

THE UNIVERSITY OF MANITOBA

A Comparison of Yellow Perch, Walleye, and  
Northern Pike Population Characteristics  
in Two Saline-Eutrophic Lakes of  
Southwestern Manitoba

by

Glen Edward Hopky

A Thesis

Submitted to The Faculty of Graduate Studies  
in Partial Fulfillment of the Requirements for the Degree  
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## ABSTRACT

Lake trophy and fish population characteristics were studied in two small saline lakes in southwestern Manitoba during the 1978 and 1979 open-water periods. Greater eutrophy in St. Dalmas Lake (area = 61.3 ha; T.D.S. = 2183 mg.l<sup>-1</sup>) compared to S. Thomas Lake (area = 79.2 ha; T.D.S. = 1390 mg.l<sup>-1</sup>) was related to highly localized edaphic conditions. A higher mean annual chlorophyll-a concentration and zooplankton biomass was observed in St. Dalmas.

Consistent with lake trophic differences, the pooled abundance or biomass of the principal fish species in St. Dalmas (yellow perch Perca flavescens, and walleye Stizostedion vitreum vitreum) was greater than that of those in S. Thomas (northern pike Esox lucius, yellow perch and walleye). Perch predominated in both lakes, but their relative abundance and biomass was greater in St. Dalmas. Mark and recapture experiments showed greater walleye biomass (10.7 kg/ha) in St. Dalmas than the biomass of either S. Thomas walleye (0.9 kg/ha) or pike (5.5 kg/ha). These estimates are comparable to mean values reported for non-saline lake populations. A more diverse piscine community was observed in S. Thomas.

There were relatively more older perch in the S. Thomas samples. Numbers of perch year classes required to comprise ~85% of the S. Thomas and St. Dalmas samples were six and two, respectively, demonstrating more variable year

class recruitment in St. Dalmas perch. The S. Thomas walleye population was dominated (93.8%) by the 1977 and 1973 year classes. Conversely, in St. Dalmas there was less variable year class recruitment with the population dominated by individuals from a number of older (<1973) year classes.

Perch fry grew faster in St. Dalmas than S. Thomas in 1978 and 1979. Growth histories, back-calculated from scales, showed that St. Dalmas perch were longer and heavier at all ages, but post age 2-3 their growth rates were relatively less than S. Thomas perch. Year-class growth fluctuated more in St. Dalmas perch. S. Thomas female perch, at any given age post age 4, showed a decline in mean back-calculated length with progressively younger year classes. Back-calculated walleye growth histories indicated that St. Dalmas walleye were longer and heavier only up to age 2. Compared to non-saline lakes, growth in length of both perch and walleye populations was poor at age 1. With increasing age perch growth fell below average while walleye growth was average.

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## INTRODUCTION

The coolwater, or percid community (Ryder and Kerr 1978) species of perch (Perca flavescens), walleye (Stizostedion vitreum vitreum), and northern pike (Esox lucius) are sympatric throughout much of North America (Scott and Crossman 1973). Although extensively studied, there is comparatively little information regarding their population biology in the saline lakes so common to the western prairies (Rawson and Moore 1944; Kerekes and Nursall 1966; Barica 1978). Their commercial harvest and regional distribution in different sized saline Saskatchewan lakes was discussed by Rawson and Moore (1944). Rawson (1956) noted that walleye growth in three large ( $>10\text{km}^2$ ) saline lakes was better than that of non-saline Lac la Ronge, Saskatchewan.

The community structure and population characteristics of fishes are determined by the independent and combined influence of various abiotic and biotic factors. Biotic factors, or interactions mediated primarily by competition and predation for food resources (Weatherley 1972; MacLean and Magnuson 1977), affects abundance and/or growth (e.g. Lawler 1965; Forney 1976; Johnson and Hale 1977; Nielson 1980). Abiotic influences, particularly on fish abundance or biomass, have long been of interest (e.g. Rawson 1952; Moyle 1956; Ryder et al. 1974; Schupp 1978). Research on this latter aspect has focused on soft water lakes and there is a need for comparable studies in saline lakes (Regier and Henderson 1973).

Large numbers of such lakes are located in the Erickson-Elphinstone region of southwest Manitoba. Despite their regional proximity and physical similarity - small (<100ha), shallow (<10m) and landlocked (Fedoruk 1971) - they show wide variation in salinity levels (Barica 1978). Additionally, studies (Barica 1975, 1978) on a sub-group of these lakes - those that winterkill and thus contain no indigenous fish populations - have shown that they differ greatly in productivity. In this context, comparison of somewhat larger and deeper non-winterkill saline lakes of the region, containing indigenous fishes, would be of value.

This study's purpose was to describe the abundance, biomass, and age composition and growth of these three coolwater species in two such lakes, Saint Dalmas and South Thomas, which are in close physical proximity and superficially similar. Limnological variables were measured and lake trophic status determined. Total fish abundance and biomass was related to abiotic and biotic conditions prevailing in each lake and differences in community structure evaluated. Species-specific population characteristics were compared and where possible, related to prevailing abiotic and biotic conditions.

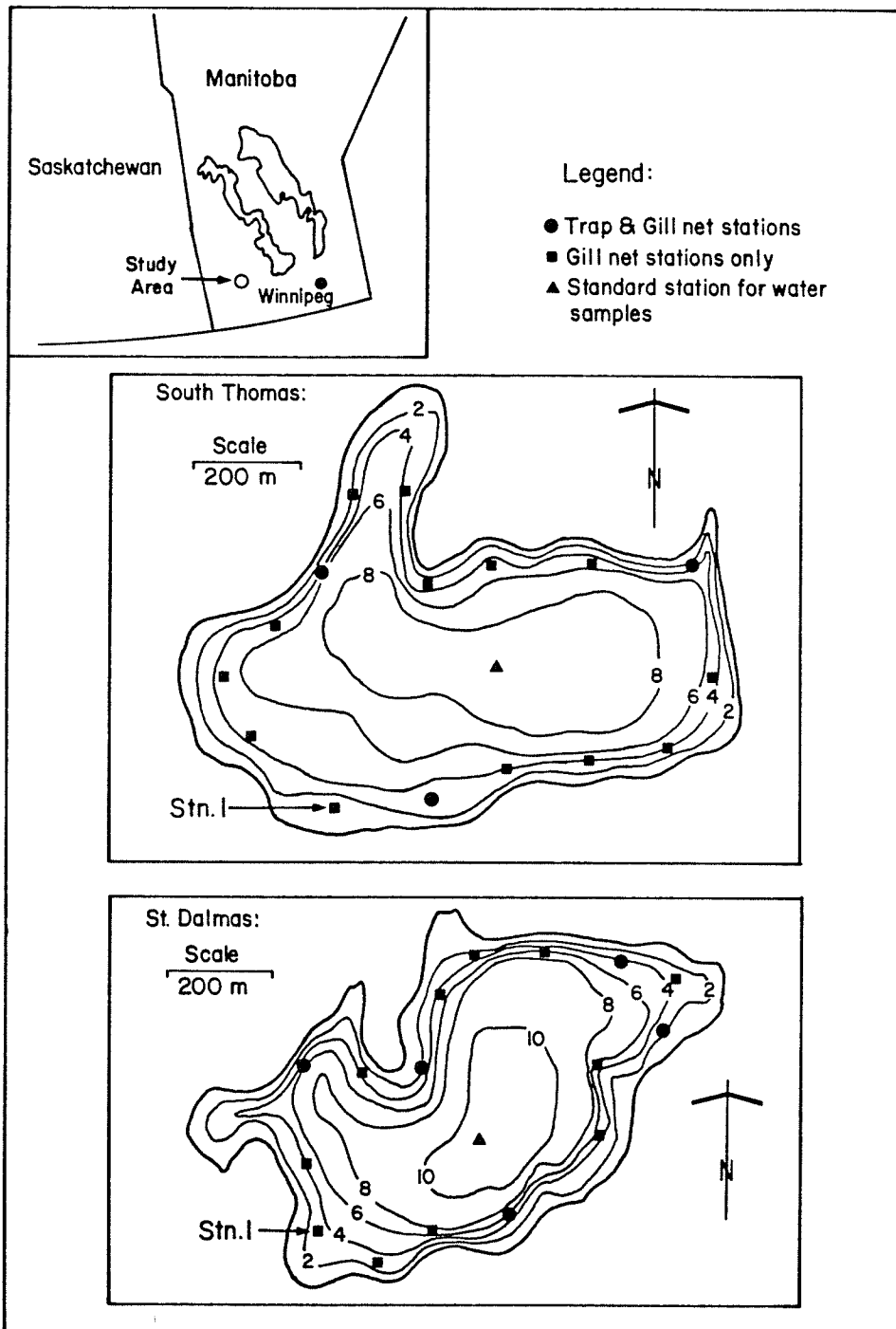
## METHODS

### Lake Limnology:

Water samples for chemical analyses were collected biweekly from June 24, 1978 to October 22, 1978, and from April 7, 1979 to September 12, 1979, at a standard station in the deepest region of each lake (Fig. 1). A standard range of depths were sampled using a 1 l van Dorn bottle. Cooled samples were sent to the Freshwater Institute in Winnipeg for analysis (Stainton et. al. 1977). Secchi disc, and temperature and oxygen profiles were measured at the standard station (Fig. 1), usually on a weekly basis during the above periods. In 1978 oxygen levels were determined using the modified Winkler method (APHA 1965), and temperatures determined with a Y.S.I. electric thermometer. Oxygen and temperature profiles in 1979 were measured using a Y.S.I. Model 54 meter. Prior to use, the meter was calibrated to 100% oxygen saturation. Contour maps, and lake morphometry were established from echograms made with a Furuno M602 echo sounder. In both years, zooplankton samples were collected with an integrated sampler, three times at approximately four week intervals from early July to late August. Samples were filtered through a 73 $\mu$  screen and weighed ( $\pm 0.01$ g), with results expressed as wet weight per litre sampled.



Figure 1. Location of study area in western Canada, and bathymetric maps of study lakes. Fish sampling stations, starting at 'Stn. 1' and proceeding clockwise, are shown.



### Fish Populations:

Perch young of the year were sampled biweekly, from mid-July to late August in 1978 and 1979, using a beach seine (30 x 2m, 0.7cm stretch mesh). Throughout 1979 perch fry relative abundance was estimated by collecting the entire catch, then volumetrically estimating total number by counting a subsample of specified volume. Samples were preserved in 5% formalin, and in September 1979, a random subsample from each collection date was measured for fork length ( $\pm 1\text{mm}$ ) and weight ( $\pm 0.01\text{g}$ ).

Lake size and logistic constraints precluded absolute estimates of perch abundance. Therefore, it was evaluated with relative indices. In 1978, from June 21 to August 26, relative abundance was based on catch per unit effort (C.P.U.E.) of trap net (2.4x1.5x1.5m box, 2.4x30m lead) catches, and expressed as total number caught per trap net hour from each net lift. Catches were periodically sampled for fork length-frequency distributions. Fishing locations were randomly selected, but site availability was limited, particularly on S. Thomas (Fig. 1). Except for the June 29 - July 6 period, trap effort was alternated between lakes on a weekly basis. Trap fishing depth varied from 3 to 7m, depending on the station, and set duration was generally 24 hours.

In 1979, indices of abundance and biomass were estimated by standard nylon multifilament gill nets with randomly arranged panels of: 2.54-3.81-5.08-6.35cm stretch measure, with each panel 15.3m long and 2m deep.

Two gear types were used to estimate relative abundance for a number of reasons: There was limited site availability for efficient and random setting of the large trap nets used in 1978. Traps were impractical in adverse weather, and subject to tampering by the public. In order to confidently assess relative differences in population abundance large sample sizes (i.e. sets) are desirable (Eberhardt 1978). Gill nets, with their higher mobility and lower effort required per set, when compared to traps, were better suited for this purpose.

The 1979 C.P.U.E. results were expressed as number and biomass (kg) per standard gill net hour, for individual gill net catches. Wherever possible, each set's entire catch was sampled for fork lengths (mm) and converted to weight using a non sex-specific weight-length relationship. Otherwise, total catch weight was recorded. All gill net sets from June and July were made parallel to shore in the littoral zone (<4m), while August sets were at right angles from shore. Duration of sets was approximately one hour .

The total number of gill net sets made from June 5 to August 30 was 168: 86 on St. Dalmas, and 82 on S. Thomas. Simultaneous sets were not possible. Therefore, in an attempt to minimize variation due to fishing the lakes at different times, a sampling experiment was designed, and from the above total number of sets, 69 from St. Dalmas and 69 from S. Thomas were made as follows:

A sampling PERIOD consisted of two consecutive days, with each of the days divided into an am (~8:00-13:00 hrs) and pm (~13:00-18:00 hrs) unit. These am and pm units were designated as the TIME variable. On the first day of a sampling PERIOD, one LAKE was fished in the am and the other in the pm, with reversal of the sequence on the second day. Each LAKE was divided into quadrats with 4 standard stations per quadrat. Quadrat 1 consisted of stations 1-4 (Fig. 1), and so on. The net setting sequence during any one TIME unit was to randomly select a quadrat, and then randomly choose one of the four stations in that quadrat. During each TIME unit in July and August four SETS were made, one in each of the quadrats. In June, when the number of SETS per TIME unit varied from four to six, quadrats were still selected as above.

For the remaining gill net sets - St. Dalmas: 17  
S. Thomas: 13 - the lakes were also fished on adjacent two day periods; but only one lake was fished per day.

Sets were made during approximately the same time of day on each lake. Net stations were selected as above, but number of sets per lake was not always four.

Inter-lake differences in both relative abundance and relative biomass were statistically evaluated by factorial analysis of variance (SAS Users Guide PROC ANOVA; Helwig and Council 1979) using the July - August sampling experiment catch data. Both the relative abundance and relative biomass data sets were  $\log_{10}$  transformed, with each having a sample size of 96 (48 sets per lake). LAKE, TIME, and PERIOD were used as the main treatment factors, while the error term was formed from the SET variable and all its higher order interactions with the other factors. An assumption made for these analyses was that there were no significant differences in perch availability between the two fishing days within a PERIOD, within LAKES.

Approximately 50 perch per month in 1978, and 100-150 per month in 1979 were collected for age and growth analyses. They were sampled from both trap and gill nets, with about 40% of the total sample collected from trap nets, for each lake. Fish were identified by sex and measured for fork length ( $\pm 1\text{mm}$ ) and weight ( $\pm 0.1\text{g}$ ). Ovaries were excised and weighed ( $\pm 0.1\text{gr}$ ) from all females

caught during May 8-15, 1979 and from an August 28-29 subsample. Maturity indices (%) were calculated as:  $(\text{ovary weight} \div \text{total body weight}) \times 100$ . A scale sample was removed from a point below the left lateral line, above the pectoral fin.

Walleye and pike were sampled with the objectives of estimating each population's relative and absolute abundance and biomass. The relative index was based on 1978 trap catches, as described above, for the perch. Gill net gangs were also set in 1978 but on a survey basis. Individual sets varied with angle, depth, time of day (none after dark), duration (generally <1 hour), and mesh size. The standard survey gang consisted of 9m long by 2m deep 2.54-3.81-5.08-6.35-7.62-8.26 cm stretched measure multifilament nylon panels. Numbers of all three species captured in each gang were recorded.

In 1979, mark and recapture experiments of 4-5 days duration were conducted at monthly intervals from May to September in St. Dalmas, and May to August in S. Thomas, except in July when water temperatures exceeded 19 C. Trap netting was confined to the May and June periods on both lakes, with traps set at right angles to shore, at depths of 3-7m, and lifted daily. A standard multifilament nylon gill net gang composed of 5.08-6.35-7.62 cm stretched measure mesh, 45.7m long and 2m deep panels, was used

during all enumeration periods in 1979. Nets were set from 15:00-01:00 hrs, but depending on results of initial sampling within a period, effort was concentrated on different times between these hours. Sets, of 20-35 minute duration were generally made parallel to shore at depths of 2-5m. Usually two gangs were fished on each sampling day, but during the last mark-recapture period on each lake most sets were 45-60 minutes long with three gangs fished. For each period, approximately equal effort was applied with both trap and/or gill nets to each designated quatrat (Fig. 1) on a lake.

During both years walleye and pike caught in gill nets were sampled in the following manner: After removal from gill nets, fish were identified as to mesh size of capture, placed in 52ℓ tubs, and then transported to larger holding cages (3.1x2.8x2.8m) suspended in 3-4m of water. On the following morning fish were examined for condition, and their fork length measured ( $\pm$  1mm). Individually numbered Floy tags (Dell 1968) were inserted in the back below the middle of the first dorsal fin on walleye, and the dorsal fin on pike. A scale sample was removed from the walleye at a point midway between the two dorsal fins above the left lateral line. Pike scale samples were removed from a point between the dorsal fin and left lateral line. Weights ( $\pm$ 10g) were measured on all fish captured, except for 1979 St. Dalmas walleye,



which were subsampled from June 18-August 31. All tagging and sampling was conducted on the lake using a unique on-board sampling station. Trap net catches were similarly treated, except that fish were processed immediately after the trap was lifted each morning. Walleye and pike, tagged in 1978, were not used in any abundance estimates.

Tag returns and general catch information from sportsmen were encouraged by the use of radio and newspaper advertisements, and by placing information signs, with gutting tables, at each lake's landing. As well, the lakes were visited on a near daily basis throughout the summer of 1979.

Walleye abundance in St. Dalmas was estimated using the Jolly-Seber models (Jolly 1965) as implemented in Popan-2 (Arnason and Baniuk 1978). Pike abundance was not estimated in St. Dalmas, because of very small catches. S. Thomas pike and walleye abundances were estimable only for May 1979, by a Petersen single sample estimate using Chapman's modification for small sample size (Seber 1973). A binomial confidence interval (Seber 1973) was estimated for pike using charts in Clopper and Pearson (1934). For the enumeration of abundance, all walleye less than 240mm and pike less than 500mm were deleted from their respective, defined populations.

The contribution of all three species by percent abundance and biomass C.P.U.E. to the seasonal total 1978 trap net catches was used as a measure of within lake interspecific,

or 'community' composition. Mean seasonal biomass C.P.U.E. for each species was derived by multiplying the mean seasonal abundance C.P.U.E. by mean fish weight. Mean walleye and pike weight was determined directly from the total catches (total catch weight  $\div$  total number caught). For perch, mean weight was determined indirectly because total catch weights were not available. It was calculated using a non sex-specific weight-length relationship, and the mean length of the total catch. For logistic reasons perch length-frequency distributions were not available for all trap sets. Therefore, mean total catch length is an estimate based on mean lengths of representative trap net sets for which frequency distributions were available, between June 29-August 16 at approximately biweekly intervals, for both lakes.

Ages, and growth histories for perch and walleye were determined by the scale method (Carlander 1943; Jobes 1952; Joeris 1956). Scale impressions on acetate strips (Butler and Smith 1953) were magnified 45x with a Baush and Lomb projector. This method was also attempted for pike scales, but independent scale re-reading trials by myself and a professional scale reader (D. Barnes, Freshwater Insititute) were so inconsistent, that their age and growth analysis was precluded.

For perch and walleye, the radial distance from the scale focus to the peripheral edge, and to each assigned annulus, was measured in the anterior field. Scales were read twice, independent of fish length, weight, sex and first assigned age. Disagreement resulted in further re-reading. Scale samples that could not be consistently re-read or did not meet the criteria of Carlander (1961) were deleted. Ages were assigned on the basis of brood year, with approximate dates of annulus formation determined by examination of the scale's peripheral edge. For walleye, only scale samples from non-recaptured fish were used in the growth analyses.<sup>1</sup> Perch age distributions were determined by the method of Ketchen (1949), for the July 11-24, 1979 period.

Linear fork length-scale radius relationships were fitted by the method of least squares on  $\log_{10}$  transformed data (Hile 1941), using data grouped by species, collection year and lake. Covariance analysis was used to determine whether within lake, across collection year, regression equations could be pooled for each of the perch and walleye. For each species, using the appropriate relationship and the actual fork length for each individual, a theoretical scale radius was calculated (Hile 1941). This value was compared to the actual peripheral scale radius, providing a correction factor used to adjust the radicies of all measured annuli distances for that individual. Back-calculated fork lengths

were then predicted using the respective adjusted annuli radicies (Hile 1941). The equation:  $\log (L) = \log a + b \log (S)$  was used; where  $L$  = predicted fork length,  $\log a$  =  $y$  intercept,  $b$  = slope,  $S$  = adjusted scale radius  $\times 46.5$  in mm.

Weight-fork length relationships were calculated for all species by least squares regression using  $\log_{10}$  transformed data (Bagenal and Tesch 1978). The equation:  $\log (W) = \log a + b \log (L)$  was used; where  $W$  = predicted weight,  $\log a$  =  $y$  intercept,  $b$  = slope, and  $L$  = fork length in mm. Perch samples collected during different periods of the study were grouped by lake, sex and according to season and year of collection: spring 1979 (May 3-28) and summers (July 1 - August 31) of 1978 and 1979. Covariance analysis was used to compare relationships within lakes, using collection year, season and sex as treatments.

Instantaneous growth rates (Ricker 1975) of perch adults and fry were calculated as follows:

$$G = (\ln W_{t+1} - \ln W_t) \div (t+1 - t)$$

where:

$G$  = instantaneous growth in weight (g)

$W_{t+1}$  = weight at time  $t+1$

$W_t$  = weight at time  $t$

$t$  = time unit

For the adults, annual rates were calculated using mean weights predicted from back-calculated mean fork lengths. For the perch fry, daily rates were calculated using mean weights from seine captured samples.

Based on results from the perch weight-length covariance analyses, walleye and pike spring sampled weights were deleted from their respective weight-length covariance analyses. Species-specific walleye and pike relationships were compared across years within lakes. The standing crops (kg/ha) of walleye and pike were estimated as follows: the relevant abundance estimate was multiplied by the mean catch weight of that period, as determined using mean catch length and the appropriate weight-length relationship.

