compared:

Table 3. Transformed weights (natural logarithm) and 95% confidence intervals for BG 3 and Shamrock pond samples collected on dates when both Group 1 and Group 2 were present.

Date	BG 3		Shamrock	
	Group 1	Group 2	Group 1	Group 2
August 5	0.4872±0.0773	1.9626	—	—
August 13	—	—	0.2252±0.1500	0.8817±0.4050
August 19	1.1449±0.1362	3.2092±0.1753	—	—
August 20	—	—	0.2103±0.0191	1.9748±1.4356
September 3	—	—	0.3708±0.0447	2.8527±0.5779
October 13	2.0857±0.0859	3.5750±0.1585	—	—

Table 4. Percent of BG 3 and Shamrock pond Group 2 walleye when sampled in walleye catches. Numbers caught are shown in parentheses.

Date	Pond	
	BG 3	Shamrock
August 5	1.5% (1)	-
August 19	17.1% (6)	-
August 20	-	6.1% (4)
September 30	-	14.7% (10)
October 13	27.7% (13)	-
total sample	3.4% (20/589)	2.4% (14/587)

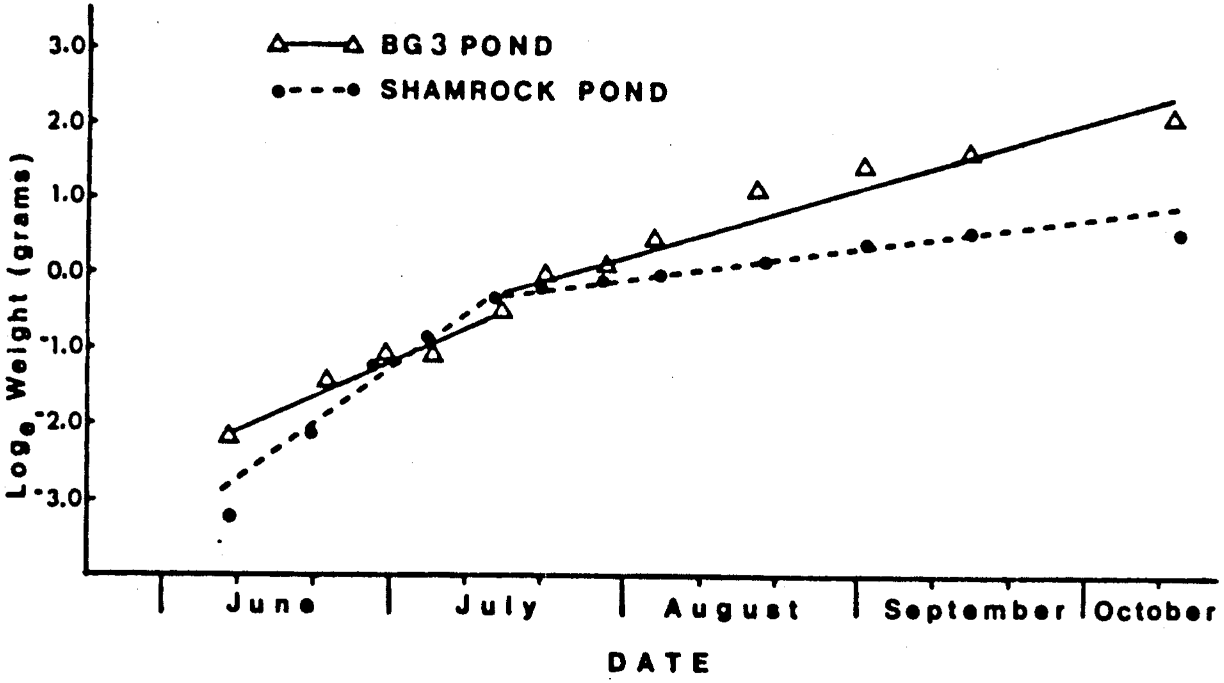


Figure 5: Instantaneous growth data for BG 3 and Shamrock ponds, 1982.

	BG 3	Shamrock		
pre-July 15	0.0435	0.0753	P < 0.001	*
post-July 15	0.0290	0.0146	P < 0.001	*

Results indicate that the instantaneous growth rates were significantly different between ponds. Before July 15, 1982 Shamrock pond Group 1 walleyes displayed a greater instantaneous growth rate than did those in BG 3 pond (P <0.001). Confidence intervals about the mean log weight for Shamrock pond and BG 3 pond on June 10 and June 19-20 indicated that Shamrock pond samples were significantly smaller for those dates. After July 15 however, the growth rate in Shamrock pond decreased by 81%. BG 3 pond growth did not decrease until August 19, however to compare growth between ponds the same time interval was examined. This resulted in an overall decrease in growth in BG 3 pond of 33% after July 15, 1982. As a result, the overall growth of Group 1 walleyes was much greater in BG 3 pond than in Shamrock pond (Figure 5).

Feeding of Group 1 Walleye

Kind and Size of Food Consumed

Group 1 walleyes consumed zooplankton throughout the period of June 10 (age=24 days) to September 16, 1982 (age=122 days). Zooplankton contributed 47.0% of the total dry weight consumed in BG 3 pond and 59.5% in Shamrock pond.

Copepods were the most frequently occurring and the most important zooplankters in terms of weight consumed in both ponds (Table 5). *Diaptomus sanguineus* were present in 73.5% of BG 3 pond walleyes and accounted for the full copepod contribution of 33.2% of the total dry weight. Group 1 walleyes in Shamrock pond consumed *D. sanguineus* and *Cyclops bicuspidatus* at 68.5% and 60.4% frequencies of occurrence. *D. sanguineus* contributed 26.4% of the seasonal ration and *C. bicuspidatus* contributed 22.8%.

Cladocerans were present in 51.7% of BG 3 pond walleyes and accounted for 13.8% of the total weight consumed. *Daphnia pulex* were the most frequently occurring (47.0%) and the most important contributing 13.7% of the stomach contents weighed. *Moina micrura* was found in 3.3% of walleyes stomachs and contributed 0.1% of the total diet weight. Although *Leydigia* sp. was present in 4.0% of the stomachs examined it was not found in the zooplankton samples and accounted for less than 0.1% of the total weight of walleyes food. Neither *M. micrura* nor *Leydigia* sp. contributed significantly to Group 1 walleyes nutrition.

Cladocerans were present in 28.2% of Shamrock pond walleyes. *Bosmina longirostris* while the predominant cladoceran in the environment, were only found in 1.3% of the Shamrock pond walleyes examined and contributed 0.9% to the food weight. *D. pulex* was the most important cladoceran, contributing 9.3% of the dry weight consumed despite their relative scarcity in the environment.

Table 5. BG 3 and Shamrock food item frequencies of occurrence and percent contribution to the total Group 1 walleye diet.

Prey	Percent Frequency of Occurrence		Percent of Total Dry Weight	
	BG 3	Shamrock	BG 3	Shamrock
O. Copepoda	73.5	82.6	33.2	49.2
Diaptomus sanguineus	73.5	68.5	33.2	26.4
Cyclops bicuspidatus	-	60.4	-	22.8
O. Cladocera	51.7	28.2	13.8	10.2
Daphnia pulex	47.0	27.5	13.7	9.3
Bosmina longirostris	-	1.3	-	0.9
Moina micrura	3.3	-	0.1	-
Leydigia sp.	4.0	-	0.1	-
Zooplankton	-	-	47.0	59.4
F. Chironomidae (pupae)	19.2	-	6.0	-
F. Corixidae	-	6.7	-	22.7
O. Amphipoda (*Hyallela* sp.)	11.3	10.7	4.0	6.2
F. Agridae	-	2.0	-	0.8
O. Ephemeroptera (*Hexagenia* sp.)	2.6	1.3	2.0	1.0
Insect parts	-	-	39.2	9.1
Total Amphipods and Insects	-	-	51.2a	39.8b

a one walleye contained walleye remains in stomach contributing the remaining 1.8%

b earthworm remains in one walleye contributed the remaining 0.8%.

In BG 3 pond D. sanguineus consumed were larger than those found in plankton samples (Table 6). Although BG 3 pond walleyes consumed D. sanguineus up to 1.8 mm ML, none greater than 1.2 mm ML were encountered in BG 3 pond plankton subsamples. Subsequent examination of BG 3 June 14 and June 28 total zooplankton samples revealed D. sanguineus greater than 1.2 mm ML, present at low densities of 0.23 $litre^{-1}$ and 0.13 $litre^{-1}$ respectively. D. sanguineus less than 1.2 mm ML were present in 23.2 % of Group 1 walleye stomachs and contributed 2.6% of the walleye diet.

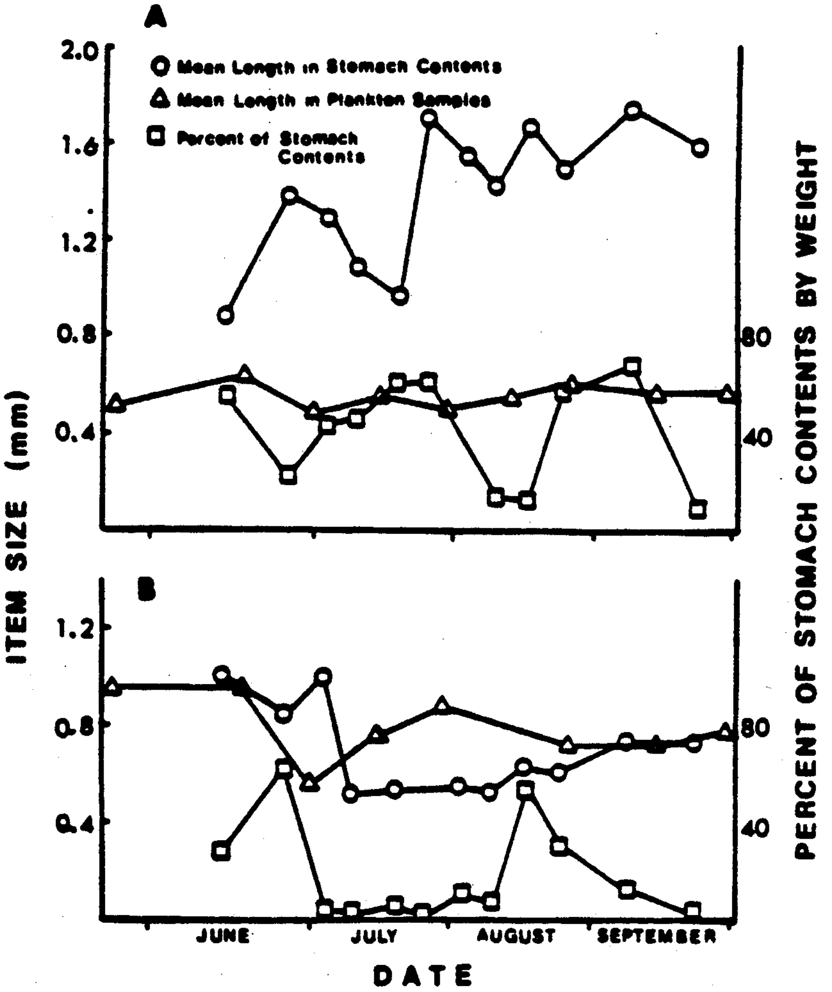
While the overall mean metasome length of D. sanguineus found in BG 3 pond remained relatively constant (ML=0.55 mm) the mean metasome length of those consumed, increased from 0.89 mm on June 10 to a maximum of 1.75 mm on September 2 (Figure 6A). D. sanguineus less than 1.2 mm ML disappeared from the diet after July 22 indicating selection for larger D. sanguineus by Group 1 walleyes. D. sanguineus diet contribution was variable through the season (Figure 6A). Low contributions on June 23 and August 5-12 were augmented by periods when D. pulex contributed significantly to the diets (Figure 6B).

Relatively large D. pulex (L=0.84 mm) occurred in plankton samples until June 23 but smaller D. pulex (L=0.63 mm) were present thereafter. The fact that D. pulex diet contribution was low between June 23 and August 5 lessens any apparent significance of consumption of D. pulex smaller than those found in the environment during this period.

Table 6. BG 3 and Shamrock pond mean metasome lengths (ML) of copepods and mean "eye to spine" lengths (L) of cladocerans present in plankton samples and in Group 1 walleye stomachs.

Prey	BG 3		Shamrock	
	Environment	Stomach	Environment	Stomach
D. sanguineus	.55 mm	1.43 mm	.58 mm	.80 mm
C. bicuspidatus	-	-	.27 mm	.75 mm
D. pulex	.83 mm	.66 mm	.56 mm	.76 mm
B. longirostris	-	-	.21 mm	.36 mm
M. micrura	.48 mm	.88 mm	-	-
Leydigia sp.	-	.60 mm	-	-

Figure 6: Mean zooplankton size in BG 3 pond Group 1 walleye stomachs and plankton samples and percent item contributions to daily total dry weight consumed for A: *Diaptomus sanguineus* and B: *Daphnia pulex*.



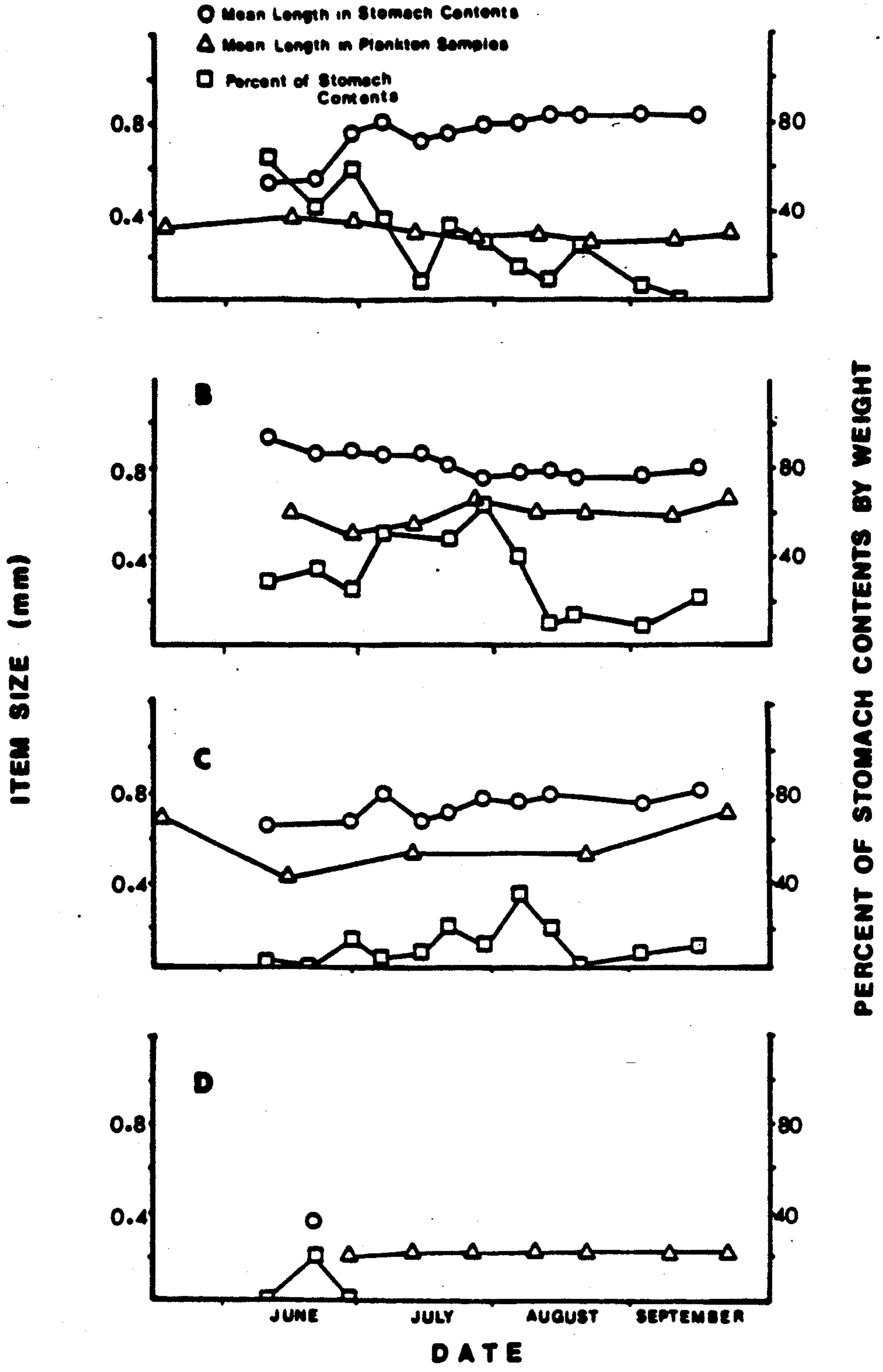
Shamrock pond walleyes consumed smaller *C. bicuspidatus* (ML=0.75 mm) and *D. sanguineus* (ML=0.80 mm) than BG 3 pond walleyes did (Table 6). *C. bicuspidatus* were consumed at increasing sizes as the season progressed (Figure 7A). This selection of progressively larger organisms resulted in an increasing difference between sizes consumed and those present in the environment. After June 29, *C. bicuspidatus* contribution to the diet decreased.

The contribution of *D. sanguineus* to the diet increased in importance until July 30, when sizes consumed and sizes present in plankton samples became similar (Figure 7B). As the contribution of *D. sanguineus* decreased, that of *D. pulex* increased to 32.0% on August 6 (Figure 7C). Unlike BG 3 pond, *D. pulex* consumed in Shamrock pond throughout the season were consistently larger than those found in plankton samples.

B. longirostris were only consumed on June 21 (Figure 7D) and contributed little to the overall diet (Table 8). Again the size consumed was greater than sampled in plankton samples. Apparently, *B. longirostris* were only important to the diet of Group 1 walleyes early in the season when the fish were small.

Amphipods and insects contributed to Group 1 walleye diets earlier in the season in BG 3 pond than in Shamrock pond (Figure 8). Dipteran pupae were the most important of

Figure 7: Mean size in Shamrock pond Group 1 walleye stomachs and in plankton samples, and percent contribution to daily total dry weight consumed for A: *Cyclops bicuspidatus*, B: *Diaptomus sanguineus*, C: *Daphnia pulex* and D: *Bosmina longirostris*.



the larger identifiable invertebrates found in BG 3 pond Group 1 walleyes, contributing 22.0% of the total weight consumed on July 1 and July 7 (Figure 8A). This corresponds closely to the occurrence of *Leydigia* sp. in the diet on July 7 and July 16, immediately prior to the divergence of the Shamrock and BG 3 pond growth curves (Figure 5). Similarly BG 3 pond insect part weight rose in importance through this period to a peak of 57.0% on August 5 (Figure 8B). *Hyalella* sp. and *Hexagenia* sp. were identified in BG 3 pond walleye diets after July 16 (the point of growth curve divergence); however they contributed greater than 10.0% of a sample date's diet twice, 13.0% on August 5 and 17.0% on August 19 (Figure 8C and D). This was well after the two growth curves had diverged.

In contrast to BG 3 pond, corixids were the most important large invertebrates found in Shamrock pond walleye diets (Table 5, Figure 9A). They contributed 22.7% of the overall weight consumed and first appeared on August 13, immediately following the decline in the contribution of *D. sanguineus* and four weeks after the Group 1 walleye growth curves in the two ponds diverged (Figure 5). From this time on they contributed 53.3% of the dry weight consumed and were the single most important item in Shamrock pond Group 1 walleye diets. Corixids were rarely found disarticulated, accounting for the low insect part contribution (Figure 9B).

Figure 8: Percent contributions to BG 3 pond Group 1 walleye daily total diet by A: Dipteran pupae, B: Insect Parts C: *Hyallela* sp. and D: *Hexagenia* sp.

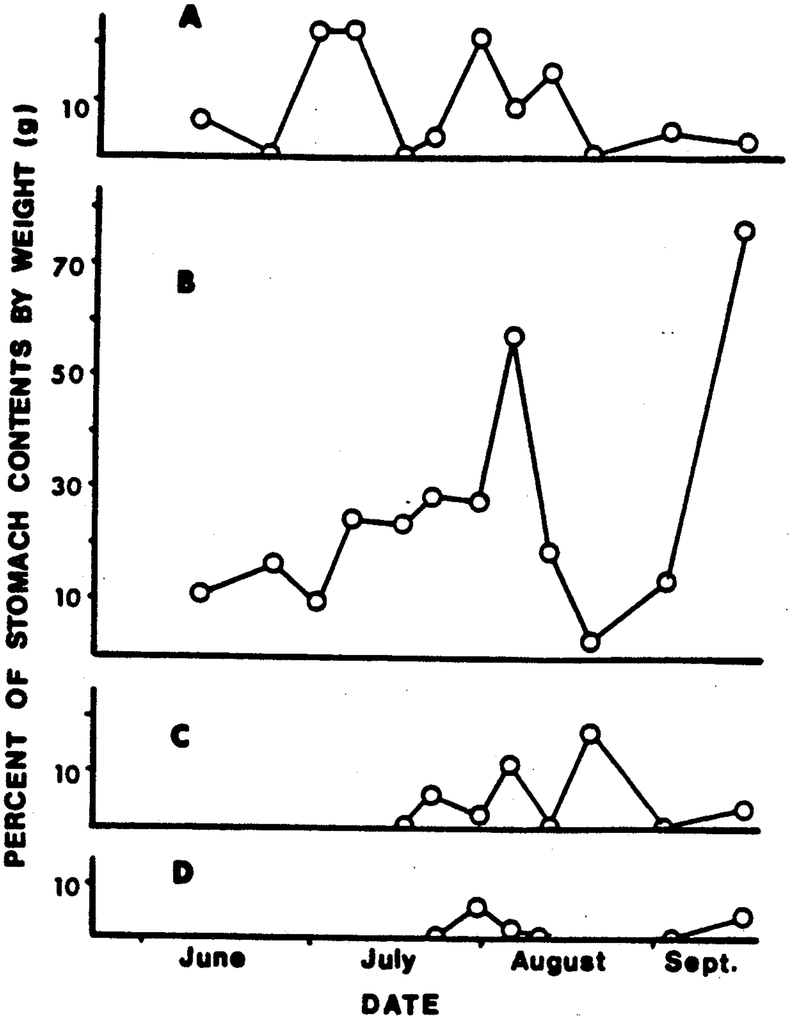
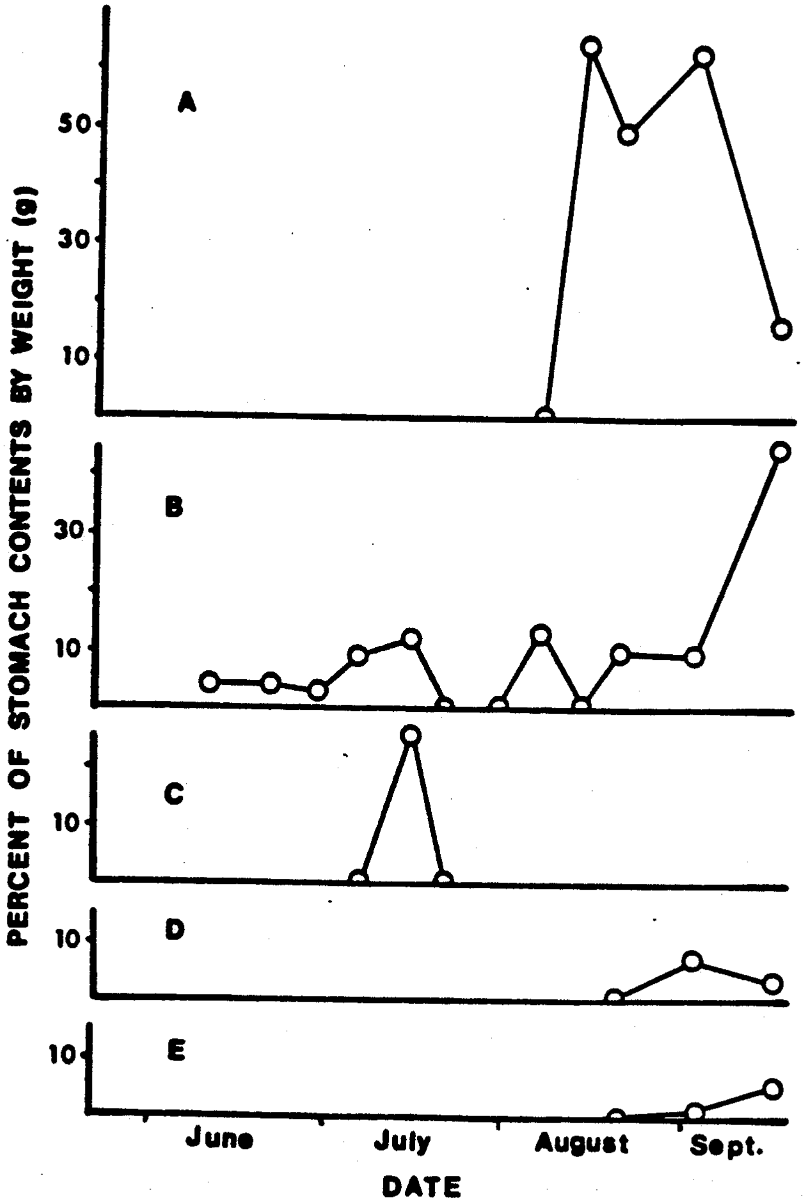


Figure 9: Percent contribtutions to Shamrock pond Group 1 walleye daily total diet by A: F. Corixidae, B: Insect Parts, C: *Hexagenia* sp., D: *Hyallela* sp. and E: F. Agriidae.



Shamrock pond walleyes were observed to consume the benthic mayfly nymph Hexagenia sp. on July 15 at a mean total length of 47.6 mm (Figure 9C). This was the first occurrence of an identifiable demersal food item in Shamrock pond walleyes diets. Both amphipods (Hyalella sp.) and Odonatids (F. Agriidae) appeared in the diet late in the season and did not account for greater than 7.0%, by weight of the stomach contents, on any given sample date (Figure 9D and E).

Relationship of Walleye Size to Food Size

As Group 1 walleyes grew, larger food items (i.e. amphipods and insects) were consumed. Larger food items were consumed earlier in the season in BG 3 pond than in Shamrock pond as noted. To compare size of food items consumed by Group 1 walleyes in the two ponds, the fish were grouped into 10 mm length classes and the sizes of items in their stomachs noted. Larger prey were present in smaller BG 3 pond walleyes than in Shamrock pond fish (Figure 10). In fact no measurable items greater than 1.0 mm were observed in Shamrock pond walleyes less than 40.0 mm long and only a single occurrence of the large Hexagenia sp. was noted in walleyes less than 50.0 mm long. Hence items greater than 1.0 mm were not consumed by walleyes 20 to 50 mm long in Shamrock pond. Conversely, BG 3 pond walleyes in this size range consumed larger zooplankton in general and larger D.

sanguineus in particular. Furthermore, larger items such as dipteran pupae and Hyalella sp. were utilized by smaller walleyes in contrast to Shamrock pond.

BG 3 pond walleyes less than 100 mm long consumed large D. sanguineus (Figure 11A). They formed an average of 43.3% by weight of the diet. The contribution of D. pulex was variable depending on the size of the walleyes and M. micrura was consumed by walleyes 90 to 99 mm long, at a single peak of 12.0% (Figure 11B and C). Leydigia sp. were consumed in small amounts by walleyes 40 to 59 mm TL indicating demersal habits at this size (Figure 11D). Unlike Shamrock pond, a greater proportion of the diet of walleyes less than 50 mm TL was insects. Insect part contribution was much greater, rising to 26.0% of the diet of walleyes 30 to 39 mm long (Figure 11E). Similarly, dipteran pupae were present at all lengths greater than 19 mm and their contribution rose to 10.0% in 40 to 49 mm long walleyes (Figure 11F).