Prior to all covariance analyses involving either the fork length-scale radius or the weight-length regressions the specific groups involved were subjected to Bartlett's  $\chi^2$  test for homogeneity of residual variances about the independent regression lines (Steel and Torrie 1980). A significant  $\chi^2$  did not necessarily invalidate the subsequent F-test, since these tests are robust to violation of the homogeneity assumption as long as the purpose of the pooled relationship was for estimation and not the formation of confidence intervals about the estimates (A.N. Arnason pers. comm., Univ. of Man.). More importantly, when non-significant F-tests were preceded by a

significant  $\chi^2$ , then further tests were made to ensure that each regression model was, in fact, linear. For all statistical tests conducted,  $\alpha=0.05$  was the designated level of significance.

## STUDY AREA DESCRIPTION

## Lake Description and Limnology:

St. Dalmas and S. Thomas lakes are located in southwestern Manitoba at  $50^{\circ}30'N$  -  $100^{\circ}10'W$  (Fig. 1). St. Dalmas, also known as Crawford Lake, is located about 5 km due south of S. Thomas, also known as lake 613. St. Dalmas is located in the Erickson clay loam soil region, while the S. Thomas basin lies in a transition zone between the Erickson soils, and a grey wooded zone which is lower in both organic material and nutrients (Ehrlich et al. 1956). Typical of this region (Sunde and Barica 1975), the land surrounding both basins is cultivated, although S. Thomas has about 30% more wooded area along its shoreline, compared to St. Dalmas.

The lakes are landlocked and receive water input from precipitation, spring runoff and ground seepage. Surface drainage basins of both lakes are limited to their immediate periphery, but the St. Dalmas basin is larger as it receives spring, and high precipitation runoff via a stream connected to two small, nearby potholes. S. Thomas had been joined to an adjacent lake, but construction of an access path during the mid-1950's prevented further exchange.

The shoreline substrates of both lakes consist mainly of mud and silt. Unlike S. Thomas, large sections of the St. Dalmas shoreline - the eastern and north-eastern shores -

consist of rock and rubble with a gravel beach along the most north-easterly corner. The eastern end of S. Thomas consists of a sand-silt beach, and rock-rubble substrates were present only on a small section of the south-central shore.

The morphometry of both basins is quite similar (Fig. 1). Ovoid in shape, they have gently sloping sides along much of their shorelines. St. Dalmas has a greater maximum and mean depth, but occupies 23% less surface area than S. Thomas (Table 1). St. Dalmas also has a marginally larger littoral zone (Table 1). An additional difference is that the deepest region of the St. Dalmas basin is oriented such that it is not as fully exposed to the fetch of the prevailing westerly winds, as is S. Thomas (Fig. 1).

The extent of direct thermal stratification varied between lakes, and annually within lakes. S. Thomas was weakly stratified from late June to late July in 1978, and became homiothermous at 21C by late July. In 1978, St. Dalmas stratified from mid-June to mid-August, when circulation occurred at 18C. Both lakes were stratified by May 30, 1979 but S. Thomas was homiothermous at 17C in mid-August, while St. Dalmas circulated in mid-September at 14.5C. For both lakes, the epilimnion descended from 5 to 7m during the 1979 period of maximum stratification. During this same period mean epilimnion and hypolimnion temperatures for St. Dalmas



Table 1. Morphometric features of St. Dalmas and S. Thomas lakes.

Variable	Unit	Lake	
		St. Dalmas	S. Thomas
Area	ha	61.3	79.2
Volume	m <sup>3</sup>	3.63 x 10 <sup>6</sup>	4.30 x 10 <sup>6</sup>
Maximum length	km	1.31	1.31
Maximum width	km	0.77	1.04
Maximum depth	m	10	8
Mean depth	m	5.9	5.4
Littoral zone ( $\leq 4\text{m}$ )	%	34	29
Shoreline length	km	4.04	4.38

were 22.5 and 8.9C, respectively. Comparable values for S. Thomas were 22.9 and 12.6C, respectively. Maximum surface temperature of 25.0C was observed on both lakes during the week of July 8-13, 1979.

Seasonal variations in oxygen concentrations were related to the degree of stratification. While dissolved oxygen in the hypolimnia of both lakes decreased to anoxic levels during the 1979 stratification period, only St. Dalmas developed an anoxic hypolimnion in 1978. Prior to the disappearance of ice on May 19-21, 1979, oxygen levels of  $4.0 \text{ g.m}^{-3}$  and less were observed in the bottom 7 and 2m, of St. Dalmas and S. Thomas, respectively.

A summary of physical and chemical variables (Table 2) showed that the lakes have an alkaline pH and are highly saline, as indicated by either TDS or conductivity. TDS values were marginally lower than conductivity (Table 2), as would be expected, since  $\text{CO}_2$  is lost in the measurement of TDS, but not conductivity (Wetzel 1975). However, the two variables are essentially equivalent measures of total salinity (Ryder et al. 1974; Barica 1975). Levels of most dissolved nutrients were higher in St. Dalmas, as were TDS and conductivity (Table 2). Unlike the nutrients, levels of the latter two variables showed little seasonal or annual variation.

Mean annual chlorophyll-a levels were higher in St. Dalmas (Table 2). Algal blooms were observed in St. Dalmas

Table 2. Annual mean values of physical and chemical variables for St. Dalmas and S. Thomas, from June 1978 to June 1979.

Variable	Units	St. Dalmas	S. Thomas
Chlorophyll-a	mg.m <sup>-3</sup>	10.12	7.66
Secchi disk	m	2.81	3.30
Oxygen	g.m <sup>-3</sup>	6.87	8.12
Temperature	°C	11.25	11.70
pH		8.80	8.73
Total dissolved solids	mg.l <sup>-1</sup>	2183	1390
Conductivity	µmhos.cm <sup>-1</sup>	2401	1422
Suspended carbon	mg.m <sup>-3</sup>	1534	1211
Total dissolved phosphorus	mg.m <sup>-3</sup>	34.75	20.90
Suspended phosphorus	mg.m <sup>-3</sup>	18.65	18.48
Soluble reactive phosphorus	mg.m <sup>-3</sup>	15.87	8.98
Total dissolved nitrogen	mg.m <sup>-3</sup>	1576	1375
Ammonia	mg.m <sup>-3</sup>	147.81	88.71
Nitrate	mg.m <sup>-3</sup>	37.61	66.94
Suspended nitrogen	mg.m <sup>-3</sup>	184.45	193.13

in early July, and late August to September, 1978. The only major bloom on S. Thomas occurred in May 1979, prior to, and after ice-out. Secchi disc, temperature and oxygen values were lower in St. Dalmas (Table 2).

The conductivity values measured here (Table 2) agree closely with those found by Barica (1978), from a sample collected in the early 1970's. An earlier sample in 1963 (Driver 1965) showed a TDS level of  $10,311 \text{ mg.l}^{-1}$  for St. Dalmas. Reasons for the discrepancy between this value, and the more recent ones are not known. Lake morphometry, oxygen, temperature, and pH conditions reported by Driver (1965) for St. Dalmas, are comparable to those found here.

#### Zooplankton:

Zooplankton biomass<sup>2</sup> was greater in St. Dalmas:

Lake	Year	Annual Mean (g/l)	Grand Mean (g/l)
S. Thomas	1978	0.0042	0.007
	1979	0.0104	
St. Dalmas	1978	0.0136	0.013
	1979	0.0115	

In 1978, 1979 and overall, St. Dalmas zooplankton biomass was 3.3, 1.1, and 1.9 times greater, respectively, than in S.

Thomas. Within lakes, S. Thomas 1978 zooplankton biomass was 0.5 times less than in 1979; while in St. Dalmas 1978 biomass was 1.2 times greater than in 1979.

#### Fish Fauna:

In addition to the perch, walleye and pike, other species present in both lakes are: fathead minnows (Pimephales promelas Rafinesque), brook stickleback (Culaea inconstans Kirtland), and Iowa darters (Etheostoma exile Girard). Present only in S. Thomas are the blacknose shiner (Notropis heterolepis Eigenmann and Eigenmann) and burbot (Lota lota Linnaeus). Only two burbot were captured. Excluding burbot, these fish are referred to as forage species.

The relative abundance of forage species was assessed on a survey basis only. On August 8 and 9, 1979, 19 minnow traps per day were simultaneously set around each lake's circumference, for 24 hours, in 1-3m of water; and on August 8, 2 seine hauls per lake in which all species captured were counted, were made (Table 3). Forage species, in either gear, were more abundant in S. Thomas, while the seine catches showed they were less abundant than perch in either lake. This latter result is consistent with observed catches in other seine samplings. In addition, standard trap nets set in S. Thomas on June 28, 1978, and June 27 and July 5, 1979 each captured large numbers of blacknose shiners, generally gilled in the mesh.

Table 3. Numbers of fish caught in St. Dalmas and S. Thomas by minnow traps and seines on August 8-9, and August 8, 1979, respectively; with percent in parenthesis for seine catches.

Species	Minnow Trap <sup>a</sup>		Seine	
	St. Dalmas	S. Thomas	St. Dalmas	S. Thomas
Perch	5 <sup>b</sup>	15 <sup>b</sup>	1816 (96)	363 (80)
Stickleback	6	95	19 (1)	32 (7)
Iowa darter	4	12	15 (1)	27 (6)
Fathead minnow	9	2	42 (2)	14 (3)
Blacknose shiner	-	0	-	17 (4)
Totals	24	124	1892	453

a. Not included are 0 and 13 crayfish, for St. Dalmas and S. Thomas, respectively.

b. St. Dalmas - 0<sup>+</sup> only perch were caught; S. Thomas - 0<sup>+</sup> and 1<sup>+</sup> perch were caught.

Walleye were the principal sport fish captured in spring and late summer in St. Dalmas, whereas pike dominated catches in S. Thomas. The latter were caught regularly from spring to mid-summer. Perch were readily available in both lakes, particularly in St. Dalmas. Both lakes have a long record of walleye stocking for sport fishing purposes (Anon. 1979). Since S. Thomas became an independent basin the only stocking was of 169,000 fry in 1969. St. Dalmas was regularly stocked from the 1930's to 1955, and once again in May 1972 when 846 fingerlings were released.

Provincial authorities have used St. Dalmas as a source of live perch for re-stocking in other lakes. Between 1969 and 1979 an average of 16,730 perch per year were removed (B. Thomas pers. comm., Man. Dept. Nat. Res.). Removals were made on a demand rather than supply basis, so annual data did not reflect relative perch availability.

## RESULTS

### Perch Populations:

#### Indices of Abundance and Biomass:

Results from standard seine samples in 1979 indicated that perch fry were more abundant in St. Dalmas (Fig. 2). There was a marked seasonal variation in the C.P.U.E. ratio St. Dalmas: S. Thomas, but it was always greater than 1:1 (mean ratio=17:1). Number caught per seine varied more for St. Dalmas than S. Thomas (Fig. 2).

Relative abundance of perch, based on C.P.U.E. in trap net catches was higher in St. Dalmas throughout the 1978 sampling season (Fig. 3). No consistent trend in catchability was observed, but both lake's catches increased during mid-summer then declined by August. Trap net catch results from sampling each lake on alternate weeks were compatible with the observed difference during the week of simultaneous sampling, June 29-July 6. The mean seasonal C.P.U.E., with total numbers of catch, trap net hours, and sets in brackets, were St. Dalmas - 23.780 (6996, 337.2, 14) and S. Thomas - 3.595 (1966, 611.8, 21), with a mean seasonal C.P.U.E. ratio St. Dalmas: S. Thomas of 6.6:1.

As measured by standard gill nets, relative abundance of St. Dalmas perch was consistently higher in 1979 (Fig. 4), except in mid-June when erratic fluctuations in C.P.U.E.



Figure 2. Seasonal C.P.U.E. ratio (Number/seine St. Dalmás: Number/seine S. Thomas) for perch fry sampled from standard seine hauls in 1979. In brackets: (Number/seine St. Dalmás, Number/seine S. Thomas).

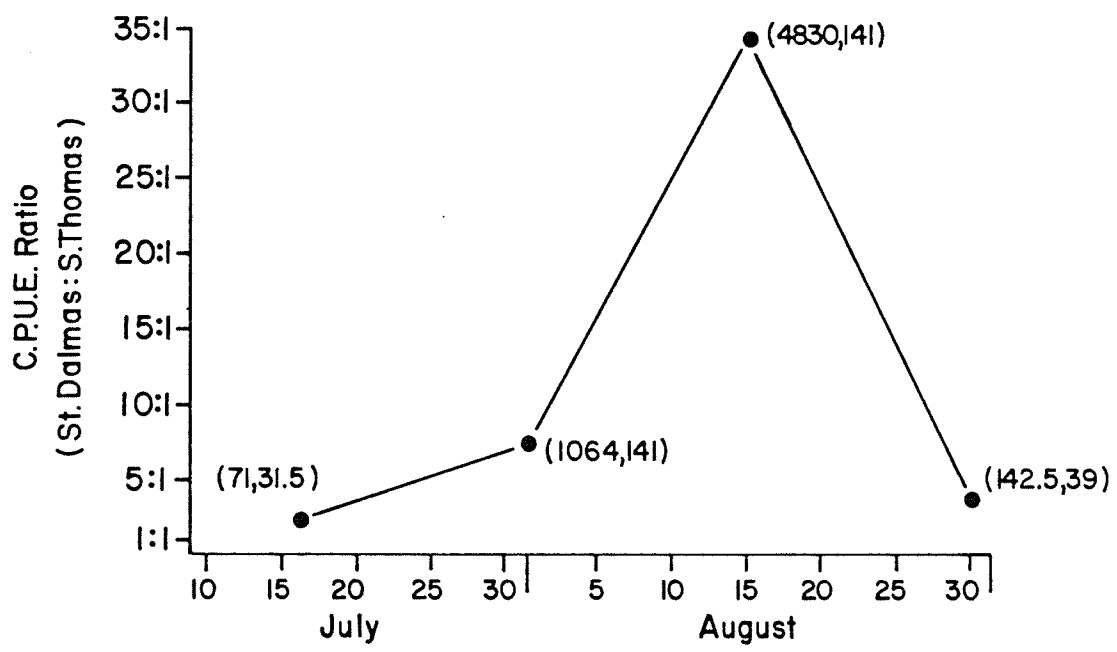


Figure 3. Perch mean abundance C.P.U.E., by period,  
for 1978 trap net catches, from St. Dalmas  
(○—○) and S. Thomas (△--△). In brackets:  
(Number caught, number of sets). Dates are  
mid-points of sampling periods.

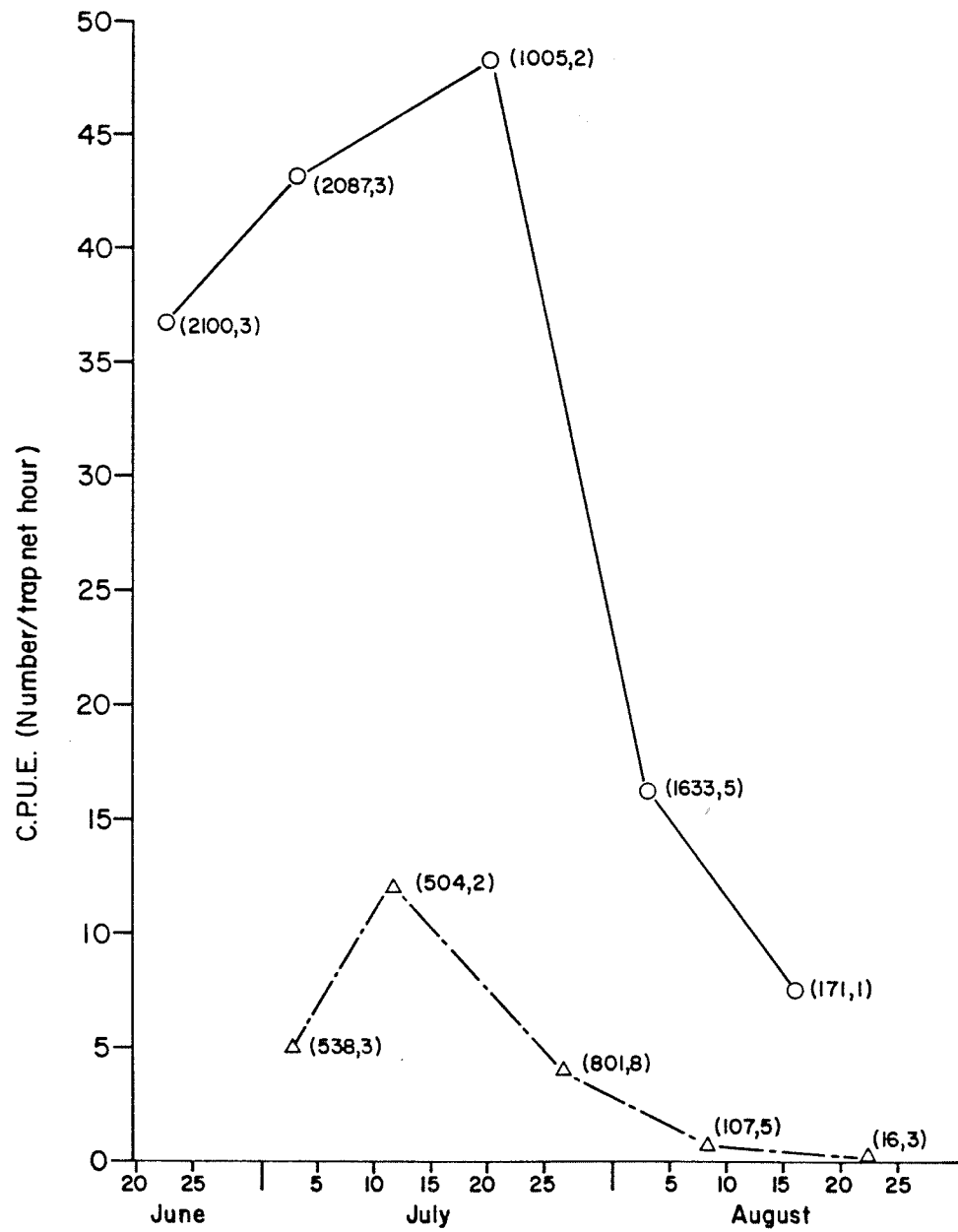
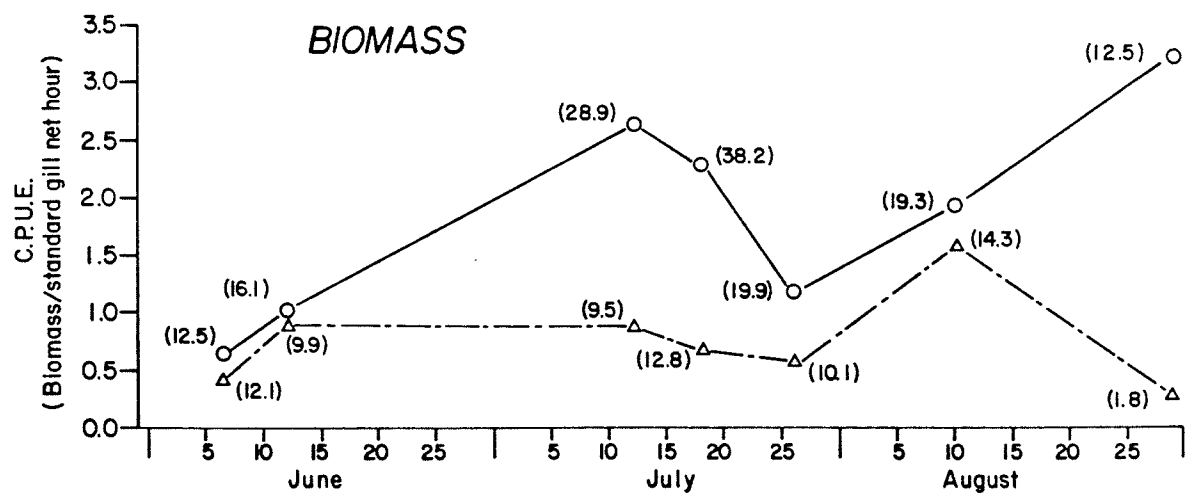
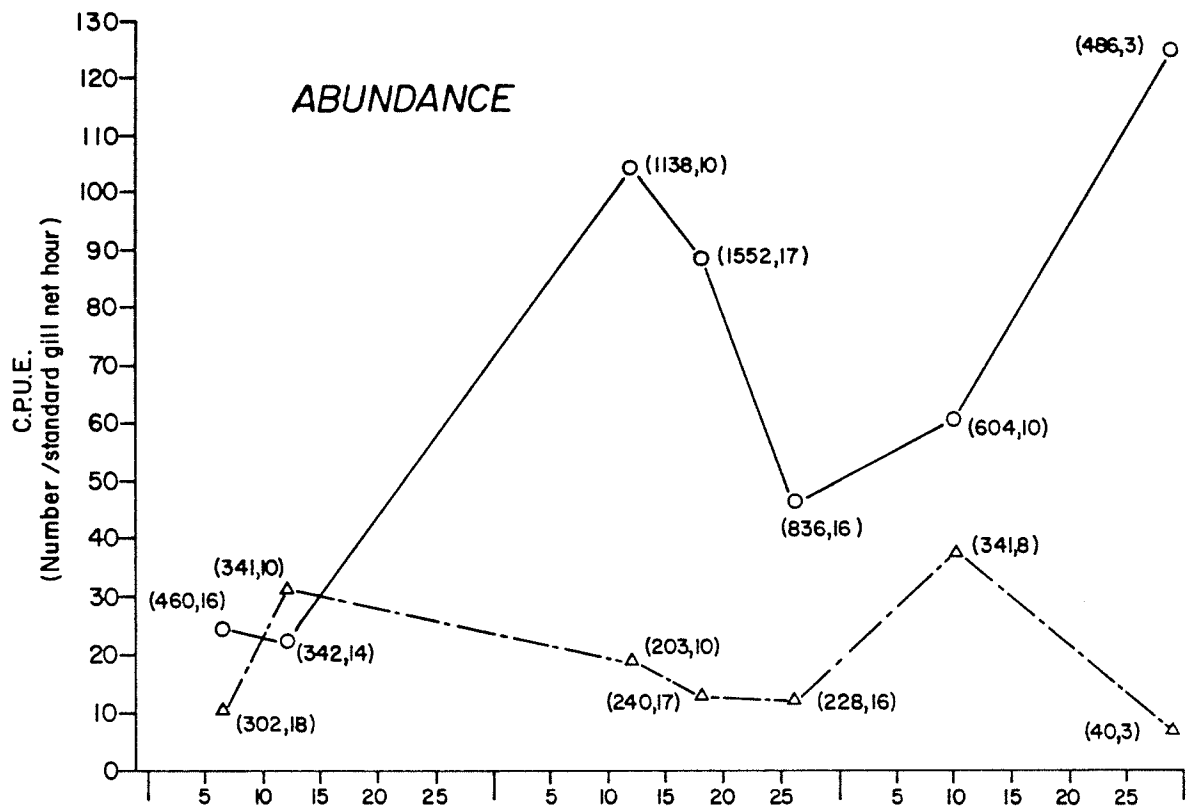


Figure 4. Perch mean abundance and mean biomass (kg ) C.P.U.E. from gill nets fished in 1979, for St. Dalmas (○—○), and S. Thomas (△---△). In brackets, for abundance: (Number caught, number of sets), and biomass: (Biomass caught). Dates are mid-points of sampling periods.



were observed on both lakes. By mid-July, St. Dalmas C.P.U.E. increased dramatically, and then catches on both lakes declined only to increase again by mid-August (Fig. 4). The higher abundance C.P.U.E. on June 11-14 in S. Thomas (Fig. 4) resulted from an unusually high proportion of smaller perch (relative to that in other sets during the summer) caught in just one of the 10 gill net sets that week. Of 224 perch - of the week's total of 341 - in this single set, 67% were less than 120mm, compared to the summer average of ~30%. Biomass C.P.U.E. results were comparable to those for relative abundance, and showed the same seasonal fluctuations, except during the June 11-14 period (Fig. 4).

The extent of the larger relative abundance and biomass in St. Dalmas was shown by the arithmetic monthly and total seasonal C.P.U.E. means, and ratios St. Dalmas:S. Thomas (Table 4). Total seasonal C.P.U.E. ratios for relative abundance and biomass were 3.1:1 and 2.2:1 respectively, while on a monthly basis, only the June ratios approximated 1:1 (Table 4).

Results of the factorial ANOVA of log transformed C.P.U.E. data, from sets made during the sampling experiment (July 11 to August 10), indicated LAKE differences for both relative log abundance (d.f. 1 72,  $F=14.33$ ,  $p<0.001$ ) and relative log biomass (d.f. 1 72,  $F=5.90$ ,  $p=0.018$ ). There

Table 4. Monthly, and seasonal total summary of 1979 perch gill net catches from St. Dalmas and S. Thomas. Shown are the mean abundance and mean biomass C.P.U.E. values, the coefficients of variation (C.V.%) and the respective C.P.U.E. ratios St. Dalmas:S. Thomas.

Month	Lake	Number of Sets	Number of Hours	Abundance				Biomass (kg)			
				Number Caught	Mean C.P.U.E.	C.V. (%)	Ratio	Biomass Caught	Mean C.P.U.E.	C.V. (%)	Ratio
June											
	St. Dalmas	30	32.2	802	23.4	263	1.3:1	28.56	0.83	263	1.3:1
	S. Thomas	28	36.8	643	18.7	209		21.94	0.62	163	
July											
	St. Dalmas	43	46.8	3526	76.4	97	5.4:1	88.17	1.96	106	2.8:1
	S. Thomas	43	47.7	671	14.2	66		32.95	0.70	68	
August											
	St. Dalmas	13	13.9	1090	75.2	103	2.6:1	31.80	2.22	89	1.8:1
	S. Thomas	11	15.1	381	29.3	104		16.15	1.25	129	
Total											
	St. Dalmas	86	92.9	5418	57.8	129	3.1:1	148.53	1.61	134	2.2:1
	S. Thomas	82	99.6	1695	17.7	148		71.04	0.75	121	



were no significant PERIOD differences (log abundance: d.f. 5 72,  $F=1.06$ ,  $p=0.391$ ; log biomass: d.f. 5 72,  $F=1.33$ ,  $p=0.262$ ); and LAKE differences were observed over all PERIODS for relative log abundance (PERIOD\*LAKE interaction: d.f. 5 72,  $F=0.66$ ,  $p>0.500$ ) and relative log biomass (PERIOD\*LAKE interaction: d.f. 5 72,  $F=0.45$ ,  $p>0.500$ ).<sup>3</sup>

Log biomass C.P.U.E. differences were less significant than those for log abundance. This result, and the smaller arithmetic biomass ratios than those for abundance (Table 4) indicated that although on a per unit effort basis, more fish were caught in St. Dalmas, the mean weight of individual fish was less than those caught in S. Thomas. The lower weight per fish reduced the extent of C.P.U.E. biomass differences between lakes.

Perch, with catches pooled over both LAKES, were equally catchable in either the am or pm (TIME: d.f. 1 72,  $F=0.23$ ,  $p>0.500$ ), regardless of PERIOD fished (PERIOD\*TIME interaction: d.f. 5 72,  $F=0.56$ ,  $p>0.500$ ). Thus, during the experiment, TIME of day fished had no effect on catch size. More important, perch within each LAKE had the same relative catchability regardless of time (LAKE\*TIME interaction: d.f. 5 72,  $F=2.42$ ,  $p=0.124$ ), over all PERIODS (LAKE\*TIME\*PERIOD interaction: d.f. 5 72,  $F=1.48$ ,  $p=0.206$ ).<sup>4</sup> These latter tests lend support to the critical assumption that

3. Appendix C<sub>I</sub>

4. Appendix C<sub>I</sub>

the experimental sampling design would be essentially equivalent to fishing the lakes simultaneously. A significant LAKE\*TIME effect would have indicated that some of the observed C.P.U.E. differences may have been attributable to temporal variation resulting from non-simultaneous fishing of the lakes.

Subsequent analyses of log abundance C.P.U.E. data suggested the absence of catch differences between all parallel July sets and all right angle sets made in August, within each LAKE (ANGLE: d.f.1 106,  $F=1.94$ ,  $p=0.167$ ; LAKE\*ANGLE interaction: d.f.1 106,  $F=0.06$ ,  $p>0.500$ ), although the analysis was confounded by a seasonal effect.<sup>5</sup>

The coefficients of variation, calculated on the mean abundance and mean biomass C.P.U.E. data, from June through August (Table 4) indicated greater variation about the means of St. Dalmas catches, particularly during June. This was consistent with observed field results where on a set-to-set basis, catch size varied more on St. Dalmas than S. Thomas. For example, the maximum range of number caught in consecutive sets was as large as 373 fish in St. Dalmas, while only 192 fish in S. Thomas. Additionally, there were a total of 13 empty net sets in St. Dalmas: ten in June, two in July, and one in August; but only five in S. Thomas, all in June.

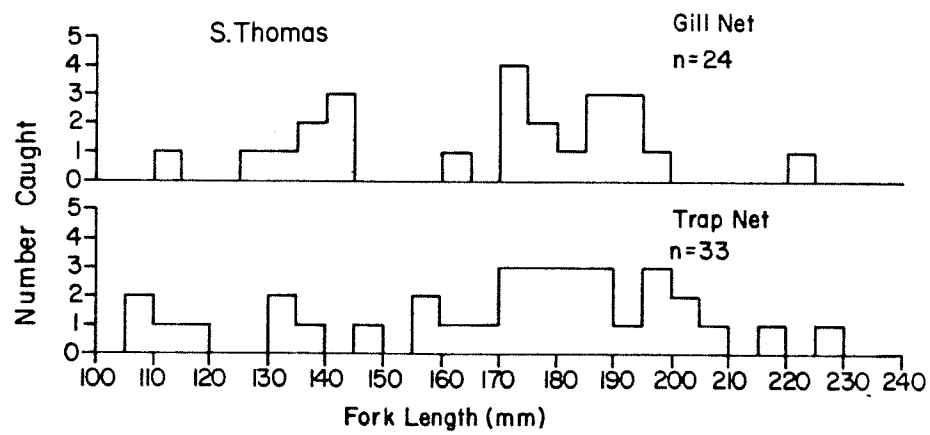
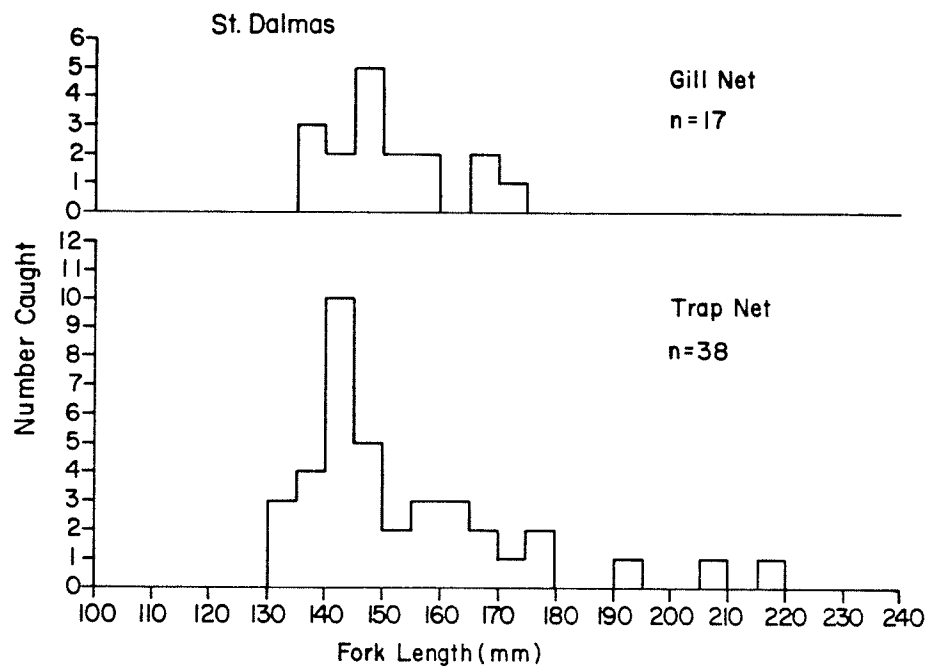
Even during the time of greatest relative abundance differences in July (Table 4), there were still empty net sets in St. Dalmas.

#### Spawning Activity:

In 1979, egg strands from female perch were first observed in St. Dalmas on May 23 (surface water temperature: 7.5 C). S. Thomas was not sampled between May 18-27, but on May 28 (surface water temperature: 10 C) both ripe and spent females were observed in equal proportions. Therefore, spawning activity probably began in both lakes at approximately the same time, in late May. Daily sampling of both lakes from June 5-15 indicated that by June 7, most spawning activity was completed, but mature perch were caught as late as June 12.

The maturity indices of females caught during May 8-15, were similar ( $p > 0.500$ , Student's t-test): St. Dalmas (mean = 20.7%,  $n = 56$ ), S. Thomas (mean = 21.0%,  $n = 57$ ). However, the catch distributions were quite different (Fig. 5), with the pooled mean length ( $\pm$ S.D.) of St. Dalmas females (153.8 $\pm$ 17.3mm) smaller than S. Thomas females (171.5 $\pm$ 29.1mm). Maturity indices for the August 28-29 samples were different ( $p = 0.005$ , Student's t-test): St. Dalmas (mean = 2.4%,  $n = 26$ ), S. Thomas (mean = 2.0%,  $n = 26$ ).

Figure 5. Fork length-frequency distributions of all mature female perch caught by gill and trap nets, in St. Dalmas and S. Thomas during May 8-15, 1979 prior to spawning.



May, 1979 samples indicated that both S. Thomas male and female perch matured at age 3, with mean sample lengths of 92 and 113mm, respectively. In St. Dalmas, mature age 2 males (mean length = 91mm) and age 4 females (mean length = 149mm) were sampled in May. The August 28-29 St. Dalmas samples had maturing female perch of age 3 (mean length = 114mm). This was probably the true age of female maturity, and the complete absence of age 3 females and males from May catches was, as will be shown, due to weakness of the specific year class (that is, the 1976 year class).

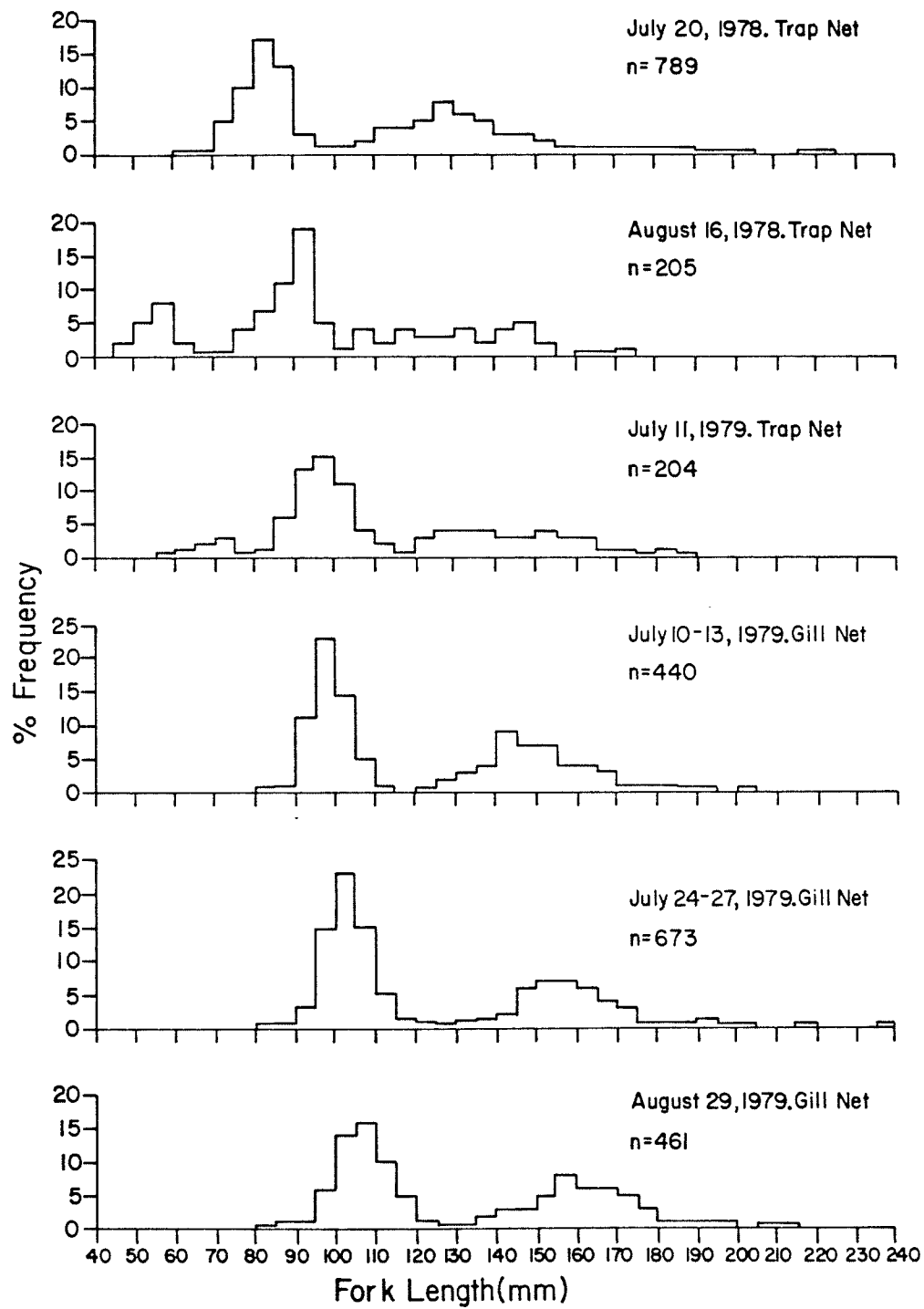
#### Age and Growth:

#### Length and Age Distributions:

Results from trap and gill net catches showed that the length-frequency distributions of St. Dalmas perch were dominated by two modes (Fig. 6). With respect to the July 20, 1978 frequency distribution, these were the 70-95 and 115-150mm groups (Fig. 6). Each group's progressive movement to a larger size reflected growth in length. For example, the former mode shifted from a mean of 80 to 107mm between July 20, 1978 and August 29, 1979 (Fig. 6).

For any given period, aging of scale samples indicated that these two modes consisted of identifiable year class groups. Virtually all perch sampled from the smaller of the two modes were aged to the 1977 year class, while perch of the 1975 year class were dominant in samples from the largest frequency mode. Perch from other year classes were

Figure 6. Fork length-frequency distributions for St. Dalmas perch from trap and gill net catches in 1978 and 1979.





sampled only from the leading (1974 year class) and trailing (1976 year class) edges of this larger mode. The proportional contribution of each of the two modes, to each period's total catch, was relatively constant throughout the study (Fig. 6).

By mid-August, 1978 a third mode consisting of perch less than 65mm long first appeared in the trap catches (Fig. 6). It was also present, but proportionally smaller in the July 11, 1979 trap net catch. This was the 1978 year class, as shown by scale samples collected in both years. Although present in the July 11, 1979 trap net catch, this year class was not observed in the 1979 gill net catches until the third week of July, when they formed part of the 1977 year class mode's trailing edge.

The absence of perch less than 80-90mm long in the 1979 gill net catches (Fig. 6) resulted from differences in trap and gill net selectivity. This was evident from comparison of the July 10-13, 1979 gill net catch distribution, where fish less than 80mm long were absent, with the July 11, 1979 trap net catch distribution in which 50-80mm perch were present (Fig. 6). Seine catches during mid-July also contained large numbers of 50-80mm long perch. Therefore, St. Dalmas perch were not recruited into gill nets until 80-90mm in length. However, at any given size larger than 90mm the gill net catch distribution from this period was similar in proportion to that observed in the corresponding trap net catch (Fig. 6).

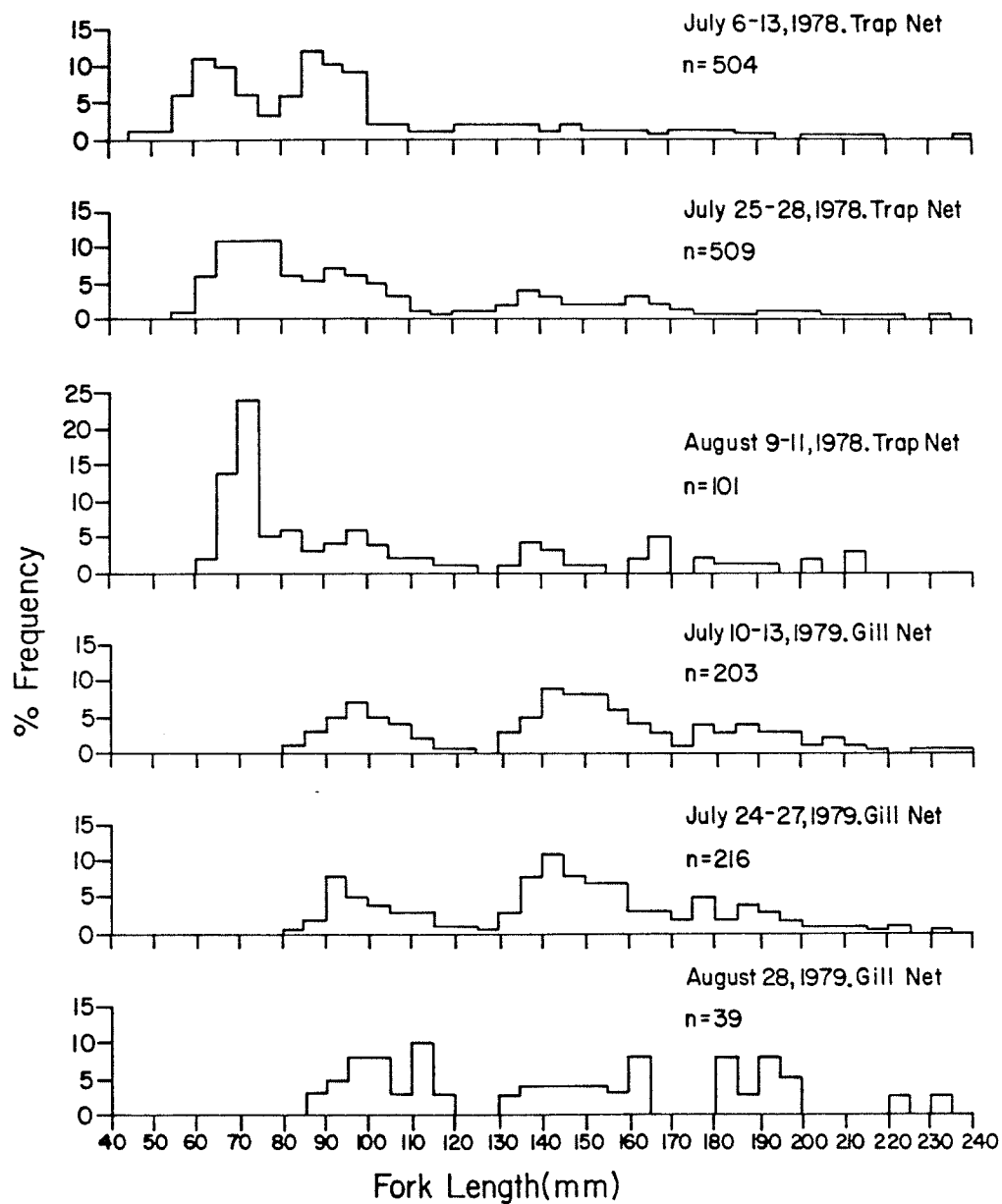
Length-frequency distributions for S. Thomas perch (Fig. 7) showed that a broader range of sizes were caught than in St. Dalmas (Fig. 6). In particular, the proportion of fish longer than 170mm was greater (Fig. 7).

The 1978 S. Thomas trap net catches indicated the presence of two frequency modes, both less than 110mm in length (Fig. 7). Perch sampled from the smallest mode were aged to the 1977 year class, while those of the larger mode were predominantly 1976 year class perch. Except for these two year classes no others were distinguishable.

S. Thomas young of the year perch were not captured in any of the 1978 trap net sets. By mid-August 1978 (Fig. 7), the 1977 year class was still the smallest mode. As will be shown, seine samples at this time captured another, smaller (mean size = 34mm) mode of scale aged 1978 year class perch.