In Shamrock pond walleyes the contribution of C. bicuspidatus to stomach contents decreased as they grew (Figure 12A). The percentage by weight of D. sanguineus in stomachs was variable, showing an initial tendency to increase in walleyes less than 50 mm long, then declining in larger fish (Figure 12B). The cladoceran contribution rose in importance to 13.0% in the stomachs of fish in the 30 to 39 mm length class; thereafter it was variable and relatively low (Figure 12C). B. longirostris were present in significant

Figure 10: Mean size of food items, in 10 mm walleye length intervals, in BG 3 and Shamrock ponds

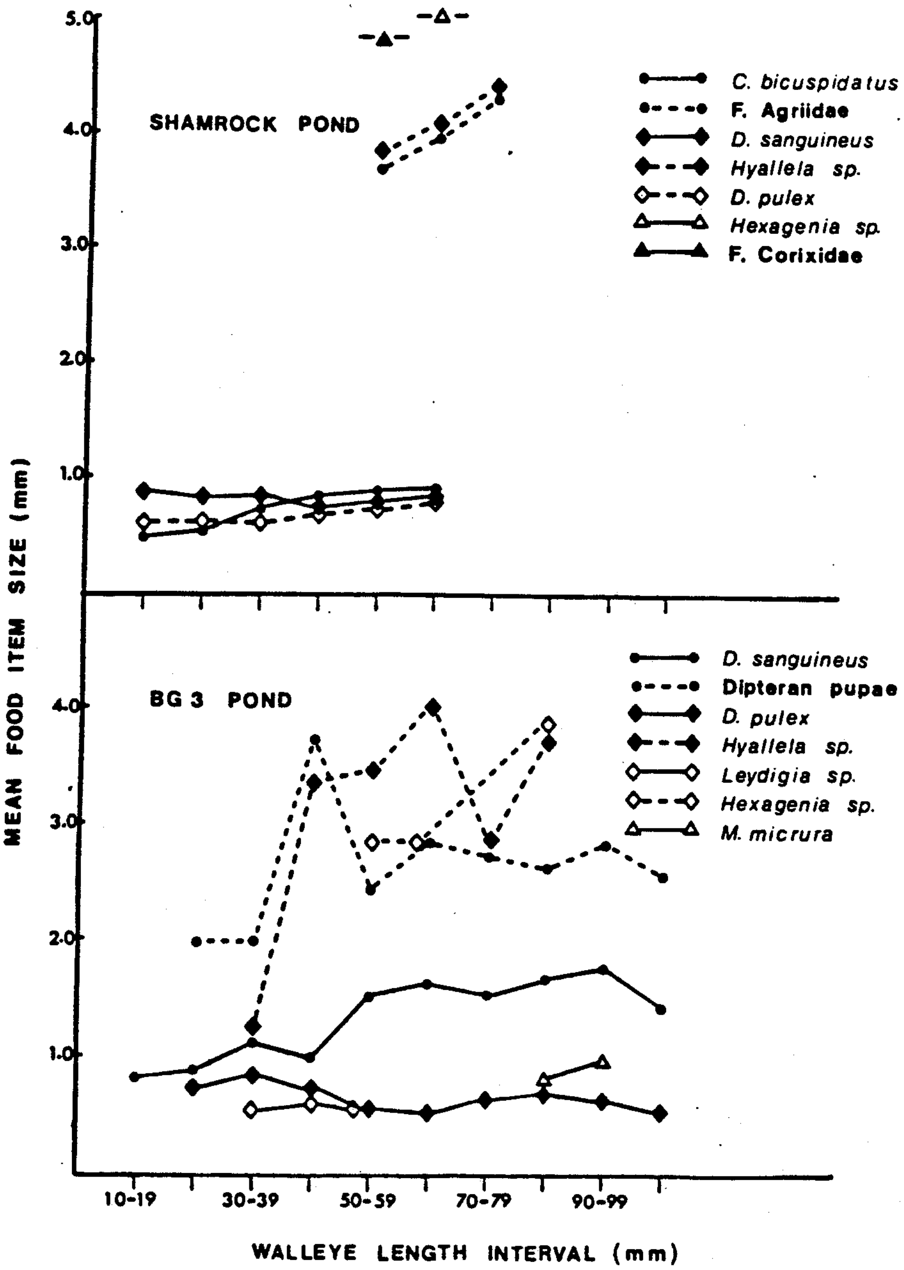
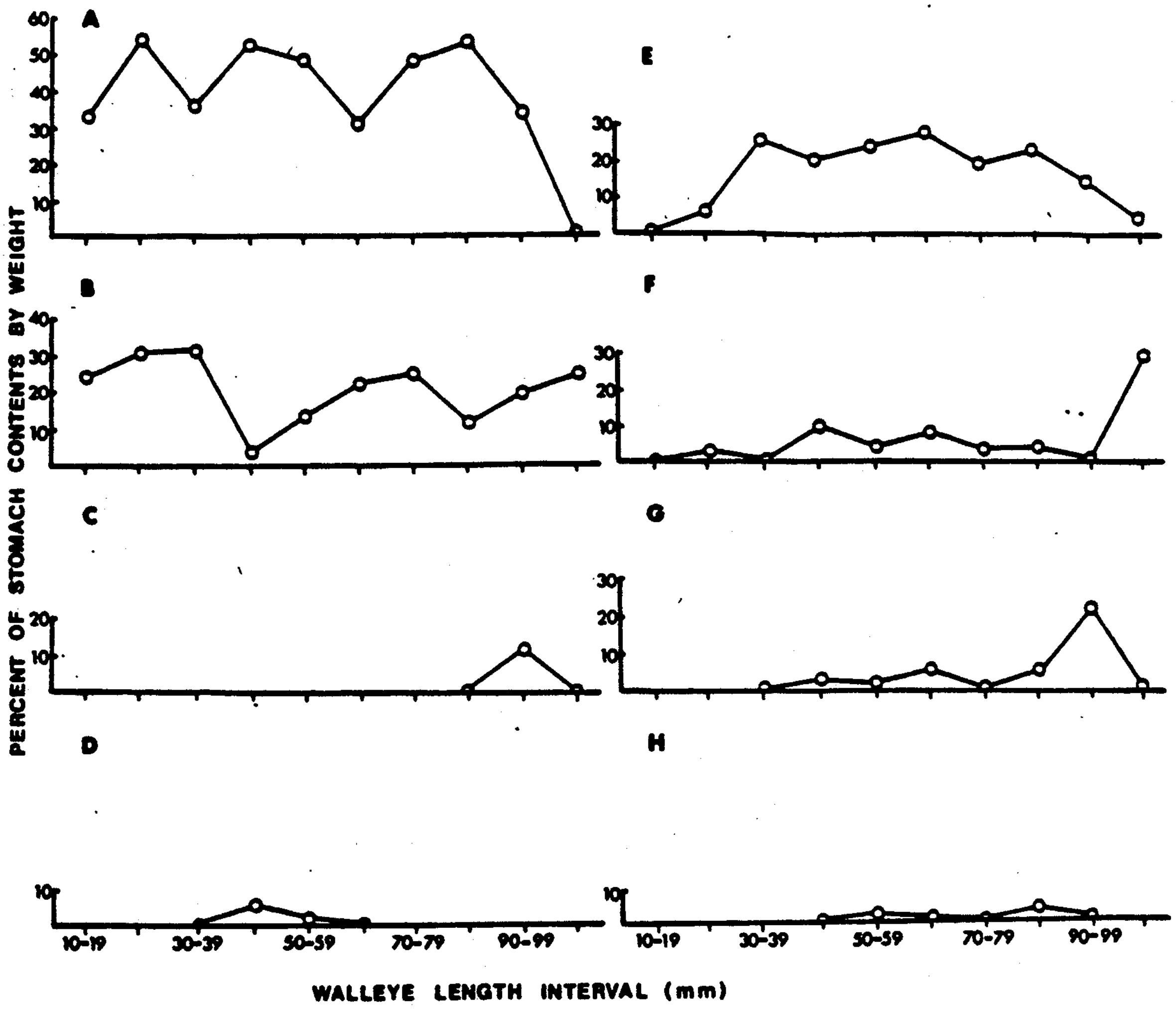
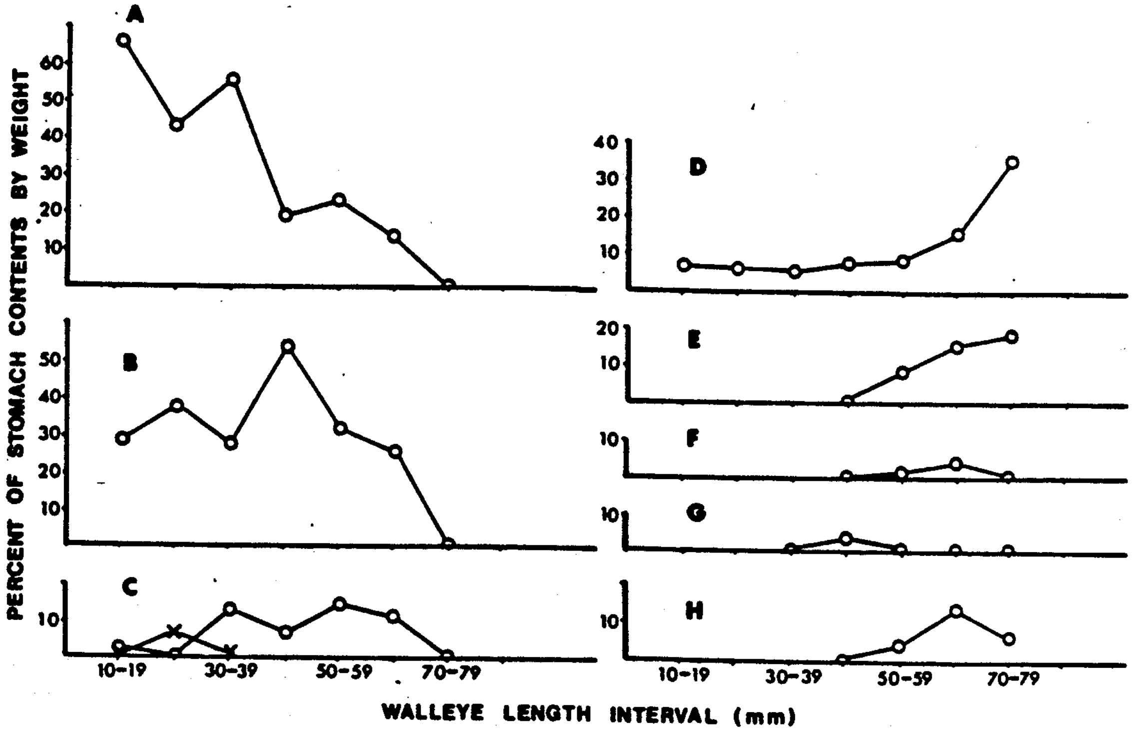


Figure 11: Percent contribution by weight, in 10 mm walleye length intervals, to BG 3 pond walleye diets for A: *Diaptomus sanguineus*, B: *Daphnia pulex*, C: *Moina micrura*, D: *Leydigia* sp., E: Insect parts, F: Dipteran pupae, G: *Hyallela* sp. and H: *Hexagenia* sp.



amounts in only the 20 to 29 mm class (Figure 12D). Insects and amphipods contributed little to the diets of Shamrock pond walleyes less than 50 mm long (never more than 10.0%). Insect parts, corixids, Hyalella sp. and to a lesser extent agriids, rose in importance in the diet of walleyes more than 50 mm long as the zooplankton contribution decreased (Figure 12E to H). The presence of Hexagenia sp. in walleyes in the 40 to 49 mm class and Hyalella sp. in the 60 to 69 mm length class may indicate benthic feeding.

Figure 12: Percent contribution by weight, in 10 mm walleye length intervals to Shamrock pond walleye diets for A: *Cyclops bicuspidatus*, B: *Diaptomus sanguineus*, C: *Daphnia pulex* (0) and *Bosmina longirostris* (X), D: Insect parts, E: F. Corixidae, F: F. Agriidae, G: *Hexagenia* sp. and H: *Hyallela* sp.



Group 2 Walleye Feeding

In BG 3 pond, five of the seven Group 2 walleyes examined were piscivorous containing walleye remains in their stomachs (Table 7). None contained zooplankton and only one (14.3%) contained another food item, insect parts , which contributed less than 0.1% of the daily total weight consumed. Cannibalized walleye remains accounted for more than 99.9% of the total Group 2 walleyes diet, indicating that these fish subsisted almost entirely on smaller individuals of the same species. Two of the seven stomachs examined were empty indicating that while these fish were not obviously piscivorous, neither had they consumed any other food item in perceptible amounts.

Shamrock pond Group 2 walleyes were also highly piscivorous with ten of the sixteen stomachs examined (62.5%) containing fish remains. All of the identifiable fish remains were fathead minnows which contributed 84.3% of the total dry weight consumed by these walleyes. Other fish remains were unidentifiable due to digestion and contributed 13.1%, which when combined with the fathead minnow contribution, totaled 97.4% of the total weight consumed. No zooplankton were discovered and corixids, which were found in two stomachs, and insect parts, found in five stomachs, combined for a total contribution of 2.6% of the total Group 2 walleyes stomach content by dry weight. Again two stomachs were empty, indicating that while not obviously piscivorous, neither

Table 7. BG 3 and Shamrock pond fooditem frequencies of occurrence and percent contribution to the total Group 2 walleye diet. Number of Group 2 walleyes with item in their stomach are given in parentheses.

Item	Percent Frequency of Occurrence		Percent of Total Dry Weight	
	BG 3	Shamrock	BG 3	Shamrock
Insect Parts	14.3 (1)	31.3 (5)	<0.1	1.7
Corixids	- (0)	12.5 (2)	-	0.9
Walleye	71.4 (5)	- (0)	>99.9	-
Unidentified fish remains	0 (0)	31.3 (5)	0	13.1
Fathead minnows	-	31.3 (5)	-	84.3
Empty	28.6 (2)	12.5 (2)	-	-
Totals	- (7)	- (16)	100 (5)	100 (16)

had they consumed other organisms in the immediate past. Consequently, Group 2 walleyes in both ponds were almost entirely piscivorous. While BG 3 pond walleyes could only consume other walleyes, 100% of the identifiable fish remains in Shamrock pond were fathead minnows.

Using a daily consumption rate of 3.0% of body weight (Swenson 1977), estimates of the potential rate of Group 2 walleye cannibalism were calculated for those dates when Group 2 walleyes were captured (Table 8). The hypothetical cannibalism is seen to increase from 0.2% per day of the Group 1 walleyes on August 5 to 4.7% on August 19. In fact, cannibalism was observed as early as July 7, four weeks before the first "Group 2" walleye was sampled. Prey to predator length ratios as great as 0.55 were observed.

Catch per effort in BG 3 pond, where cannibalism was greatest, decreased seasonally. Although large weekly samples were initially caught in BG 3 pond, ease of obtaining the desired level of 50 fish decreased after August 5, 1982. Consequently, numerous seine attempts were required to obtain 50 fish (Swanson and Ward 1985). Additionally, on October 13, intensive effort using a 30.5 m and 45.8m seine harvested only 111 juvenile walleyes. In total 1367 walleyes were removed from BG 3 pond. Few juvenile walleyes remained in BG 3 pond.

Table 8. Relative frequencies of Group 1 and 2 walleye, Group 2 dietary requirement (theoretical), Group 1 total sample weight and percent of Group 1 walleye cannibalized (theoretical) in BG 3 pond, 1982.

Date	Number of Group 2	Number of Group 1	GP 2 Sample Wt. req. (g)	GP 1 Total Sample wt. (g)	% GP 1 Consumed per day
August 5	1	63	.214	108.851	0.2
August 19	6	29	4.506	96.442	4.7
October 13	13	34	14.352	281.673	5.1

The soft mud bottom and shoreline of Shamrock pond made it harder to seine. However weekly samples were obtained throughout the season with relatively little effort. A purse-seine technique using a 18.3 m seine (used from late August on) was the most successful method, a technique which did not enhance catches in BG 3 pond. Walleye for transfer were also captured using this method in Shamrock pond. On October 14, 513 walleyes were captured in six hauls. In total, 1748 walleyes were removed from Shamrock pond. Ease of capture of juvenile walleyes in Shamrock pond indicated that a significant number probably remained after collections were completed.

DISCUSSION

Differences in first year growth of walleyes was observed between BG 3 and Shamrock pond. First year growth of walleyes is variable between years as a result of the many abiotic and biotic factors which regulate growth and suitable environmental conditions (Serns 1982). While Rawson (1957) reported that in Lac LaRonge, Saskatchewan, walleyes were 104 mm by the end of September, Lake Winnipegosis walleyes had reached a mean length of 123 mm on August 23, 1979 (Gillis and Green 1980). Young of the year walleyes attained mean lengths ranging from 75.1 to 118.0 mm by early October in rearing ponds beside Lake Winnipegosis (Gillis and Green 1980). Li and Ayles (1981b) harvested walleyes with mean total lengths ranging from 102 mm to 153 mm, in early September from farm dugouts near Erikson, Manitoba and 127 mm to 164 mm from constructed earthen ponds at the Rockwood hatchery in late September to mid October in 1980. Young of the year walleyes were 120 mm long by August 30 in the Red Lakes, Minnesota (Smith and Pycha 1960), 127 mm to 172 mm by October 1 in Oneida Lake, New York (Forney 1976), 127 mm to 185 by the end of October in Lake Winnebago, Wisconsin (Priegel 1970), 160 mm to 188 mm by the fall in Pike Lake, Wisconsin (Mraz 1968), and 94 mm to 168 mm by the fall in Escanaba Lake, Wisconsin (Serns 1982). Dobie (1969) found walleyes to reach a mean total length of 58.4 mm (40.6 mm to 88.9 mm) in 60 days in Minnesota. Similar if not greater growth rates for age 0+ walleyes were observed in rearing ponds at Lake Winnipegosis, Manitoba (Campbell and Rowes 1980; Gillis and Green 1980) and in rearing ponds at the Rockwood hatchery (Li and Ayles 1981b). Mean size attained, of combined Group 1 and Group 2 walleyes in BG 3 pond (118 mm TL), on October 13 was similar to previously reported sizes reached in natural waters and rearing ponds at similar latitudes. Shamrock pond combined Group 1 and Group 2 walleyes, did not attain a size comparable to that in natural waters and were smaller than those in Lake Winnipegosis rearing ponds.

The growth of fish is influenced by many factors (Fry 1971; Brett 1979). The three most important independent factors governing growth rate are ration, fish size and temperature (Weatherly 1966; Brett 1979). In general, increased fish size affects growth by reducing its rate through reduced metabolic activities (Brett 1979). The fact that only age 0+ walleyes were considered in 1982 minimizes the effect of size in explaining growth differences between Shamrock and BG 3 ponds. Furthermore, instantaneous growth rates after July 15 indicated that larger BG 3 pond walleyes grew significantly faster than did the smaller Shamrock pond walleyes. Hence, other factors must have more strongly regulated the observed growth rates.

The range of temperatures experienced in BG 3 pond was not lethal and was, in fact, closer to optimal. A maximum temperature of 25o C was recorded in BG 3 pond on July 26, 1982 (Figure 2). Temperature increases in BG 3 pond were gradual and 25o C is below the lethal temperature range of 29 to 31.6o C (Laarman and Reynolds 1974; Koenst and Smith 1976). Fry (1971) considered temperature to be the most important abiotic factor governing growth. Temperature acts as a controlling factor by pacing the metabolic requirements for food and governing the rate processes involved in food processing (Brett 1979). Thus, temperature affects fish activity, food consumption rates and the distribution of assimilated energy. Consequently, rising temperature increases growth until an optimum temperature is reached, which for small percids is only a few degrees below the upper lethal temperature (Hokanson 1977). Enhanced first year growth of walleyes in natural waters has been correlated to increased May-June air temperatures (Forney 1966) and increased June and May-June water temperatures (Serns 1982). Huh et al. (1976) found growth of juvenile walleyes in the labratory to be greater at 22o C than at 16o C, This indicates that temperature stress probably did not limit growth in BG 3 pond before July 15, 1982. Furthermore, temperatures were consistently greater in BG 3 pond until September 8. This should have enhanced early growth. Temperature differences do not therefore explain the 1.7 times greater growth rate observed in the somewhat cooler Shamrock pond before July 15, 1982.

Despite faster growth early in the season, the mean length of Shamrock pond walleyes at approximately 65 days after hatching (50.3 mm TL) was slightly less than in BG 3 pond (51.3 mm TL). Smaller Shamrock pond walleye were obvious throughout the pre-July 15 period. It is possible that the warmer water temperatures in BG 3 pond may have contributed to an increased development of endogenously feeding walleyes. Since fry could not be sampled prior to June 10, 25 days after hatching, differences cannot be explained.

Differences in the size and type of prey items were observed between BG 3 and Shamrock ponds. Brett (1979) stated that "ration is the sole driving force of fish growth, with diet quality and quantity interacting to determine the energy assimilated" and therefore the growth of the fish. Natural selection should therefore select for foraging strategies that are most economical to the species. Particle (food item) size selection which optimizes foraging strategies has been demonstrated in various fish species (Hall et al. 1970; Werner and Hall 1974; Werner 1974; O'Brien 1979). Moreover, differences in growth rates have been correlated to prey size (Parker and Larkin 1959; Paloheimo and Dickie 1966). Perhaps this was the case in BG 3 and Shamrock ponds accounting for the greater growth in Shamrock pond before July 15, 1982 and its decrease thereafter.

The importance of zooplankton early in the diet of both BG 3 and Shamrock pond walleyes is obvious (Figures 6 and 7). Buckley et al. (1976) discovered that walleyes fry first contained food at a length of 9 mm in Clear Lake, Iowa, and Hohn (1966) found diatoms in the intestinal tract of fry less than 9 mm long in Lake Erie. The presence of diatoms in the diet is probably accidental, resulting from ingestion via the respiratory current. Mathias and Li (1982) concluded that small items like rotifers were not actively preyed on by walleyes and were accidently ingested during respiration. In general, walleyes less than 60 mm TL are considered to subsist on zooplankton (Smith and Moyle 1945; Smith and Pycha 1960; Dobie 1969; Priegel 1970; Buckley et al. 1976; Walker and Applegate 1976; and Gillis and Green 1980).

Shamrock pond walleyes consumed smaller zooplankton than did walleyes in BG 3 pond. This may be optimal for post larval walleyes because juvenile walleyes up to 30 mm long had difficulties capturing and consuming larger cladocerans (Mathias and Li 1982). Presumably this results from the morphological restrictions of small mouth size. Wong and Ward (1972) found such restrictions on young of the year yellow perch in West Blue Lake. Yellow perch, 18 mm TL could not readily ingest *Daphnia pulicaria* longer than 1.3 mm. Likewise Werner (1974) found that bluegill and green sunfish had "energetically optimal" prey sizes based on mouth size. *D. sanguineus* present in Shamrock pond were generally larger than *C. bicuspidatus* and were therefore ingested less frequently by small walleyes. Calanoid copepods may also be harder to capture. O'Brien (1979) found that *Diaptomus pallidus* was more difficult to capture (7% success) using a simulated suction feeding device than was *Cyclops scutifer* (24% success). He suggests that calanoid copepods may therefore have a more successful predator evasion mechanism which would have further decreased the availability of *D. sanguineus* as a suitable food item.

The fact that the contribution of *C. bicuspidatus* declined as the size of *C. bicuspidatus* in the stomach contents and those in the environment diverged, indicates that a lack of suitably sized *C. bicuspidatus* limited its contribution as food as the season progressed. This evidence for size selection is supported by the fact that C. bicuspidatus contribution to the diet decreased with increasing walleye size (Figure 12). Houde (1967) discovered that a drop in C. bicuspidatus frequency of occurrence, corresponded to increased walleyes size and a rise in frequency of the larger copepod Epischura sp. Furthermore, electivity of Cyclops sp. dropped to negative values as Epischura sp. became positive in late May. Priegel (1970) found that when Cyclops sp. were no longer selected the cladoceran Leptodora sp. compensated, presumably due to its larger size. O'Brien (1979) found that food item size is critical in terms of food perception and Werner and Hall (1974) found that bluegill sunfish reacted to Daphnia magna 3.6 mm in length at distances 2.1 times greater than for D.magna 1.4 mm long. Furthermore, larger mouths facilitate a shift to larger prey (O'Brien 1979) and walleyes, with well developed jaws and relatively large gape exhibit these characteristics (Mathias and Li 1982). The drop in C. bicuspidatus contribution, therefore, results from size selective food consumption and coincides with a rise in the contribution of larger D. sanquineus as the season progressed (Figure 6).

Despite a rise in seasonal diet contribution, D. sanquineus dietary importance was variable in Shamrock pond walleyes less than 60 mm long (Figure 12). Other authors have found that Diaptomus sp. may contribute significantly to the diet despite being negatively selected for (Houde 1967;

Priegel 1970). Houde (1967) speculated that certain species of Diaptomus may be unpalatable to walleye fry. Another possibility is that predator experience kept some walleyes looking for suitably sized C. bicuspidatus to the relative exclusion of D. sanguineus. Brooks (1968) found that planktivores may consume smaller but familiarly sized items, despite their ability to consume, and the availability o, larger items. It seems most likely, however, that increased evasion abilities of Diaptomus sp. (O'Brien 1979) and its somewhat larger size would result in its variable contribution with increasing walleye size.

Cladocerans did not contribute to the diet of Shamrock pond walleyes to the same degree that copepods did. B. longirostris, although abundant in plankton samples were extremely small (L=0.21 mm) and were probably not available as suitable prey for young walleyes. D. pulex of suitable sizes were rare in Shamrock pond and contribution was low.

The absence of large cladocerans in Shamrock pond walleye stomachs may be explained by the presence of numerous fathead minnows. Held and Peterka (1974) noted that cladocerans were the most important food item of fathead minnows in North Dakota prairie potholes and Walker and Applegate (1976) discovered that cladocerans were rare when fathead minnows were present and increased in abundance in their absence. Werner and Hall (1974) found virtually no pursuit costs in the consumption of Daphnia magna and O'Brien (1979) stated that due to continuous motion of thoracic appendages and relative immobility, large daphnids are easily located and captured. They are therefore a preferred food item of visual pump feeders. Fathead minnows are visual pump feeders (Jansen pers. comm.).

The presence of fathead minnows may have enhanced early walleyes growth in Shamrock pond via a reducction in abundance of large zooplankton and an increased abundance of small zooplankters as suitable food items. Previous studies indicate that voracious planktivores can produce a size shift both within and between species of zooplankton present, from large to small organisms (Galbraith 1967; Wells 1970; O'Brien 1979). The presence of C. bicuspidatus a small, morphologically available and relatively easily captured food item, for post larval and early juvenile walleyes in Shamrock pond, may have resulted from the presence of fathead minnows. Optimization of C. bicuspidatus capture success may have yielded greater energetic gains through reduced pursuit and handling times, hence a greater instantaneous growth rate in Shamrock pond before July 15, 1982.

BG 3 pond walleyes only grew at 58% of the growth rate in Shamrock pond before July 15. BG 3 pond did not contain any other known fish and the absence of fathead minnows may have reduced zooplankton abundance and allowed the ocurrence of larger zooplankters. In general zooplankton in plankton samples and in walleye stomachs were larger in BG 3 pond than in Shamrock pond. Wells (1970) reported such a phenomenon in southeastern Lake Michigan corresponding to a dieoff of alewives; however, Carpenter et al. (1985) state that in general the opposite occurs. No reason can be given for the discrepancy. Reduced abundance of suitable small prey items early, in BG 3 pond, constitutes more stressful conditions than were encountered in Shamrock pond. Werner and Hall (1974) demonstrated that at low prey densities bluegill sunfish optimize their diet by consuming a wider size range of Daphnia magna, in effect consuming whatever they found at low prey densities. This seems to be the case in BG 3 pond where D. sanguineus were consumed at sizes ranging from 0.6 mm ML to 1.8 mm ML. Perhaps the consumption of larger D. sanguineus resulted in a net loss, energetically, due to handling and pursuit costs (Werner and Hall 1974; O'Brien 1979).

Cladoceran contribution to walleyes stomach contents appeared to be compensatory in BG 3 pond. Peaks of D. pulex contribution were observed when D. sanguineus importance dropped (Figure 6). Perhaps this represents opportunisitic consumption of a patchily distributed prey item under stressful conditions. The consumption of smaller D. pulex than were found in the plankton sample on August 5 may support this or it may be an artifact due to an insufficient zooplankton sampling scheme. Ivlev (1961) found that fish under conditions of low prey abundance consume a greater variety of prey items. The presence of insects and amphipods earlier in the diet of BG 3 pond walleyes may reflect a similar situation. It is most likely that slower growth in BG 3 pond before July 15, 1982 was due to the reduced abundance of small zooplankton as prey and the forced consumption of larger than optimal food items.

Changes in feeding habits probably affected the observed growth curve divergence (Figure 5). After July 15, 1982, the instantaneous growth rate in weight in Shamrock pond Group 1 walleyes decreased by 81% while that in BG 3 pond did not appear to decrease until August 19 (Figure 5). Subsequently, the size of Group 1 walleyes in BG 3 pond increased at twice the rate of Shamrock pond Group 1 walleyes. The divergence of BG 3 and Shamrock pond growth curves occurred 8 to 9 weeks after hatching and at about 35 mm TL. Schooling and negatively phototactic behaviour were observed at this size in laboratory studies (Bulkowski and Meade 1983). Raney and Lachner (1942) found that juvenile walleyes gradually move from littoral shoals into deeper water as summer progresses, presumably related to an increased negative phototaxis. In Oneida Lake, New York, the transition to a demersal existence was at a length of 25 to 30 mm (Houde and Forney 1970) and in the Lake Winnebago region, deepwater trawls were needed to catch walleyes greater than 35 mm long (Priegel 1970). Negative phototaxis in walleyes is related to the presence of the tapetum lucidum, a reflective layer behind the retina which improves visual effeciency in dim light (Ali and Antcil 1968). The development of this layer would affect the feeding of young walleyes by changing behaviour and habitat to a nocturnal and demersal existence. The presence of <u>Leydigia</u> sp. in BG 3 pond walleyes indicates the shift from pelagic to demersal habits at mean total lengths of 38.5 mm and 45.6 mm on July 7 and July 16. <u>Leydigia</u> sp. is virtually never found in the water column (Hann pers. comm.),is morphologically adapted to life within a soft mud substrate and may be negatively phototactic (Fryer 1968).

Detrimental water quality may have affected Shamrock pond growth. When demersal habits were developing in Shamrocck pond oxygen levels, as low as 4 ug.litre^{-1} and increased ammonia levels were observed associated with the bottom (Figure 3). Levels returned to the previous state after July 26. Decreased oxygen levels may function to stress fish by restricting the supply or removal of metabolites (Brett 1979). This may have inhibited growth. Moyle and Clothier (1959) concluded that a healthy walleye population requires at least 5.0 ug litre^{-1} dissolved oxygen. Increased NH4+ levels may have further increased the metabolic load on walleyes in Shamrock pond, inhibiting growth and development at a critical period.

Perhaps for genetic reasons, or due to the energetic gains from consumption of a larger food item, in a situation with reduced food abundance, some walleyes experience greater growth; hence the skewed length: frequency distributions of Bg 3 pond and the ultimate divergence of Group 1 and Group 2 walleyes. Associated with the development of demersal habits in BG 3 pond was an increased contribution by the dipteran pupae and insect parts categories. When young walleyes in ponds switch to a diet of insects and other larger items, food often becomes scarce (Cheshire and Steele 1963) leading to skewed length:frequency distributions (Forney 1966).

The switch to larger invertebrates was inhibited in Shamrock pond due to the lack of suitably sized prey (Figure 12). Walleyes 20 to 50 mm long did not feed on any measurable items greater than 1mm in length. Presumably the presence of fathead minnows before walleye stocking reduced zooplankton availability. Furthermore, energetic benefits are accrued to planktivores which create powerful suction via a small, round, forward directed mouth (O'Brien 1979). Fathead minnows display such characterisitics and were therefore more efficient at consuming zooplankton and reduced their availability for walleyes. Held and Peterka (1974) found that dipteran larvae were the second most frequently occurring item in fathead minnows of all sizes in seven North Dakota lakes and that the largest size class of fathead minnows consumed dipteran larvae most frequently. Consumption of dipteran larvae would reduce the availability of dipteran pupae as food for Shamrock pond walleyes.

While the fathead minnow population more efficiently consumed intermediate sizes of food items, their small mouths limited the maximum prey size ingested (O'Brien 1979). This was demonstrated in young of the year yellow perch (Wong and Ward 1972) and in bluegill and green sunfish (Werner 1974).

The switch from consumption of small zooplankton to larger items (corixids and amphipods) by walleyes greater than 50 mm TL may indicate that there was a lack of suitably sized prey for walleyes of length 20 to 50 mm . Presumably walleyes this size were not able to capture and ingest larger items and fathead minnow competition reduced the number of intermediate sized food items. While walleyes greater than 60 mm long were able to consume corixids (after August 5) the energetic costs of pursuing and handling such a mobile food item may have outweighed the benefits of digestion. The chitonous integuement of corixids reduced the amount of digestible material as chitin is generally considered indigestible (Elliott 1972). Moreover, the mobility of corixids and their hard exoskeletons probably reduced capture success and increased handling time.

When walleyes were large enough to consume large items in Shamrock pond, water temperatures were beginning to drop and the metabolic potential for growth was decreasing. Reduced growth rates were observed in mid to late August (Forney 1966; Campbell and Rowes 1980; Gillis and Green 1980; Li and

Ayles 1981a). However, Smith and Pycha (1960) noted a "growth compensation" where slow growth in early summer was compensated by increased growth in mid-August in the Red Lakes, Minnesota. Perhaps this "compensation" was caused by mortality of smaller walleyes.

Ultimately, walleyes become piscivorous with the actual size of walleyes at piscivory varying, dependent on the presence of suitable prey fish. The presence of an established fathead minnow population in Shamrock pond might be expected to enhance piscivory in Group 1 walleyes. Being fractional spawners, fathead minnows were found to produce from 16 to 26 clutches of eggs per pair between May 22 and August 22 (Gale and Buynak 1982). This almost continuous spawning should have provided numerous small prey in Shamrock pond; however the complete absence of fathead minnows in Group 1 diets contradicts this hypothesis. Bandow (1975) found that fathead minnows reproduced poorly in walleye rearing ponds. He suggested that disturbance of male fathead minnows by fingerling walleyes limited reproductive success. Therefore, piscivory by Group 1 walleyes in Shamrock pond was eliminated due to a lack of suitably sized prey fish.

While piscivory has been observed in walleyes at lengths as small as 17.8 mm (Dobie 1969), piscivory does not generally dominate walleye food consumption until walleyes are at least 60 mm TL (Smith and Moyle 1945; Smith and Pycha 1960;

Priegel 1970; Walker and Applegate 1976). Shamrock pond Group 1 walleyes were never greater than 62.8 mm TL indicating that size also limited Group 1 walleyes piscivory.

The Group 2 walleye category probably started diverging from the primary size mode before demersal habits in BG 3 pond, in response to low zooplankton density. In Shamrock pond divergence occurred shortly after demersal habits were started and environmental and food stresses were encountered. Group 2 walleyes then continued to diverge as fish became part of their diet. Piscivory in 71.4% of BG 3 pond Group 2 walleyes examined and 62.5% of Shamrock pond Group 2 walleyes examined supports this. Similar bimodality was encountered by Scott et al. (1951). They found two distinct size classes of planted walleyes in Silver Lake, Ontario starting on August 5 and averaging 101.6 mm and 215.9 mm in length by harvest time. More recent observations relate this phenomenon to starvation and cannibalism (Cheshire and Steele 1963; Klingbeil 1971; Bandow 1975). The energetic benefits of consuming fish over invertebrates are known (Paloheimo and Dickie 1966). Individuals able to consume fish experienced increased growth effeciency and more rapid growth. Theoretically piscivory by Group 2 walleyes functions to increase the skew of the size frequency distributions resulting in "growth depensation" (Forney 1966; Brett 1979); hence the magnitude of the skew and the development of distinct groups in BG 3 and Shamrock ponds. Keast and

Eaddie (1985) reported similar results in large mouth bass, where the development of a larger size mode was associated with piscivory.

In BG 3 pond, the absence of a buffer species and adverse feeding conditions combined to produce a distinct group of larger cannibalistic walleyes. Cannibalism is inherent in walleyes (Eshmeyer 1950; Dobie 1956; Rawson 1957; Chevalier 1973) and within-cohort cannibalism of larval walleyes is well documented relating to intensive culture techniques (Cuff 1977; Cuff 1980; Li and Mathias 1982). Within cohort cannibalism is also a major source of fry loss in walleye rearing ponds (Smith and Moyle 1945; Dobie 1956; Cheshire and Steele 1963; Bandow 1975). In Bg 3 pond, size differences were large enough to facilitate cannibalism as early as four weeks before the arbitrary assignment of a Group 2 category. In fact cannibalism was observed on July 7, approximately four weeks before the Group 2 category could be assigned. Comparison of predator and prey sizes indicated that cannibalistic walleyes consumed walleyes slightly greater than half their size. Parson (1971) and Nielsen (1980) found similar results and Li and Ayles (1981a) stated that low variance size distributions at harvest probably indicated that cannibalism did not occur due to the similar size distribution.

Cannibalism in BG 3 pond may have had a severe impact on survival of walleyes in late summer and early fall. Using a walleyes daily consumption requirement of 3.0% of body weight for Group 2 walleyes (Swenson 1977) and assuming that Group 2 and Group 1 walleyes were captured relative to their abundances in the environment, estimates of the rate of Group 2 cannibalism indicate that upwards of 5% per day of Group 1 walleyes may have been lost to support Group 2 walleyes, late in the season in BG 3 pond. The validity of the equal catchability assumption is unlikely in that escape abilities of larger walleyes are greater than those for smaller walleyes. Therefore, assuming uniform distribution of both groups around the pond, the numbers of Group 2 walleyes sampled provides an under-representation of relative densities. Contagious distributions caused by schooling of walleyes (Bulkowski and Meade 1983) and mutual exclusion of Group 1 and Group 2 walleyes (Mathias and Li 1982) confounds this assumption by making the capture of one group unlikely given the presence of the other. The percent of Group 2 walleyes in the total sample in BG 3 pond were compared for dates when both groups were sampled and for all sample dates after the first Group 2 walleyes was sampled (i.e. August 5). Group 2 walleyes constituted 13.7% of the combined total catch on dates containing both groups and 11.2% of the combined total catch of all dates after August 5. As a consequence of these relatively similar values and because extensive effort was required in all areas of the pond, due to decreasing walleye abundance, patchy distributions are not believed to have negated the use of this model as a illustration of the potential effects of cannibalism in BG 3 pond.

The major difference between BG 3 and Shamrock pond size:frequency distributions was the absence of a strong peak of small walleyes in BG 3 pond. Since cannibalism in BG 3 pond was obvious and because size selective predation on the smallest walleyes has been shown, the absence of the Group 1 "peak" in BG 3 pond was attributed to cannibalism. Cannibalism has been shown to most seriously affect the smaller of first year walleyes. Chevalier (1973) found that in Oneida Lake, adult walleyes selected the smallest young of the year. The affect of this was a change in shape of the size:frequency distribution, through a reduction in the number of smaller walleyes sampled. As a consequence, the mean size of the cohort increased over winter despite negligible growth of walleyes after October 1 (Forney 1966; Chevalier 1973; Forney 1974).

Therefore the effect of Group 2 walleyes in BG 3 pond was two fold. First by reducing the abundance of the Group 1 category beginning as early a July 7, competition within Group 1 walleyes was reduced. This probably functioned to increase Group 1 growth. Moreover, by eliminating the smallest members of Group 1, the mean population size rose accordingly.

In Shamrock pond, Group 2 walleyes were piscivorous but not cannibalistic because fathead minnows buffered cannibalistic tendencies. A large Group 1 "peak" was observed throughout the season indicating increased survival. While cannibalism was buffered, Mathias and Li (1982) found that a population of larger fish, constituting 5% of the total walleyes population in a pond, caused a temporal change in feeding of smaller walleyes reducing feeding efficiency. Brett (1979) states that such hierarchies generally act to restrict food intake of subordinate fish and result in growth depensation where the relative difference in size of members of a population increases.

Direct effects of cannibalism on Group 1 walleyes by Group 2 walleyes in Shamrock pond were limited. While Group 2 walleyes probably inhibited Group 1 walleyes activities and limited their feeding to inopportune times the more direct effects of intraspecific competition with similar sized cohorts and interspecific competition with more efficiently feeding planktivores were considered most important in explaining reduced Group 1 walleyes growth in Shamrock pond.

As stated previously, the ultimate goal of walleyes pond production is to optimize growth and survival of fingerlings. Data presented here indicate that particle size composition within the pond may be critical in determining the overall growth of the population as well as the characteristics of size:frequency distributions. The availability of suitably sized items at critical developmental stages may significantly improve growth, reduce the spread of the size distributions, and enhance survival. These critical developmental stages appear to be the commencement of initial feeding (Mathias and Li 1982) and the development of demersal habits and associated prey selection changes. Moreover, the removal of large, potentially cannibalistic cohort members may increase feeding efficiency and increase survival. Finally, the presence of an established planktivorous population may not be beneficial as a result of severe competition for the intermediate sized prey required for growth exceeding the recommended goal of 100 mm.

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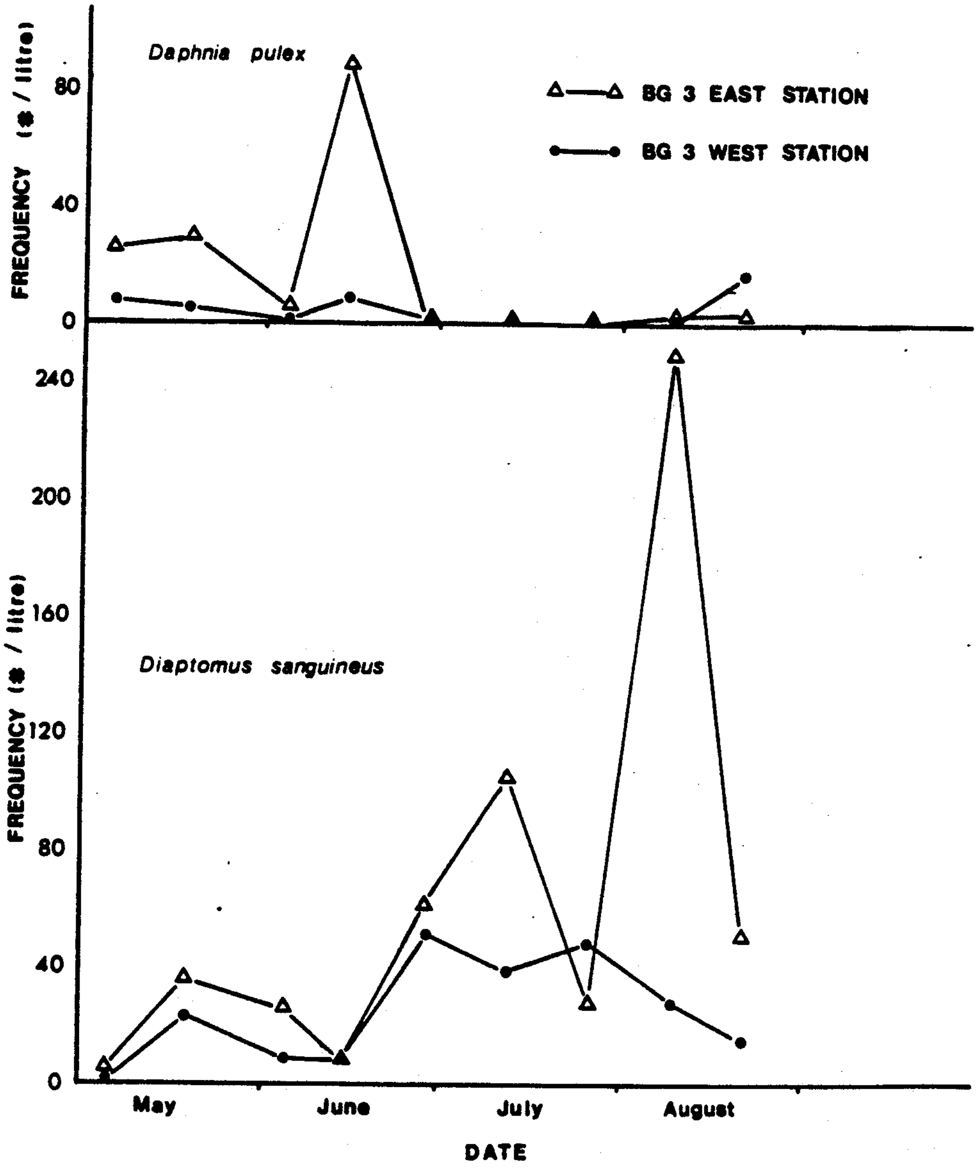
APPENDIX 1

BG 3 Pond Station Zooplankton Abundances

Station abundance estimates of Diaptomus sanguineus and Daphnia pulex are presented in Figure 13. Significantly different frequencies (D. sanguineus X^2 =202.54, 8 df, P<0.001 and D. pulex X^2 =110.62, 8 df, P<0.001) between stations were observed. Results indicate that overall, the east station had significantly larger numbers of both species.

Figure 13: APPENDIX 1: BG 3 pond east and west stations, zooplankton abundances.



_D_. _pulex_ abundance was greater at BG 3 east station until June 14, 1982 after which numbers per litre sampled were low; similar to BG 3 west station. This is not unusual as cladocerans are not strong swimmers and might be expected to congregate in the down wind portion of the pond. Moreover, seasonal abundance of daphnids is often strongly dicyclic with peaks in early spring and again in fall (Pennak 1978). The absence of a fall peak may be related to predation or it may simply have occurred after August 21, 1982 when both stations were no longer sampled.

_D_. _sanguineus_, the only copepod discovered in BG 3 pond, was also more abundant in BG 3 east samples. The difference, however, was observed in later samples (July 12 and August 9) when BG 3 east revealed an abundance of 230.litre^{-1} compared to 28.litre^{-1} at BG 3 west.

Despite the observed differences, similar seasonal trends in abundance of both zooplankters was observed and combination of BG 3 east and west station abundance estimates was considered the most appropriate representation of overall zooplankton abundances.

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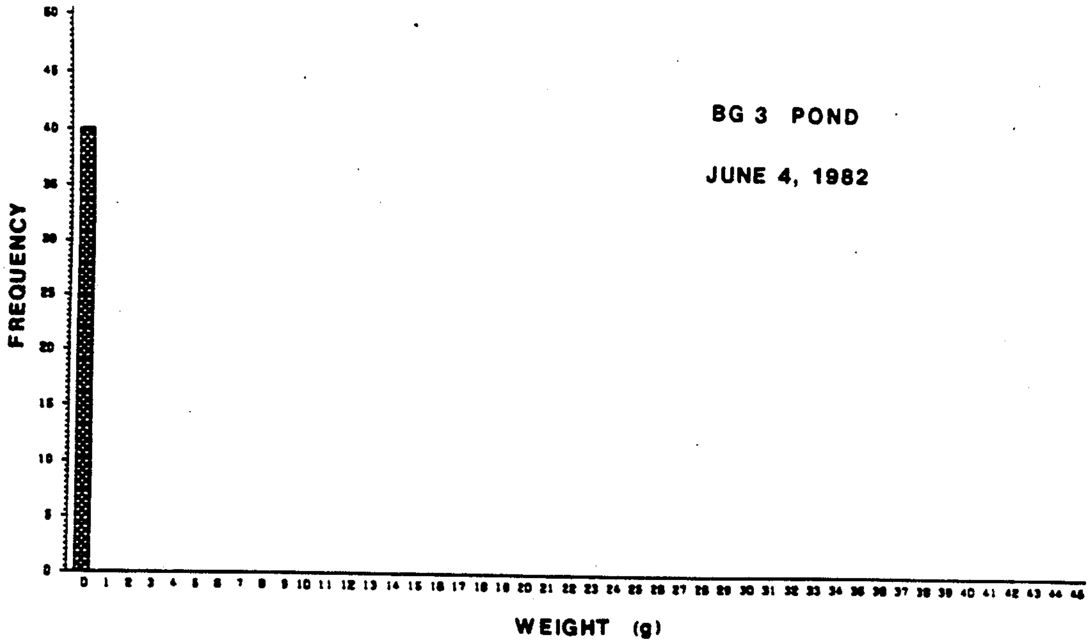
APPENDIX 2

Walleye Size:Frequency Distributions

Walleye weight: frequency and length: frequency distributions for BG 3 and Shamrock ponds are presented. Weights were rounded to the nearest whole integer and lengths were grouped into 5 mm length intervals.


BG 3 POND
JUNE 4, 1982
FREQUENCY
0
5
10
15
20
25
30
35
40
45
50
WEIGHT (g)
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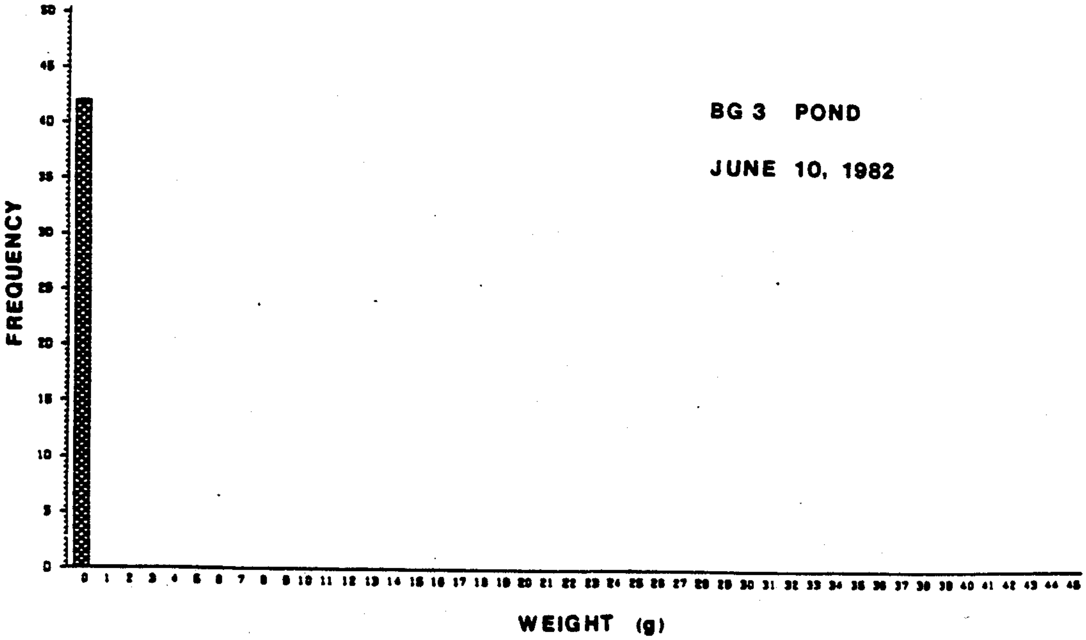
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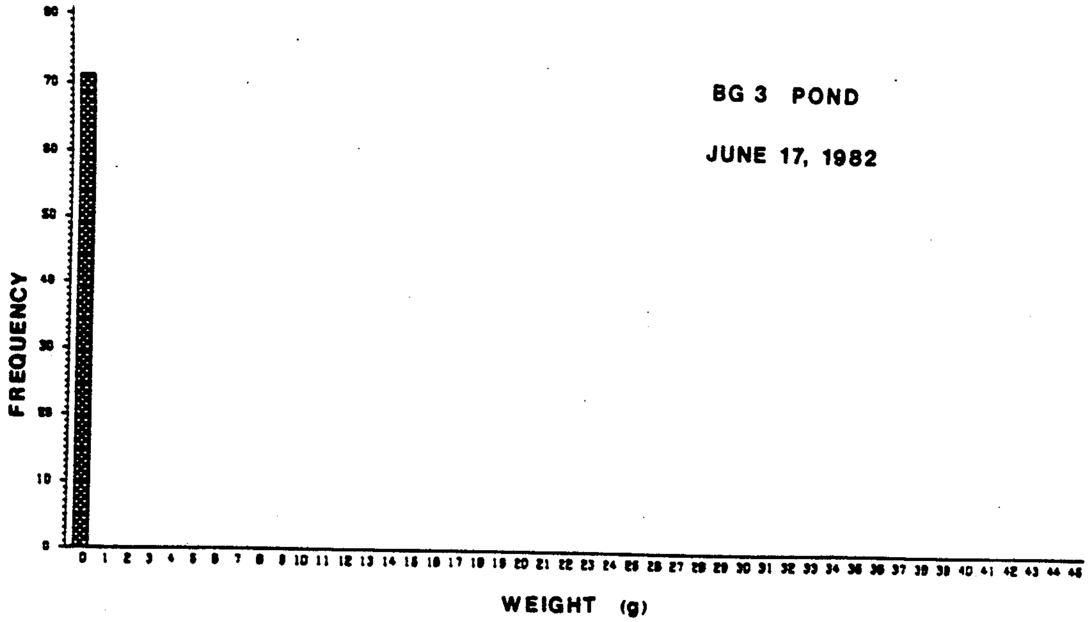

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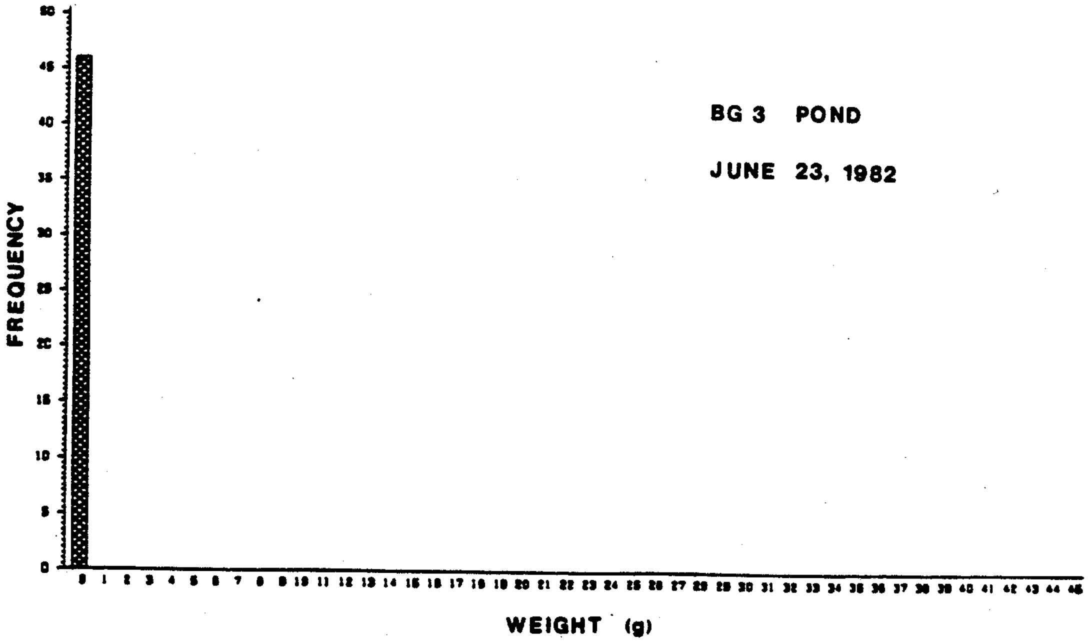

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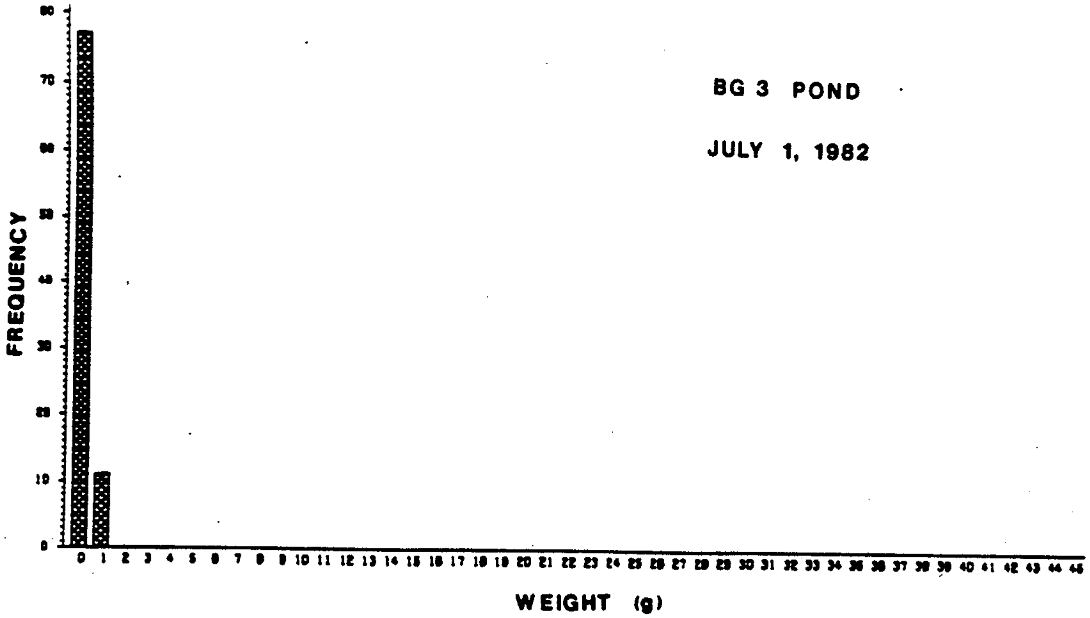
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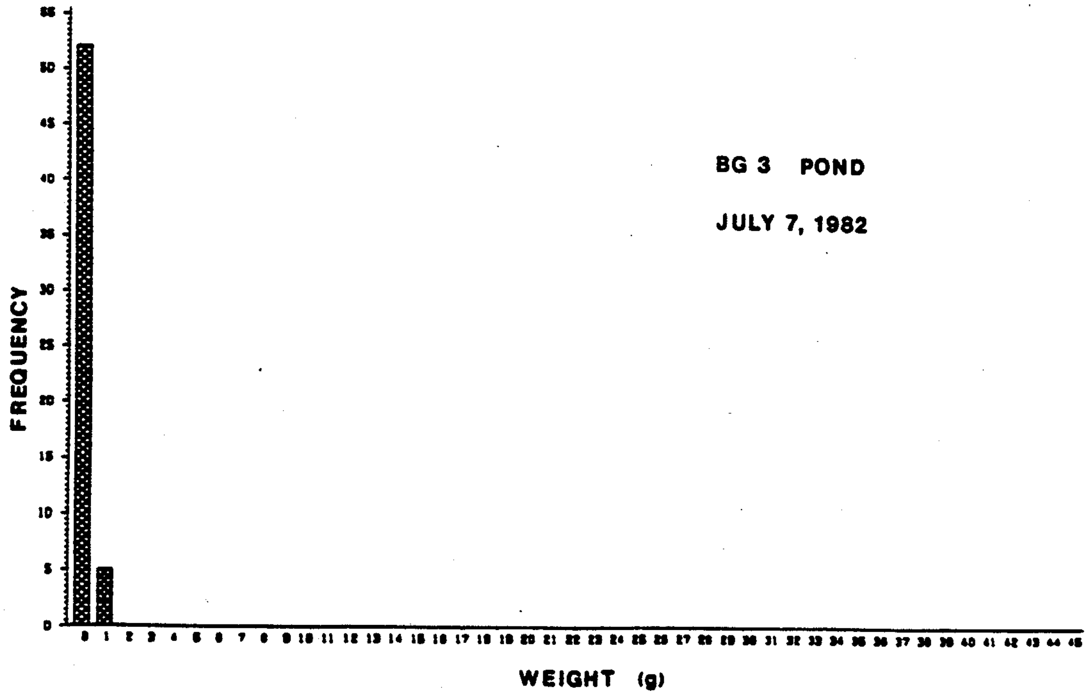
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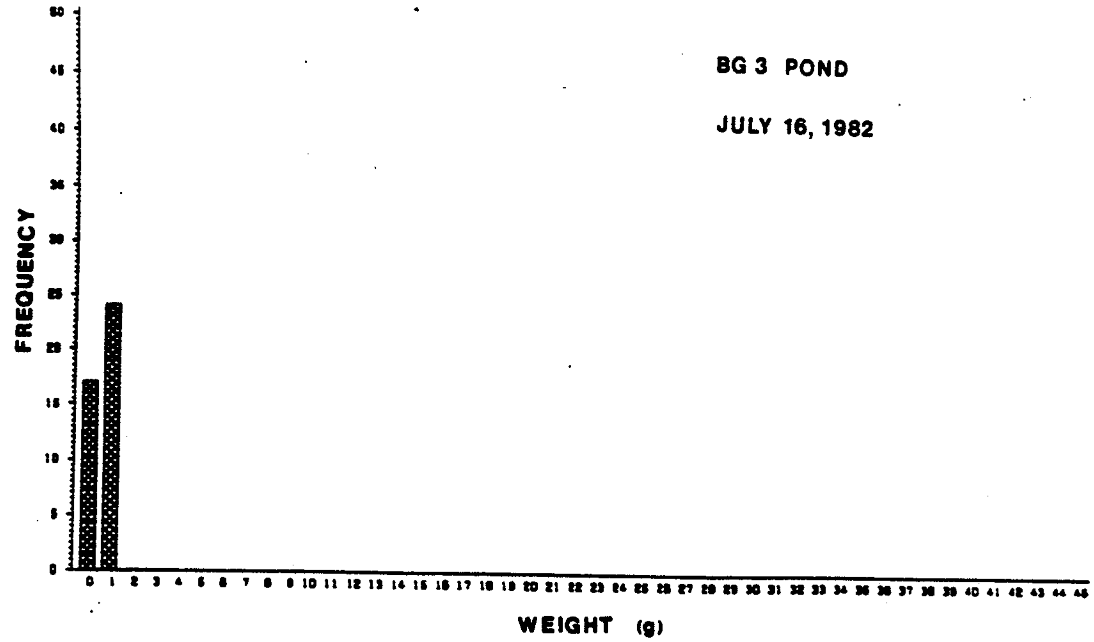
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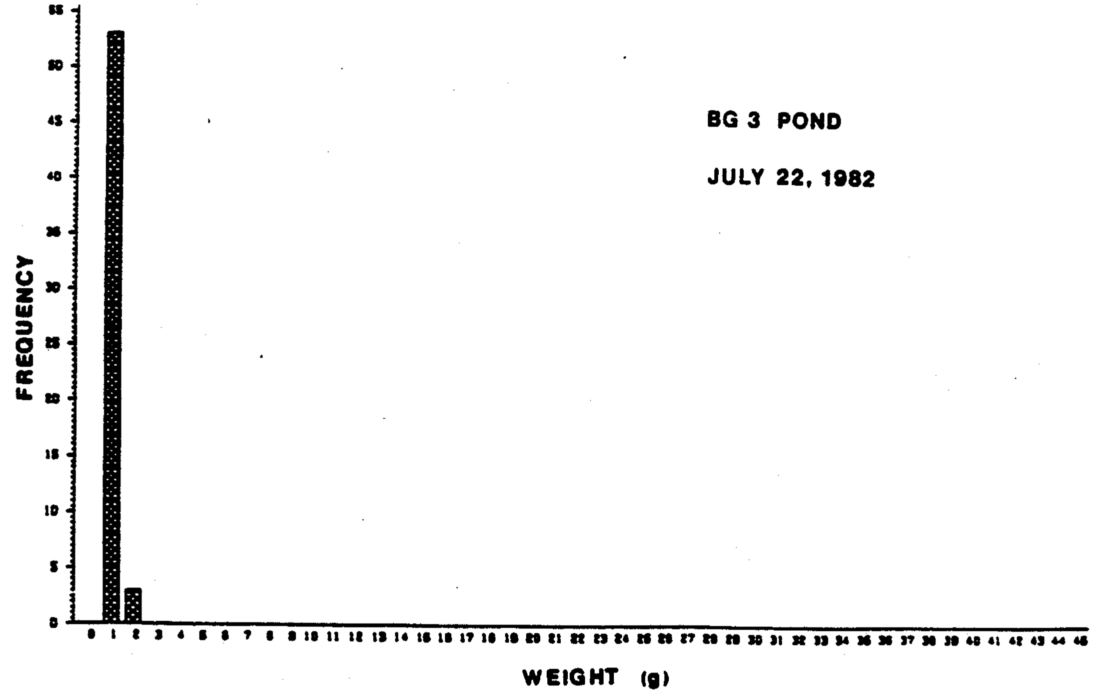
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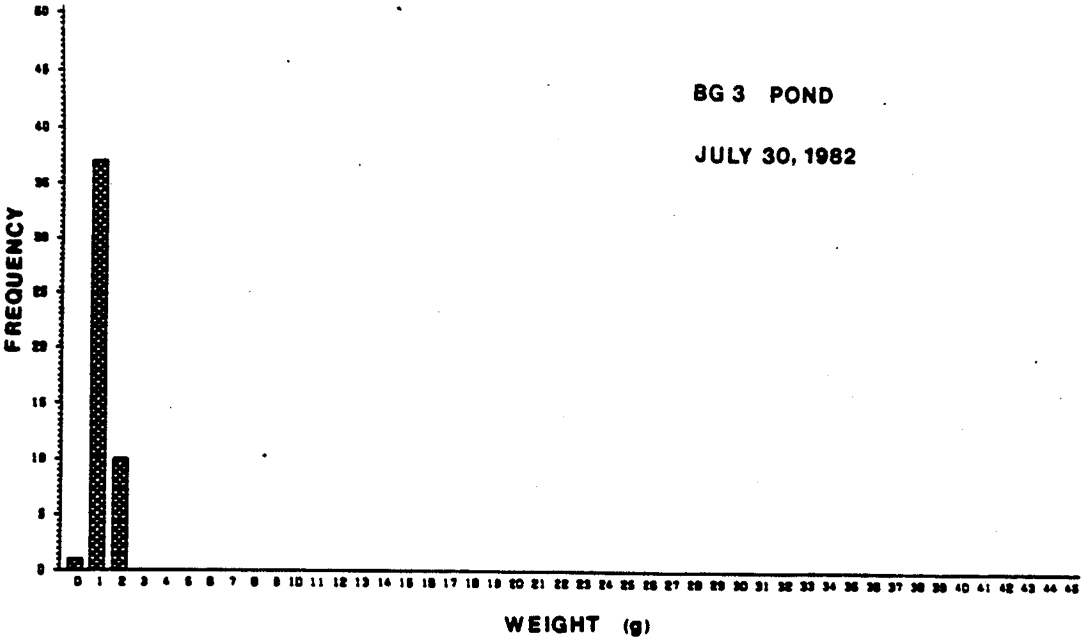
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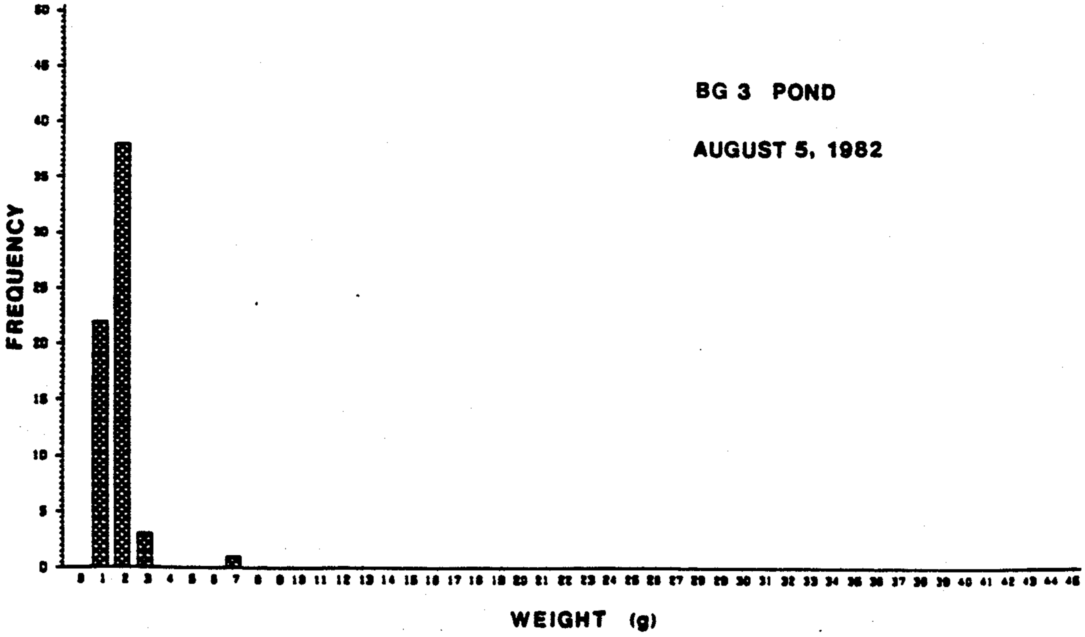
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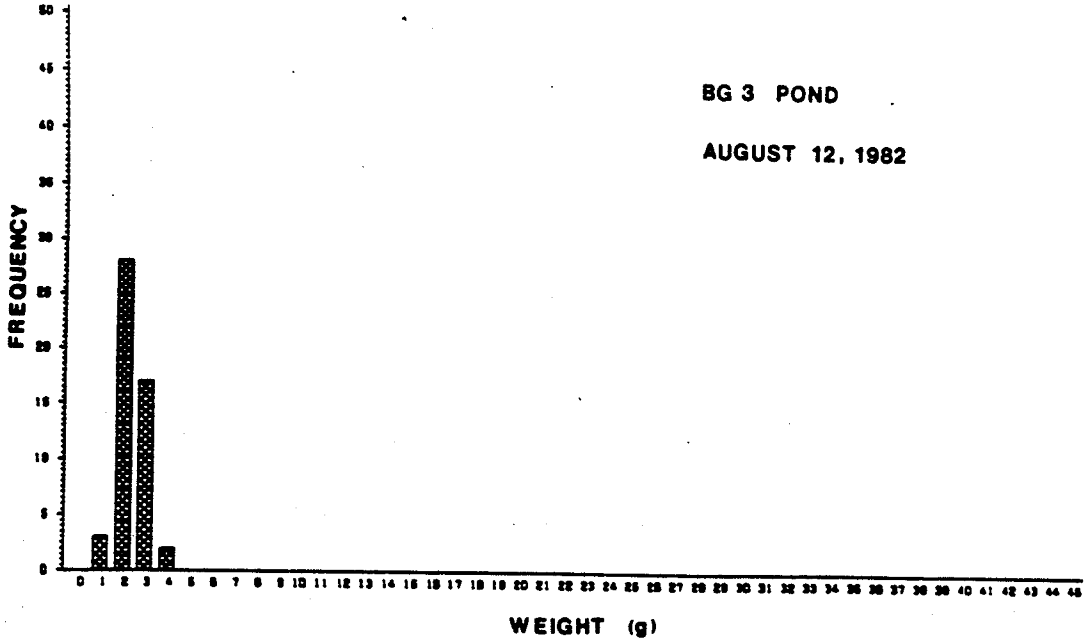
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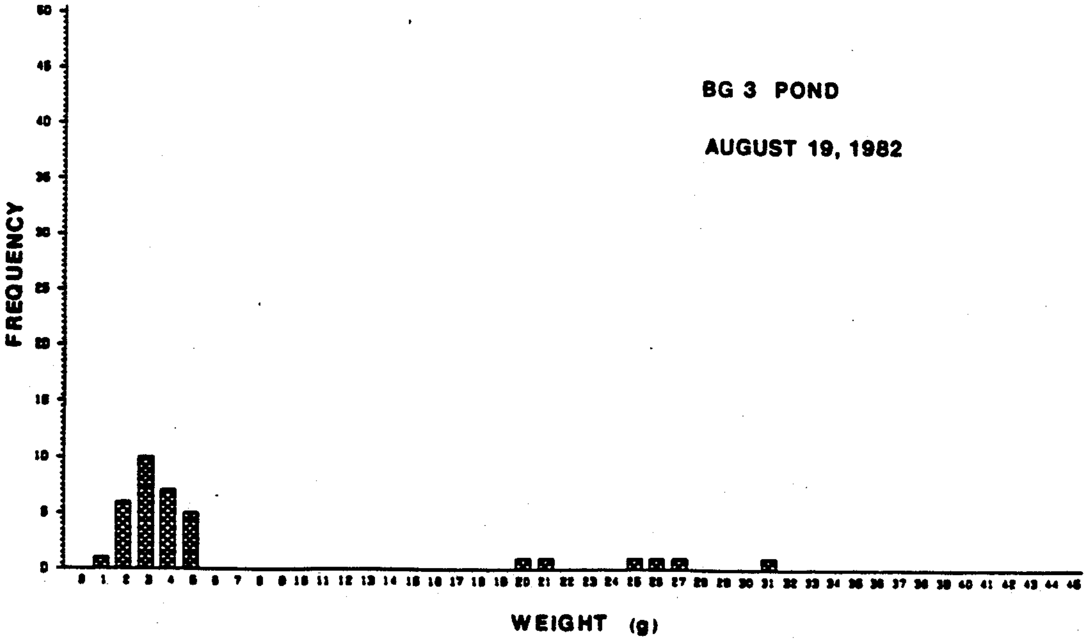
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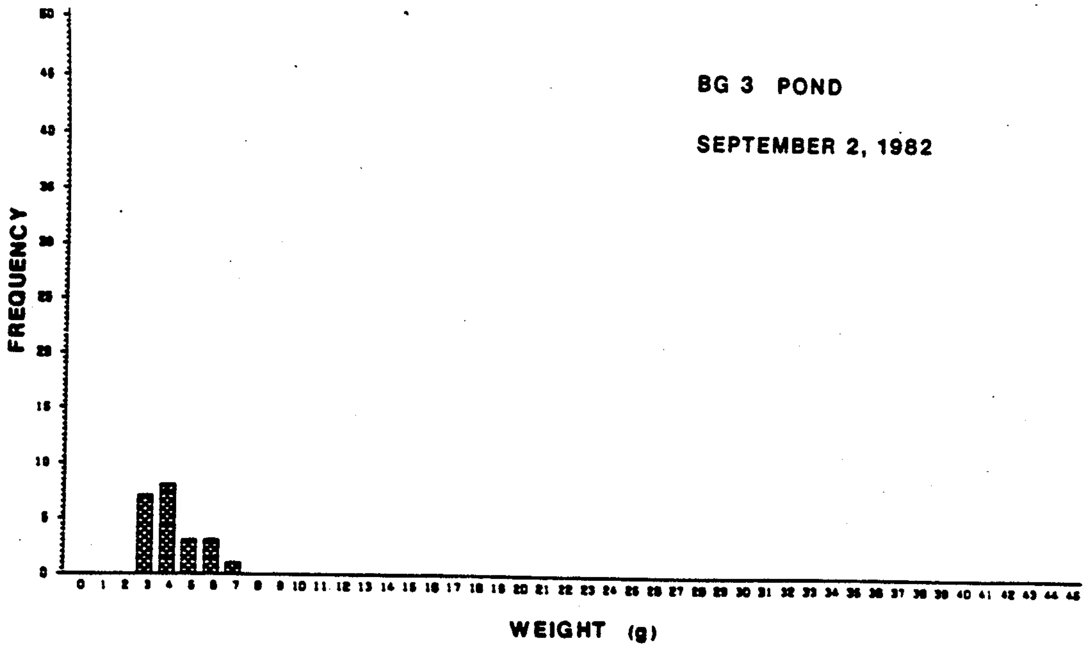