Growth of the 1976 and 1977 year classes was indicated by their rightward shift between July 6-13 and August 9-11, 1978 (Fig. 7). The distinctive gap evident between these two modes on the former date was less clear by the latter, indicating different year class growth rates. There was also an apparent seasonal change in the relative contribution of the two year classes to each period's total catch. As summer progressed, the 1976 year class mode became less prominent relative to both the 1977 year class mode, and perch larger than 120mm (Fig. 7).

Figure 7. Fork length-frequency distributions for  
S. Thomas perch from trap and gill net  
catches in 1978 and 1979.



The 1979 gill net catches indicated further changes in the relative shape of the frequency distributions. The 1977 year class mode, evident in catches throughout 1978 was absent in the July 10-13, 1979 gill net catch distribution (Fig. 7), although members of this year class were identifiable, by scale analysis, in these catches. That is, during this period, perch between only 80-100mm long were identified as 1977 year class fish. Further, seine hauls from mid-July 1979, and a July 5 hoop net catch contained 1977 year class perch less than 80mm long. Therefore, this year class was only partially recruited by July 10-13 1979, which explains their absence as a distinct mode at that time. Catches from mid-August and August 28, 1979 (Fig. 7) indicated an increasing proportion of smaller fish which resulted from progressive 1977 year class recruitment. The 1976 year class decline, observed in 1978 (Fig. 7), apparently continued in 1979. In the July 10-13, 1979 distribution, 1976 year class fish were sampled in the 100-125mm size range. They were not identifiable as a frequency mode at this, or any other time in 1979 (Fig. 7).

One other difference was observed in the frequency distributions between sampling years. For any given distribution, there was generally an increase in the proportion of fish larger than 120-130mm in 1979 gill net

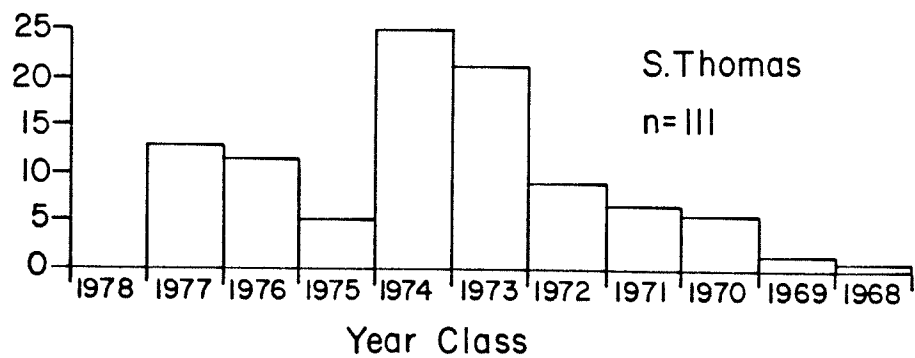
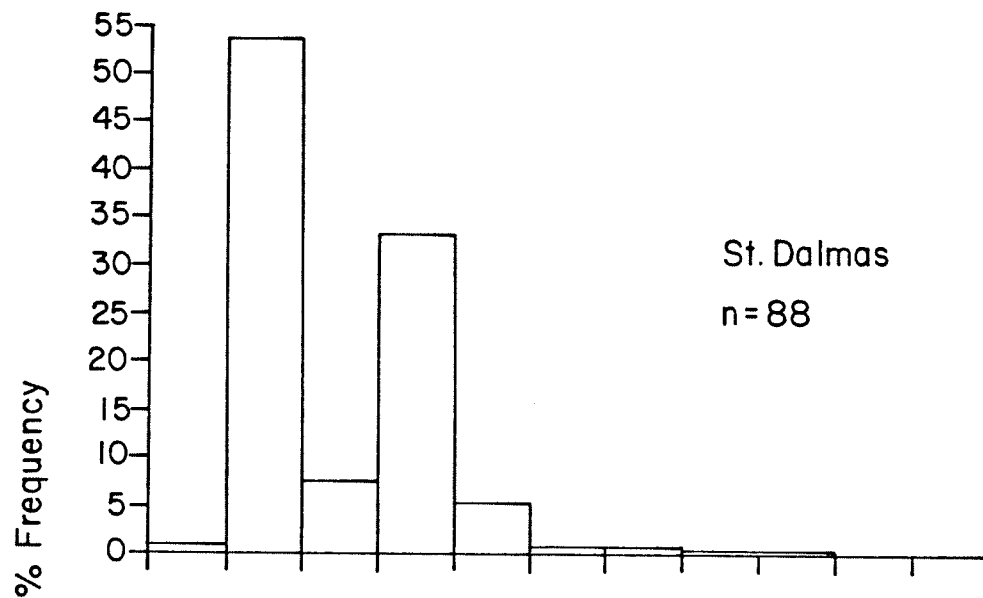
catches, compared with 1978 trap net catches (Fig. 7). As in 1978, none of the larger fish groups caught by gill nets were separable by year class.

Aging analysis of samples collected from gill net catches in mid-July 1979 indicated inter-lake differences in age composition and relative year class strength (Fig. 8). As noted, during this time the 1978 year class was only marginally recruited in St. Dalmas and not at all in S. Thomas; while the S. Thomas 1977 year class was only partially recruited. The oldest year class observed in the St. Dalmas samples was 1970, while the oldest for S. Thomas was 1968 (Fig. 8). There were proportionally more older fish in S. Thomas than St. Dalmas (Fig. 8). For example, perch of the 1974 and older year classes comprised 70% of the S. Thomas sample, but only 7% of the St. Dalmas sample.

The St. Dalmas sample was dominated by two year classes, 1977 and 1975 which contributed 85.6% (53.5 and 32.1%, respectively) to the total. No single year class was dominant in the S. Thomas sample as a minimum of six year classes were required to contribute ~85% to the total. Relative year class strength showed less annual fluctuation in S. Thomas (Fig. 8).

If 1978 trap catches (Figs. 6,7) were similarly evaluated, then the relative contribution of older perch to S. Thomas would be less - because of the additional

Figure 8. Age-frequency distributions for St. Dalmas  
and S. Thomas perch sampled from July 11 - July  
29, 1979.





contribution of the younger classes - but the observed inter-lake differences would remain.

#### Growth in Length and Weight:

Perch young of the year mean lengths were greater in St. Dalmas, in both study years (Fig. 9). The 1978 growth pattern, although similar between lakes, was less uniform than in 1979. However, the observed inter-lake 1978 fry size difference was supported by the timing of each group's first appearance in 1978 trap net catches.

Growth was poorer in 1979 (Fig. 9) and the extent of inter-year differences, based on late August samples, was greater in St. Dalmas. Calculation of instantaneous daily growth rates by weight (G), from July 16 to August 31, 1979 showed that St. Dalmas fry grew faster:

Date	St. Dalmas	S. Thomas
	Mean Weight (g) G	Mean Weight (g) G
July 16	0.416	0.259
	0.020	0.018
August 30	1.057	0.623

Examination of scale samples indicated that most perch from both lakes had begun growth by mid to late June (Table 5). Time of annulus formation was age dependent, as older perch

Figure 9. Mean fork lengths of perch fry captured by seines on St. Dalmas in 1978 (●—●) and 1979 (○—○), and S. Thomas in 1978 (▲---▲) and 1979 (△---△). Sample size in brackets, with 95% C.I. as vertical bars.

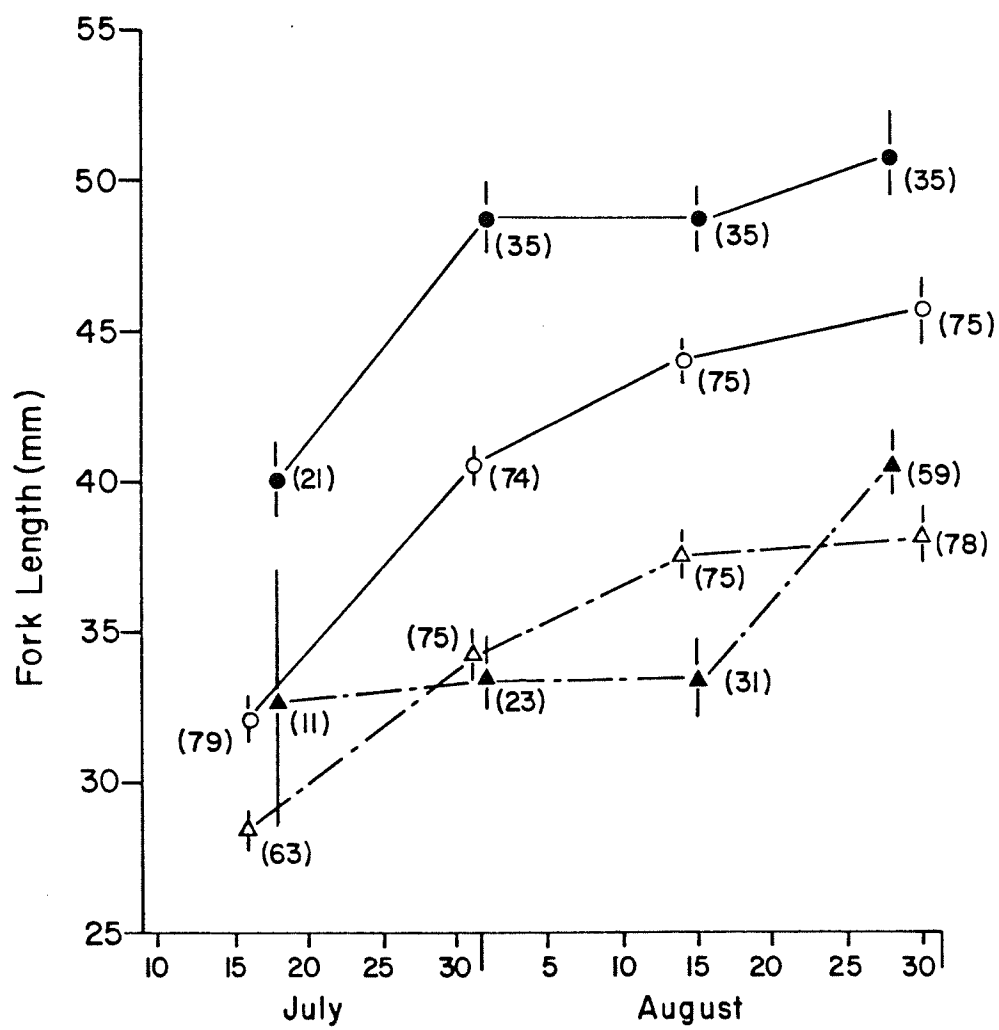


Table 5. Percentage of St. Dalmas and S. Thomas perch scales which had new annuli present, for samples collected at the indicated dates in 1979. Also shown is the mean epilimnion water temperature (C).

Date	Lake	Number Sampled	New Annuli (%)	Mean Epilimnion Water Temperature
June 5-8	St. Dalmas	36	8.3	12.8
	S. Thomas	55	5.5	11.9
June 11-14	St. Dalmas	65	50.1	16.0
	S. Thomas	43	16.3	15.5
June 18	St. Dalmas	4	75.0	15.8
June 26-28	S. Thomas	14	71.5	17.8
July 11-12	St. Dalmas	33	100.0	22.5
	S. Thomas	48	100.0	22.9

formed annuli later than younger ones. Compared to S. Thomas, the higher percentage of St. Dalmas perch with new annuli in June 11-14 samples was indicative of the greater proportion of younger fish in this lake (Fig. 8). The June 18 and June 26-28 samples consisted entirely of 1971 and older year class perch, so the proportion of each lake's total perch population with new growth at these times was probably higher than indicated by these percentages (Table 5). Mean epilimnion temperatures ranged from 12-18 C during June, and were essentially similar between lakes.

Significant differences in slopes and intercepts in the fork length-scale radius relationships, of perch age 1 and older captured in both lakes, required that separate equations be used for each sample year. The equations, with sample size, standard error (S.E.) of b, and  $r^2$  in square brackets are:

St. Dalmas:

$$1978: \log(L) = 0.923 + 0.657 \log(S); [75, 0.014, 0.95]$$

$$1979: \log(L) = 0.850 + 0.683 \log(S); [418, 0.007, 0.96]$$

S. Thomas:

$$1978: \log(L) = 0.853 + 0.688 \log(S); [118, 0.014, 0.95]$$

$$1979: \log(L) = 0.817 + 0.696 \log(S); [375, 0.007, 0.97]$$

Weight-length regressions of age 1 and older perch for each lake, categorized by sex, year, and season are summarized in Table 6. Minimum sizes of the spring 1979 male and female groups were larger than the corresponding

Table 6. Summary of log weight-log length linear regressions for perch sampled from St. Dalmas and S. Thomas, catagorized by sex, year, and season.

Lake	Sex	Year	Season <sup>a</sup>	Length Range (mm)	Sample Size	Slope (b±S.E.)	r <sup>2</sup>	Intercept (log a)
St. Dalmas								
	male	1978	Su	78-191	29	3.043±0.059	0.98	-5.001
		1979	Sp	82-191	126	3.209±0.024	0.99	-5.381
		1979	Su	61-198	46	3.074±0.033	0.99	-5.080
	female	1978	Su	70-265	111	3.074±0.033	0.99	-5.075
		1979	Sp	123-242	84	3.190±0.038	0.99	-5.320
		1979	Su	56-242	127	3.000±0.022	0.99	-4.941
S. Thomas								
	male	1978	Su	58-179	27	3.028±0.113	0.94	-4.975
		1979	Sp	86-155	49	3.069±0.055	0.98	-5.101
		1979	Su	58-178	36	2.914±0.058	0.99	-4.733
	female	1978	Su	58-221	117	3.059±0.025	0.99	-5.031
		1979	Sp	107-243	89	3.090±0.036	0.99	-5.087
		1979	Su	57-245	142	3.070±0.021	0.99	-5.058

a. Sp = Spring (May 3-28), Su = Summer (July 1-August 31).

summer sampled groups (Table 6). Spring sampled groups consisted only of mature spawners, while summer groups contained both mature fish, and the younger and smaller immature perch.

The initial step (LeCren 1951) in establishing weight-length relationships for weight estimation, was to test for differences between summer regressions, within sex and lake (Table 7). All groups, except St. Dalmas females could be pooled (Table 7). In other covariance analyses involving this female group, tests were conducted using separate, annual relationships (Table 6). Weight-length regressions were then compared across pooled summer and spring groups within lake and sex. Pooling was precluded for all groups: St. Dalmas groups had unequal slopes (Table 7) and S. Thomas groups had unequal intercepts (Table 7).

Regression equations from the summer, rather than spring groups were used in the growth study, since they provided a more accurate prediction of somatic weight increases to changes in length. Equations for the spring sampled groups were unacceptable because they would also reflect the additional influence of weight contributed by matured gonads.

Regression equations of male versus female summer sampled groups were compared within lakes. Those from S. Thomas (Table 7) could not be pooled due to unequal slopes (d.f. 1 318;  $F = 6.23$ ,  $p = 0.012$ ). The regression line of the 1978 St. Dalmas female group (Table 6) had the same

Table 7. Comparison of perch log weight-log length relationships by covariance analysis. Top: Summer 1978 vs summer 1979, within lake and sex, showing pooled regression statistics, where applicable. Bottom: Spring 1979 vs pooled summer<sup>a</sup>, within lake and sex.

Lake	Sex	Bartlett's $\chi^2$ pr> $\chi^2$	<u>Equality of Slopes</u>			<u>Equality of Intercepts</u>			<u>Pooled Regression Line</u>			
			d.f.	F	pr>F	d.f.	F	pr>F	Sample Size	Slope (b±S.E.)	r <sup>2</sup>	Intercept (log a)
St. Dalmas	male	<0.001	1,71	0.16	>0.500	1,72	1.51	0.221	75	3.056±0.035	0.99	-5.038
St. Dalmas	female	<0.001	1,234	3.52	0.067	1,235	25.69	<0.001	-	-	-	-
S. Thomas	male	>0.250	1,59	0.92	>0.500	1,60	1.58	0.211	63	2.951±0.049	0.98	-4.814
S. Thomas	female	0.060	1,256	0.12	>0.500	1,257	0.37	>0.500	259	3.062±0.015	0.99	-5.040
St. Dalmas	male	0.035	1,197	14.50	<0.001	-	-	-				
St. Dalmas	female	>0.250	1,207	16.62	<0.001	-	-	-				
S. Thomas	male	<0.001	1,108	1.77	0.183	1,109	31.70	<0.001				
S. Thomas	female	0.008	1,344	0.35	>0.500	1,345	13.75	<0.001				

a. All summer regressions, except St. Dalmas females were pooled over 1978 and 1979 (Top of this table). St. Dalmas summer females were from summer 1979, only (Table 6).



slope (d.f. 1 182,  $F=0.11$ ,  $p>0.500$ ) and intercept (d.f. 1 183,  $F<0.001$ ,  $p>0.500$ ) as the equation for the pooled St. Dalmas male group (Table 7). However, the equation of this latter group had a different intercept (d.f. 1 199,  $F=13.99$ ,  $p=0.001$ ) than that of the equation for the 1979 St. Dalmas summer sampled female group. Consequently, for both lakes, regression equations of male and female summer sampled groups were not pooled.

In summary, the weight-length equations used in the growth analyses for S. Thomas males and females, and St. Dalmas males were those formed from the pooled summer sampled groups (Table 7). For St. Dalmas females separate, annual summer equations were used (Table 6).

A non sex-specific weight-length relationship was required to estimate total catch weight, from mean catch length, for various aspects of the perch C.P.U.E. analyses. For this purpose, 1978 and 1979 male and female, within lake, summer sampled data were pooled (disregarding results of the above analyses). The loss of precision was probably not significant relative to the purpose for which they were used. These regression equations, with sample size, S.E. of  $b$ , and  $r^2$  in square brackets are:

St. Dalmas:  $\log(W) = -4.961 + 3.015 \log(L)$ ; [313,0.017,0.99]

S. Thomas:  $\log(W) = -5.005 + 3.045 \log(L)$ ; [322,0.014,0.99]

Growth histories for age 1 and older perch were back-calculated for separate growth years: July 1978 - June 1979; July 1979 - August 1979, based on the assigned annulus formation dates. Although at any given age, there was variation in mean lengths within year classes across growth years, there was greater variation between year classes, regardless of growth year.<sup>6</sup> This suggested that age assignment was reasonably accurate (Hile 1941). Growth year data were pooled to form tables of mean fork lengths for St. Dalmas (Table 8) and S. Thomas (Table 9) perch.

Negative Lee's phenomena (Ricker 1969) in which at any given age, mean length increases with progressively older year classes, was apparently present in age 5 and older S. Thomas females (Table 9). According to Ricker (1969) this implies a selective mortality for slower growing post age 4 females. Significantly, this trend was not clearly evident within year classes between sample years (1978 and 1979) suggesting that it was not a result of negative Lee's phenomena, but instead, reflected an actual decline in growth rate.<sup>7</sup>

Relative to the females there were five fewer male year classes in the S. Thomas sample, but only one less in

6. Appendix D<sub>I</sub>

7. Appendix D<sub>II</sub>

Table 8. Back-calculated mean fork lengths (mm) at annulus formation for female (top) and male (bottom) St. Dalmas perch. Number sampled during 1979 growth season is in parenthesis in sample size column.

Year Class	Sample Size	Age									
		1	2	3	4	5	6	7	8	9	10
1978	7 (7)	56									
1977	51 (32)	57	90								
1976	5 (2)	55	79	109							
1975	150 (58)	50	87	115	148						
1974	50 (32)	64	98	135	156	182					
1973	13 (6)	59	97	129	156	174	194				
1972	21 (8)	66	101	131	160	180	193	208			
1971	26 (13)	64	100	131	158	180	194	203	218		
1970	13 (10)	64	103	130	157	178	192	202	210	221	
1969	1 (0)	79	124	170	192	207	225	244	253	260	-
Total Sample Size	337	337	311	276	182	106	67	48	27	11	0
Grand Mean (+95% C.I.)		56 (0.84)	92 (1.24)	123 (1.84)	154 (2.25)	180 (2.69)	194 (3.46)	205 (4.14)	215 (6.19)	224 (11.30)	-
1978	8 (8)	57									
1977	45 (10)	57	86								
1976	5 (4)	60	84	102							
1975	75 (32)	47	80	100	121						
1974	6 (1)	52	88	116	131	147					
1973	4 (0)	64	98	125	143	153	-				
1972	3 (1)	63	98	120	141	157	167	178			
1971	9 (1)	61	93	111	133	149	159	166	187		
1970	1 (0)	49	70	109	135	157	173	182	187	-	
Total Sample Size	156	156	113	102	55	18	13	11	2	0	
Grand Mean (+95% C.I.)		53 (1.11)	83 (1.49)	103 (1.96)	126 (2.88)	150 (3.95)	162 (5.16)	196 (6.41)	187 (0.34)	-	

Table 9. Back-calculated mean fork lengths (mm) at annulus formation for female (top) and male (bottom)  
S. Thomas Perch. Number sampled during 1979 growth season is in parenthesis in sample size column.

Year Class	Sample Size	Age											
		1	2	3	4	5	6	7	8	9	10	11	12
1978	4 (4)	45											
1977	31 (18)	44	76										
1976	59 (21)	46	75	102									
1975	22 (8)	46	77	106	131								
1974	45 (19)	43	71	95	125	142							
1973	57 (21)	44	69	99	125	145	162						
1972	20 (9)	46	72	99	128	147	165	177					
1971	41 (10)	50	75	102	128	149	166	180	188				
1970	62 (20)	48	75	100	129	153	172	185	195	211			
1969	23 (11)	44	72	102	126	154	175	191	201	210	220		
1968	13 (6)	44	73	102	132	159	181	196	206	215	222	231	
1967	1 (0)	53	80	112	139	175	186	196	202	206	215	220	-
Total Sample Size	378	378	361	305	270	236	181	149	109	57	25	7	0
Grand Mean (±95% C.I.)		46 (0.53)	73 (0.80)	100 (1.31)	127 (1.65)	149 (1.92)	170 (2.29)	185 (2.52)	197 (3.15)	211 (3.54)	221 (4.45)	229 (6.86)	-
1978	8 (8)	48											
1977	18 (7)	44	69										
1976	47 (10)	45	72	91									
1975	8 (2)	44	71	93	118								
1974	17 (4)	43	69	93	112	131							
1973	12 (4)	46	72	93	114	128	136						
1972	6 (6)	44	64	85	106	122	135	143					
Total Sample Size	116	116	97	53	37	22	10	6					
Grand Mean (±95% C.I.)		45 (0.89)	71 (1.51)	92 (2.35)	112 (3.84)	127 (6.04)	135 (12.09)	143 (20.11)					

St. Dalmas. Male and female mean lengths diverged at age 2 in St. Dalmas (Table 8) but not until age 3 in S. Thomas (Table 9). Male and female St. Dalmas perch were longer and heavier at all ages than those from S. Thomas (Fig. 10). Length differences appeared by age 1, but weight differences particularly in the slower growing males, were not readily apparent until age 2.