BG 3 POND

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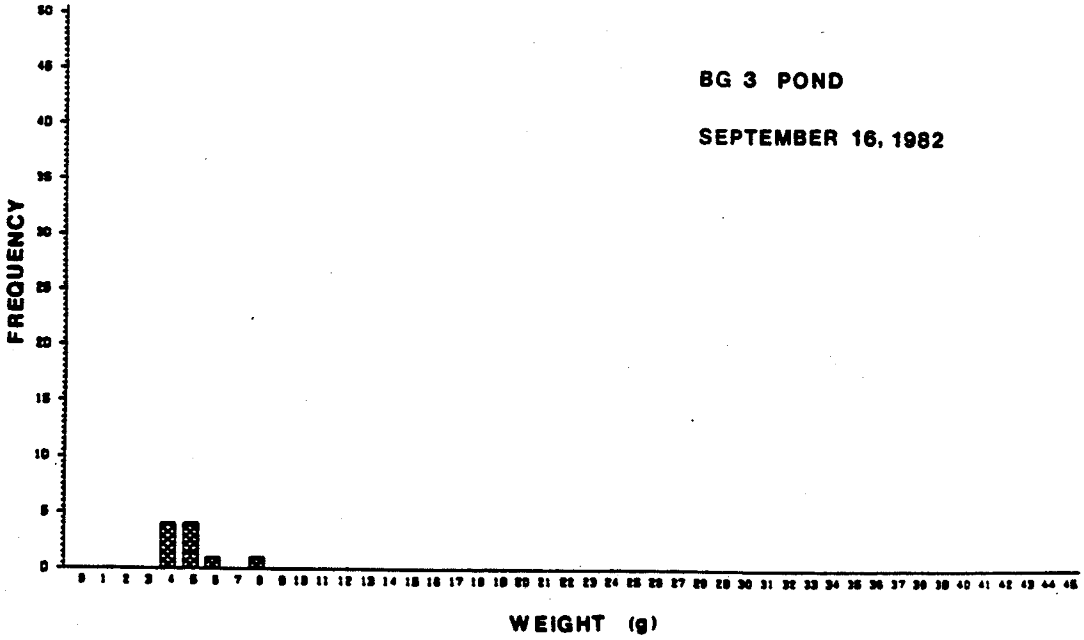

BG 3 POND

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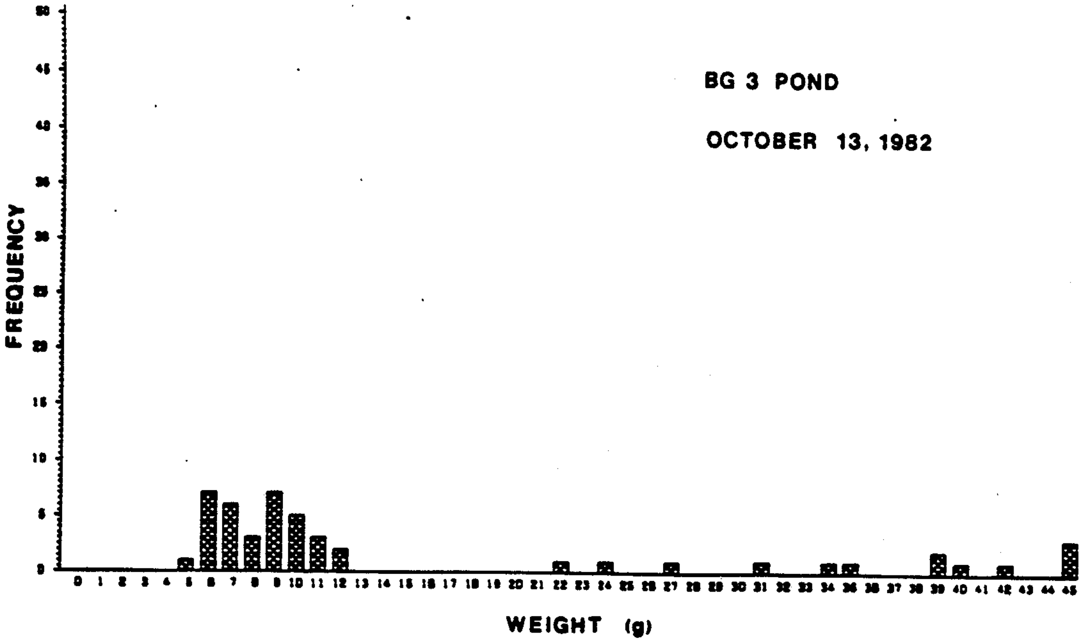
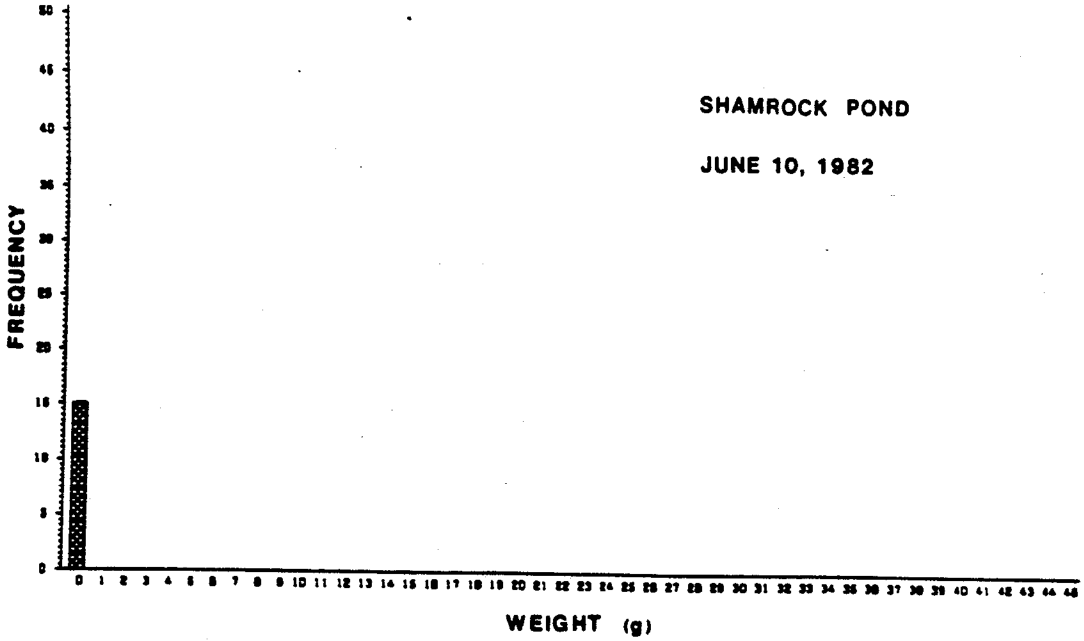


BG 3 POND

OCTOBER 13, 1982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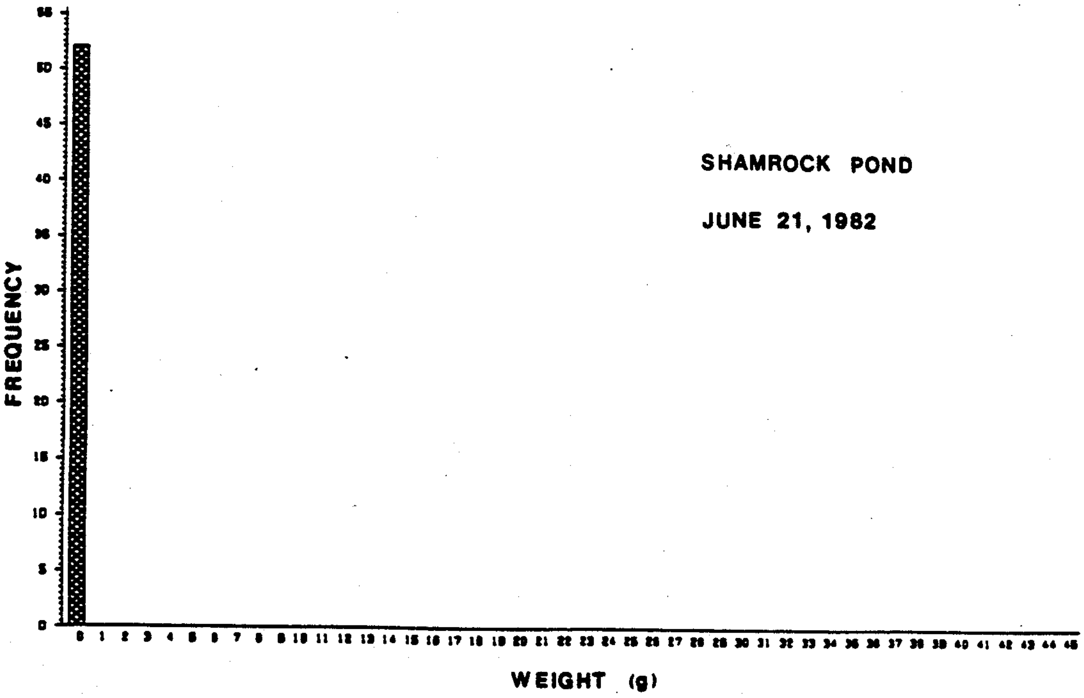
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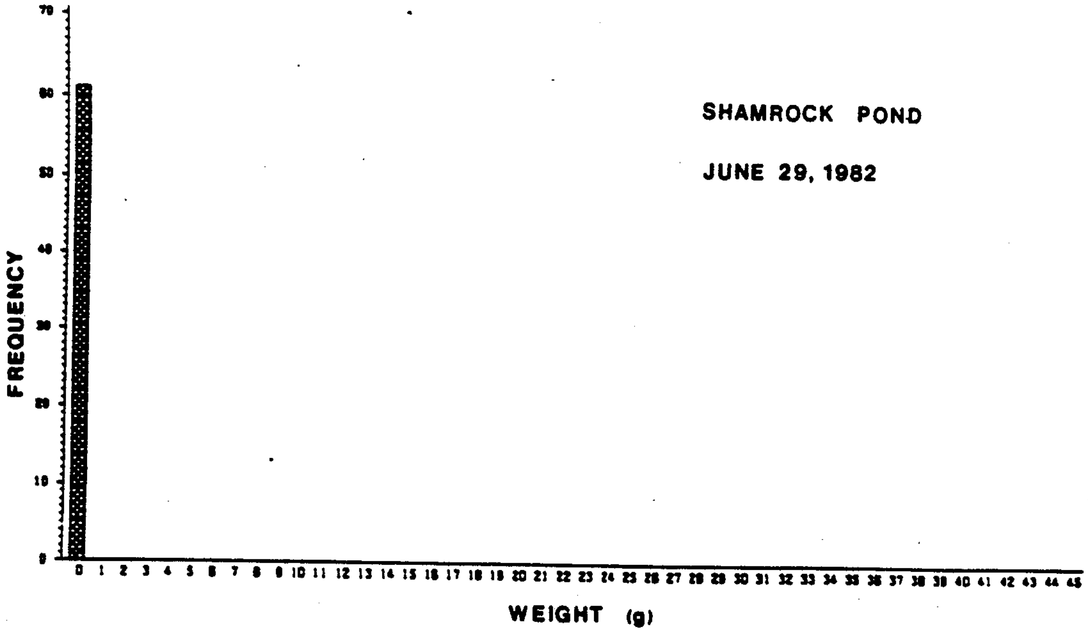
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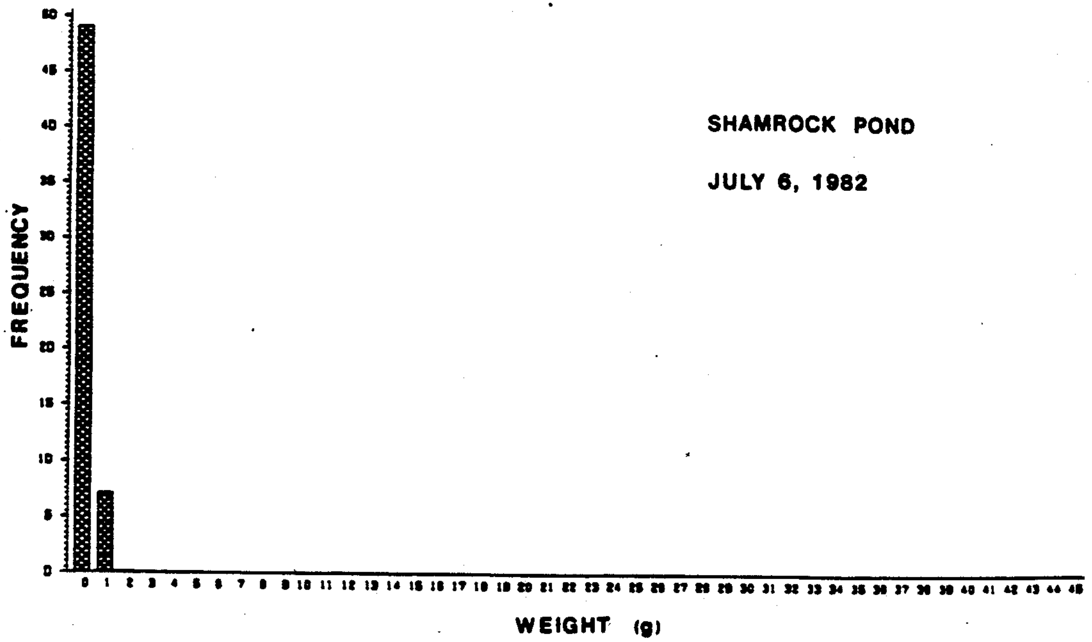
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JULY 6, 1982
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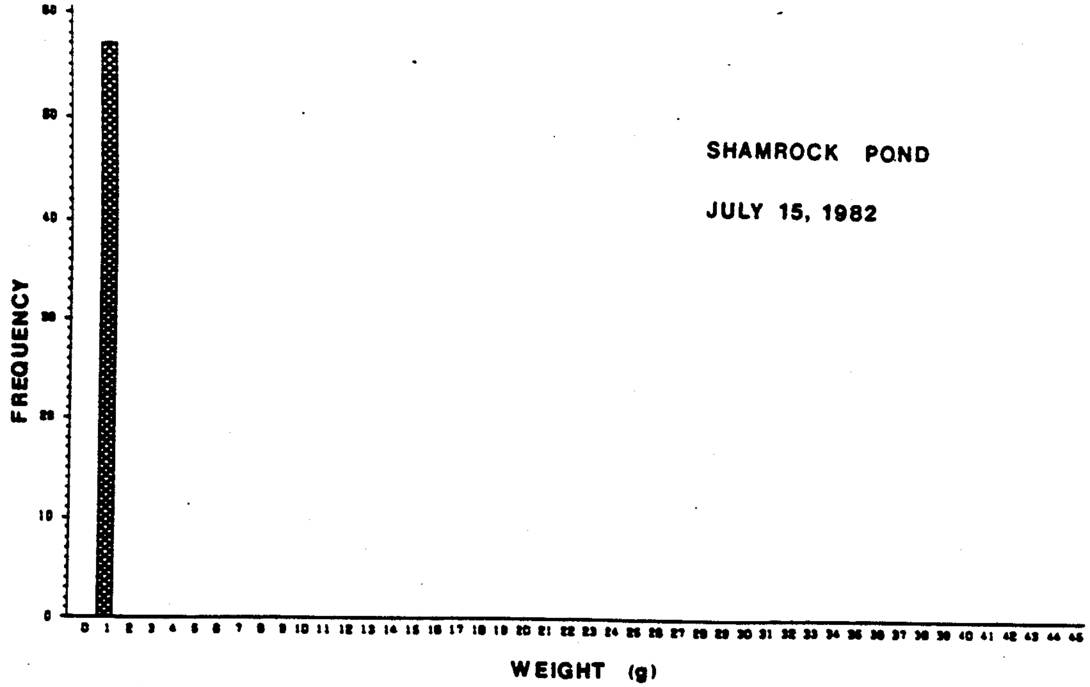
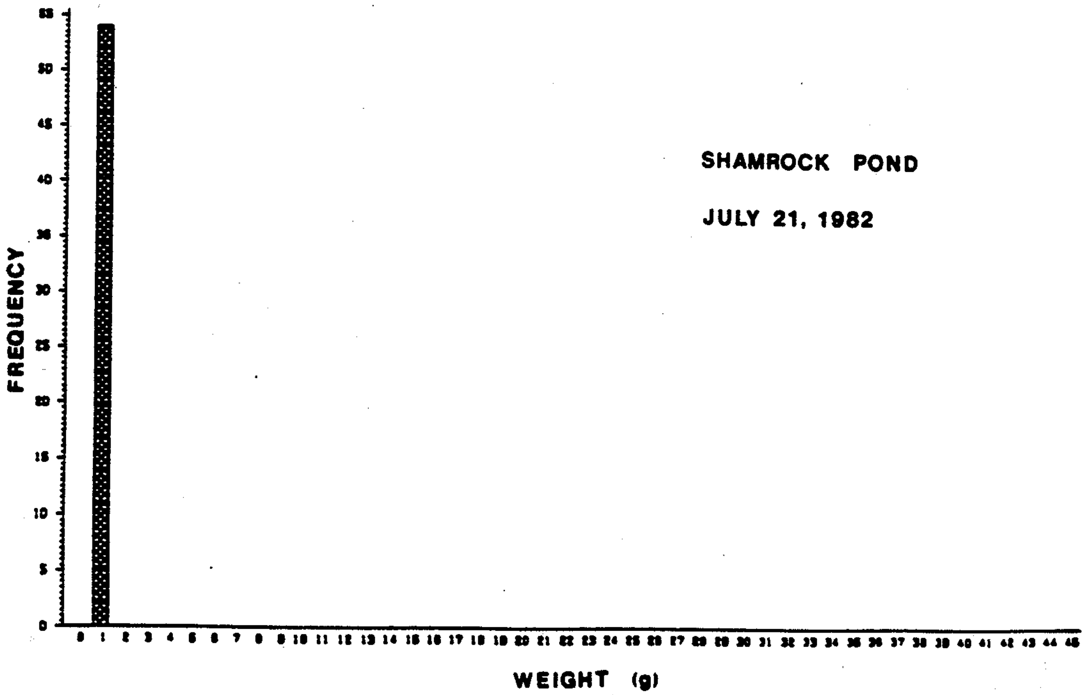


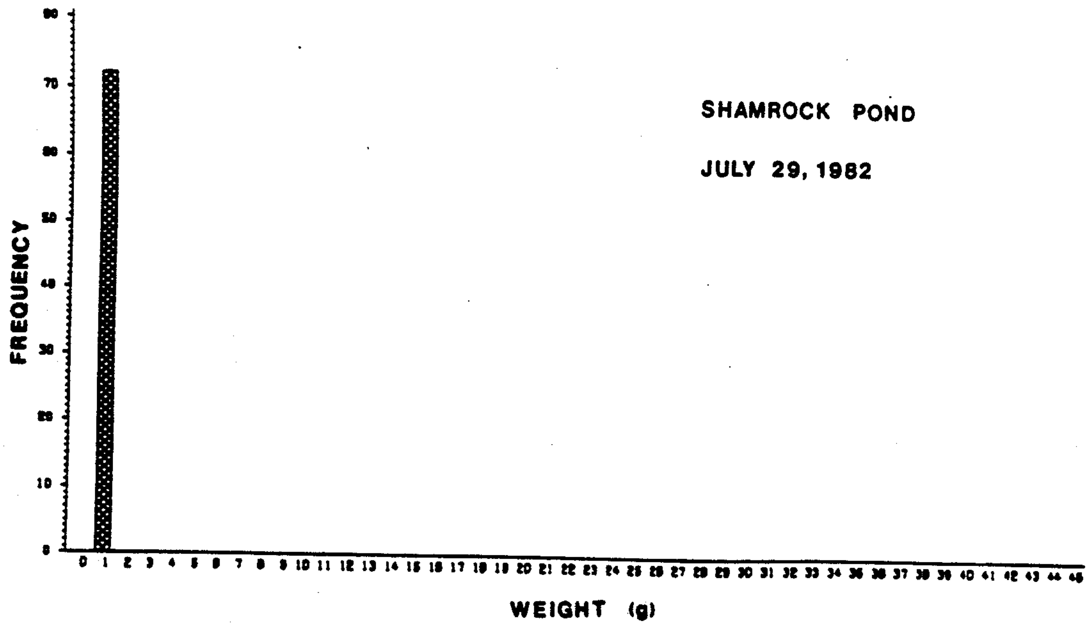
SHAMROCK POND

JULY 15, 1982



SHAMROCK POND

JULY 21, 1982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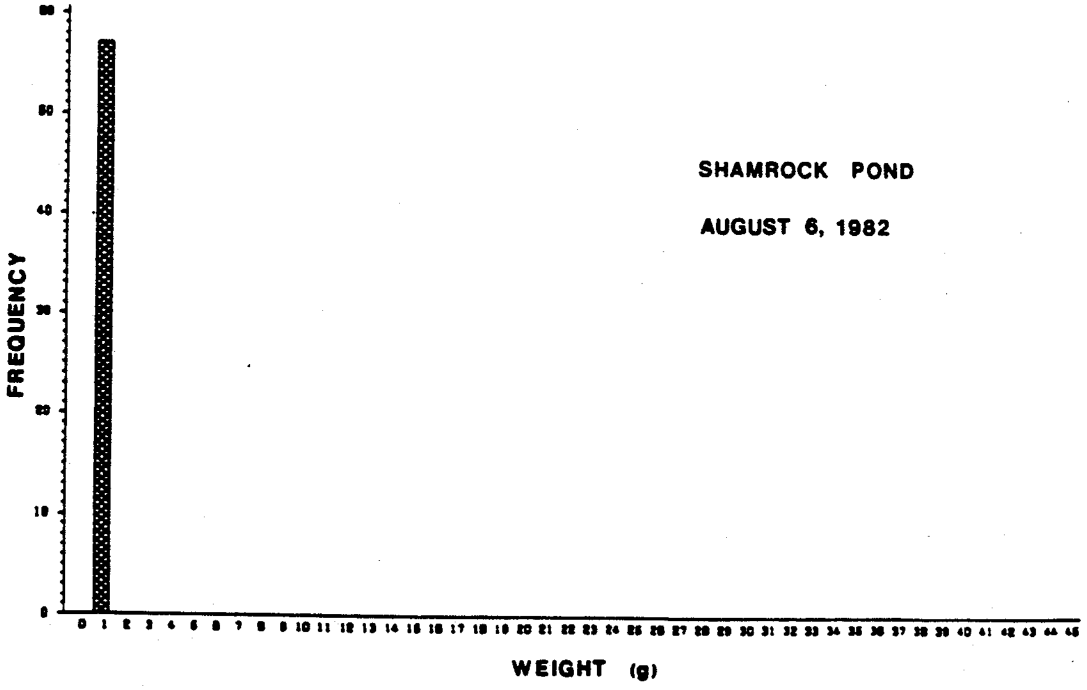
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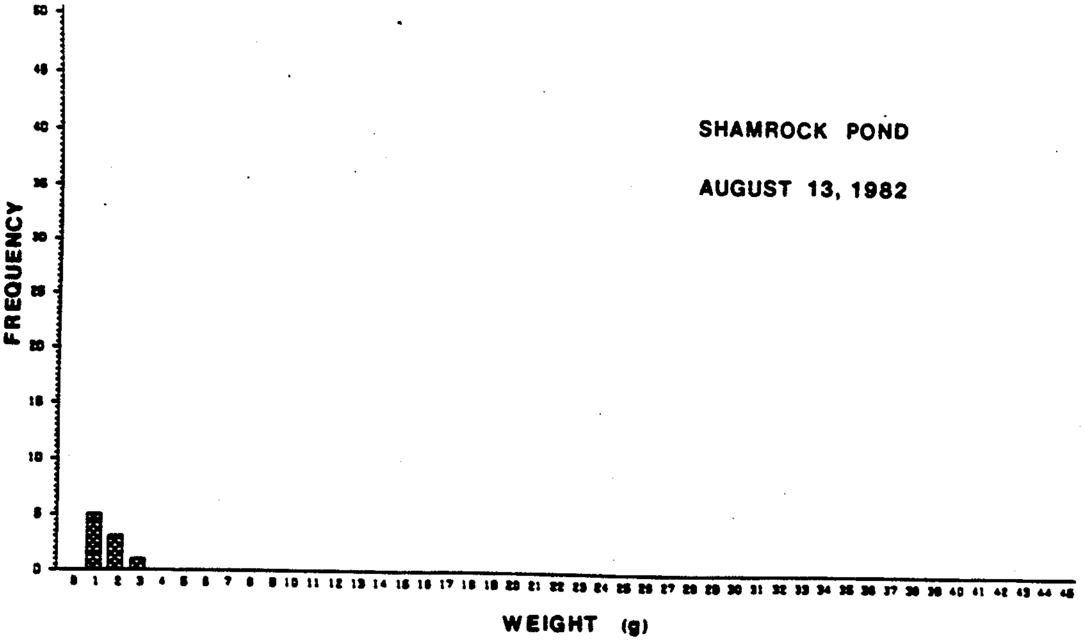
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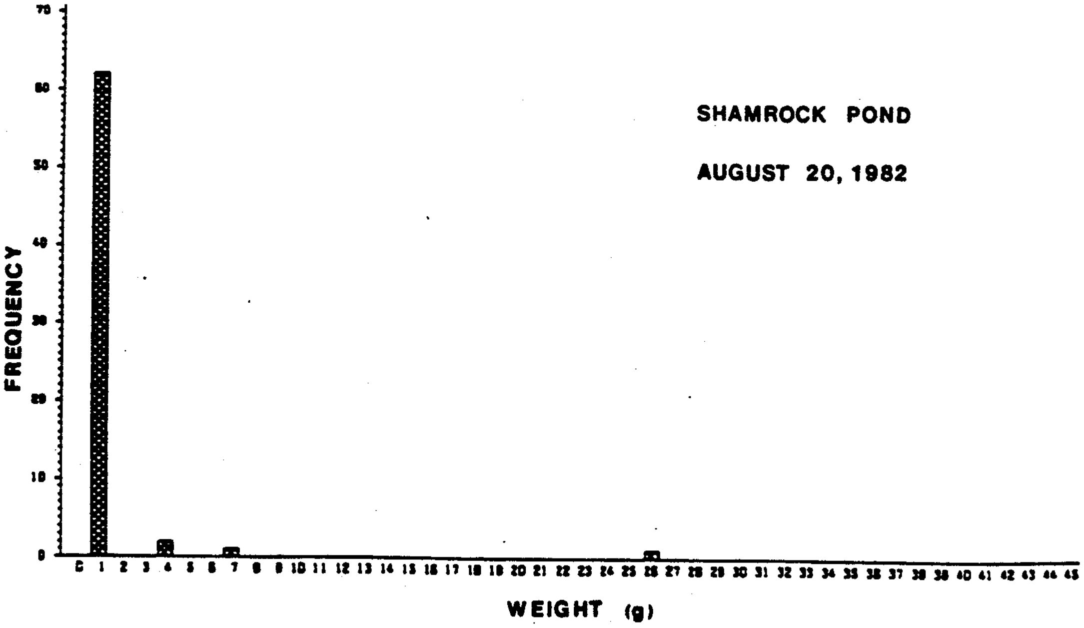
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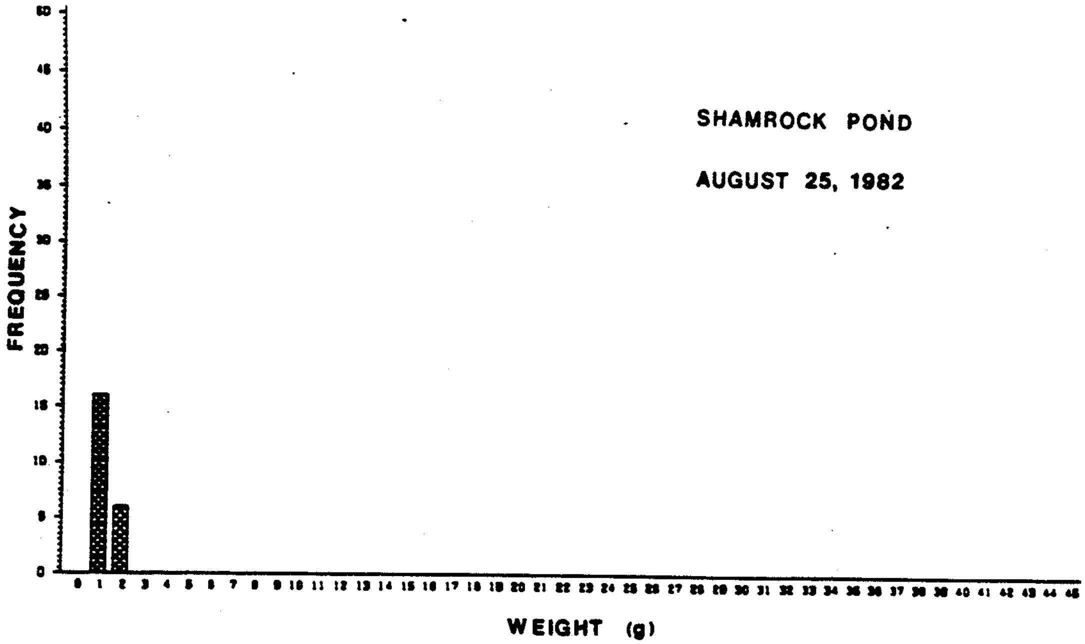
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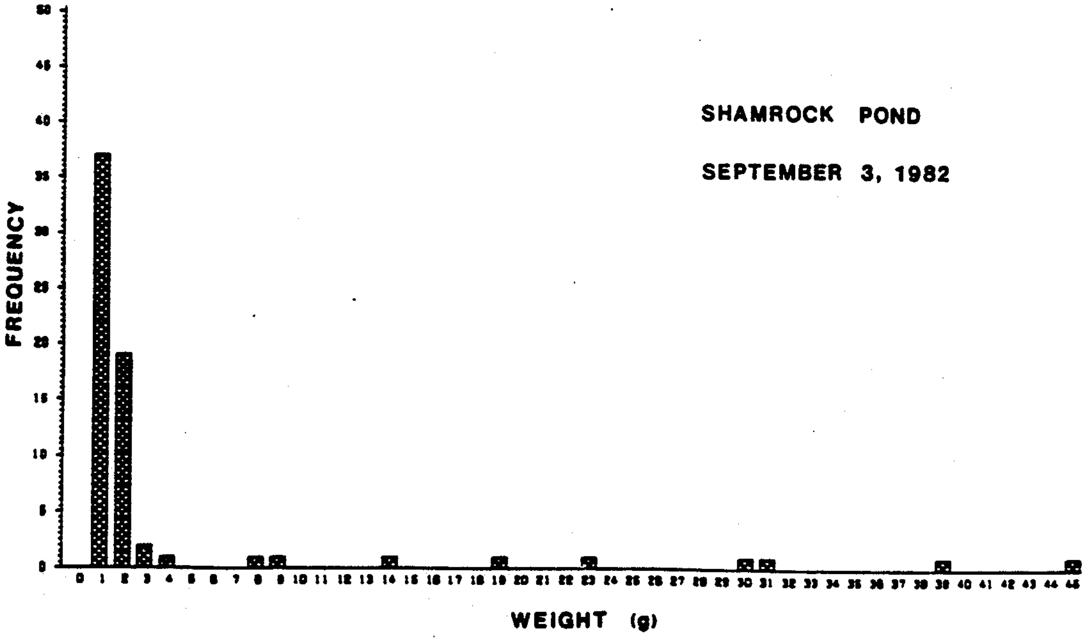
WEIGHT (g)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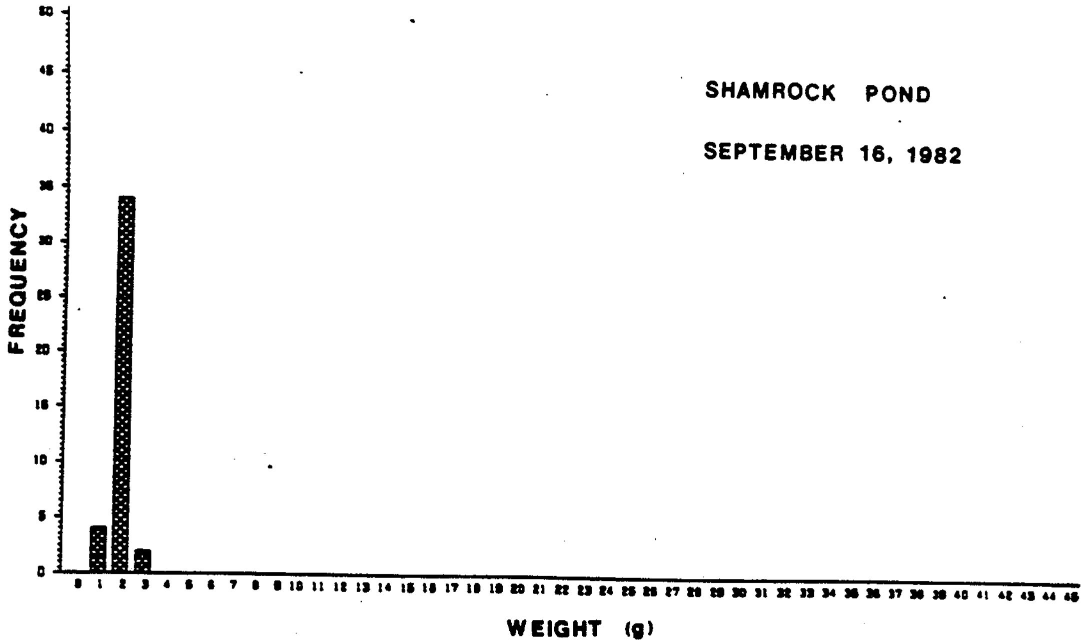
WEIGHT (g)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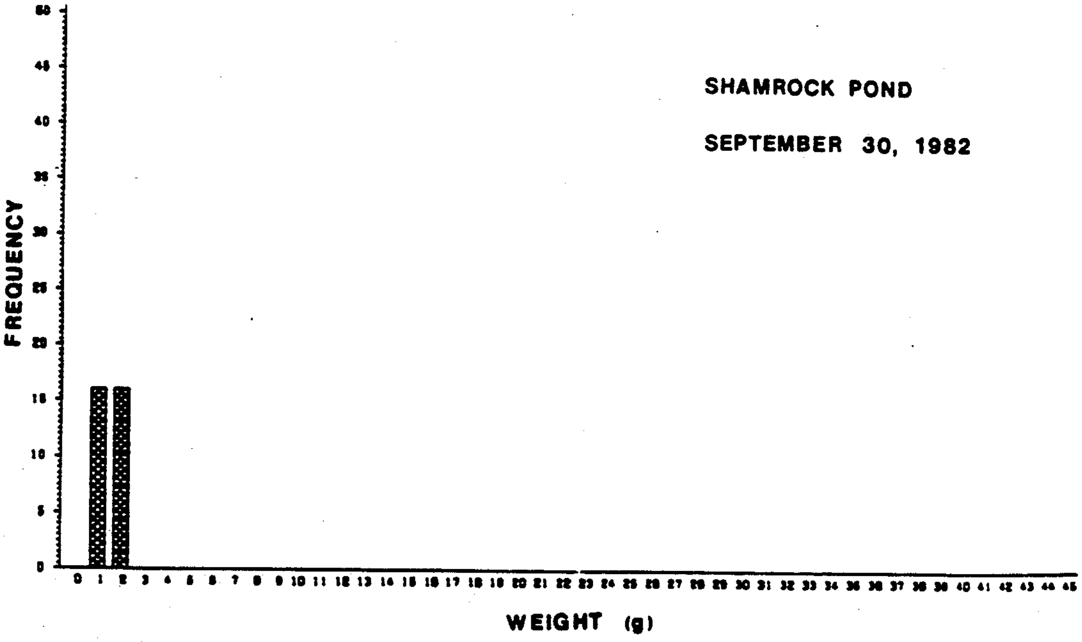
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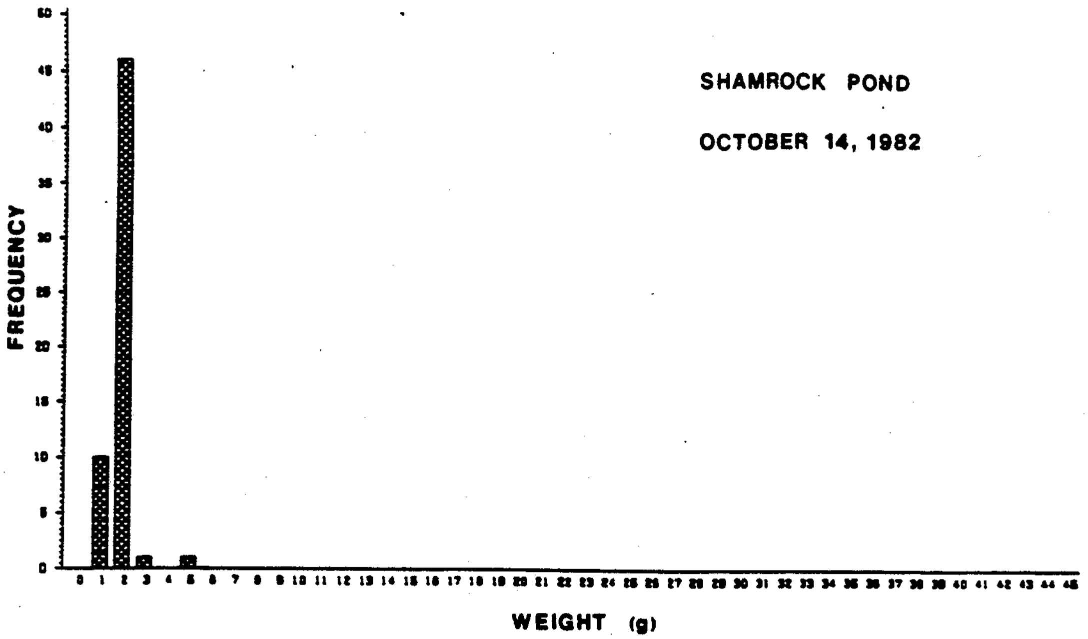
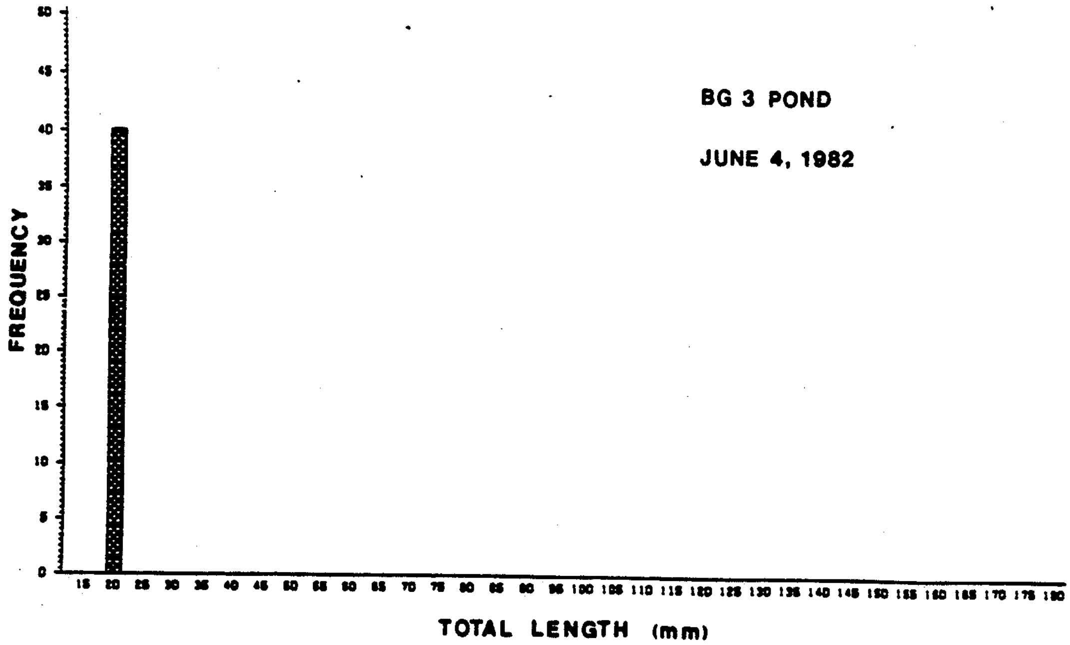

SHAMROCK POND

OCTOBER 14, 1982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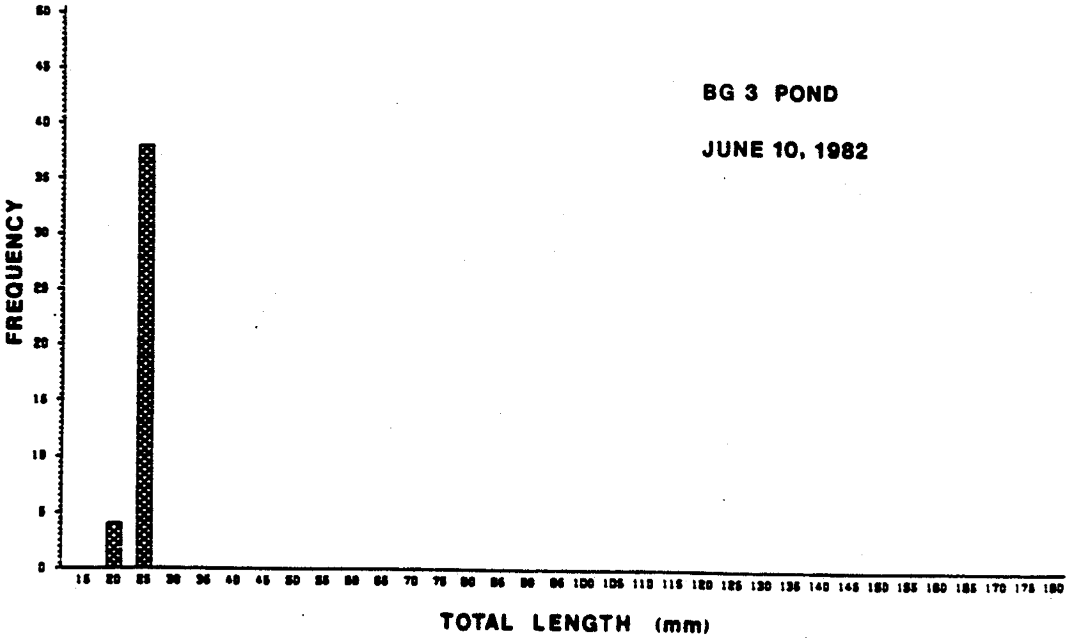
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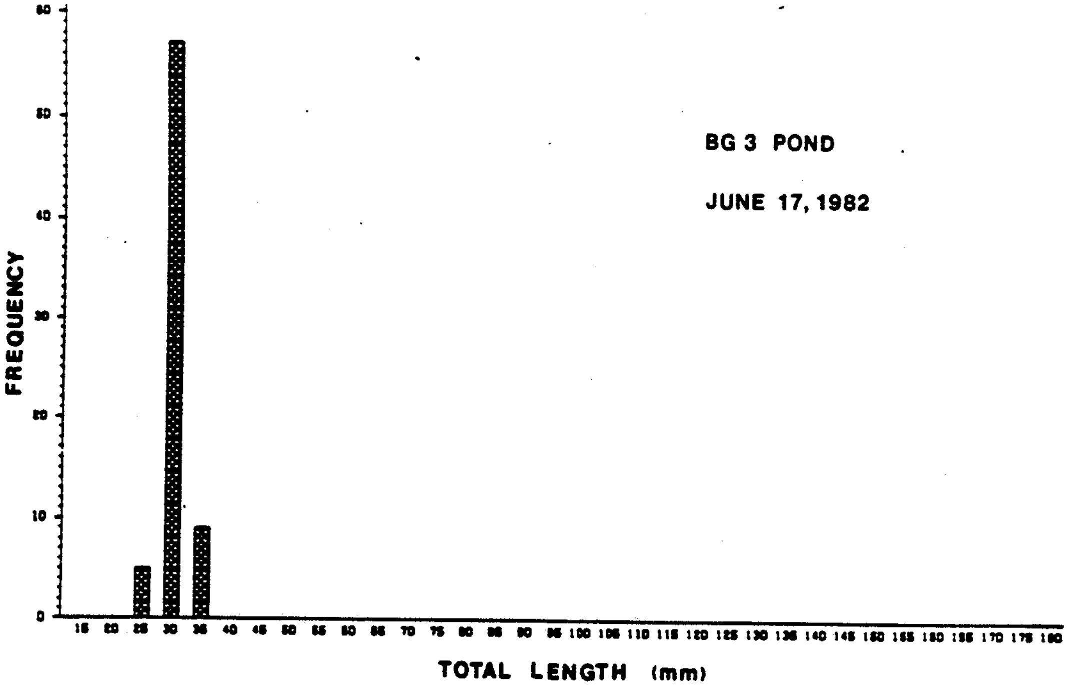
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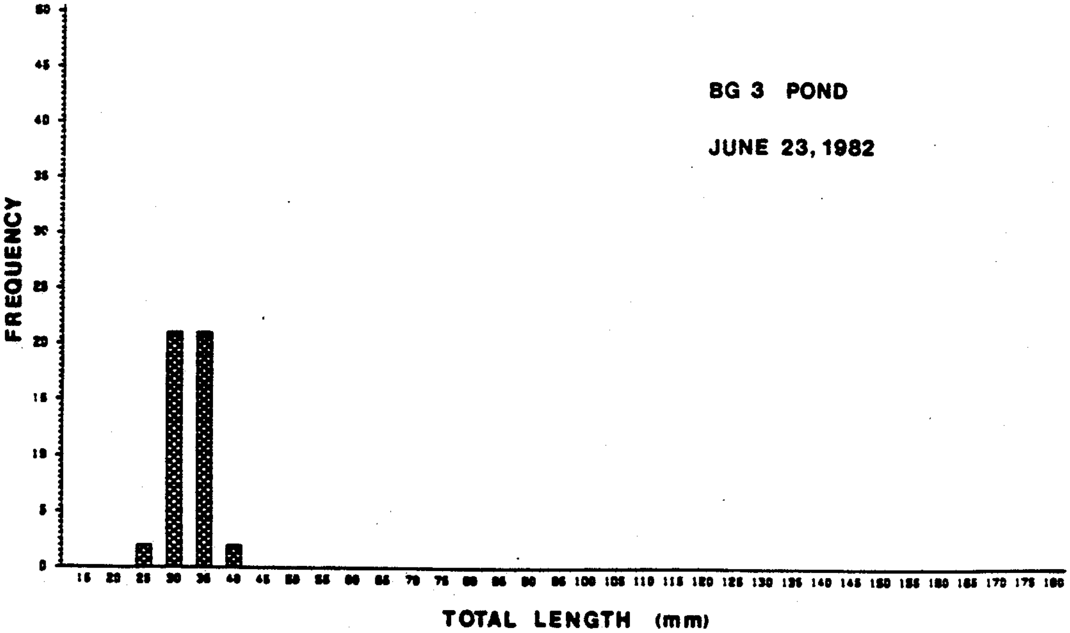
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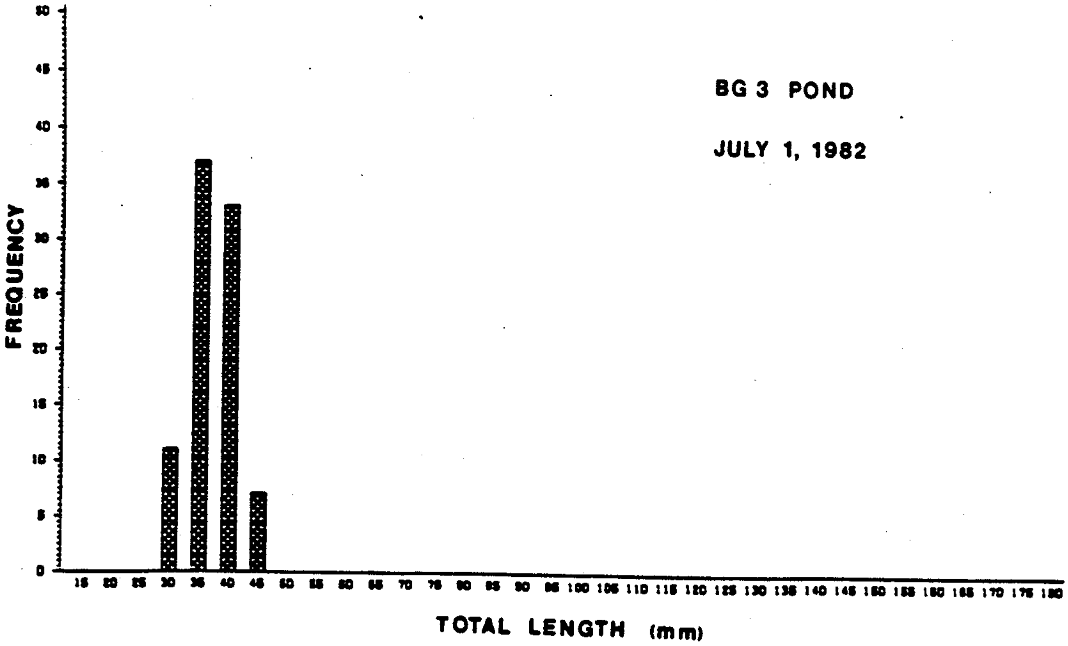
TOTAL LENGTH (mm)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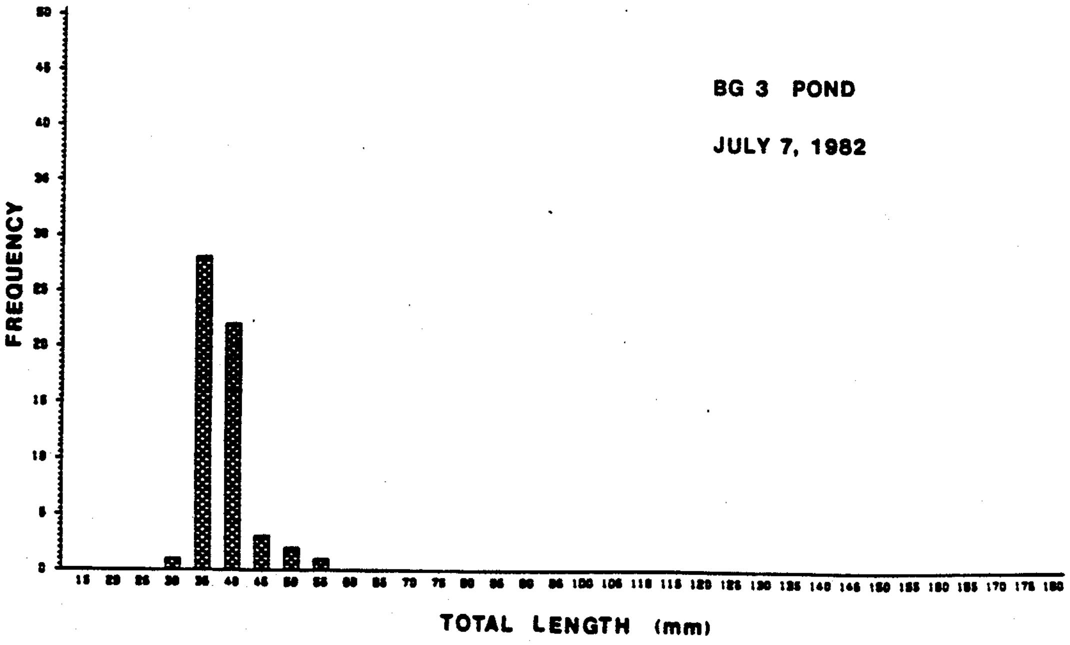
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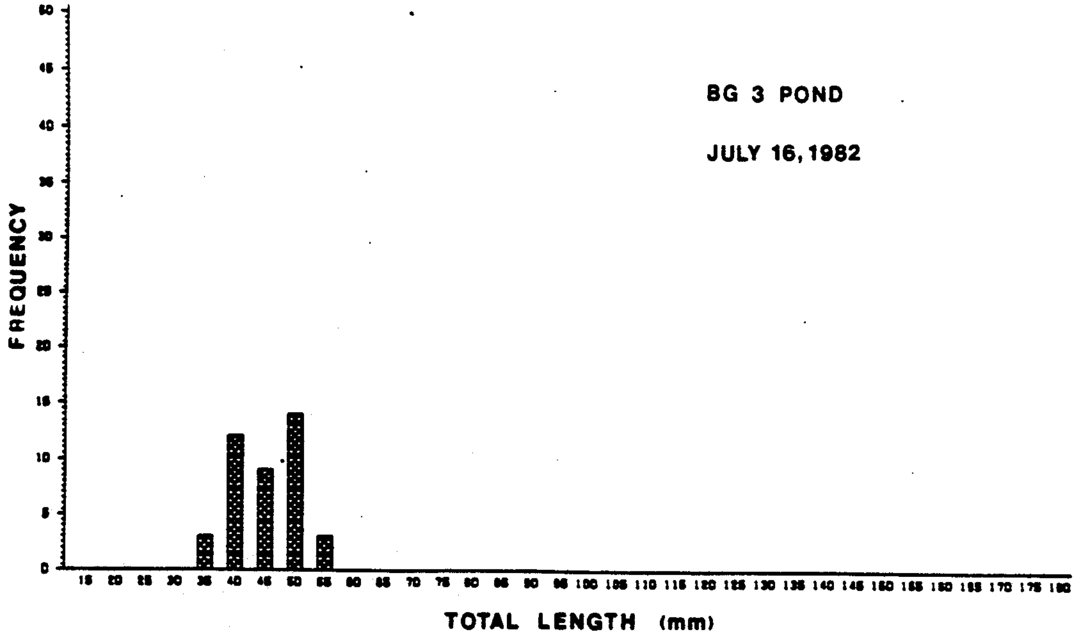
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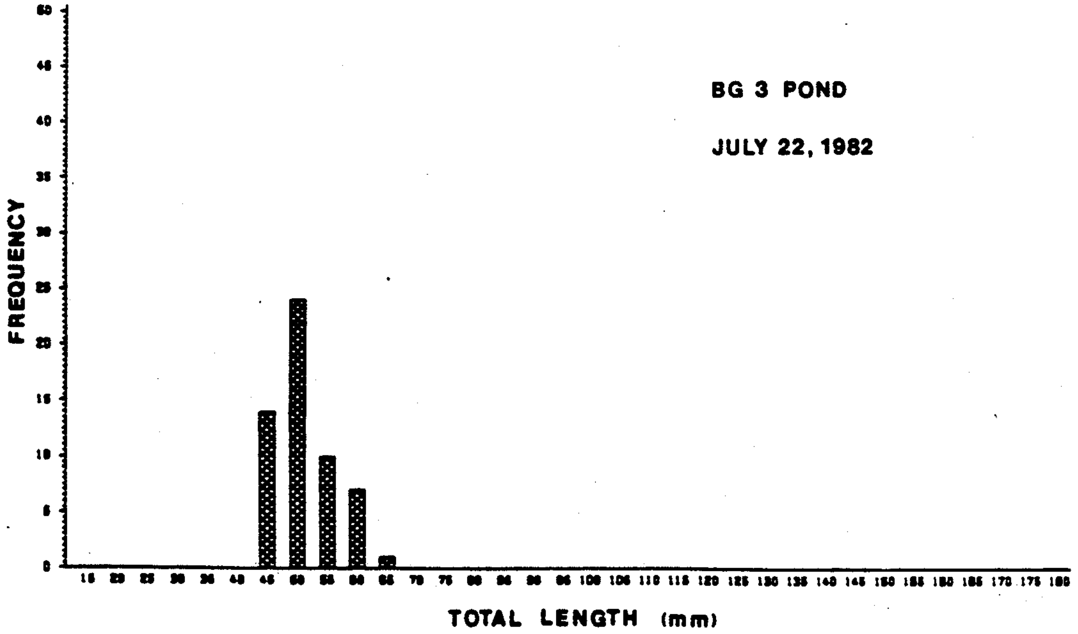
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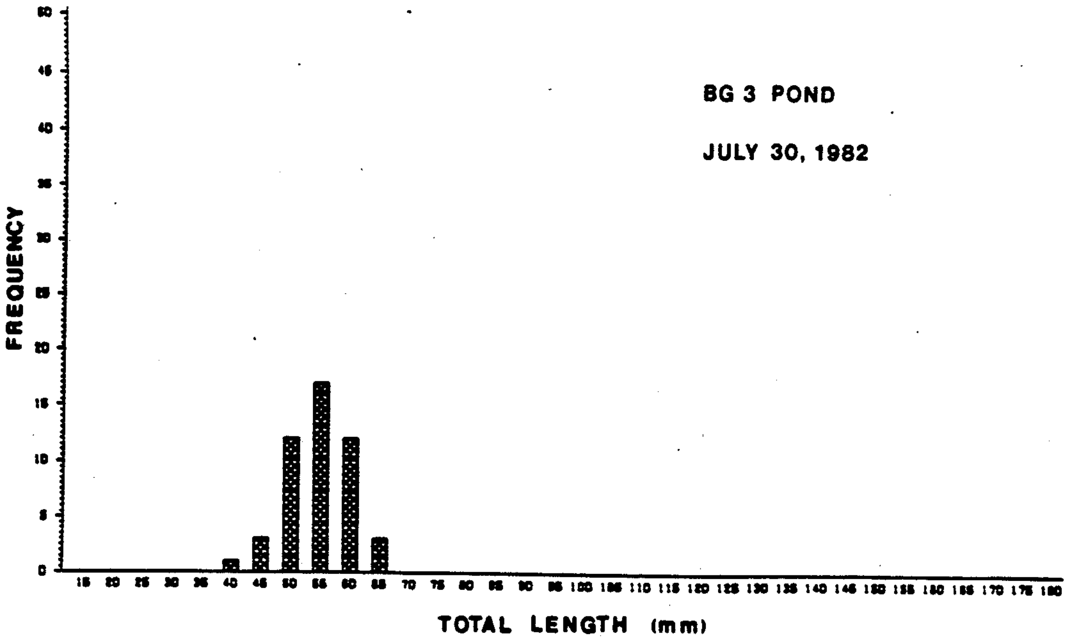
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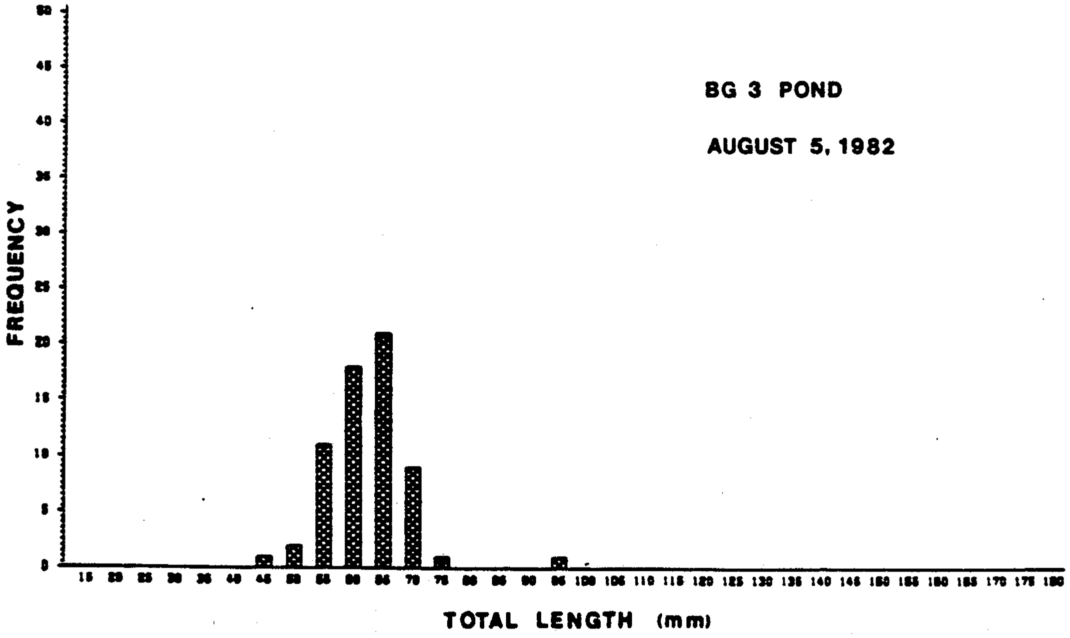
JULY 30, 1982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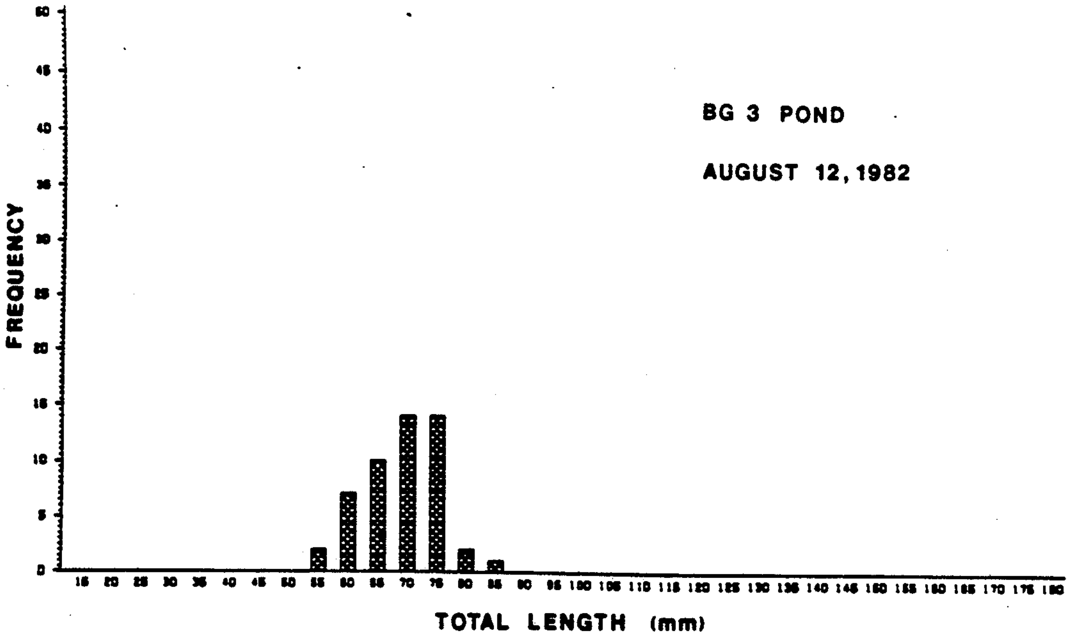
AUGUST 5, 1982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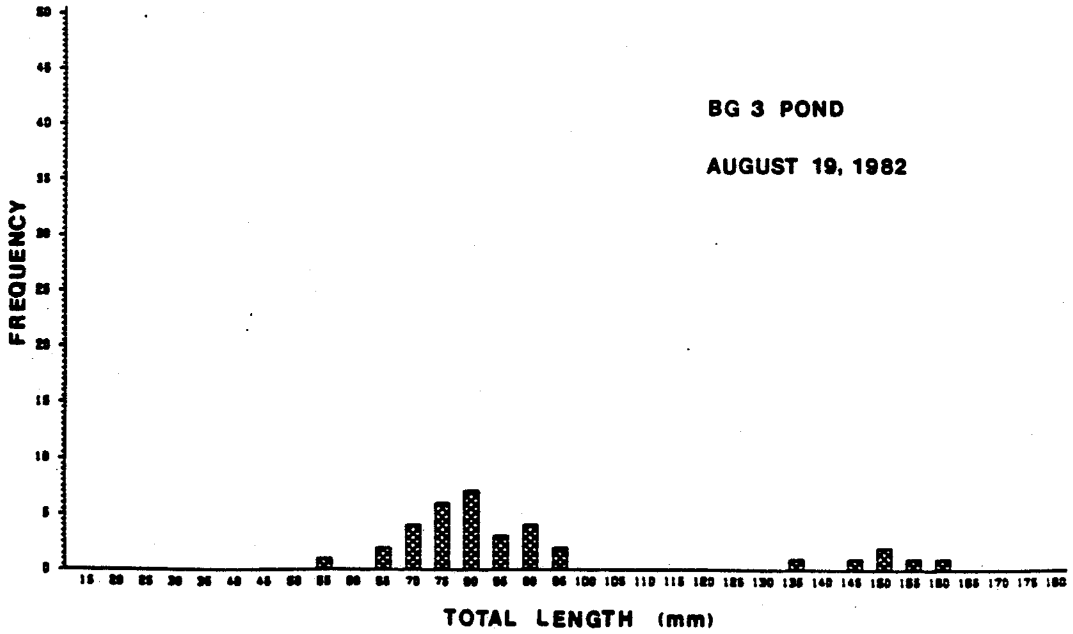
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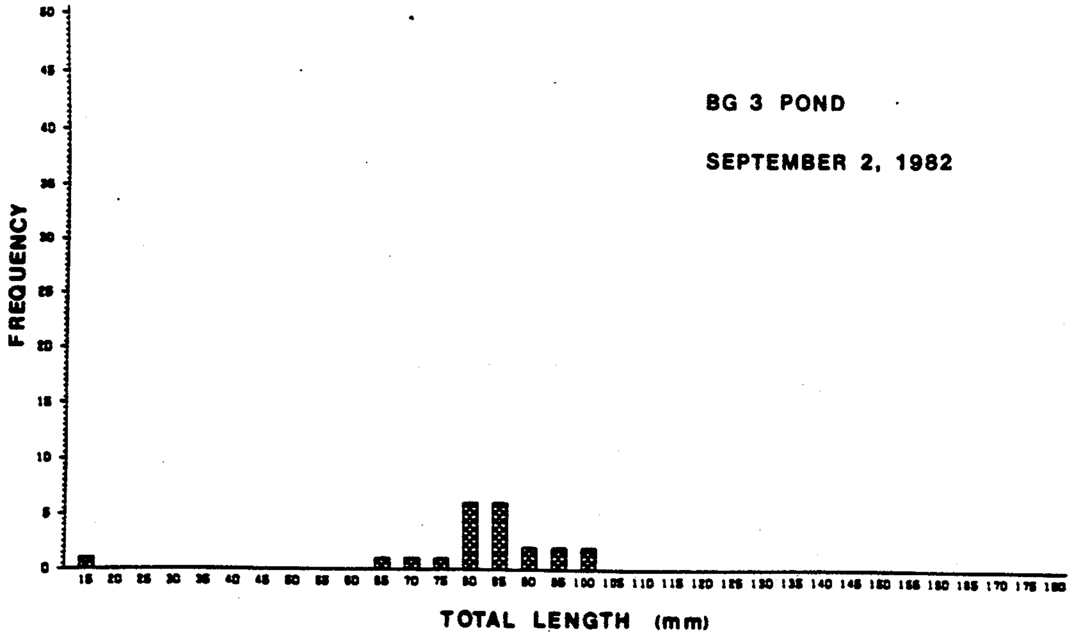
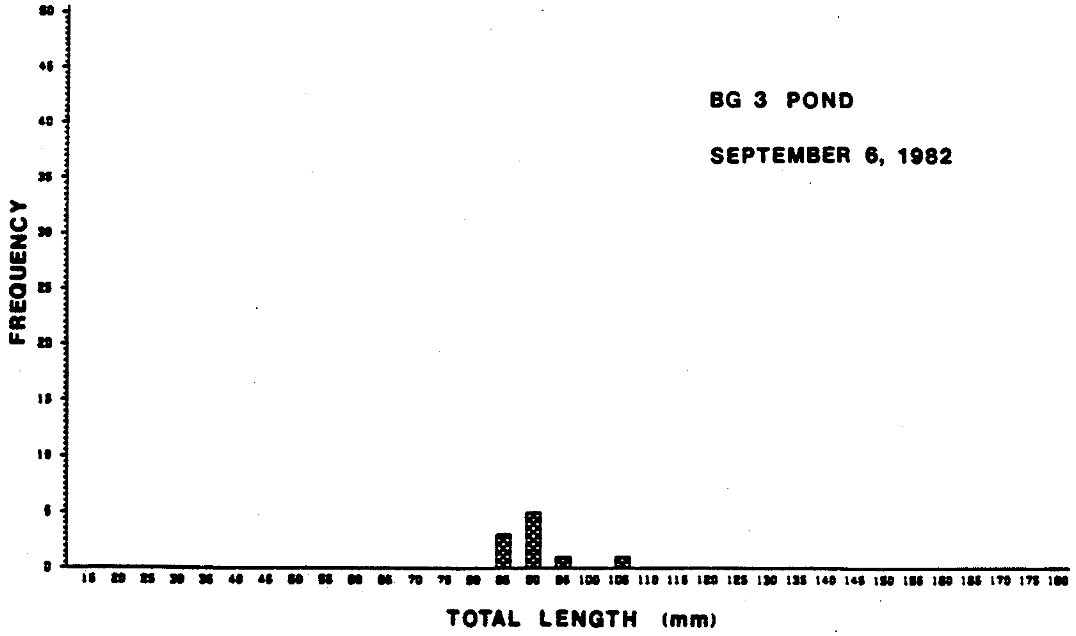