There were no marked year class growth fluctuations in S. Thomas perch (Fig. 11). But, the declining growth rate of females is illustrated, and the 1972 male year class generally had poorer than average mean length at any given age, when compared to other year classes (Fig. 11). Greater year class mean length fluctuations were seen in St. Dalmas (Fig. 11). The abundant 1975 year class was comparatively smaller at virtually all ages, for both sexes, than the other year classes (Fig. 11). But, except for their first year of life in 1975 when they had the lowest mean length increment, subsequent increments were comparable to those of the other year classes' at any given year of life (Fig. 12). The 1976-1978 St. Dalmas male and female year classes were generally longer at any given age than perch of the 1975 year class, and were without exception, shorter at any given age than the 1974 and older year classes (Fig. 11). Figure 11 also shows that for individual year

Figure 10. Mean back-calculated fork length and predicted mean weight, at a given age for female and male perch sampled from St. Dalmas (○—○) and S. Thomas (△---△). Solid points have sample size of two or less.

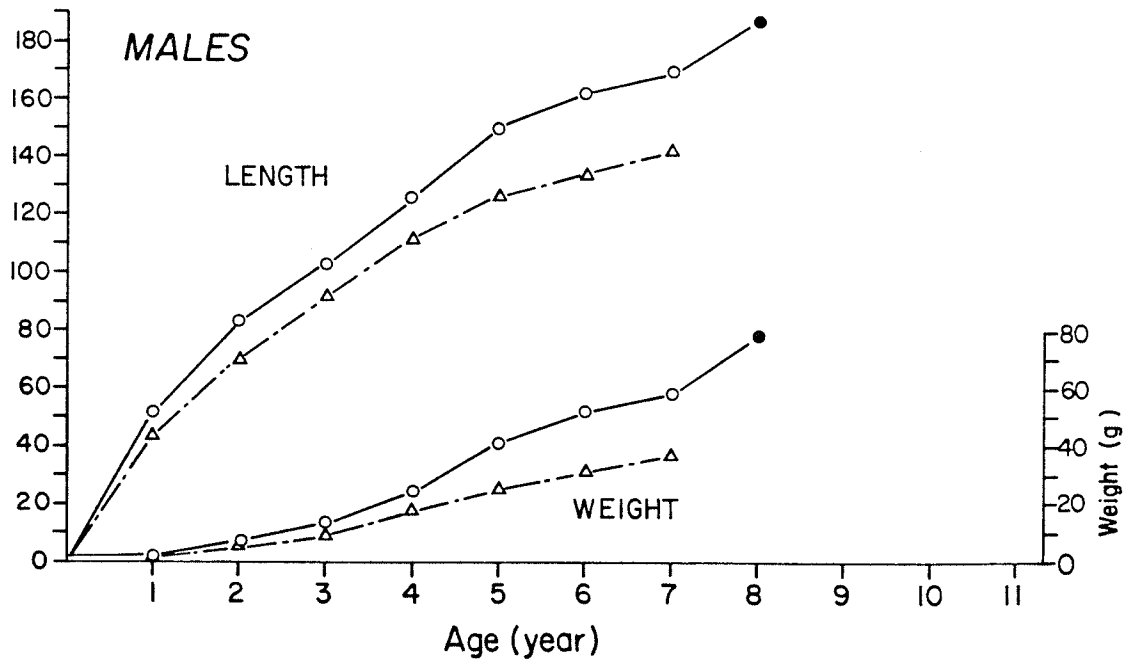
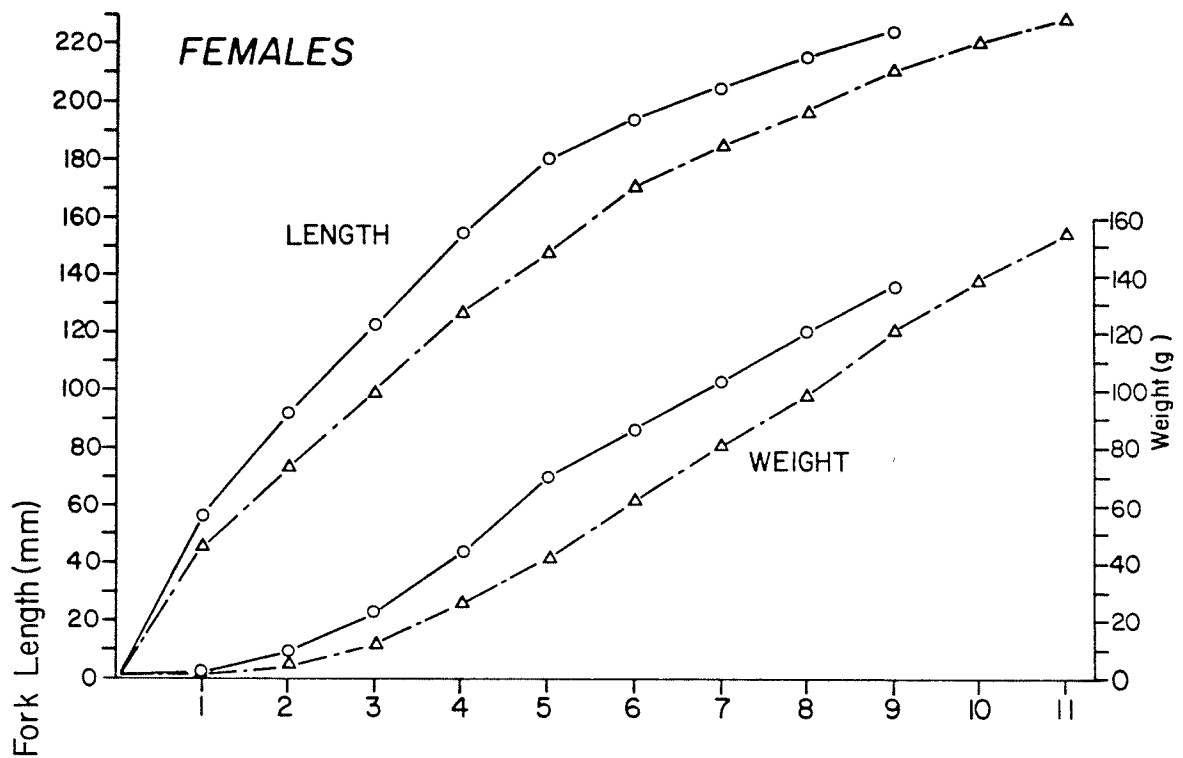


Figure 11. Mean back-calculated fork lengths of individual year classes for male and female St. Dalmas and S. Thomas perch. Growth of each year class is represented by the ascending solid line, while the broken line joins year class points of the same age. Ages are indicated by the numbers in the right hand margin of each figure.



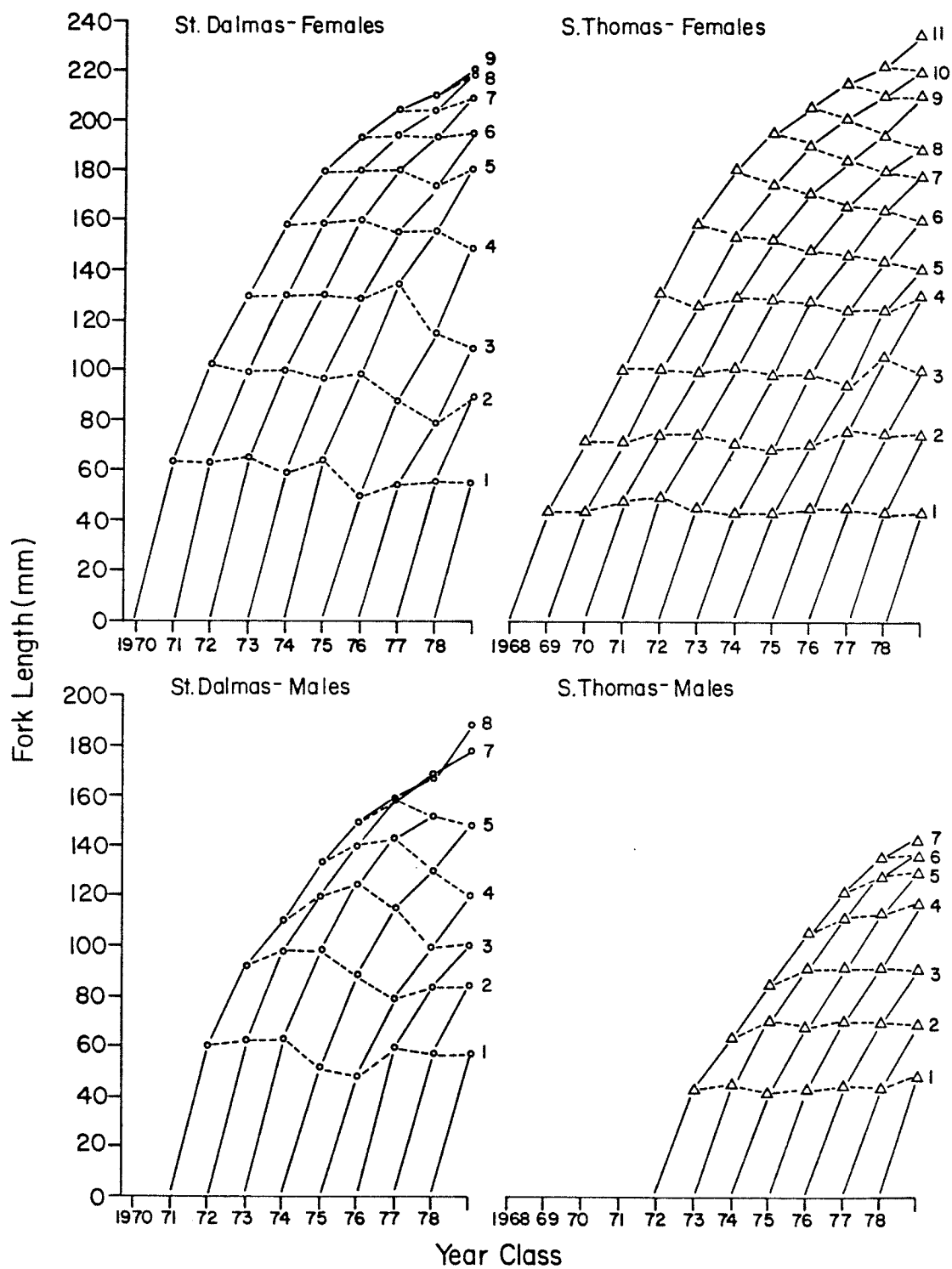
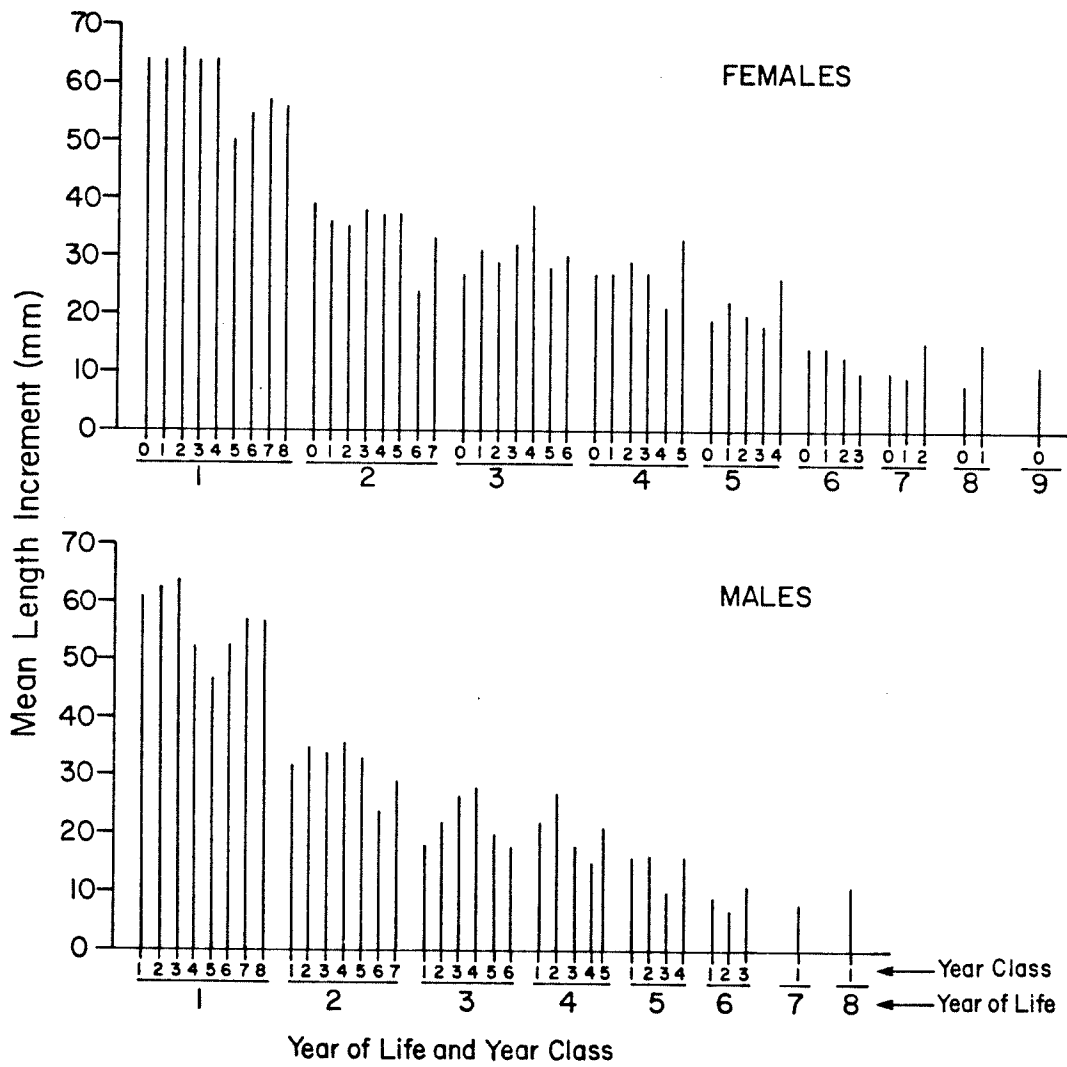


Figure 12. Mean back-calculated length increments of individual year classes at each year of life for female and male St. Dalmas perch. Year classes are identified by the number below each length increment vertical bar, and are pooled by year of life as indicated by the number below each group of underlined year classes. For example: Year Class '0' is the 1970 year class, and Year of Life '1' represents the first growth year.



classes, St. Dalmas perch of both sexes were longer at any given age than those from S. Thomas, with the exception of age 1, 1975 year class fish.

Year class growth, when expressed as a mean annual instantaneous rate by weight, showed that for both sexes, St. Dalmas perch generally grew faster throughout their second and/or third year of life (Table 10). Thereafter, S. Thomas perch grew faster even though their absolute weight increments, as a function of length, were usually smaller.

#### Walleye and Pike Populations:

##### Absolute and Relative Abundance:

A necessary condition for valid abundance estimation using mark and recapture methods is the fulfillment of a number of statistical and sampling assumptions (Seber 1973). Where possible, these assumptions were examined with respect to each of the three groups in question: walleye from St. Dalmas, and walleye and pike from S. Thomas.<sup>8</sup> Only violations of assumptions that may have biased an estimate will be discussed.

Numbers of S. Thomas walleye captured, released, and recaptured in 1979 were very small (Table 11). The modified Petersen estimate of abundance for the May 28 - June 1 period was 73 fish. This estimate's validity was doubtful because the product of the two sample sizes ( $n_1 \times n_2$ )

Table 10. Mean annual instantaneous growth rates (G), by weight, for female and male St. Dalmas and S. Thomas perch.

Year Class	Lake	Females								Males						
		Year of Life								Year of Life						
		2	3	4	5	6	7	8	9	2	3	4	5	6	7	
1977	St. Dalmas	1.39								1.28						
	S. Thomas	1.66								1.26						
1976	St. Dalmas	1.08	0.98							1.14	0.68					
	S. Thomas	1.51	0.96							1.25	0.65					
1975	St. Dalmas	1.65	0.86	0.77						1.64	0.66	0.58				
	S. Thomas	1.60	0.96	0.64						1.44	0.77	0.70				
1974	St. Dalmas	1.49	1.04	0.42	0.47					1.64	0.81	0.38	0.36			
	S. Thomas	1.54	0.91	0.82	0.39					1.41	0.86	0.63	0.39			
1973	St. Dalmas	1.51	0.90	0.59	0.34	0.32				1.24	0.84	0.40	0.26	-		
	S. Thomas	1.38	1.09	0.72	0.47	0.31				1.30	0.78	0.54	0.39	0.20		
1972	St. Dalmas	1.45	0.81	0.61	0.36	0.21	0.23			1.35	0.62	0.50	0.32	0.20	-	
	S. Thomas	1.41	0.97	0.78	0.42	0.35	0.24			1.12	0.84	0.64	0.44	0.31	0.16	
1971	St. Dalmas	1.35	0.81	0.57	0.40	0.23	0.14	0.17								
	S. Thomas	1.28	0.93	0.70	0.47	0.34	0.23	0.16								
1970	St. Dalmas	1.44	0.70	0.55	0.39	0.24	0.16	0.11	0.17							
	S. Thomas	1.38	0.90	0.78	0.52	0.36	0.23	0.15	0.13							

Table 11. Numbers of S. Thomas walleye and pike captured, released and recaptured throughout 1979.

Species	Period	Number of Fish		Recaptures from marking periods		
		Captured	Released	1	2	3
Walleye						
	1. May 28-June 1	11	9	-		
	2. June 25-28	21 <sup>a</sup> .	12	2	-	
	3. August 20-23	14	8	2	1	-
Pike						
	1. May 28-June 1	59	58	-		
	2. June 25-28	30 <sup>b</sup> .	19	7	-	
	3. August 20-23	29 (10 <sup>c</sup> .)	16	1	3	-

a. Includes 1 walleye from sportsman's July 2 catch, of which 1 was tagged in May.

b. Includes 4 pike from sportsman's June 27 catch, of which 1 was tagged in May.

c. Number of recruits (fork length  $\leq$  500 mm) in total sample.

exceeded the estimate of  $N(73)$  by a factor of 2.6. There is significant negative statistical bias in the estimate of  $N$  unless this factor exceeds 3 or 4 (Robson and Regier 1964). Bias here was about 5%.

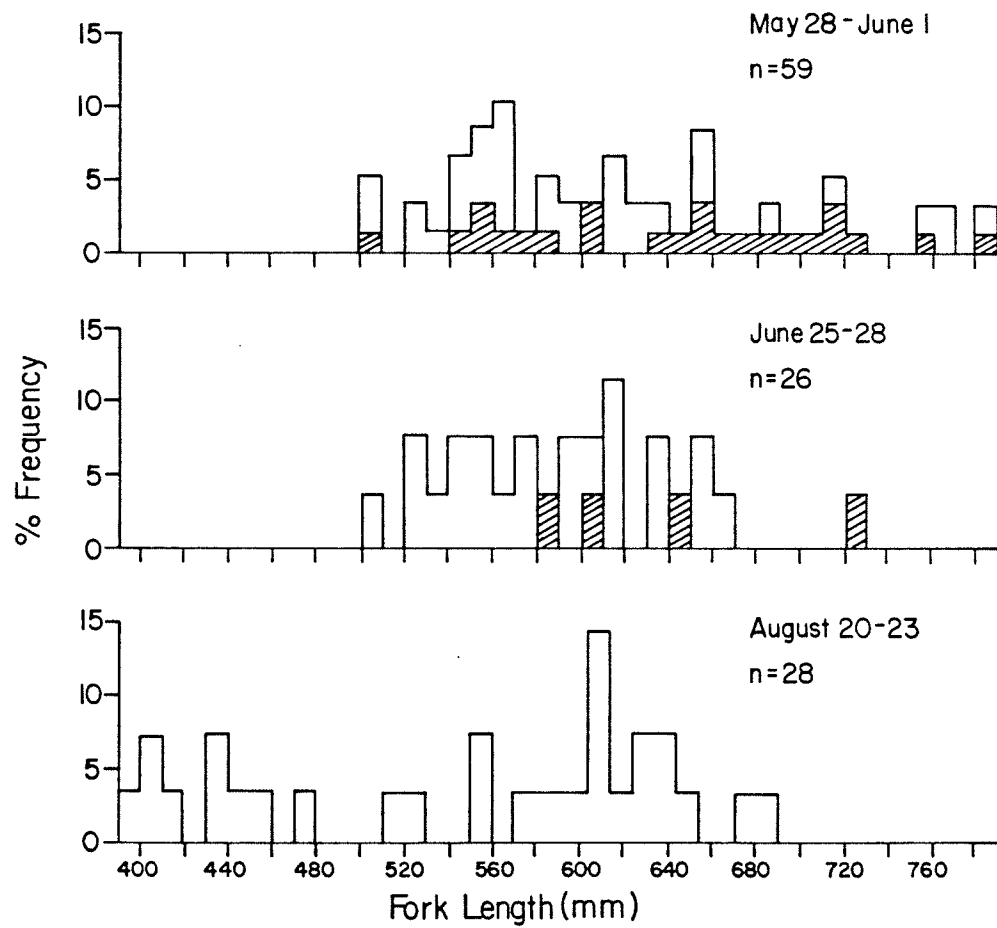
Catches of pike in S. Thomas were considerably better than those for walleye (Table 11), but again only a modified Petersen estimate was possible for the May period, using June 25-28 recapture data. The estimate, with 95% binomial confidence intervals was 229 (142,610), or 3.1 times more than the S. Thomas walleye estimate.