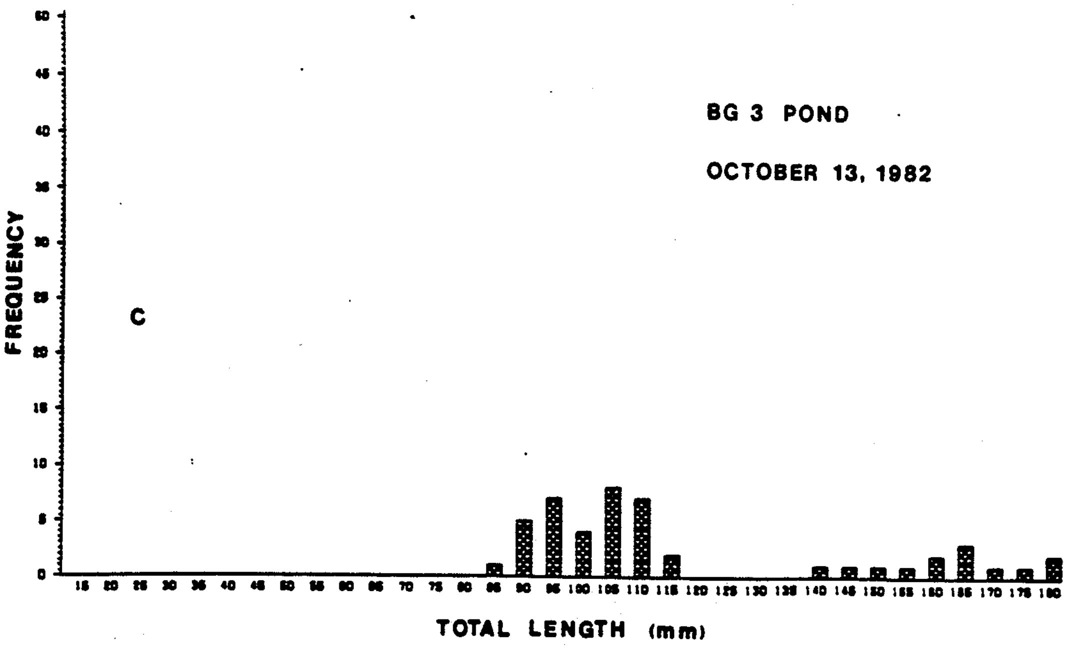
BG 3 POND

SEPTEMBER 2, 1982



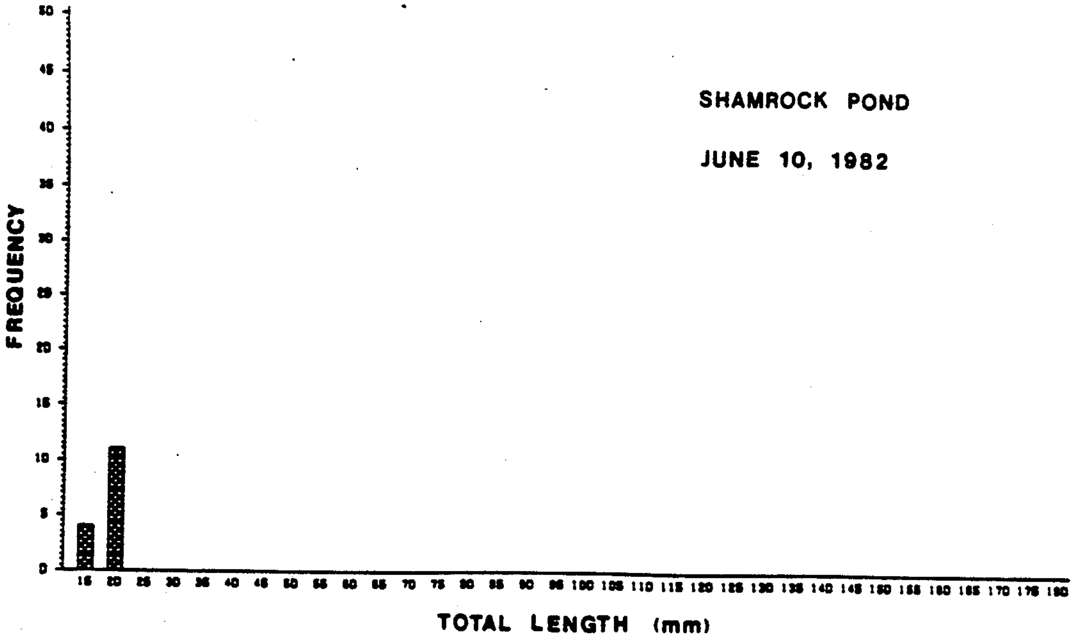
BG 3 POND

SEPTEMBER 6, 1982



BG 3 POND

OCTOBER 13, 1982


SHAMROCK POND
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TOTAL LENGTH (mm)
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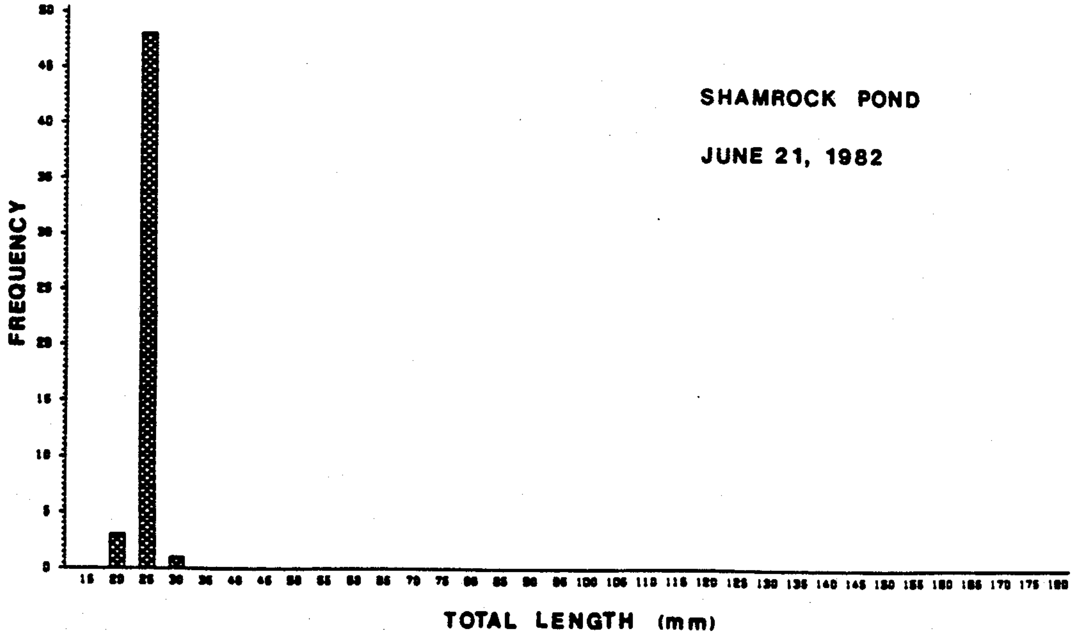
SHAMROCK POND
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TOTAL LENGTH (mm)
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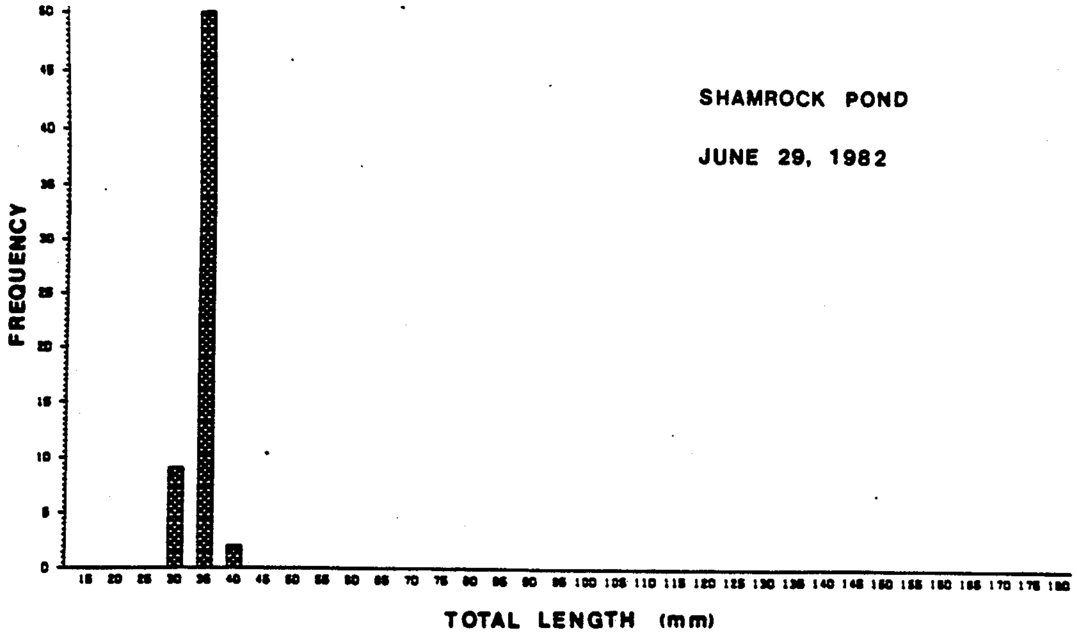
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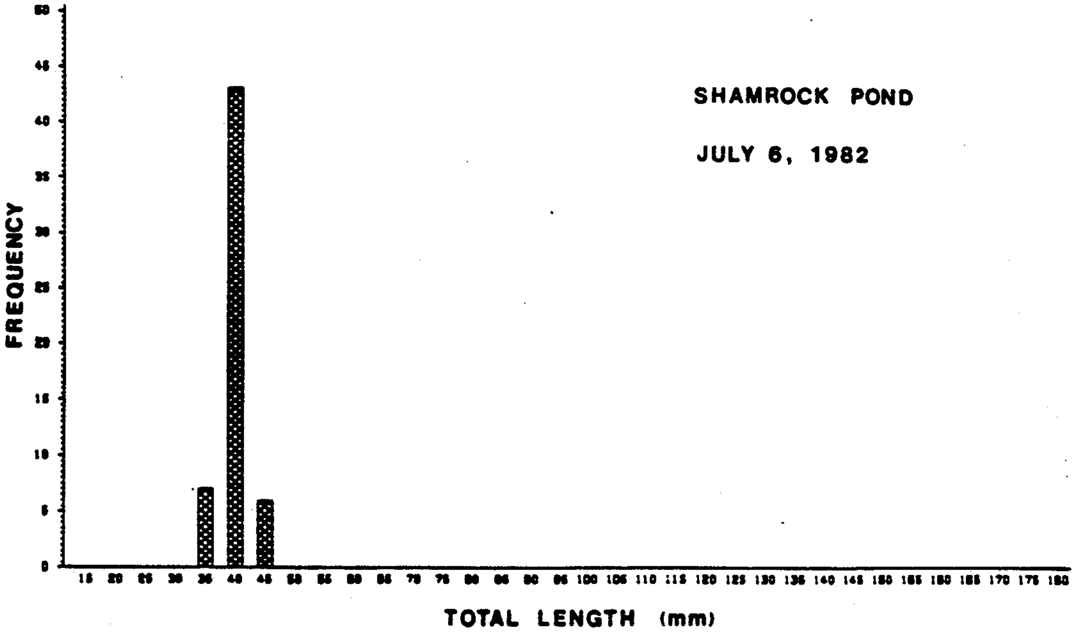
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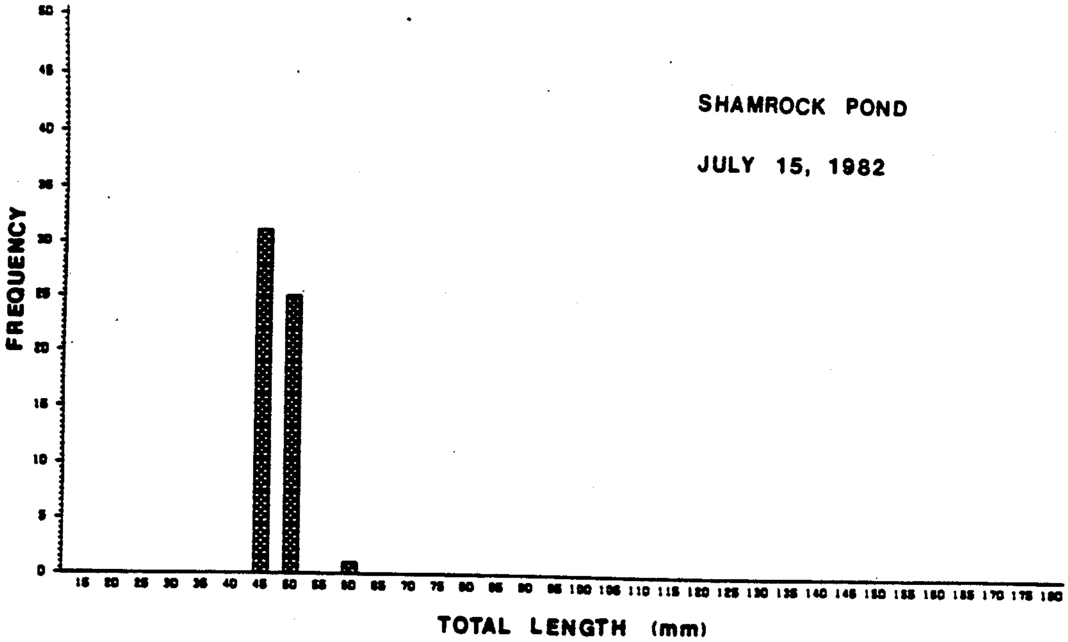
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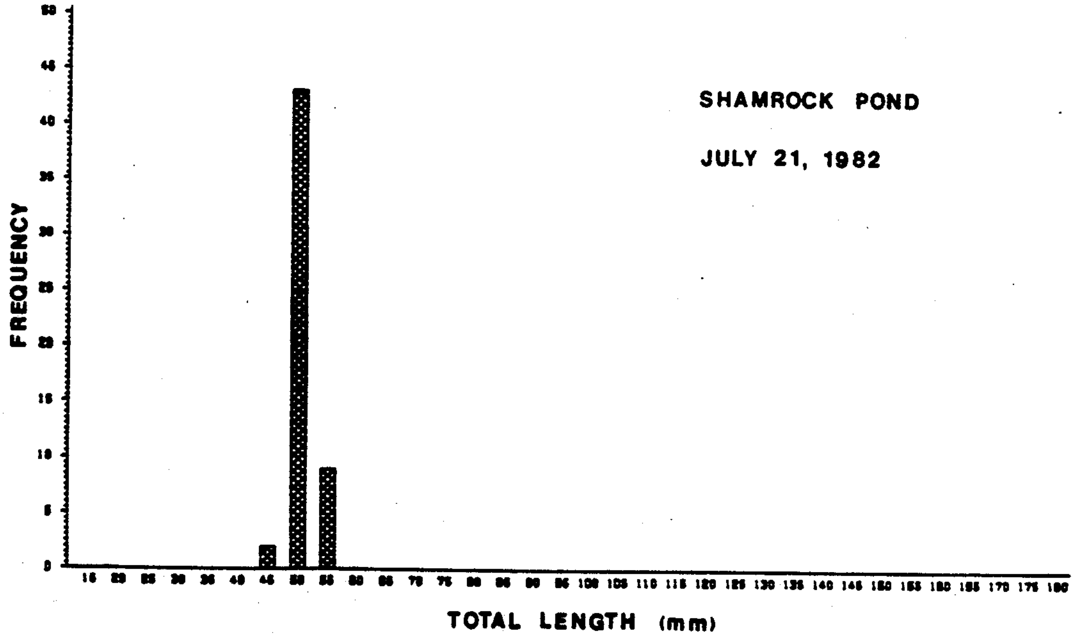
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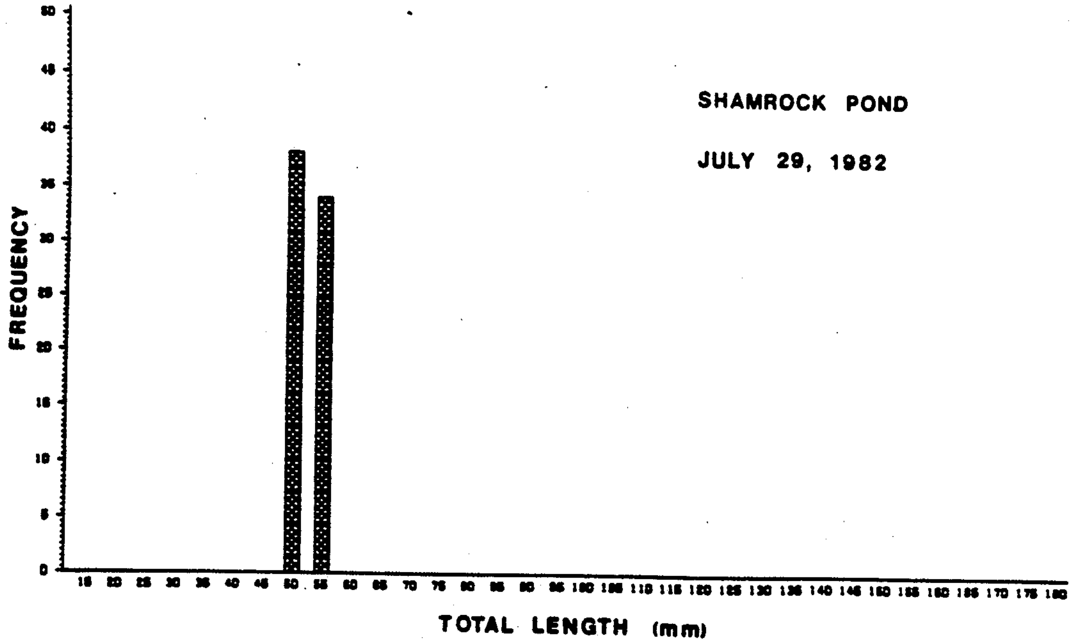
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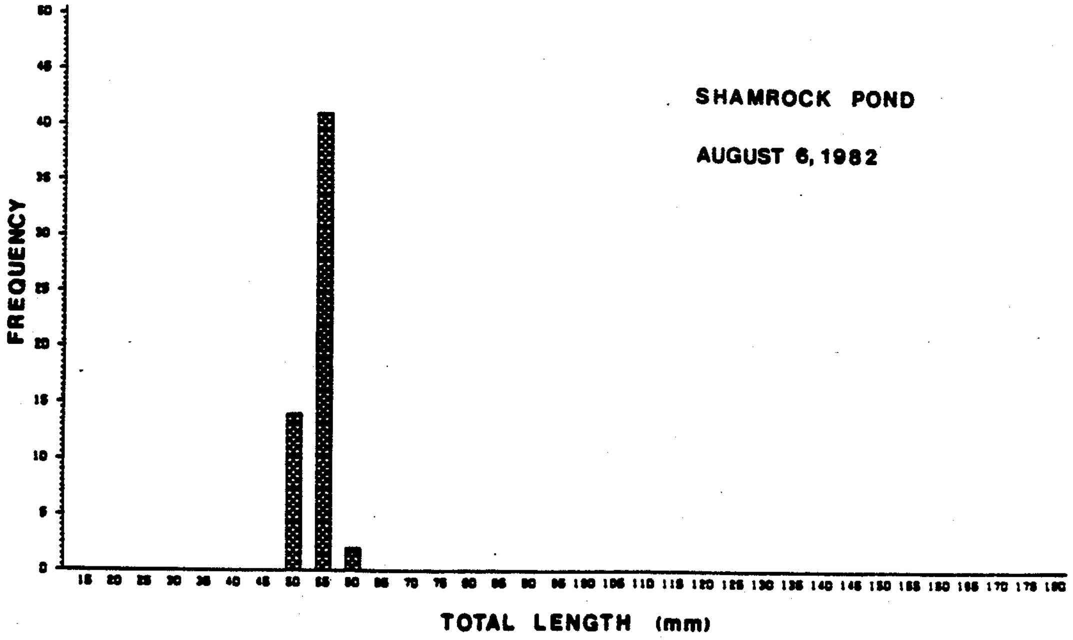
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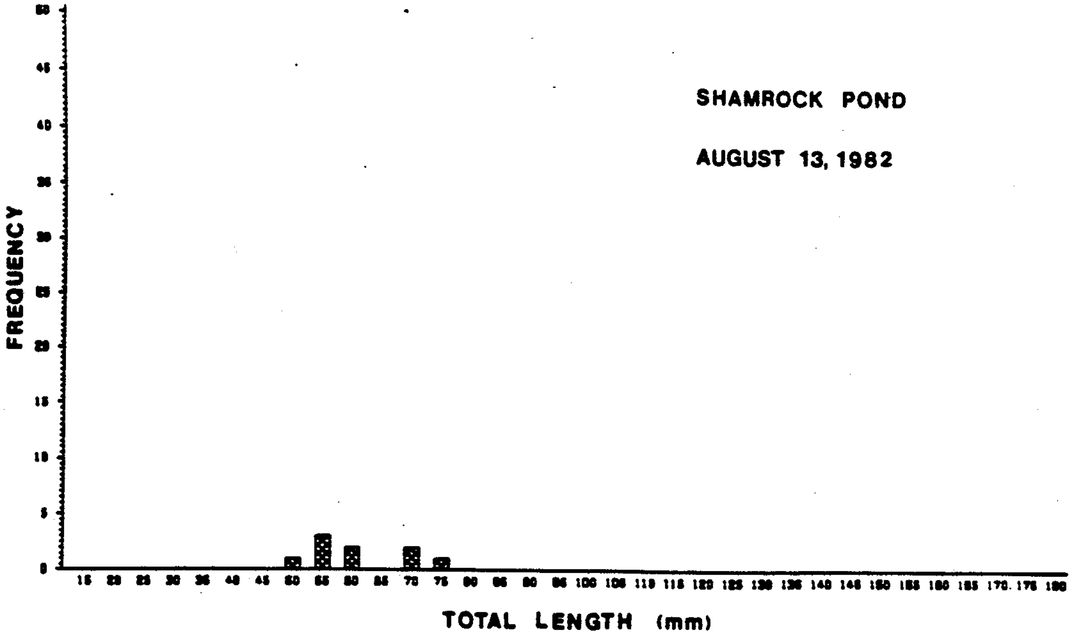
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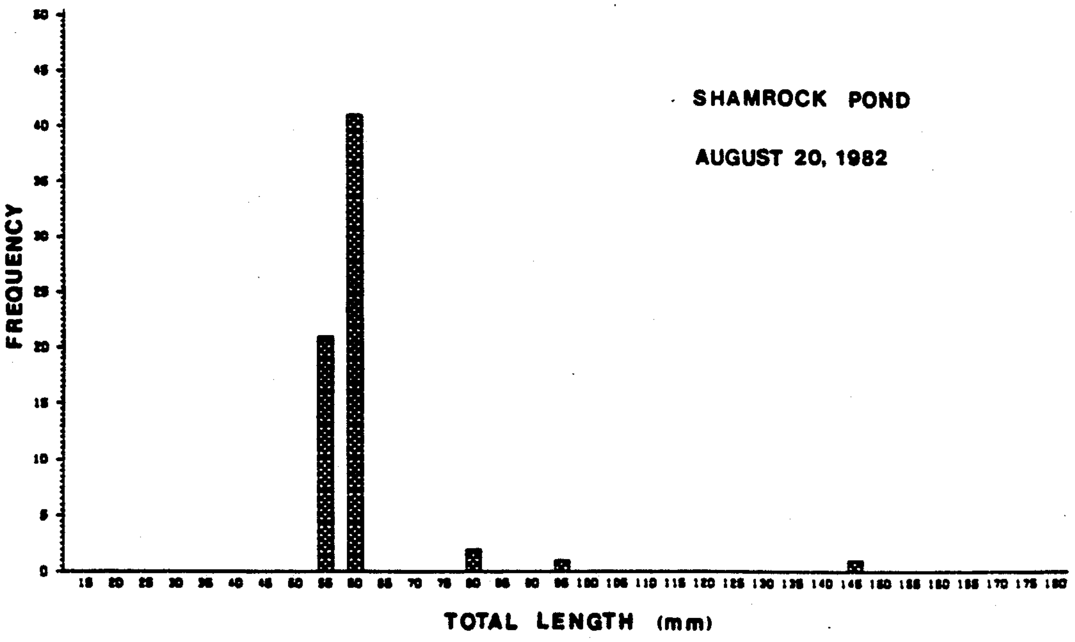
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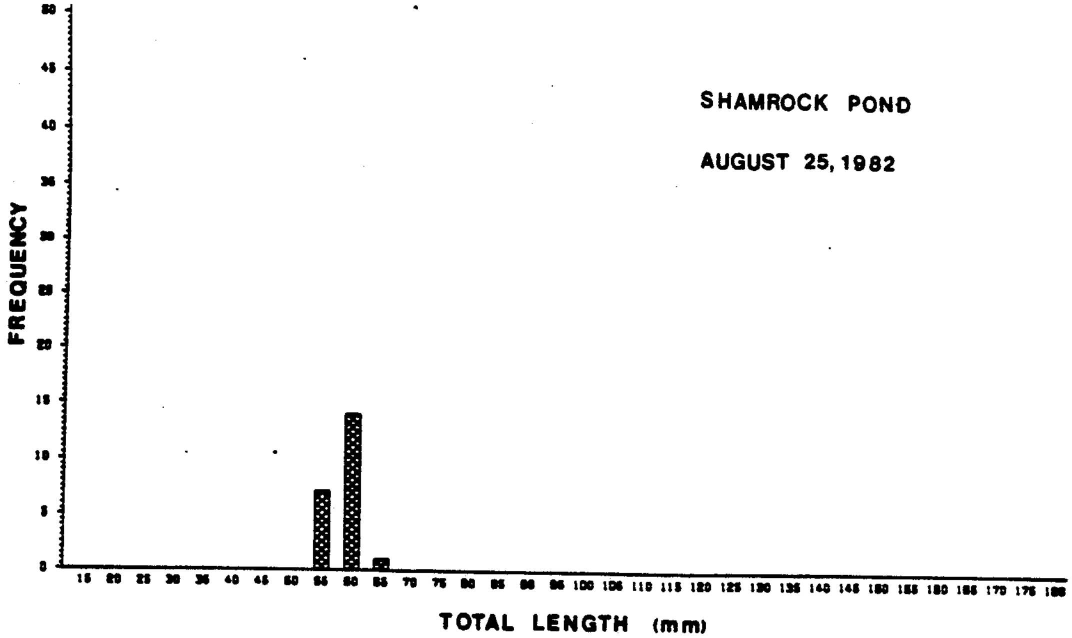
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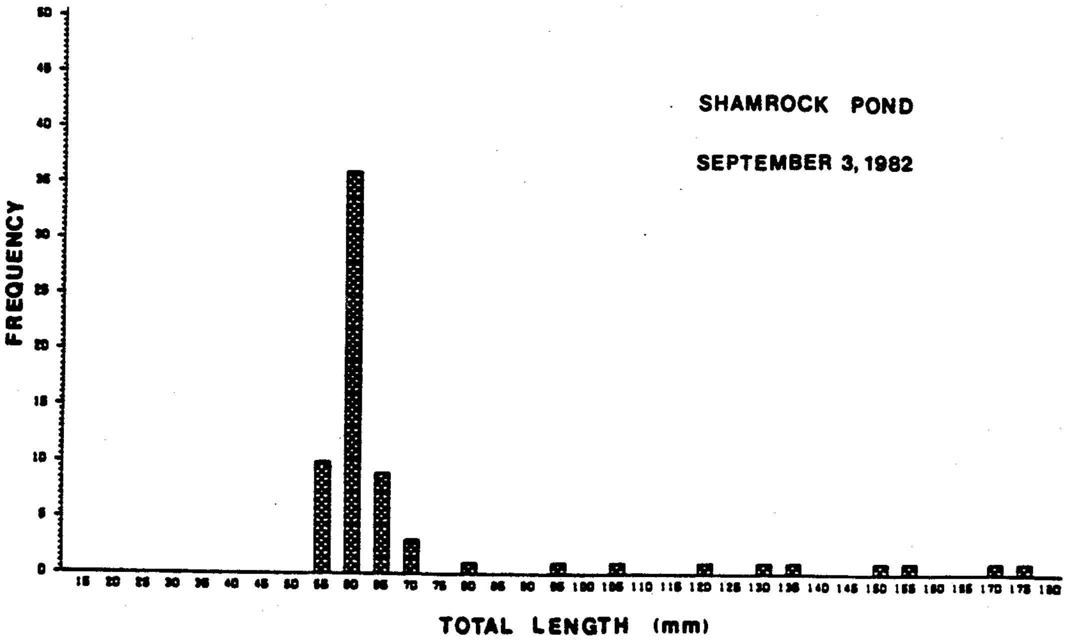
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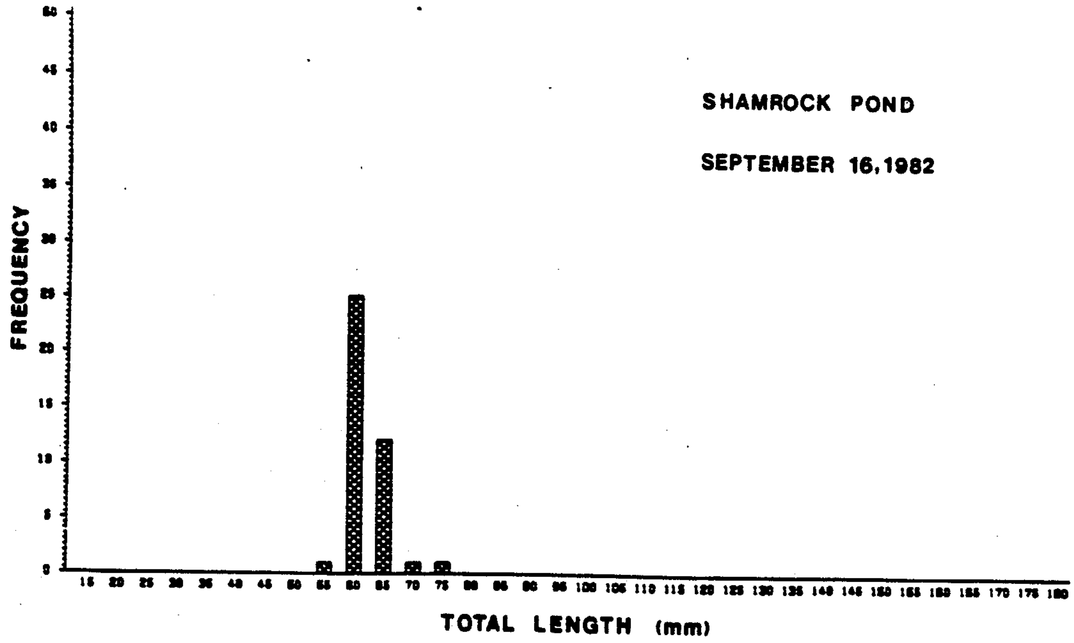