The pike estimate appeared biased by the lack of closure (Seber 1973), as the proportion of pike greater than 670mm long decreased markedly between the May and June periods (Fig. 13). None of the tagged pike from this larger size class, released in May, were subsequently recaptured in June. However, assuming that the initial May sample was random, then pike tagged and released in May would be randomly distributed. With an additional assumption that this group's absence in the June period catches was not a consequence of their tagging history, then the June sample is an unbiased abundance estimate for May (Seber 1973).

By August 13 (Fig. 13) recruitment of young pike was evident, while pike greater than 670 mm

Figure 13. Fork length-frequency distributions of S. Thomas pike caught during the 1979 mark and recapture periods, by trap and gill nets. Hatched area is proportion caught by trap nets only.





remained relatively absent from the catches. Distributions of pike caught in trap and gill nets were similar (Fig. 13).

Mark and recapture statistics relevant to the St. Dalmas walleye abundance estimates are summarized in Table 12. Analysis by the Jolly-Seber death only model indicated recruitment occurred between the May and June periods.<sup>9</sup> This was attributed to a post-spawning increase in the availability of females between May and June. In May, 95.7% of sex-identified walleye were males, and if it's assumed that all non-identified fish were females - which was probably true - the percent of males would still be 78.9%. However, the sex ratio of all non-recaptured walleye between late June and September - too few walleye were sexed in June to establish a ratio for that period alone - was about 1:1. Because the marked population was diluted by this female recruitment, abundance estimates using the death only model are biased positively, and therefore invalid.

Consequently, a Jolly-Seber full birth and death model (Table 12) was employed to provide estimates of population parameters for June and August, only. Use of the full model accounted for this behaviour-related female recruitment. Walleye less than 240mm were still excluded. The June

Table 12. Mark and recapture statistics for St. Dalmas walleye captured in 1979, and used in the Jolly-Seber population analyses. Unless specified, statistics are the same for the death only, and birth and death models.

Period (I)	$N(I)^a$	$M(I)^b$	$L(I)^c$	$S(I)^d$	$R(I)^e$	$ZP(I)^f$	$Z(I)^g$
1. May 23-26	140	0	1	139	71	249	0
2. June 18-22	88	20	11	77	24	232	51
3. August 14-17	144	41	8	136	37	112	34
4. September 10-14	149	71	2	147	0	0	0

a. Sample size at time I, excluding injected animals.

b. Size of marked subset of  $N(I)$ .

c. Losses on capture.

d. Number returned to population, excluding losses.

e. Number of recaptures out of  $S(I)$ .

f. Number known to be alive at I but not seen at I (first seen after I). Death only model.

g. Number seen before I, after I, and not at I. Full birth and death model only.

estimate of abundance with 95% C.I. was 759 (366,1152)<sup>10.</sup>, or 10.4 times more walleye and 3.3 times more pike than estimated for May in S. Thomas.

Pike were extremely rare in St. Dalmas, as only three were captured. Two were caught in 1979, one of which was the only pike captured, tagged and released in 1978.

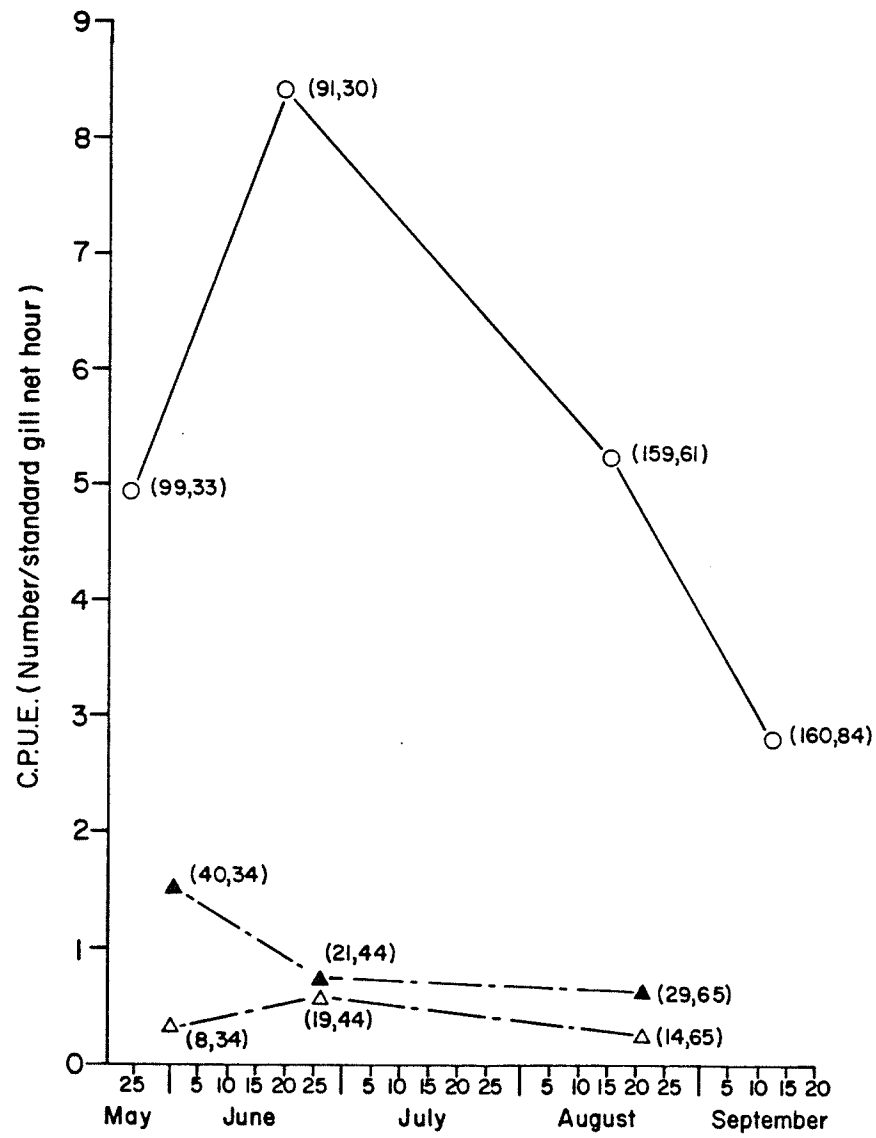
Catches were also compared as a C.P.U.E. (number caught/hour). Trap net results from 1978 and 1979 (Table 13) indicated that in terms of both presence or absence in the gear, and by C.P.U.E., St. Dalmas walleye were relatively more abundant than walleye from S. Thomas. S. Thomas pike were more abundant than walleye of the same lake, but less abundant than St. Dalmas walleye. The mean seasonal C.P.U.E. values, and number caught, for walleye and pike sampled in 1978 from trap net sets in which perch were also counted were: St. Dalmas walleye - 0.1502(56), S. Thomas walleye-0.0096(9) and pike-0.0276(16). The walleye C.P.U.E. ratio for St. Dalmas:S. Thomas was 15.6:1, the St. Dalmas walleye:S. Thomas pike C.P.U.E. ratio was 5.4:1, and the pike:walleye C.P.U.E. ratio within S. Thomas was 2.9:1.

When gill net catches from the 1979 mark and recapture periods were expressed as a C.P.U.E., similar seasonal trends as above, were observed (Fig. 14). For example, C.P.U.E. of both walleye populations increased from May to June then

Table 13. Trap net mean C.P.U.E. (number caught/hour) for walleye and pike caught in St. Dalmas and S. Thomas during 1978 and 1979.

Lake	Year	Period	Number of Hours	Number of sets	Total Catch		Mean C.P.U.E.	
					Walleye	Pike	Walleye	Pike
St. Dalmas								
	1978	June 21-23	66.6	3	33	0	0.393	0.0
		June 29-July 6	71.8	3	0	1	0.0	0.014
		July 20-21	42.5	2	5	0	0.069	0.0
		August 2-4	132.5	5	2	0	0.009	0.0
		August 16	23.8	1	16	0	0.672	0.0
	1979	May 23-26	335.8	15	49	0	0.138	0.0
		June 19-22	88.7	4	0	0	0.0	0.0
S. Thomas								
	1978	June 29-July 6	97.3	3	8	4	0.061	0.045
		July 11-13	62.4	2	0	5	0.0	0.087
		July 25-28	189.7	8	0	6	0.0	0.031
		August 8-11	164.6	5	1	1	0.004	0.004
		August 22-26	97.8	3	0	0	0.0	0.0
	1979	May 30-June 1	90.8	3	3	23	0.042	0.310
		June 25-28	164.6	7	0	5	0.0	0.030

Figure 14. Gill net mean abundance C.P.U.E., by period, for St. Dalmas walleye (○—○) and S. Thomas walleye (△---△) and pike (▲---▲) caught in 1979. In brackets: (Number caught, number of sets). Dates are mid-points of sampling periods.



declined by August. The mean C.P.U.E with total numbers of catch, hours and sets, in brackets, for May through August were: St. Dalmas walleye - 5.38 (344,61.3,124), S. Thomas walleye - 0.401 (41,101.5,143) and pike - 0.935 (90,101.5,143). The corresponding C.P.U.E. ratios, in the same order as those from the 1978 trap nets were: 13.4:1, 5.8:1, and 2.3:1. These ratios were comparable to those observed from the 1978 trap net catches, and to the absolute estimates.

On a seasonal basis, the 1979 walleye gill net C.P.U.E. ratio St. Dalmas:S. Thomas remained quite stable: May 16.2:1, June 15.0:1, August 17.6:1. Similarity of the May and June ratios suggested the occurrence of similar biological events (eg. female recruitment, mortality) in each lake. Therefore, the June ratio was applied to the St. Dalmas June abundance estimate, resulting in an estimate of 52 walleye in S. Thomas for June. This supports, at least to the same order of magnitude, the dubious Petersen May estimate of 73 fish.

In addition to seasonal changes in total C.P.U.E. (Fig. 14), there were also seasonal changes in daily availability of walleye and pike. St. Dalmas walleye and S. Thomas pike were most frequently caught between 15:00-22:00 hours in May. By August St. Dalmas walleye were caught most frequently between 18:00-01:00 hours, but



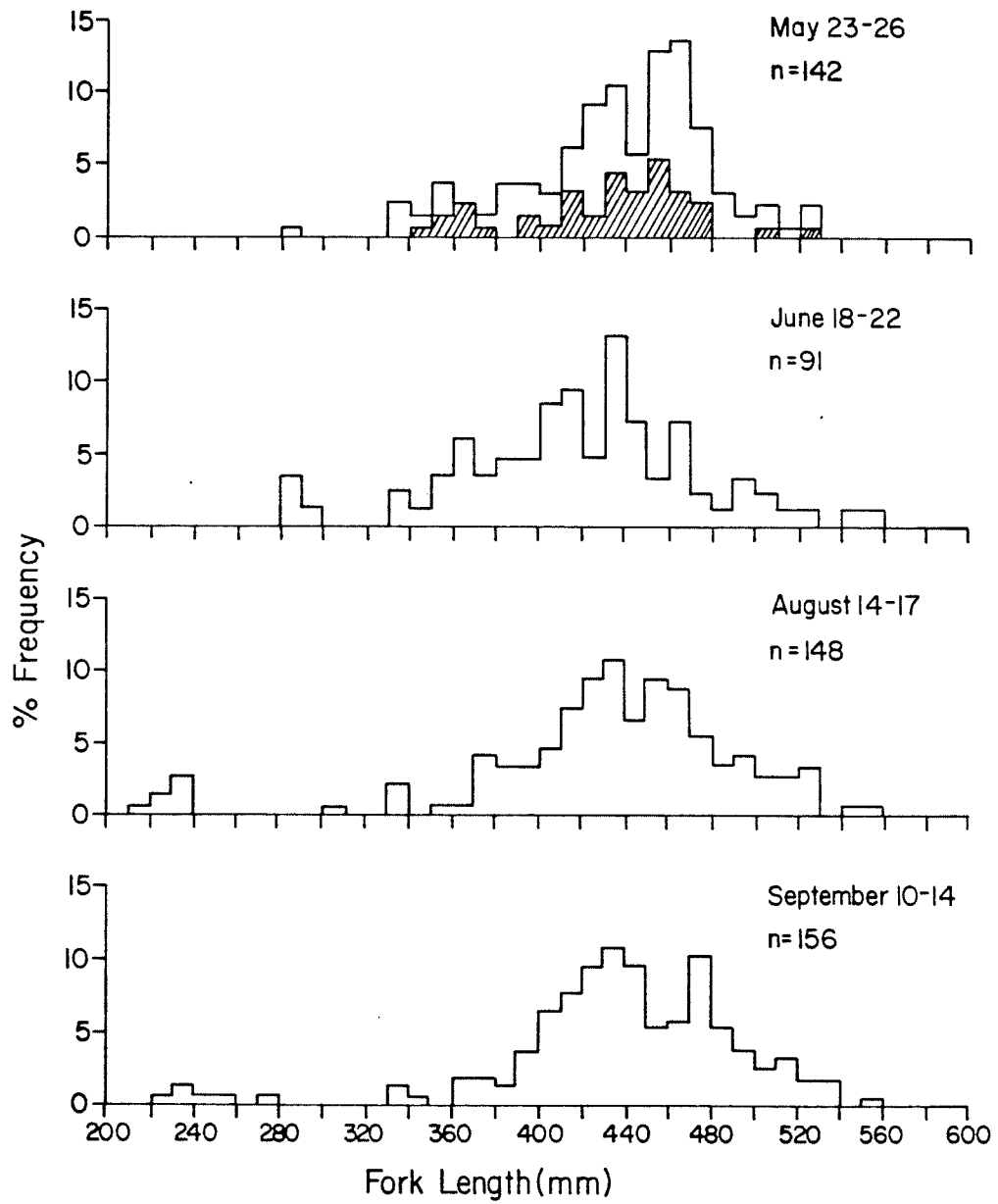
the hours for S. Thomas pike were still 15:00-22:00. S. Thomas walleye catches were sparse, but they showed greatest availability between 19:00-24:00 hours, regardless of season. These observations were substantiated by their capture (or lack of) in the perch C.P.U.E gill net sets during July and August.

#### Age and Growth:

##### Length and Age Distribution:

Length-frequency distributions of St. Dalmas walleye caught during the mark and recapture periods in 1979 were basically unimodal, with secondary peaks at 410-440mm and 450-480mm (Fig. 15). The distributions remained similar in form throughout the growth season (Fig. 15). Growth in the population was illustrated by rightward movement of the catch distributions from June through September, while similarity of the May and June distributions indicated minimal growth during this time. Walleye greater than 500mm long were common in the catches, and fish smaller than 360mm formed an insignificant proportion of any catch (Fig. 15). In conjunction with scale sample age assignment, two frequency modes were identifiable as specific year classes. The 1977 year class was the mode that shifted from about 290mm in June to 340mm by September. Recruitment of the

Figure 15. Fork length-frequency distributions of St. Dalmas walleye caught during the 1979 mark and recapture periods, by trap and gill nets. Hatched area is proportion caught by trap nets only.

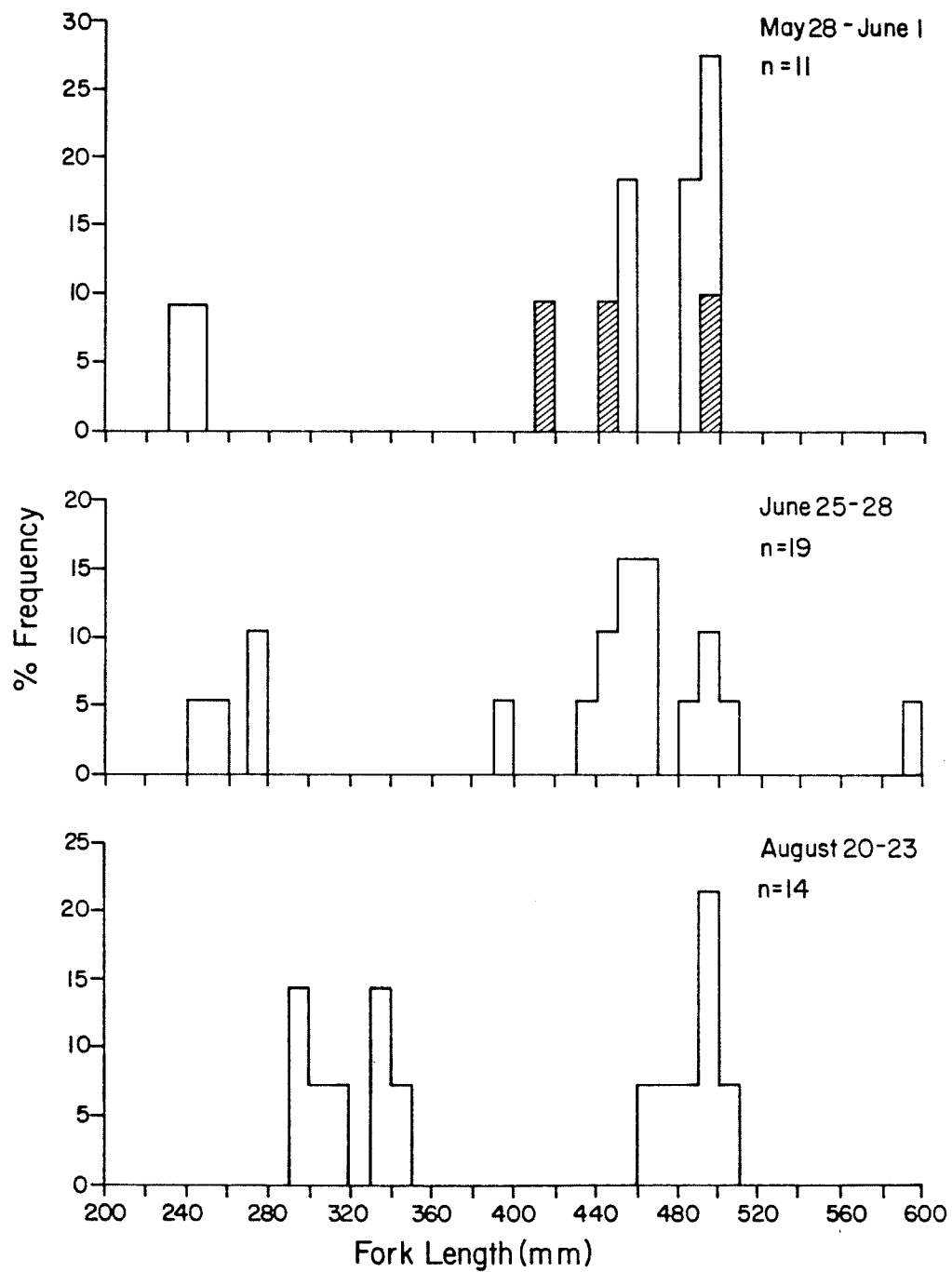


1978 year class into the catchable population occurred by mid-August (Fig. 15), with growth from 228mm in August to 239mm by September. In addition, a single young of the year walleye 125mm in length was captured during September.

Frequency distributions of walleye caught by the trap and gill nets fished during the May period in St. Dalmas were similar (Fig. 15). Walleye were not caught by trap nets during the June period.

S. Thomas walleye length-frequency distributions were irregular in form because of very small sample sizes (Fig. 16). Results from scale aging showed that the population was bimodal (Fig. 16), with each frequency mode representative of a specific year class. The smallest mode, the 1977 year class, contributed proportionally more to the S. Thomas total catch, particularly in August, than did the smaller fish from St. Dalmas to their respective catches (Fig. 15). The 430-500mm size group observed in May and June, and the 460-510mm group from August, were walleye of the 1973 year class (Fig. 16). Movement of each mode to larger sizes reflected seasonal growth, notably between June and August. Also evident was the occurrence of two smaller modes within each year class mode, for most periods (Fig. 16). These could have resulted from small sample size

Figure 16. Fork length-frequency distributions of S. Thomas walleye caught during the 1979 mark and recapture periods, by trap and gill nets. Hatched area is proportion caught by trap nets only.



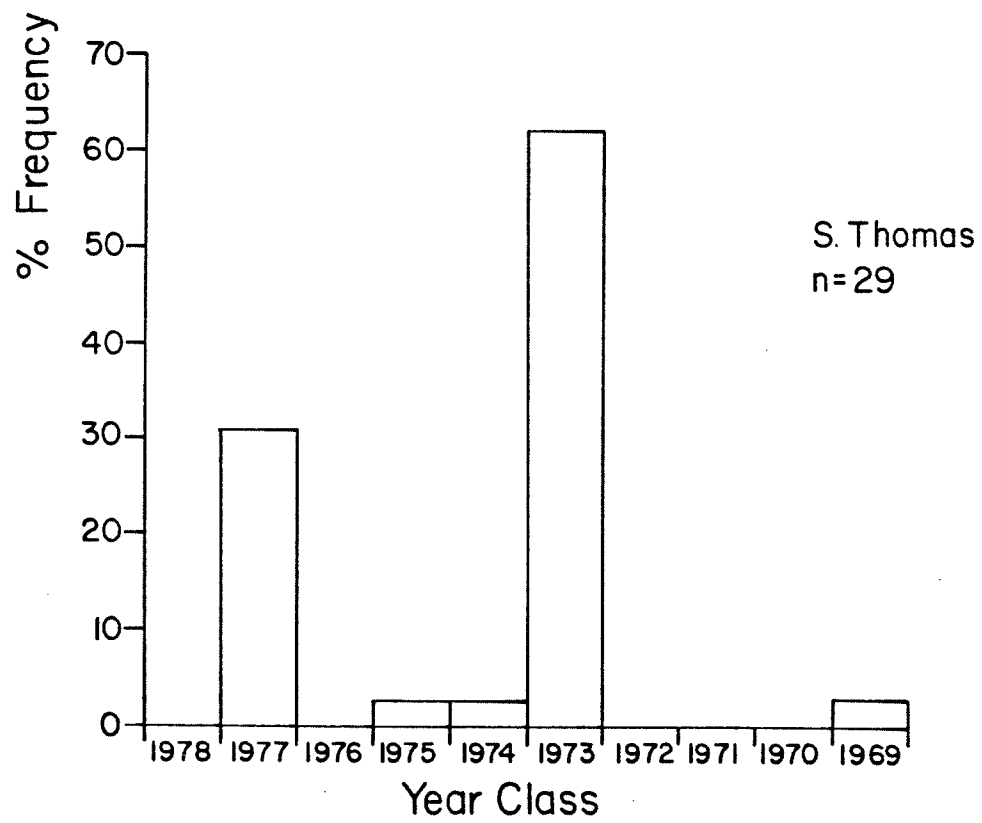
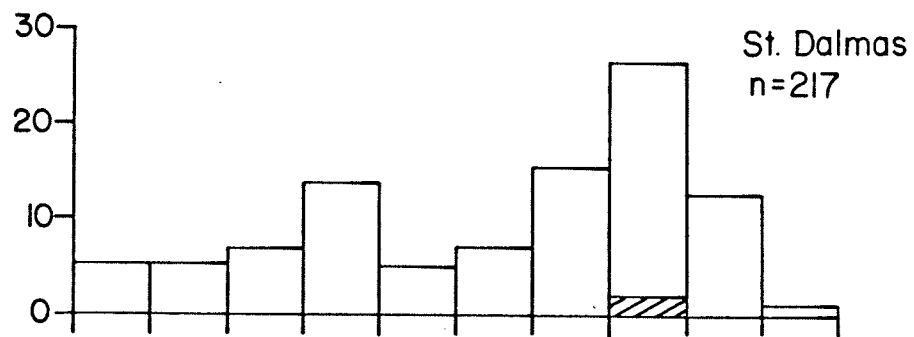
variation, or as a consequence of sexual dimorphism in growth rates. The paucity of data precluded comparison of gill and trap net catches (Fig. 16).