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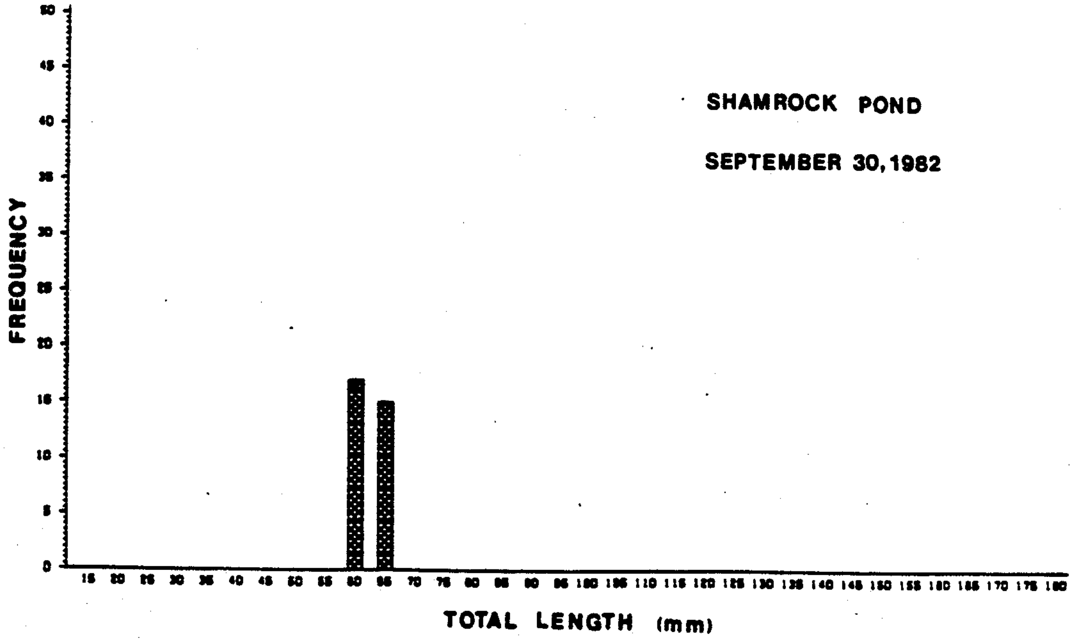

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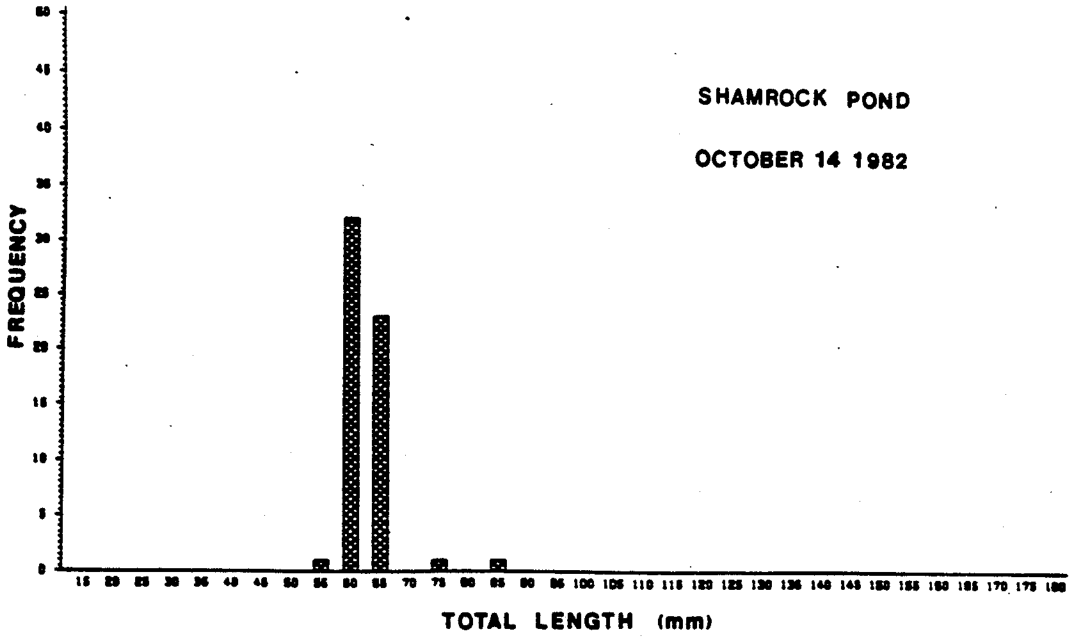
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TOTAL LENGTH (mm)

Chapter 2

CHAPTER 2

ABSTRACT

Walleye introductions in Fort Whyte Lakes 3 and 4 in 1982 experienced limited success. Habitat alterations resulting in increased turbidities and insufficient littoral zone and the presence of spiny-rayed forage fish were the most deleterious factors. Lower returns of stocked fry and fingerlings from Lake 4 was associated with a more abundant northern pike population, and smaller size of walleyes at time of transfer (means less than 64 mm TL). Within Lake 3 evidence was obtained for increased over-winter survival of larger autumn plants; however over-winter survival of yearlings transfered in autumn was not greater than for young of the year autumn transplants (6.5% vs. 6.3% returns). While fewer yearlings than young-of-the-year (YOY) fish should be required to contribute equally to a population, the risk of overwintering fingerling walleyes in rearing ponds is too great to consider this as a viable option.

In terms of absolute returns, fingerling transfers (yearling and YOY) into Lakes 3 and 4 at stocking densities ranging from 10 to $95.ha^{-1}$, contributed 17% and 3% of total returns respectively. Fry stocking contributed the most (83%

and 97%) despite lower survival (.16% and .03%). These were therefore deemed the most successful plants at stocking densities of 9,534 and 7,949.ha^{-1} in Lakes 3 and 4 respectively.

INTRODUCTION

Walleye stockings have a history of varied success dating back over a century. In a review of case histories Laarman (1978) distinguished between introductory, maintenance and supplemental stocking strategies. He found that while 48.2% of introductory stockings yielded "good" returns 29.6% were still "poor". Maintenance stockings in waters with poor or absent natural reproduction, were less successful (32.5% "good") and supplemental stockings, to enhance weak year classes in established walleye populations revealed an 86.2% "poor" classification. Klingbeil (1971) concluded that those plants of fingerling walleye less than 80 mm were generally poor in waters with established populations. Laarman (1978) stated that there is inconclusive evidence indicating that the survival rate of larger fingerlings is better than smaller ones in maintenance stocking strategies. Schweigert et al.'s (1977) findings are contradictary. Fry planted into West Blue Lake, although initially smaller than introduced fingerlings of the same age, contributed significantly more to year class abundance. In fact, after two years in the lake members of both groups were the same size.

The controversy regarding fry versus fingerling stockings centers around survival and economics. While stocked fingerlings may survive better, whether or not the cost of rearing them to a suitable size is commensurate with the end result, is debatable. Kempinger and Churchill (1972) obtained a successful return of 13% from one fingerling stocking while three other plants returned less than 1% of the number stocked. Similarly, stocked fingerlings in Spirit Lake, Iowa yielded returns varying from 12.8% to 1.1% (Jennings 1970). Schneider (1969) found that introduced fingerlings made a real contribution to the population and to the fishery in four of 70 planted lakes, while limited success was observed in 20 other lakes. Mraz (1968) found extremely poor survival of stocked fingerling walleye in Pike Lake, Wisconsin yielding returns of less than 1%.

Klingbeil (1971) suggested that stocking walleye earlier in the season may increase survival through decreased intraspecific competition and more effecient utilization of available prey items. Schweigert et al. (1977) suggested that fry introductions may be most appropriate in populations in which natural reproduction and survival rates are usually low or the exploitation of adults is high. Carlander et al. (1960) found that regular alternate year stocking of fry at the rate of 12 to 24,000 $.ha^{-1}$ appeared to supplement the walleye population in Clear Lake, Iowa. Carlander and Payne (1977) then found that abundance indices were highly correlated with the number of fry stocked according to an irregular stocking pattern. McWilliams (1976) found that stocking walleye fry contributed 81%, 90% and 85% to the larval walleye population in Spirit Lake, Iowa; however subsequent fingerling populations were not correlated to larval walleye density, indicating that survival after stocking was variable and may be more important.

Thus, the controversy regarding walleye stocking strategies is set. Transfers of batch marked walleye fingerlings, at different times and sizes, and spring fry plants in 1982 into two man-made lakes in Winnipeg, Manitoba were examined to determine: 1. The effect of time of transfer and size of walleyes at transfer on subsequent survival and contribution to introduced walleye stocks, 2. Growth of individual transfers and 3. The most effecient walleye stocking strategy.

METHODS AND MATERIALS

Transfers

In 1982 YOY and age 1+ walleye were planted into Fort Whyte Lakes 3 and 4 (Table 9). Plants ranged from 3-4 day old fry (TL=8.0 mm) planted on May 22 into both lakes to age 1+ subadults (TL=170.0 mm) planted into Lake 3 on October 22. Quantities of 3-4 day old fry were obtained from the Province of Manitoba, Swan Creek fish hatchery on May 22, 1982 and were transported to Winnipeg as previously described (Part 1). After acclimation to Fort Whyte Lakes 3 and 4 surface temperatures, approximately 100,000 fry were released by boat into the middle of each lake. Estimation of numbers of fry planted into each lake was via the previously described volumetric method. Age YOY fingerlings were obtained from two City of Winnipeg stormwater retention ponds where they had been planted on May 22 and 23, 1982 (i.e. BG 3 and Shamrock ponds). Age 1+ subadults were similarly obtained from two retention ponds (BG 1 and BG 2 ponds) where they had over-wintered from plants made in 1981 by the Department of Fisheries and Oceans, Freshwater Institute, Winnipeg, Manitoba.

Harvest of walleye from the Bishop Grandin (BG) ponds was accomplished by beach seining areas approximately one quarter of the pond surface area, with one large seine (30.5 m) while another larger barrier seine (45.8 m) prevented movement of walleye back into previously seined areas. Shamrock pond walleye were harvested using a purse-seining technique over the stern of a 12' aluminum boat. This was necessitated by the soft mud bottom and shoreline of Shamrock pond. Walleye were transfered to the Fort Whyte Lakes in a 1000 litre tank filled with water pumped from the pond being harvested. Each transfer was batch marked with a unique partial fin-clip for identification and assessment of transfer efficacy in 1983. To minimize marking mortality of juvenile walleye, holding experiments with 10 marked and 10 unmarked

Table 9. Numbers of walleyes transferred, stocking densities and mean size of walleyes at transfer into Fort Whyte Lakes 3 and 4 in 1982. Ages of stocked walleye are given in parentheses.

Lake	Stocking Date	Number Stocked	Density (/ha)	$\overline{TL}$(mm)
3	May 22 (0+)	107,450	9534	8
	June 3 (1+)	1,070	95	109
	October 13 (0+)	111	10	118
	October 22 (1+)	200	18	170
	total fingerling	1,381	-	-
4	May 22 (0+)	106,120	7949	8
	August 4 (0+)	539	40	63
	August 25 (0+)	516	39	60
	October 12 (0+)	513	38	63
	total fingerling	1568	-	-

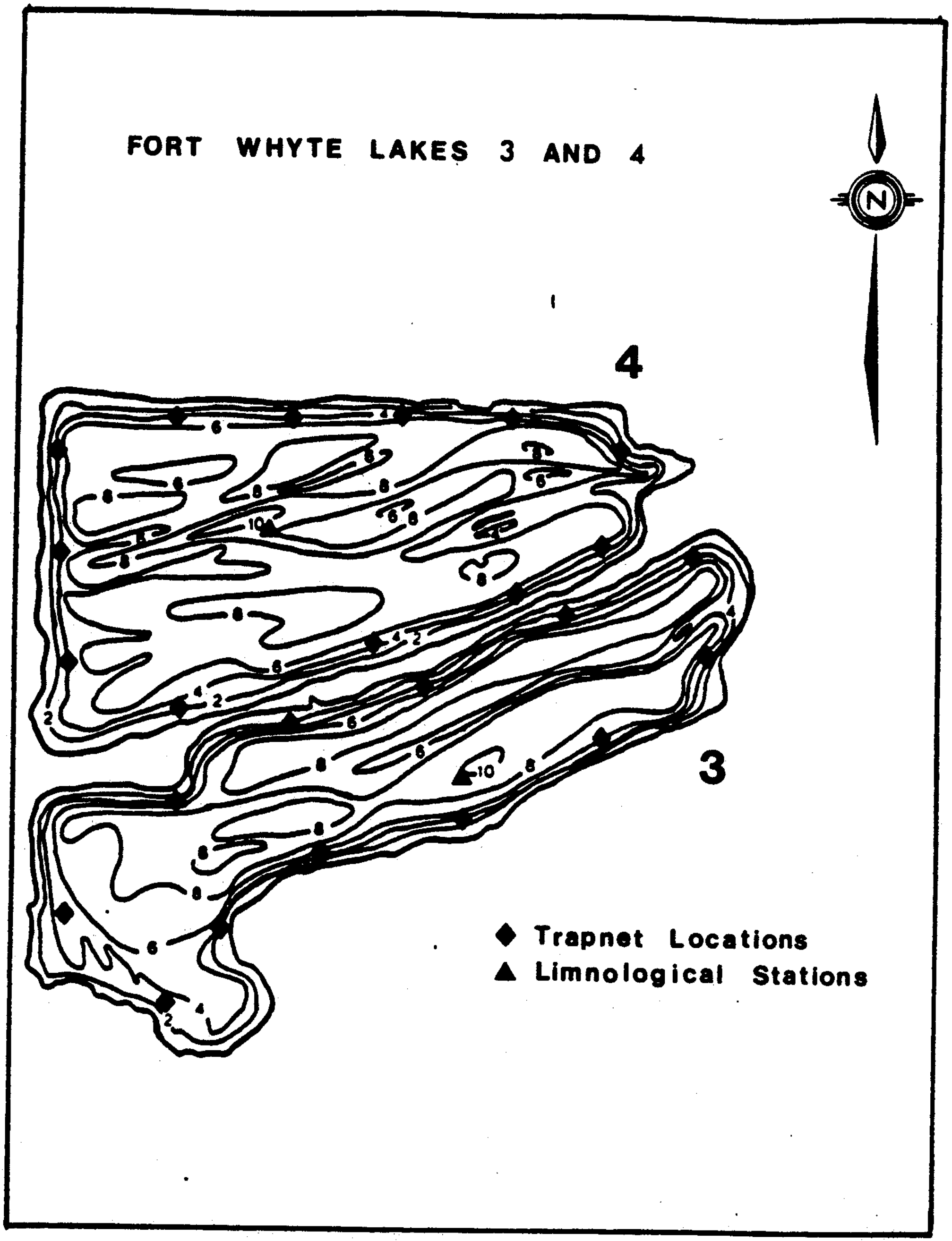
walleye were conducted on on BG 3 pond walleye July 22 (TL= 51.3 mm) and July 30, 1982 (TL= 55.2 mm). Transfers were only attempted after July 30 when no marking mortality was observed.

Age YOY fingerlings were released by boat into deeper water in the Fort Whyte Lakes on all dates except October 12, 1982 when they were released along the shore in Fort Whyte Lake 4. Yearling walleye were released along the shore into Lake 3 on both occasions.

Limnology

In 1982 Fort Whyte Lakes 3 and 4 were sampled biweekly for physical and chemical characteristics at one station each, located in the deepest portion of the lake (Figure 14). Oxygen and temperature profiles were determined via a YSI model 54 oxygen meter at 1 meter intervals until July 26, 1982 after which the modified Winkler titration (A.P.H.A. 1965) was used for oxygen profiles at 1 meter intervals. Temperature profiles were determined at 1 meter intervals using an Austin Inc. model FT3 hydrographic thermometer after July 26 and a Radiometer model 29 meter was used to determine the pH of integrated water samples throughout the season. Secchi disc measurements were recorded to the nearest cm.

Figure 14: Fort Whyte Lakes 3 and 4, trapnet locations and physical/ chemical limnology stations



Integrated samples were collected using a tube sampler modified from Pennack (1962). The water column was emptied from the tube sampler into a previously rinsed tub and a 1 litre sample was taken for further analyses at the Freshwater Institute, Environment Canada, Winnipeg, according to the standard procedures outlined in Stainton et al. (1974).

In 1983, daily surface temperatures were recorded using a hand held thermometer. Monthly temperature profiles were determined using the Austin Inc. model FT3 hydrographic thermometer and monthly oxygen profiles were determined via the modified Winkler titration (A.P.H.A. 1965).

Sampling Schedule

In 1983 each of Fort Whyte Lakes 3 and 4 were divided into three sections, each section with four uniformly spaced stations (Figure 144). Trapnets, used to reduce capture stress on young walleye, were set at one station per section in both Lakes until August 14, 1983. The set location and sequence were determined randomly and used for both lakes. Trapnets were set in Lake 3 in the morning on Monday and Tuesday and in the afternoon on Thursday and Friday. The timing was reversed for Lake 4 allowing equal numbers of morning and afternoon sets in each lake. Trapnets were checked 24 hours after each set and were lifted on Wednesdays and Saturdays for relocation to another set of randomly chosen locations. A two week on and two week off sampling schedule was used to allow for recovery of those walleye marked during the previous sampling period. After August 14, 1983 only two trapnets per lake were available to set per lake and the section as well as station to be set was determined randomly.

Gill nets were set from June 28 to September 7, 1983 during the two week sampling periods as a secondary method to reduce bias from any unequal catchability associated with the trapnets and to increase catches. Weeks fished with gillnets in Lake 3 were double the number in Lake 4 because two age classes were stocked into Lake 3 and it was thought that catchability might vary between groups. Moreover, because catches were greater in Lake 3, it was felt that increased effort there was most beneficial.

Gillnet sets consisted of two standard gangs of three panels each, 25.5 m long by 1.8 m deep. Mesh sizes were 1.91, 2.54 and 3.81 mm stretched measure. Sets were placed in randomly selected locations and run at approximately 30 minute intervals between 2200 and 2400 hours. In addition, bottom otter trawls were used in late September to early October in the deep-water portion of each lake. Trawl durations were two to three minutes long at approximately 7-8 knots.

Marking

Captured walleye were measured to the nearest mm (TL), identified by transfer mark and tagged with "Carlin" tags. The tagging procedure entailed the insertion of two ends of a polypropylene line under the walleyes' first dorsal fin. The ends were tied with an individually numbered plastic tag remaining on the other side. Marking experiments were carried out on June 16-20 and July 24-26. No marking induced mortality could be inferred (Appendix 3). Because catches in general and recaptures of marked individuals were low, marking data did not yield useable results.

Numbered individual floy tags were used to tag other larger species captured (i.e. pike). The total number of yellow perch and young of the year yellow perch caught each sample date was also recorded.

Catch per unit effort (CPUE) was calculated for pike and expressed as catch per hour for the gillnet data. CPUE was calculated per 24 hour set using trapnet data for both categories of yellow perch. Walleye catches were generally small and consequently the percent of walleye recovered, relative to the number stocked per transfer, was calculated to compare transfer success.

Growth of walleyes in log weight for 1983 total catch data, was estimated from weight conversions from a sexually undifferentiated length-weight relationship obtained from BG 3 and Shamrock pond underyearlings in 1982.

STUDY AREA

Fort Whyte Lakes 3 and 4 are located in southwestern Winnipeg, Manitoba. The lakes are part of a series of four man-made lakes, excavated by Canada Cement Lafarge, Ltd., for clay used in cement making. Excavation of Lake 3 began in 1951 and was completed in 1962 (Loadman 1980; Ratynski 1982). While Lake 4 excavation commenced in 1962 and was still operational in 1979 (Ratynski 1982), operations had ceased by 1982.

Water levels were low in 1982-83 and no channels connected any of the lakes (1,2,3 or 4) rendering each a closed system. Identical mean depths (6.07 m) and similar surface areas (11.27 ha and 13.35 ha) were calculated with Lake 4 being the larger (Loadman 1980). As a result of the dredging procedure, Lakes 3 and 4 are deep relative to their surface area. Loadman (1980) stated that none of the lakes have a true littoral zone with depths increasing rapidly to two meters just offshore. In 1982-83, Lake 3 water levels were approximately 2 m lower than in 1977-79, reducing the littoral zone to a small region in the south bay of section 1 (Figure 14). Lake 4 water levels were higher, however basin slopes were uniformly steep around its perimeter.

Loadman (1980) and Ratynski (1982) found that thermal stratification was not strong in either Lakes 3 or Lake 4. Results obtained in 1982-83 were similar (Figure 15). While there was some tendency towards thermal stratification (July 14, 1982) no distinct hypolimnion was formed in either lake. Ratynski (1982) found that Lake 3 stratified briefly during calm periods while Lake 4 was circulated more or less continuously. Calm weather resulted in the minor stratification observed in 1982.

Mean epilimnion (0-3 m) and hypolimnion (3 m-bottom) dissolved oxygen levels indicated a larger biochemical oxidation in Lake 3 than in Lake 4in 1982 (2.8 $mg.l^{-1}$ on July 28) (Figure 16). The lowest level recorded in Lake 4 was 4.2 $mg.l^{-1}$ on July 28. Loadman (1980) and Ratynski (1982) found similar differences between Fort Whyte Lakes 3 and 4 oxygen values.

Mean seasonal nutrient values and chlorophyll-a content were greater in Lake 3 in 1982 (Table 10) in agreement with previous work (Loadman 1980; Ratynski 1982). The greater mean and overall secchi disc measurements (Figure 17) in Lake 4 was due, in part, to the fact that all shores of Lake 3 were bulldozed while the north shore of Lake 4 was left intact. This meant that Lake 4 did not experience the same input of suspended inorganic matter. Moreover, landscape operations were concentrated on Fort Whyte Lake 3. Consequently a larger quantity of inorganic material was loaded into Lake 3 in 1982-83.

Figure 15: Monthly temperature profiles for Fort Whyte Lakes 3 and 4 in 1982-83.