Aging of walleye collected during the 1979 June to September mark and recapture periods indicated that ten year classes were present in the St. Dalmas population but only five in S. Thomas (Fig. 17). The 1978 year class, if present in S. Thomas, was not observed in the catchable population by late August (Fig. 16). The 1978 St. Dalmas year class was under-represented in the total age frequency distribution (Fig. 17), as it was not recruited until mid-August (Fig. 15).

As noted, the S. Thomas population consisted essentially of two dominant year classes; 1977 and 1973, which contributed 31.0 and 62.8% respectively, for a total of 93.8% of the total catch. The minimum number of year classes required to comprise approximately 90% of the total St. Dalmas catch was seven. The 1971 year class contributed most (26.3%) of this total, while three year classes; 1975, 1972, and 1970 contributed 13.8, 15.7, and 12.9% respectively. The remaining year classes each contributed approximately 5% to the total. The 1975 and 1971 year classes were comparatively strong relative to those preceeding and following them (Fig. 17).

Figure 17. Age-frequency distributions of non-recaptured walleye, caught between June and September 1979, in St. Dalmas and S. Thomas. Hatched area of 1971 St. Dalmas year class represents contribution of fin-clipped walleye to the total catch.





Direct evidence of walleye stocking success in St. Dalmas was provided by the capture of 16 fin-clipped walleye. Prior to knowledge of the lake's stocking history, these fish were assigned to the 1971 year class. This concurs with the age of fingerlings stocked in May 1972, and is significant because it provides direct independent evidence for validity of walleye age assignment. The contribution of non-recaptured fin-clipped walleye to the June - September 1979 catches was 7.0% to the 1971 year class, and 1.8% (n=4) overall.

#### Growth in Length and Weight

On each lake walleye growth began at approximately the same time as it did for perch, in mid to late June (Table 14). Younger walleye formed annuli sooner than older ones. In St. Dalmas, 71% of the 88 walleye netted during June 18-22, 1979 had new growth. Twenty-eight St. Dalmas walleye, caught on June 21, 1978 with a similar age distribution as above, showed 89% with new growth, which was indicative of the earlier and warmer spring in 1978. Commencement of growth was observed in 16 of the 19 S. Thomas walleye captured from June 25-28, 1979 (Table 14). In 1979, none of the 11 S. Thomas walleye caught during May 28 - June 1, and only 5% of the 141 St. Dalmas walleye examined from the May 23-26 catch, indicated annulus formation. After July 13, 1979 new scale growth was observed on all walleye from both lakes.

Table 14. Percentage of walleye scales examined, by lake and year class,  
with an annulus formed or forming at the indicated date in 1979.  
Total number examined is shown in parenthesis.

Lake	Date	Year Class								
		1977	1976	1975	1974	1973	1972	1971	1970	1969
St. Dalmas	June 18-22	80(5)	100(9)	95(18)	80(5)	40(5)	50(12)	61(23)	55(11)	-
S. Thomas	June 25-28	100(3)	-	100(1)	100(1)	77(13)	-	-	-	0(1)

A single fork length-scale radius relationship was used for back-calculation of S. Thomas walleye growth for each sample year, as there was no difference in slopes or intercepts. Separate 1978 and 1979 relationships were used for St. Dalmas walleye because inequality of intercepts precluded pooling. These relationships, with sample size, S.E. of b, and  $r^2$  in square brackets are:

S. Thomas:

$$\log(L) = 0.521 + 0.919 \log(S); [51, 0.035, 0.93]$$

St. Dalmas:

$$1978: \log(L) = 0.856 + 0.774 \log(S); [128, 0.039, 0.76]$$

$$1979: \log(L) = 0.842 + 0.785 \log(S); [362, 0.012, 0.92]$$

Walleye growth histories were back-calculated for separate growth years<sup>11</sup>, and since results were similar to those observed for perch, the data were pooled. Unlike perch, sex-specific identification of walleye was feasible for only a limited proportion of each lake's total sample. For St. Dalmas, the proportion identifiable by sex (36%) was sufficient to show that females were longer than males as early as age 2, and that growth differences increased with increasing age (Table 15). Inter-lake comparison of sex-specific growth was precluded because too few S. Thomas walleye (4%) were separable by sex. Therefore, in order to make such a comparison growth calculations were made on the within lake total samples, disregarding effects introduced

11. Appendix F

Table 15. Back-calculated mean fork lengths (mm) at annulus formation of St. Dalmas walleye that were identifiable by sex. Top: females; bottom: males. Number sampled during 1979 growth season is in parenthesis in sample size column.

Year Class	Sample Size	Age									
		1	2	3	4	5	6	7	8	9	10
1977	0	-									
1976	1(0)	141	256	-							
1975	11(3)	130	284	358	408						
1974	1(1)	113	246	344	397	416					
1973	4(0)	142	265	334	391	427	-				
1972	4(2)	132	250	326	374	409	431	434			
1971	7(3)	148	275	355	397	433	459	477	503		
1970	2(1)	153	254	334	391	414	456	478	491	497	
1969	2(1)	135	269	350	399	433	454	471	482	493	491
Total Sample Size	32	32	32	31	23	20	15	13	7	3	1
Grand Mean ( $\pm 95\%$ C.I.)		138 (5.05)	271 (6.66)	348 (7.83)	393 (10.86)	424 (11.68)	451 (14.24)	470 (16.87)	493 (14.17)	494 (17.46)	491 (-)
1977	1(1)	125	246								
1976	8(2)	146	266	350							
1975	18(7)	129	277	347	393						
1974	4(1)	122	252	335	377	377					
1973	5(1)	118	243	317	366	395	390				
1972	24(4)	132	253	331	376	402	421	406			
1971	57(5)	138	252	327	368	396	417	431	451		
1970	26(3)	138	255	331	374	403	425	439	451	462	
1969	2(0)	133	264	334	371	394	413	428	442	452	-
Total Sample Size	145	145	145	138	125	115	110	89	33	5	0
Grand Mean ( $\pm 95\%$ C.I.)		135 (2.40)	256 (3.21)	331 (3.58)	373 (3.76)	399 (3.90)	419 (3.94)	433 (4.69)	451 (7.09)	459 (14.63)	-

by the 'pooling over' of observed and/or potential sex-specific differences occurring within each lake's population.

Tables of mean fork lengths at given ages, derived by the above procedure, are shown for S. Thomas (Table 16) and St. Dalmas (Table 17). Underrepresented year classes in the S. Thomas sample (Table 16) may account for some of the year class growth differences at any given age. St. Dalmas walleye year classes generally showed little fluctuation in mean length at any given age (Table 17); but the 1975, 1976 and 1977 year classes had better than average mean lengths at age 2-4, 2-3 and 2 respectively.

To express walleye growth in weight, weight-length relationships based on the total summer collected samples were used. S. Thomas relationships for each year were pooled (equality of slopes: d.f. 1 37,  $F=2.48$ ,  $p=0.124$ ; equality of intercepts: d.f. 1 38,  $F=0.25$ ,  $p>0.500$ ), as were those for St. Dalmas walleye (equality of slopes: d.f. 1 234,  $F=0.00$ ,  $p>0.500$ ; equality of intercepts: d.f. 1 235  $F=1.62$ ,  $p=0.204$ ). These equations with sample size, S.E. of b, and  $r^2$  in square brackets are:

S. Thomas:

$$\log(W) = -5.041 + 3.041 \log(L); [41, 0.052, 0.99]$$

St. Dalmas:

$$\log(W) = -5.120 + 3.063 \log(L); [238, 0.023, 0.99]$$

Table 16. Back-calculated mean fork lengths (mm) at annulus formation for S. Thomas walleye. Number sampled during 1979 growth season is in parenthesis in sample size column.

Year Class	Sample Size	Age									
		1	2	3	4	5	6	7	8	9	10
1978	0	-									
1977	11 (9)	110	246								
1976	1 (0)	136	268	-							
1975	1 (1)	115	254	347	399						
1974	2 (1)	130	260	354	417	449					
1973	34 (17)	125	255	351	418	451	474				
1972	0	-	-	-	-	-	-	-			
1971	1 (0)	143	308	373	433	475	494	512	-		
1970	0	-	-	-	-	-	-	-	-	-	
1969	1 (1)	144	245	362	462	517	550	568	581	592	598
Total Sample Size	51	51	49	39	39	37	19	2	1	1	1
Grand Mean ( $\pm$ 95% C.I.)		123 (3.28)	255 (5.37)	351 (6.02)	419 (6.91)	453 (8.45)	478 (17.01)	540 (116.1)	581 (-)	592 (-)	598 (-)

Table 17. Back-calculated mean fork lengths (mm) at annulus formation for St. Dalmas walleye. Number sampled during 1979 growth season is in parenthesis in sample size column.

Year Class	Sample Size	Age									
		1	2	3	4	5	6	7	8	9	10
1978	15(15)	128									
1977	15(13)	131	272								
1976	36(19)	145	270	353							
1975	89(35)	129	279	354	397						
1974	26(12)	124	253	335	380	416					
1973	31(16)	135	256	331	380	410	421				
1972	65(35)	131	252	329	374	402	421	429			
1971	137(58)	140	255	331	374	403	426	441	464		
1970	68(30)	141	258	336	381	413	439	455	468	494	
1969	9 (4)	133	264	346	390	416	436	452	464	475	491
Total Sample Size	491	491	474	444	371	322	295	249	135	39	4
Grand Mean (± 95% C.I.)		136 (1.34)	261 (1.80)	337 (2.11)	379 (2.47)	407 (2.86)	428 (3.23)	444 (3.88)	466 (5.88)	490 (10.47)	491 (23.64)



St. Dalmas walleye were longer and heavier than S. Thomas walleye at age 1, only marginally so at age 2, and thereafter S. Thomas walleye became increasingly longer and heavier (Fig. 18).

#### Biomass:

The biomass estimate of walleye from St. Dalmas in June 1979 was 656.5kg, or 10.7kg/ha. Using the rather tenuous May estimate of 73 S. Thomas walleye, the standing crop of this group was 71.1kg. or 0.89kg/ha.

The weight-length relationship used to predict mean pike weight in May 1979, formed by pooling all summer sampled fish from both years (equality of slopes: d.f. 1 67,  $F=0.80$ ,  $p>0.500$ ; equality of intercepts: d.f. 1 68,  $F=0.02$ ,  $p>0.500$ ) was, with sample size, S.E. of  $b$ , and  $r^2$  in square brackets:

$$\log(W) = -4.996 + 2.961 \log(L); [71, 0.069, 0.96]$$

The estimated standing crop of pike in May was 433.3kg or 5.47kg/ha.

#### Interspecific Relative Abundance and Biomass:

Contributions of the principal study species as a percent of mean seasonal abundance and biomass C.P.U.E. to the 1978 trap net catches are shown in Table 18. In terms of percent abundance, perch predominate in both lakes (~99%), but as a percent biomass, their contribution drops significantly. Perch contributed 75.3 and 53.0% to the St. Dalmas and S. Thomas biomass C.P.U.E., respectively.

Figure 18. Mean back-calculated fork length and predicted mean weight at a given age for St. Dalmas (○—○) S. Thomas (△--△) walleye. Solid points have sample size of two or less.

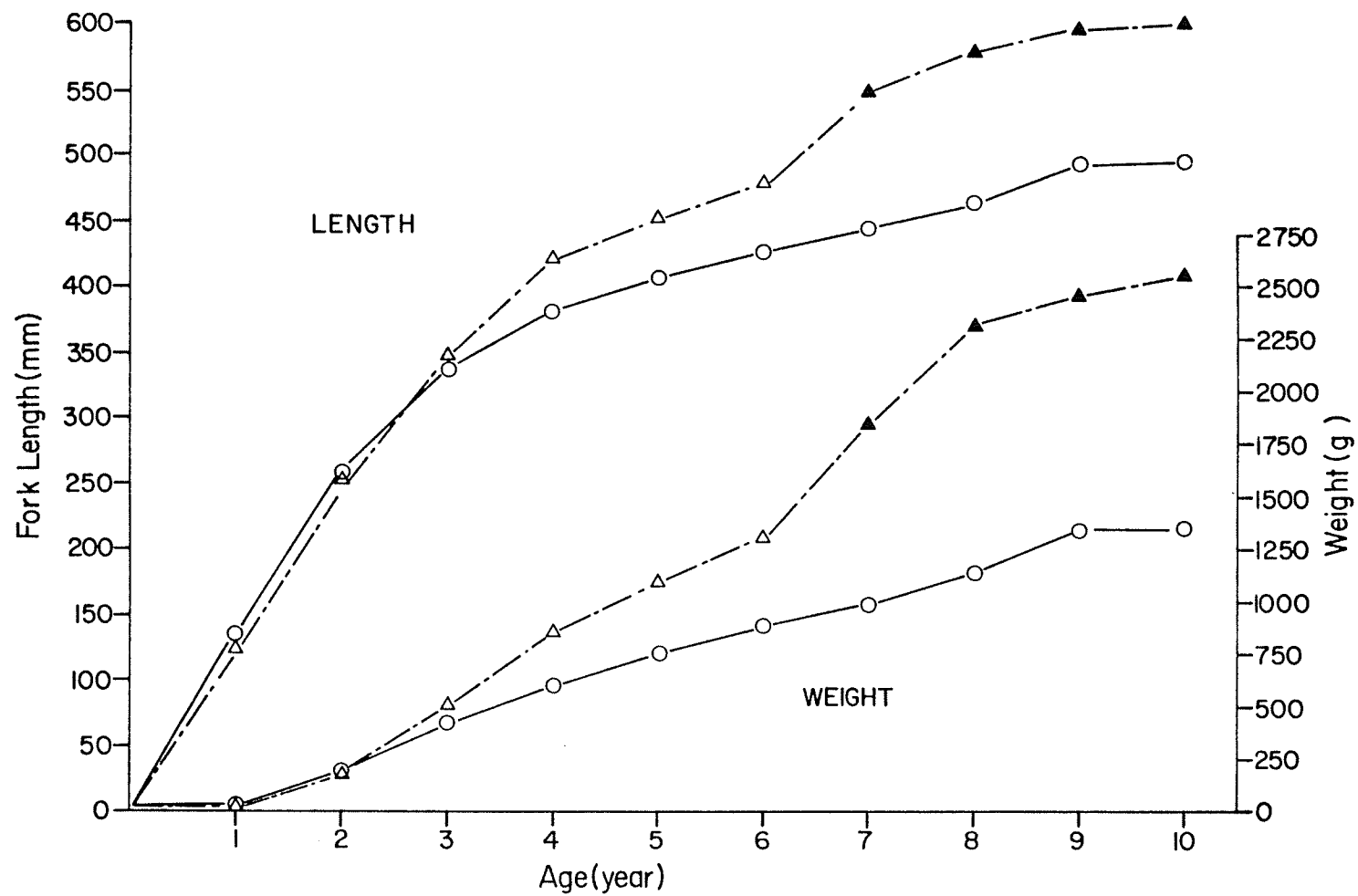


Table 18. Within lake species contribution, as a percent of seasonal mean abundance and biomass C.P.U.E., to the 1978 trap net catches.

Lake	Species	Abundance		Seasonal Mean Weight (g)	Biomass (g)	
		Mean C.P.U.E	Percent		Mean C.P.U.E.	Percent
St. Dalmas						
	perch	23.780	99.4	15.6	370.97	75.3
	walleye	0.150	0.6	812.6	121.89	24.7
S. Thomas						
	perch	3.595	98.7	18.5	66.51	53.0
	walleye	0.010	0.3	950.1	9.50	7.6
	pike	0.028	0.8	1770.3	49.57	39.5

The greater decline of perch biomass C.P.U.E. in S. Thomas was indicative of the larger mean weights of walleye and pike there, compared to St. Dalmas walleye (Table 18).

Percent abundance C.P.U.E. contributions of the fish species to these trap nets were very comparable to results obtained from the survey standard gill net gangs set over the same time period. As a percent abundance, St. Dalmas (number of sets = 16) perch and walleye contributed 96.1 and 3.8%, respectively; while S. Thomas (number of sets = 20) perch, walleye, and pike contributed 95.2, 2.6, and 2.1% respectively.

## DISCUSSION

This study clearly demonstrated community and species-specific differences between the fish populations in St. Dalmas and S. Thomas. An important aspect in assessing these differences is the extent to which they may be biased by non-representative sampling. The degree to which underlying assumptions were fulfilled, and the effects of non-fulfillment are considered and evaluated in the following section.

Size-selection by the fishing gear can bias estimates of growth and abundance (Ricker 1975). With respect to growth, the length-frequency distributions of both perch populations were consistent and reproducible temporally, and modes that were identifiable by year class shifted in response to growth both within and between sample years. This was particularly evident in St. Dalmas where only two modes predominated. The apparent inter-year change in proportions of the S. Thomas frequency distributions was a sampling artifact resulting from only partial recruitment of the 1977 year class into the 1979 gill net catches. As this year class was progressively recruited into August 1979 catches, the relative contribution of larger perch declined. When available, frequency distributions from different gear types were compatible. These results, for both lakes, further suggest minimal bias in the 1979 age data, except

for contributions by those year classes not fully recruited into the gill nets. Walleye and pike catch distributions met similar criteria, indicating minimal gear selection by size and age (see also Appendix E<sub>I</sub>). Some gear sampling size bias is inevitable (Latta 1959; Hamley 1975), but systematic effects on growth estimates were minimized (Ricker 1975) by collecting fish samples over the course of two years, in different seasons and habitats, with different gear types.

In addition to random sampling by the gear, other assumptions relevant to the walleye and pike absolute abundance estimates were fully evaluated in Appendix E<sub>I</sub> and will be summarized here. The representative and intense allocation of sampling effort using two gears, in such small lakes, precluded the possibility of failing to sample biologically discrete sub-populations, as found by others (Forney 1963; Ryder 1968). Tests (Pollock 1975) of the critical assumption of equal catchability of marked versus non-marked walleye - for St. Dalmas only - were insignificant, indicating their homogeneity of distribution and equal availability to the fishing gear. When available, catch information from sport fishermen corroborated the observed proportion of tagged fish in each of the populations. Tag loss bias of abundance estimates were insignificant (Arnason and Mills 1981) in all populations. Potential mortality

from tagging and handling was minimized. There was Robson's Type I loss of marked fish (Seber 1973) for the St. Dalmas June period, but abundance estimates were not biased (Arnason and Baniuk 1978).

St. Dalmas May and June walleye abundance estimates were biased by a post-spawning (i.e. May to June) recruitment of females, as suggested by sex ratio changes and the Jolly-Seber death only analysis. Previous abundance studies (eg. Olsen 1957; Ryder 1968; Schneider et al. 1977) have also utilized a male predominated spawning population, but few have evaluated the potential bias to abundance estimates. Kelso (1972), using the Petersen method, observed a similar May to June abundance increase and suggested that non-random sex distributions may be responsible. The value in applying the full Jolly-Seber model here, is that walleye marked in the May period did not have to be excluded from subsequent mark-recapture recovery periods and a Jolly-Seber analysis could still be used to form population estimates; thereby making fuller use of available data and field effort.

The S. Thomas walleye abundance estimate for May was statistically biased (~5%) (Robson and Regier 1964), and probably by female recruitment as well. However, as a rough check on this estimate, when the June walleye C.P.U.E. ratio was applied to the St. Dalmas June walleye estimate, the



resulting S. Thomas June estimate (N=52) was comparable to the May one (N=73). In long-term, within lake population studies seasonal total walleye C.P.U.E. estimates are converted to estimates of absolute abundance by use of a similar procedure. The C.P.U.E. index is periodically calibrated by comparison to a simultaneously measured estimate of absolute abundance (Carlander and Payne 1977; Forney 1977).

A C.P.U.E. index does not directly measure absolute abundance but is assumed a function of it, and will reflect actual abundance differences when data are collected simultaneously, and randomly (Moyle 1949; Eberhardt 1978). The former assumption was violated in both the 1978 trap net and 1979 pike and walleye gill net sampling. However, in 1978 minimal 'time effect' bias was suggested by similarity of the C.P.U.E. differences observed between results of alternate week sampling with the week of simultaneous sampling. Results were temporally consistent. Absence of adequate trap net sites precluded representative sampling, but available sites were randomly selected. The 1979 perch gill net C.P.U.E. programme met these assumptions.

Although wide seasonal variability in perch C.P.U.E. was annually observed in both lakes, the changes between lakes tended to be similar. Craig (1975) observed comparable

seasonal abundance fluctuations in European perch (Perca fluviatilis) and attributed them to behavioural changes. Of particular significance here, however, is the June 1979 period. It was the only time of the entire study in which a weekly - June 11-14 - abundance C.P.U.E. value was greater in S. Thomas, and it had the lowest monthly C.P.U.E. abundance ratio (1.3:1) in 1979. During June, gill net sets from both lakes but particularly St. Dalmas, characteristically showed wide set-to-set variation in number caught. The greater June 11-14 abundance C.P.U.E. in S. Thomas, which resulted from the catch of just one set, and the large number of empty net sets in St. Dalmas were indicative of this variation.