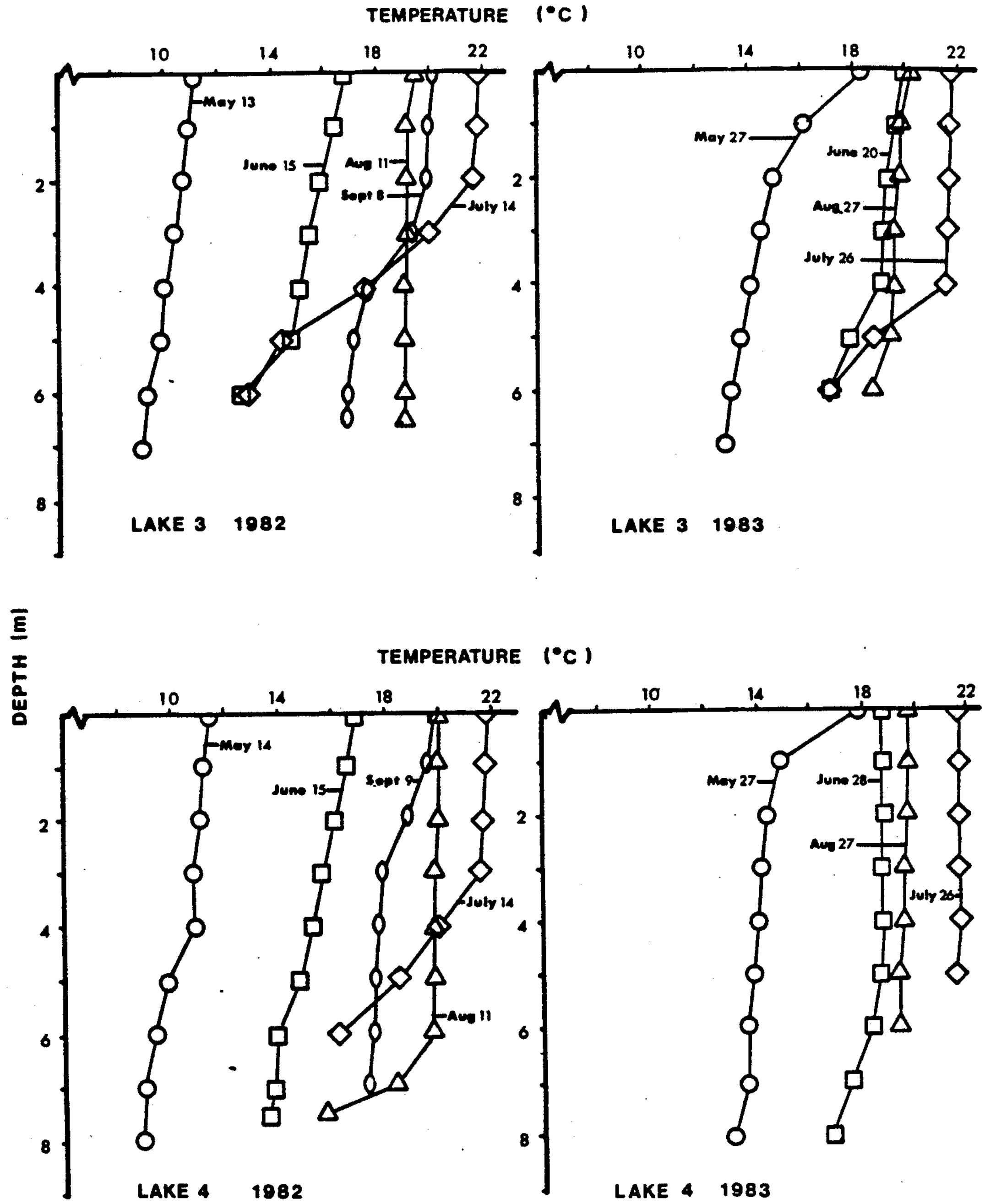


Figure 16: Mean epilimnetic and hypolimnetic oxygen levels for Fort Whyte Lakes 3 and 4 in 1982

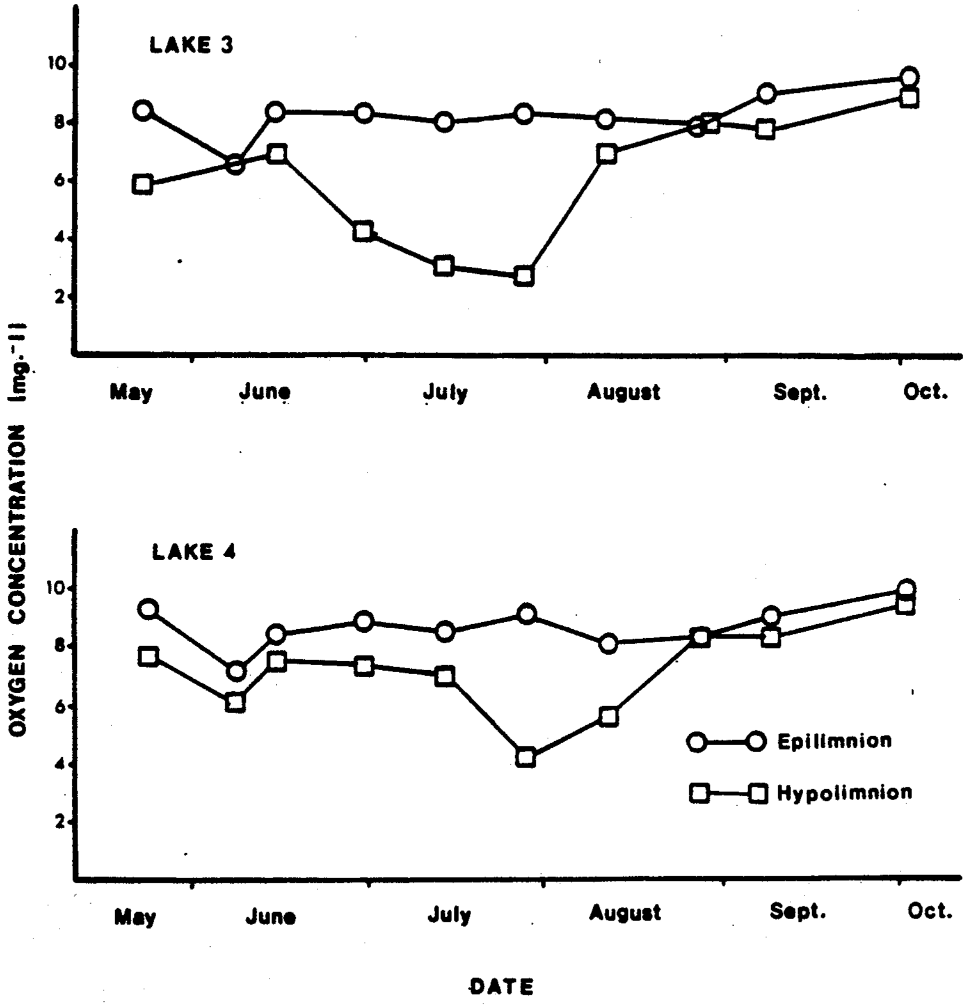
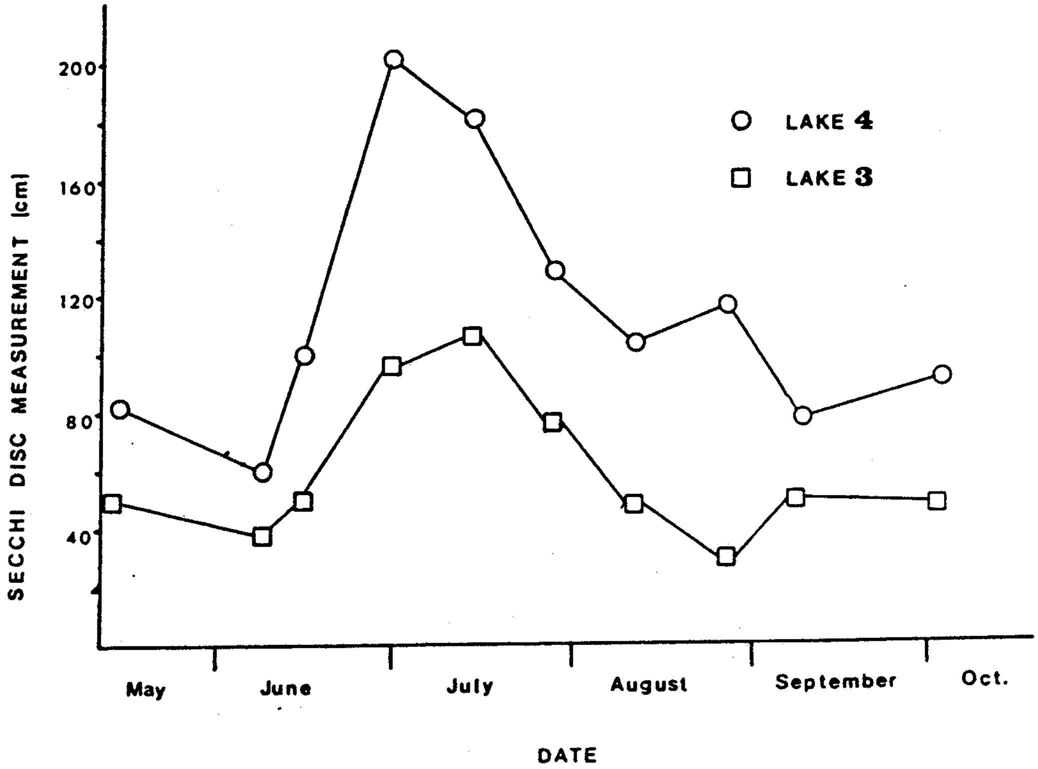


Table 10. Mean June to October, 1982 values of chemical parameters for Fort Whyte Lakes 3 and 4.

Parameter	Lake	
	Lake III	Lake IV
pH	8.1	8.2
NH_4-N (ug/l)	86	43
NO_3-N (ug/l)	7.9	1.3
SRP (ug/l)	9	4
TDP (ug/l)	27	14
Chlorophyll-A (ug/l)	2.0	.6
Conductivity (uS/cm)	513	666
Secchi disc (cm)	59	114
Surface area (ha)	11.27	13.35

Figure 17: Secchi disc measurements for Fort Whyte Lakes 3 and 4 in 1983



RESULTS

Walleye Catch

Capture data for all gears combined and for the entire field season, indicated poor over-winter survival of walleye in both Fort Whyte Lakes 3 and 4. Survival in 1983 was greatest in Lake 3 with 0.16% (n=176) of the fry planted and 2.6% (n=36) of all fingerlings planted recaptured in 1983 (Table 11). Survival was much lower in Lake 4 with 0.03% (n=31) of the planted fry recaptured and less than 0.01% (n=1) of all fingerlings planted recaptured. In fact, none of the fingerling walleye planted into Lake 4 on August 4 and 25, 1982 were recaptured. While all fingerling transfers into Lake 3 had mean total lengths greater than 100 mm, those in Lake 4 averaged 63, 60 and 63 mm TL (Table 11). Despite this size difference, differential mortality above and beyond size selective mortality, was observed between lakes. This was indicated by the 5.3 times greater return from the fry plant in Lake 3 than in Lake 4 (0.16 % vs. 0.03 %).

Within Lake 3, the lowest relative return per number stocked, (0.16%) was from the fry plant. The yearling spring transfer (June 2, 1982) was the next least successful providing a 1.5% return in 1983. This indicates lower survival when compared with transfers made four to four and a half months later (i.e. YOY autumn and age 1+ autumn). The YOY fingerlings introduced on October 13, 1982 and 1+ suba-

Table 11. Total walleye catch (all gears) relative to the number stocked in Fort Whyte Lakes 3 and 4, 1983. Age of walleyes at transfer are given in parentheses.

Lake	Transfer	Number Stocked	Number Recaptured	Number Recaptured
3	May 22 (0+)	107,450	176	0.16
	June 3 (1+)	1,070	16	1.50
	October 13 (0+)	111	7	6.30
	October 22 (1+)	200	13	6.50
	total fingerling	1,381	36	2.60
4	May 22 (0+)	106,120	31	0.03
	August 4 (0+)	539	0	0.00
	August 25 (0+)	516	0	0.00
	October 12 (0+)	513	1	0.19
	total fingerling	1,568	1	0.01

dults planted on October 22, 1982 exhibited the greatest return per number stocked. Despite a 50 mm difference in mean total length between these transfers, the return rates were similar. Autumn fingerling plants provided returns of 6.3 and 6.5% from stocking densities of 10 and 18.ha^{-1} while the spring yearling plant, which was stocked at a density of 95.ha^{-1} yielded a return of only 1.5%.

Fry were introduced into Lake 3 at a density of 9500.ha^{-1} and in absolute terms contributed 83.0% (n=176) of the combined walleye catch in Lake 3 in 1983. This is 4.9 times the combined catch of all other plants (n=36), indicating the largest contribution by number.

In Lake 4, no walleyes were recovered from plants of YOY walleye, at mean total lengths of 63 and 60 mm and at stocking rates of 40 and 39.ha&S-1 on August 4 and 25, 1982 This indicates a total failure of both introductions (Table 11). The return rate of 0.19% (n=1) for the autumn plant of YOY walleye (October 12, 1982) also indicates a failure. Thus transfers of age YOY walleye less than 65 mm TL were not successful in Fort Whyte Lake 4. Total returns from Lake 4 (n=31) indicated that the greatest absolute contribution, 96.9%, was from the 1982 fry plant.

Growth

Four of eight transfers to Fort Whyte Lakes 3 and 4 were caught in sufficient numbers, between May and October, 1983 to warrant growth analyses (Table 12). Comparison of instantaneous growth rates (Ricker 1975) for all 4 plants indicated significant differences at p=0.0001 (SAS Users Guide, Proc GLM; Helwig and Council 1981). Confidence interval estimates overlapped for slope estimates of the Lake 3 and Lake 4 fry plants indicating similarity. While growth was fastest in the fry plants, confidence limits overlapped for the Lake 4 fry plant and the Lake 3 1+ spring and 1+ autumn plants. Therefore, the Lake 3 fry plant demonstrated significantly faster growth than did Lake 3 fingerling transplants while the Lake 4 fry plant did not. While the yearling spring transfer in Lake 3 did not exhibit any significant growth (p=0.5150) (Table 12), regressions of log weight on time for the Lake 3 yearling autumn and Lake 4 fry plants were both significant (p=0.0017 and p=0.0003 respectively). No significant differences were observed in the slope estimates of these regressions despite the tendency for the Lake 4 fry plant to grow faster (b=0.0025 versus b=0.0011).

Table 12. Walleye instantaneous growth rates and 95% confidence intervals for catches in Fort Whyte Lakes 3 and 4 in 1983. Total numbers caught are presented in parentheses.

Lake	Transfer	Instantaneous Growth Rate	p	c.v.	R^2
III	May 22-0+ (176)	.0032 ± .0003	.0001*	9.8	0.703
	June 3-1+ (16)	.0004 ± .0011	.5150	9.2	0.031
	October 13-0+ (7)	-	-	-	-
	October 22-1+ (13)	.0011 ± .0006	.0017*	4.6	0.644
IV	May 22-0+ (31)	.0025 ± .0012	.0003*	16.5	0.382
	August 4-0+ (0)	-	-	-	-
	August 25-0+ (0)	-	-	-	-
	October 12-0+ (1)	-	-	-	-

Other Species

Relative abundance of yellow perch (*Perca flavescens*, Mitchill) in Lakes 3 and 4 was estimated using catch per unit effort (CPUE) using each 24 hour trapnet set as the unit of effort. Comparison of mean weekly CPUE values between lakes was made using analysis of variance on a randomized block design (SAS Users Guide, PROC ANOVA; SAS Institute 1982). Two groups of yellow perch were considered; YOY and "overyearling" (total perch catch - YOY). "Lake" was taken as the treatment factor blocked by week. To meet the assumptions of the analyses, Taylor's power law was applied to the data and consequently a log transformation was used to stabilize the variance. Bartlett's chi-square test (Snedecor and Cochran 1967) indicated homogeneity of variances for overyearling perch after transformation (P=0.5605). Significant differences in variances after transformation were observed between lakes for YOY yellow perch (P=0.0028). This functioned to reduce the sensitivity of the analysis to significant differences in CPUE between lakes (A.N. Arnason pers. comm.). Therefore any observed differences are probably more significant than indicated by analysis of variance.

Results of the analyses indicate that the relative abundance of overyearling yellow perch was not significantly different between lakes (P=0.4343). Initially, relative abundance estimates were greater in Lake 3 but they were greater in Lake 4 after July 11 (Figure 18A). Relative abundance of YOY yellow perch was significantly higher in Lake 4 than in Lake 3, despite the more conservative model, after their initial appearance in trapnets during week 8 (Figure 18B). The reason for this difference was a precipituous decline in Lake 3 CPUE as the season progressed (Figure 18B).

Combined gillnet and trapnet catch data, indicated a more abundant northern pike (_Esox_ _lucius_, Mitchill) population in Fort Whyte Lake 4. While only two pike were sampled all season in Lake 3, seventeen were sampled in Lake 4 (Table 13). Despite greater effort afforded to Lake 3, no pike were sampled in gillnets during the entire ice-free season. Lake 4 however, demonstrated a greater CPUE with a maximum of 2.3 pike per gillnet hour in week 10 (late July).

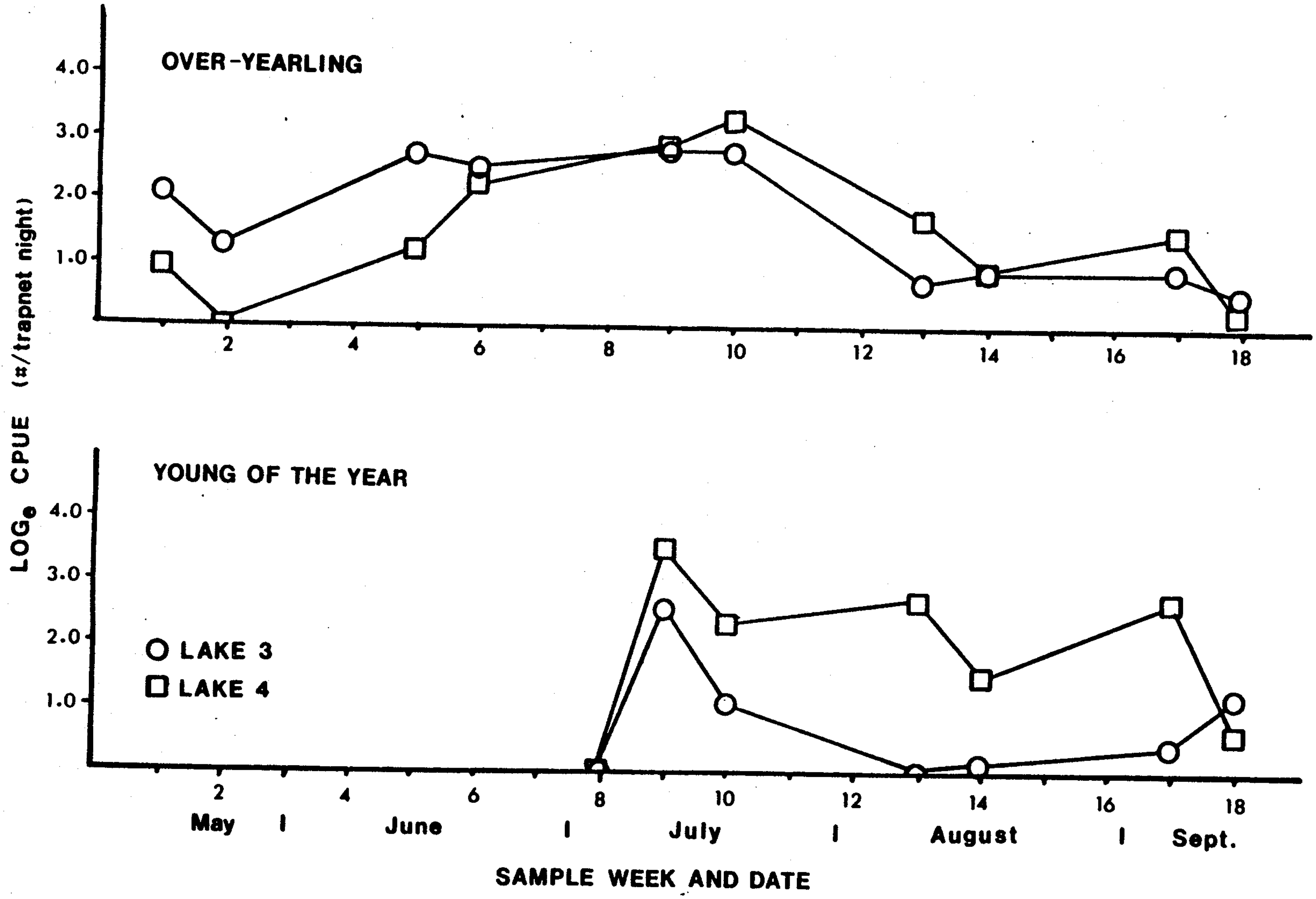


Figure 18: Seasonal CPUE data for yellow perch categories in Fort Lakes 3 and 4 in 1983

Table 13. Northern pike catch per unit effort (CPUE) for gillnet sets and total catch (both gillnets and trapnets) for Fort Whyte Lakes 3 and 4 in 1983. Percent of total pike catch (both lakes) in parentheses.

Week	Lake 3 CPUE (/hour)	Lake 4 CPUE (/hour)	Lake 3 Total Catch	Lake 4 Total Catch
3	-	-	1	3
7	0	-	1	-
9	0	-	0	-
10	-	2.3	-	11
13	0	-	0	-
14	-	0.4	-	3
17	0	-	0	-
Totals			2 (10.5)	17 (89.5)

DISCUSSION

Overall Survival

Fin clipping is not considered to have affected over-winter survival of walleyes planted into Fort Whyte Lakes 3 and 4. Partial fin-clips are an accepted batch marking technique, remaining recognizable after significant regeneration (Eipper and Forney 1965). Maloney (1953) found that pelvic fin clips did not affect the survival of walleye in Maloney pond, Minnesota while Churchill (1963) found no difference in survival of fin-clipped walleye in Nebish Lake, Wisonsin. He concluded that the removal of one fin on 75 mm walleye fingerlings had no significant effect on their survival. Moreover, Mraz (1968) found no effect of fin clipping on survival or growth of walleye in Pike Lake, Wisconsin. Therefore, partial fin-clips are not considered as a serious source of mortality in Lakes 3 and 4.

Increased turbidities in both lakes through the summers of 1982 and 1983 may have affected walleye feeding efficiencies. Walleye are selective "strike" feeders (Mathias and Li 1982) and increased turbidities produced by shoreline alterations in 1982 and 1983 could affect feeding. Secchi disc measurements in Lake 3 rose to 106 cm on July 14, after which they declined to less than 50 cm. Secchi disc measurements were generally higher in Lake 4, rising to 2 m in late June- early July, 1982 and falling to a level of 1 m in early August (Figure 17). Erickson and Stevenson (in Laarman 1978) found survival of walleyes stocked in impoundments in the United States was enhanced in waters with low turbidities. Ryder (1977) states that 1-2 m secchi disc measurements may represent optimum daylight transparencies for walleye. Perhaps this allows for intermittent feeding throughout the day (Scott and Crossman 1979). Transparencies at the lower level of Ryder's (1977) optimum may therefore indicate detrimental conditions for walleye feeding.

Secchi disc measurements from Lake 3 rose to 106 cm on July 14, after which they declined to below 50 cm. Thus, Lake 3 transparencies were at the lower end of Ryder's (1977) optimum until shoreline alterations began. After this time, lowered transparencies may have inhibited walleye feeding. Secchi disc measurements were generally higher in Lake 4, rising to 2m in late June-early July, 1982. Again, shoreline alterations resulted in an increased sediment load and transparecy readings dropped to the lower end of Ryder's (1977) optimum transparency (1 m).

The absence of suitable habitat may also be a factor in reduced walleye survival. The basin slopes of Fort Whyte Lakes are predominantly steep clay banks, providing little or no rubble which provides cover and seems to be a preferred habitat of walleye (Ryder 1977). Moreover, the absence of a substantial littoral zone may have affected walleye feeding efficiencies through dispersion of prey items present (i.e. yellow perch) throughout the lake.

The presence of yellow perch as the sole forage species may have been less than optimal for planted walleye in Lakes 3 and 4. Beyerle (1978) found that growth and survival of stocked walleye fingerlings was greater in a lake containing soft-rayed forage species (fathead minnows and golden shiners) than in a lake containing only spiny- rayed forage fish (bluegill and green sunfish). Furthermore, recent evidence for the preference of soft-rayed fish as forage for walleye was demonstrated in Western Lake Erie (Knight et al. 1984).

While walleye and yellow perch often coexist (Forney 1974; 1976; McWilliams 1976; Kelso and Ward 1977), competition between the two species and predation by walleye on yellow perch have been demonstrated (Kelso and Ward 1977). This may have a significant impact on their respective year class strengths (Neilsen 1980). As the major forage species in Oneida Lake, New York, yellow perch abundance was inversely related to the mortality rate of YOY walleye (Forney 1974; 1976). Presumably yellow perch acted as a buffer on predation of small walleye by larger fish (Chevalier 1973).

Young of the year walleye may feed primarily on yellow perch early in their first season (Smith and Pycha 1960; Forney 1966; Parsons 1971). Forney (1966) suggests that this is due to the availability of the smallest yellow perch early in the season. Size selective consumption then results in perch populations composed of individuals too large to consume later in the season (i.e. August). Consequently, it may not be desirable to introduce small walleye into lakes in which perch are the sole forage species, late in the season.

No evidence for increased perch-walleye competition was found as an explanation for limited survival in Lake 4. Analyses of 1983 perch CPUE data indicated that "overyearling" perch populations were not significantly different between lakes. Although Lake 4 perch catches did exhibit a larger YOY component, this was a result of the drop in Lake 3 CPUE after mid-July (Figure 18B). Presumably the decrease in young of the year perch abundance was caused by predation by the larger (abundance and size) Lake 3 walleye population. Ratynski (1982) found no significant difference in Fort Whyte Lake 3 and 4 yellow perch abundance or biomass CPUE. This supports the 1983 CPUE data indicating no significant difference in the perch populations between the two lakes.

A more abundant northern pike population may partially explain reduced survival in Lake 4. Pike catch data indicated a larger pike population in Lake 4 than in Lake 3. Pike are probably the most important predator of walleye across most of its range (Colby et al. 1979; Scott and Crossman 1979). Johnson et al. (1977) found that, in a survey of Ontario lakes, pike and walleye tended to be mutually exclusive. Similarly, the implication of a pike motivated suppression of walleye in Heming Lake, Manitoba was presented by Lawler (1965). A larger population of northern pike might, consequently, be expected to cause increased mortality among Lake 4 walleyes. Moreover, the plants of smaller fingerlings (60 mm TL) in Lake 4 would increase susceptibility to pike predation.

While low overall survival in Fort Whyte Lakes 3 and 4 may be attributed to a combination of factors (i.e. high turbidities, reduced littoral zones, and spiny-rayed forage fish) lower survival in Lake 4 is probably due to predation of stocked walleye by an established pike population. While the larger individual size of Lake 3 fingerling plants confounds this "lake" effect, the 5.3 times greater survival of fry in Lake 3 supports the generalization that over-winter survival of stocked walleye was greater in Lake 3.

Fry vs. Fingerling Plants

In terms of actual contribution to the walleye stock, absolute returns are the most relevant. While fry stocking densities must be high (Schneider 1969; McWilliams 1976) the availability of walleye fry makes high stocking densities practical. High fingerling stocking densities are more impractical, as rearing area is limiting for fingerling production programs of a large enough scale to affect a major walleye fishery, due to the extreme variability of pond production (Smith and Moyle 1945). Despite the lowest survival (% recaptured), in Lakes 3 and 4, fry plants in 1982 contributed the greatest numbers to the 1983 walleye population in both Fort Whyte Lakes 3 and 4. Fry stocking required the least time and man power making it the most economical.

While previous studies provide some evidence for enhanced year classes with supplemental fry stocking (Carlander and Payne 1977) and maintenance fry stocking (Schweigert et al. 1977), fry stocking into waters with existing walleye is variable (Laarman 1978) and maintenance stocking with fry has generally met with poor success (Laarman and Reynolds 1974). Therefore, because no walleye were in Lakes 3 and 4 prior to 1982, the implied benefits of increased contribution of fry plants, with decreased effort, may not apply in the rehabilitation of existing walleye populations.

Previous work indicates that high stocking rates (12 to 24 thousand $.ha^{-1}$) were required in fry maintenance stocking programs (Schneider 1969). Similarly, Schweigert et al. (1977) found that fry plants of 600 to 1200 $.ha^{-1}$ met with limited success while a fry plant of $4570.ha^{-1}$ produced excellent results. Similar returns from high stocking densities have been reported by Rose (1955), Carlander et al. (1960) and, Forney (1975;1976). Mc Williams (1976) however, found that fingerling walleye abundance was not correlated with larval walleye density. This indicates that survival of fry to fingerling size may be more important than initial fry density. Schneider (1969) stated that, in maintenance stocking of fry, survival is generally poor and is only successful occassionally when stocking densities are high. While stocking densities of 9,534 and 7,949 $.ha^{-1}$ in Lakes 3 and 4 did not achieve the desired level of success, they were within the range of previously reported success.

Effect of Time of Transfer on Survival

While the YOY and 1+ autumn introductions (6.3% and 6.5% survival) showed some evidence for increased survival of late plants, the 1+ spring transfer (1.5% return) was present in Lake 3 for four months longer resulting in increased absolute mortality. Perhaps the tendency towards stronger thermal stratification and decreasing hypolimnetic oxygen levels in Lake 3 during the summer contributed to the stress on the 1+ spring plant, thereby effecting a lower survival rate. Moyle and Clothier (1959) state that a healthy walleye population requires at least 5.0 $mg.l^{-1}$ of dissolved oxygen.

Effect of Transplanted Walleye Size on Survival

The 1+ spring plant, at TL=109 mm, was somewhat smaller than the YOY (TL=118 mm) and 1+ (TL=170 mm) autumn plants. Therefore, decreased oxygen levels, increased absolute mortality and size differences of transplanted walleyes confound and obscure the apparent benefits of autumn walleye stocking to over-winter survival and subsequent contribution to walleye stocks. While the autumn plants were larger (TL) and yielded better returns, they were present in Lake 3 for four months less and subsequently were not subject to the same absolute mortality while in the retention ponds as the spring plant was in the lake. While Lake 4 transplants were smaller in size and yielded lower returns, the possibility of increased pike predation prevents direct comparison to Lake 3 catch data. Therefore, while there is some evidence for increased survival of larger fingerlings, the effects of pike predation in Lake 4 and timing of planting in Lake 3 again confounds the relative contribution of fingerling size to over-winter survival.

Growth of stocked walleye plants, recaptured in 1983 (n>12) was evaluated using a combined BG 3 - Shamrock pond length-weight relationship. While this does not allow for comparison of fish condition factors between plants and lakes, it does give some indication of relative growth. In general the fry plants exhibited the greatest growth and did not differ significantly (Table 12). Perhaps the greater variability in the Lake 4 fry plant growth is an indication of stressful conditions as noted in Part 1 (Ivlev 1961; Forney 1966) or is simply due to small sample size (n=31 versus n=176). Yearling recoveries in Lake 3 were the only other walleyes caught in numbers sufficient to attempt growth analyses. These fish showed significantly slower growth than the Lake 3 fry plant. This too, may be a function of small sample size; however in general, larger, older fish demonstrate a decreased growth rate through decreased metabolic activities (Brett 1979).

In conclusion, a combination of less than optimal habitat and stressful biotic conditions in Fort Whyte Lakes 3 and 4 resulted in poor returns in 1983 of age YOY and 1+ walleye stocked as fry and fingerlings in 1982. Increased pike predation probably decimated the small fingerling introductions into Lake 4.

General Conclusions

Results indicate that consideration should be given to fry stocking as the most economical program, yielding the greatest return per unit of effort (time and manpower) despite lower survival. While stocking densities must be high to counter low survival, the availability of walleye spawn and the state of walleye hatchery technology makes high stocking densities practical. High fingerling stocking densities are harder to achieve and are more impractical due to the limitations of pond production. Additionally, rearing area may be limiting for fingerling production programs of a scale large enough to affect a major walleye fishery. Perhaps walleye fry stocking would be the most valuable approach in supplementing larger stocks, experiencing severe exploitation and limited reproduction, while stocking fingerling walleyes may be the most beneficial in introductory and supplementary approaches in smaller bodies of water.

While there is some evidence for increased survival of autumn plants at larger sizes, results are far from conclusive. Clearly, more work is required to determine the contributions of timing and size of fingerling walleye at stocking to over-winter survival.

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APPENDIX 1

Marking Experiment

On June 16, 1983 four of seven yearling plant walleyes (151-207 mm TL) and five of eleven fry plant walleyes (89-99 mm TL) were Carlin tagged to determine marking mortality. Unmarked fish were held as controls along with marked individuals in a 560 litre tank at a water temperature of 20o C. No mortalities were observed until June 20, 1983. On that date 3 marked and 3 unmarked fry plant mortalities were discovered. It was then discovered that the water flow had been interrupted for approximately 17 hours and the experiment was terminated. Consequently, the duration of the experiment was four days, and no yearling plant mortalities (marked or unmarked) were observed. Survivors were released back into Fort Whyte Lake 3.

A 2x2 contingency table was constructed for each of the fry and yearling walleye categories and are as follows;

FRY

	survived	died	
marked	2	3	5
unmarked.	3	3	6

YEARLINGS

	survived	died	
marked	4	0	4
unmarked	3	0	3

Because cell size in all cases was less than five, the Fisher-Yates (nonparametric) test of significance in 2x2 contingency tables (Conover 1971) was used to test the hypothesis of similar mortality in marked and unmarked fry plant and yearling walleye plant categories. Significance levels were P=0.61 for the fry plant walleyes and P=1.0 for the yearling plant walleyes. Both values are strongly non-significant indicating that no evidence can be inferred for differences in mortality between marked and unmarked walleyes in either category.

The high mortality of fry plant walleyes is attributed to reduced water flows in the holding tanks. Water flow may be critical in holding walleye as Nickum (1978) found water exchange rates of less than two per hour unsatisfactory. While Huh et al. (1976), found that one exchange per 7.3 hours had no adverse affect, the fact that water from highly eutrophic Lake 1 (Loadman 1980) was utilized for this experiment could perhaps have necessitated a higher exchange rate than was possible with the system present. For this reason as well as the small number of classes, no significant mortality could be attributed to Carlin tagging of the smaller fry plant or the larger yearling plant walleyes in Fort Whyte Lake 3 in 1983.

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