Such variation might not be unexpected. This was a transition period between spawning, and commencement of feeding and growth. The C.P.U.E. fluctuations may be a consequence of erratic and changing behavioural patterns associated with these different biological activities. Nakashima and Leggett (1975) attributed similar C.P.U.E. distortions in Lake Memphrémagog perch catches to the presence of spawning aggregations.

Another possible factor contributing to the low June C.P.U.E. ratio was a violent wind storm on June 7, which appeared to reduce perch availability to gill nets more so on St. Dalmas than S. Thomas. Prior to this storm perch

were readily caught throughout St. Dalmas. Afterwards, catches of exceptionally high numbers were made, but at only a few stations on the north-west shore, while empty net sets were the rule at other stations. On S. Thomas, with the exception of the set noted above, numbers caught remained quite uniform across stations, and there were fewer empty net sets. Interpretation of June gill net catches is further complicated because trap nets, used during the June mark-recapture periods on both lakes and set for about 24 hour periods, caught far greater numbers of perch on St. Dalmas.

For any given species the presence of gear-specific selectivity, by size or shape, is not a serious problem as long as identical gear is used for C.P.U.E. comparisons, whether between lakes or years (Moyle 1949; Bulkley 1970). Additionally, if a species is more efficiently caught by one gear than another then inter-gear comparisons are precluded (Ricker 1975). For the perch, both of these conditions were violated. Different gears were used in each year, while their dissimilar recruitment sizes indicated unequal catching efficiencies (Ricker 1975). A different type of problem with the pike and walleye was that in 1979 C.P.U.E. means and absolute estimates were largely derived from the same sample, and consequently were

not independent measures of abundance. Therefore, except for general inferences no specific biological significance can be attributed to differences observed in the abundance comparisons. Given this, the results indicated that perch C.P.U.E. differences observed for the 1978 trap net catches were again apparent in the 1979 gill net catches, both on a weekly and seasonal mean basis; and that for the walleye and pike the various relative and absolute abundance estimates were also in agreement.

The 1978 trap net catches, when used for estimating within lake interspecific relative abundance and biomass, may also be subject to biases. As observed in this study, and others (Carlander and Cleary 1949; Craig 1975; Diana et al. 1977), these fishes exhibited species-specific seasonal and diurnal behavioural differences. This could have biased their relative contribution to trap net catches. Traps lifted from S. Thomas, which captured pike, frequently contained numbers of half-eaten perch and/or blacknose shiners. Worthington (1950) and Bagenal (1972) indicated that predators in a trap may reduce catches of other species. Perch may visually select for traps if others are already captured (Craig 1974), or may exhibit sex-specific trap selection (Mann 1978). Despite these observed and potential biases traps are extensively employed for this purpose (see Clady 1978) and by use of pooled seasonal catches,

possible sources of variation were minimized. Significantly, the percent species contributions to 1978 standard gill net sets were comparable to those from trap nets. The latter were set only during daytime, while the former were fished throughout day and night periods.

The preceeding evaluation suggests the absence of serious, systematic sampling biases inherent in the data. The diverse sampling methodologies employed would tend to compensate for any specific sampling biases that may have occurred. Consequently, the observed population characteristics of growth, age, and abundance are representative of the respective populations, and result from the independent and/or combined effects of abiotic and biotic variables.

An important abiotic factor is lake trophy. Based on nutrient levels, secchi disc depths and chlorophyll-a concentrations (Leach et al. 1977), and the typology of Rawson and Moore (1944) both lakes are trophically defined as saline-eutrophic; but, despite their physical proximity and superficial similarity St. Dalmas is more eutrophic than S. Thomas.

This resulted primarily from different edaphic conditions. According to Leach et al. (1977) percid community lakes with total dissolved nutrient concentrations as high as those found in St. Dalmas border on the hypereutrophic, while levels in S. Thomas indicate a less eutrophic environment.

Unless their dynamics are known, use of nutrient concentrations alone, to assess lake trophy may be misleading (Brylinsky and Mann 1973; Ryder et al. 1974). For example, the tendency for slightly stronger thermal stability in St. Dalmas, the effect of a morphometric and climatic interaction, could result in reduced nutrient availability to its epilimnion during peak summer productivity periods (Richardson 1975; Fee 1979). However, both lakes exhibited annual variations in patterns of thermal stratification, and the absence of any significant morphometric differences suggests minimal influence on lake trophy. Finally, the more edaphically conservative TDS and conductivity variables are also considerably higher in St. Dalmas, and the secchi disc depth is less, which further supports the conclusion of greater eutrophy there (Ryder et al. 1974; Dillon and Rigler 1975).

Higher levels of dissolved nutrients in St. Dalmas may be attributed to a combination of the basin lying in a slightly richer soil zone, more intense cultivation around its margin and the larger drainage basin per se. Highly localized groundwater flows may also be important (Barica 1978). Because of their landlocked status, nutrient enrichment from peripheral agricultural practices is a cumulative process leading to progressive eutrophication (Barica 1974). Consequently, not only is St. Dalmas more eutrophic, but it is probably eutrophying more rapidly than S. Thomas.

The pooled abundance, or biomass, of the principal fish species was greater in St. Dalmas. This was demonstrated by the 1978 trap net catches in which all three species were considered, and in 1979 by the perch gill net index and walleye and pike absolute estimates. Although these 1979 relative and absolute estimates are mutually exclusive they provide a valuable substantiation of 1978 results.

These results are also measures of total fish abundance and biomass differences because those fishes not quantitatively considered do not appear to contribute disproportionately more to one lake's fish population than to the other. When compared to St. Dalmas, forage species were relatively more abundant in S. Thomas but they were never nearly as abundant as perch. Further, given their diminutive weight (Scott and Crossman 1973) relative to the principal study species, their relative abundance in S. Thomas would have to be much greater than indicated before inter-lake biomass differences were significantly biased.

The abiotic factors most indicative of greater fish biomass in St. Dalmas are edaphic ones. Positive correlates with fish biomass are TDS or conductivity (Northcote and Larkin 1956; Jenkins 1967), and these variables were highest in St. Dalmas. More specifically, total phosphorus was also greater in St. Dalmas and, as found by Moyle (1946, 1956) for Minnesota lakes and Hrbáček (1969) for

Czechoslovakian lakes, fish biomass was directly related to increased phosphorus levels. St. Dalmas had a slightly greater mean depth than S. Thomas but the difference was relatively insignificant, limiting its use as an index of fish biomass (Rawson 1952; Ryder 1965).

Ryder et al. (1974) predicted that beyond an optimal MEI (TDS:mean depth) of 100, conditions suitable for fish productivity - as yield or biomass (Jenkins 1967) - would become sub-optimal, and productivity would decline with increasingly greater MEI values. This was not apparent here, because St. Dalmas (MEI=370) with a considerably higher MEI than S. Thomas (MEI=257) would therefore be expected to have a lower fish biomass, but it does not. MEI's may not be a realistic index for prediction of fish productivity in these saline lakes.

Inter-lake fish biomass differences were comparable to those observed with phytoplankton (as chlorophyll-a) and zooplankton, and indicative of generally greater productivity in St. Dalmas. Similar relationships between fish and these biotic groups have been documented in non-saline lakes, both on a regional basis (Patalas and Zawiza 1966; Hrbáček 1969; Oglesby 1977), and even between basins of a single lake (Nakashima and Leggett 1975).

In addition to absolute differences in inter-lake fish abundance and biomass there were also relative



differences in community composition. As observed in the 1978 trap net catches, perch were clearly the most abundant (~99%) of the three species caught in either lake. However, when expressed as biomass (Weatherley 1966) their relative contribution dropped to 53.0 and 75.3% in S. Thomas and St. Dalmas, respectively. This, and the inter-lake walleye and pike biomass differences, suggests a more complex and diverse community in S. Thomas in which perch are relatively less predominant than in St. Dalmas. Additional evidence: the mature burbot, and the seasonally abundant blacknose shiners and generally greater forage fish abundance in S. Thomas, supports this conclusion.

Although these community differences may have resulted from the longer-term interaction of abiotic and biotic influences, they may also reflect the result of extrinsic perturbations, particularly species introductions. The previous connection of S. Thomas to an adjacent, larger lake may account for its greater number of species. However, the number of years since separation is substantial and it is probable that these fishes are an integral and viable component of the S. Thomas community. Sport fishermen indicated that walleye were present in S. Thomas prior to the 1969 walleye stocking, but it is possible that this stocking supplemented the indigenous stock, as has been successfully shown elsewhere (Schweigert et al. 1977). The

St. Dalmas walleye stocking only made a minor contribution to an already strong native stock. More importantly, since these lakes are landlocked and there is limited opportunity for natural introductions, it cannot be known whether the present species compositions result simply from a species never having been present, or from its extinction or decline because of influences within the lake.

Given this limitation, percid species are clearly more predominant in the more eutrophic St. Dalmas. Their proportionate biomass contribution to the coolwater fish community generally increases with increased lake eutrophy, while less tolerant predators and competitors decline (Leach et al. 1977). The forage species considered here are less tolerant of turbid eutrophic conditions (Scott and Crossman 1973), and this may account for their relatively smaller contribution to the St. Dalmas community.

Clady (1978) found that the relative importance of perch in North American fish communities is negatively correlated with community species diversity (number of species and their relative abundance). Similarly, biomass of European perch in Finnish lakes was inversely related to the number of fish species present (Sumari 1971; Lind 1977). Results from this study are consistent with these observations. Perch biomass was greater in St. Dalmas and

they were a more predominant member of that fish community than in S. Thomas.

As indicated, this may have directly resulted from trophic differences, but it is probable that biotic factors were also influential, although in a more complex way. That is, the differences may reflect the consequence of either competitive interactions involving other fish (Lind 1977; Clady 1978), and/or the predatory effects on perch from walleye, pike, or burbot (Sumari 1971; Clady 1978). For example, Moyle et al. (1948) extensively sampled coolwater fish communities in Minnesota with gill nets, and found that if the combined biomass of pike and walleye exceeded 40% or if pike biomass alone was 20-30% of the total catch then there was not likely to be an overabundance of perch - as in S. Thomas, compared to St. Dalmas. Therefore, the perch's greater predominance in the St. Dalmas fish community may have resulted from a more favourable combination of both biotic and abiotic (trophic) influences.

Another aspect of perch abundance differences was indicated by the 1979 gill net C.P.U.E. coefficients of variation and numbers of empty net sets. St. Dalmas results, particularly during the peak July period of greatest catches, showed a tendency for perch to be caught in clumps implying heterogeneous spatial distribution. In S. Thomas results suggested a more homogeneous distribution. One possible explanation for this difference is that St. Dalmas perch

were more inclined to form schools or aggregations. Discrete aggregations of perch were frequently observed in the St. Dalmas littoral zone, but not in S. Thomas.

Although walleye and pike are present in both lakes, when expressed in terms of the dominant piscivore St. Dalmas is a 'walleye' lake while S. Thomas is a 'pike' lake. S. Thomas walleye abundance may be limited by the poorer quantity and quality of spawning habitat there, as walleye spawning success is reduced when only sub-optimal substrates are available (Johnson 1961). Walleye abundance was greatest in regions of a large Minnesota lake that had the optimal spawning zones of rock-gravel shorelines (Schupp 1978). In addition, because walleye must spawn in groups, successful reproduction is dependent on their density at the spawning grounds (Regier et al. 1969; Balon et al. 1977). Considering their low density in S. Thomas this may also be a controlling factor of abundance and, possibly contribute to their erratic year class strengths.

Pike are an important competitor with, and predator on walleye (Scott and Crossman 1973; Colby et al. 1979; Ryder and Kerr 1978). Johnson (1949) has suggested that if pike biomass comprised 25% of a lake's total fish biomass it would achieve dominance in the fish community. Pike formed 39.5% of the S. Thomas 1978 trap net biomass C.P.U.E., suggesting they are a factor contributing to the relatively smaller walleye population. In Heming Lake,

pike and walleye were both abundant until a single spawning catastrophe reduced the walleye population (Lawler 1965), but walleye subsequently did not recover despite adequate spawning conditions, while pike flourished.

Similarly, biotic interactions might also explain the failure of pike to reach higher abundance levels in St. Dalmas. Johnson et al. (1977) examined fish associations in Ontario lakes and found that pike and walleye tended to be mutually exclusive in lakes with areas of the size in this study. A low probability of mutual coexistence was a hypothesis suggested (Johnson et al. 1977) to explain this observation.

The standing crop of walleye and pike in these saline lakes provides comparative information with non-saline ones. Walleye biomass in St. Dalmas (10.7kg/ha) is less than the mean (16kg/ha) reported by Carlander (1977) for lakes of variable areas (4-34,000ha) and mean depths (2.0-12.0m), but all with TDS levels (18-272mg/l) substantially lower than in St. Dalmas (2183mg/l). S. Thomas (TDS=1390mg/l) walleye biomass (0.9kg/ha) was comparable to the lowest values reported by Carlander (1977), and he also found that, as in S. Thomas, other predators predominated in these lakes. Unexploited, oligotrophic West Blue Lake, some 150km north of the study area, had

a walleye standing crop of 6.7kg/ha (Kelso and Ward 1972). S. Thomas pike biomass (5.5kg/ha) is somewhat less than the North American average of 6.7kg/ha (Carlander 1955).

The age and year class compositions, and length frequency distributions of both the perch and walleye populations were very different between lakes. However, characteristic of percids (Koonce et al. 1977), all groups showed fluctuations in year class strengths. These are attributable to the individual and/or cumulative effects of abiotic (eg. rates of water warming, water levels, winds) and biotic (eg. predation, cannibalism) factors during the initial larval to post-larval stages and up to the third year of life (Koonce et al. 1977; Nielson 1980; Forney 1980).

The asynchrony of inter-lake year class strengths here, suggests that general climatic effects, as measured by rates of water warming (Busch et al. 1975) or cumulative summer degree days (Kipling 1976), are not the only factor determining ultimate year class strength. Such factors would influence each lake comparably.

The larger proportion of older perch in S. Thomas, and their less variable year class recruitment may reflect the presence of a more complex predator-prey fish community than in St. Dalmas. Nelson and Walburg (1977) found that in a fish community where alternate prey was available

adult perch abundance remained relatively constant. Because, during times of weaker perch year classes predators switched from younger perch to alternate prey items, and thus a compensatory mechanism stabilized perch abundance. The relatively greater proportion of forage fishes in S. Thomas, including crayfish - a common pike food item (Scott and Crossman 1973) - represents such an alternate prey resource.

Conversely, St. Dalmas perch results suggest a simpler, more dynamic piscine community which may be attributable to biotic interactions within the lake. In communities dominated by perch and walleye the primary source of perch mortality is walleye predation (Swenson, in Colby et al. 1979). Forney (1971) found that walleye predation in Oneida Lake regulated perch year class strength in a depensatory fashion, because alternate food resources were generally scarce (Forney 1974). Highly variable perch recruitment and a relatively high adult mortality rate, as observed in St. Dalmas, would be two consequences of this type of predatory pressure.

The high adult mortality rate might also be explained by other factors, because Colby et al. (1979) demonstrated that although walleye will consume larger prey items like adult perch, they prefer small items (eg. perch fry). When subjected to overexploitation both high mortality and

variable recruitment can occur in perch (Nepszy 1977). Provincial perch removals combined with sportfishing, which would 'select' for larger perch, could constitute such a pressure. However, St. Dalmas perch C.P.U.E. levels were not reduced after provincial removals in early July, suggesting that numbers removed were small relative to the population size, at least in 1978 and 1979. The absence of older perch is perplexing given the preponderance of older walleye, suggesting a species-specific mortality factor. A perch-specific fungal induced epizootic decimated the Lake Windemere population (Craig et al. 1977), and possibly a similar event occurred in St. Dalmas. In 1977 large dead perch were observed (J. Gibson pers. comm., Freshwater Institute) on the St. Dalmas lake bottom; while in 1978 up to 28% of trap netted St. Dalmas perch - compared to none in S. Thomas - were infected with an unidentified fungus.

In contrast to the S. Thomas walleye population, which exhibited highly variable and intermittent year class recruitment with only two groups dominating, the St. Dalmas population demonstrated less annual variability in recruitment and, as noted, was dominated by older individuals from a number of year classes. These latter factors suggest a relatively unexploited population (Kelso and Bagenal 1977).



Unlike biomass, inter-lake perch and walleye growth differences could not be clearly related to lake trophy. Early growth in both species was better in St. Dalmas, but the trend reversed in older fish. In general, the principal factors affecting growth (Weatherley 1966, 1972; Colby et al. 1979) are the intensity of competition - a function of both forage availability and predator density - and temperature. Weatherley (1966) concluded that fish growth is very flexible and alters quite readily in response to changes in these factors, particularly the former, biotic one.

The extent of variability in growth is summarized in Fig. 19 and Fig. 20 where respectively, perch and walleye mean total lengths<sup>12</sup> at age, from St. Dalmas and S. Thomas, were compared to those from selected North American non-saline lake populations. For both species, the slowest and fastest reported growth curves are shown, and results indicate equally wide variation at all ages. Perch growth in the study lakes is comparatively poor, but especially so at age 1 in S. Thomas (Fig. 19). Conversely, walleye growth (Fig. 20) is generally intermediate, and specifically, better than that in other lakes of comparable latitude - Lake of the Woods, Red Lakes - except at age 1. As Colby et al. (1979) observed, walleye growth rates increase with decreasing latitude (Fig. 20), reflecting temperature effects.

Figure 19. Mean lengths at age for the St. Dalmas and S. Thomas perch populations, compared to those for perch from selected non-saline North American lakes. All lengths are total, and back-calculated except for Heming Lake which is mean fork length averaged over a number of capture dates.

Sources: Lake Winnipeg, Man. (Bajkov 1930); Lake Washington, Wash. (Nelson 1977); Lake Erie (Jobes 1952); Heming Lake, Man. (Lawler 1953); Red Lakes, Minn. (Smith 1977); Lake Opinicon, Ont. (Keast 1977); Lake Hertel, Que. (Grimaldi and Leduc 1973); Fort Whyte, Man. (Ratynski 1982); Southern Reservoirs, So. Car. (Clugston et al. 1978).

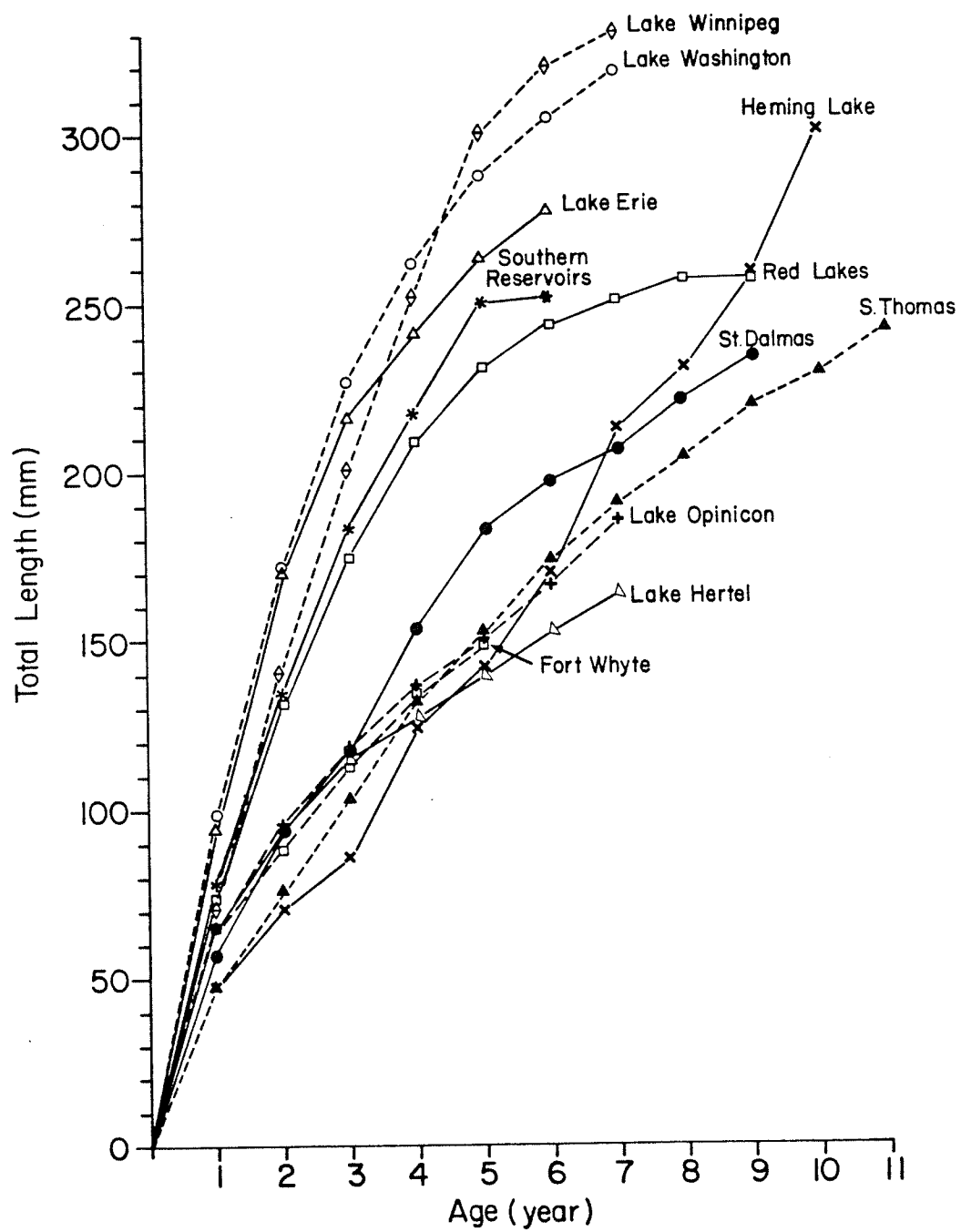
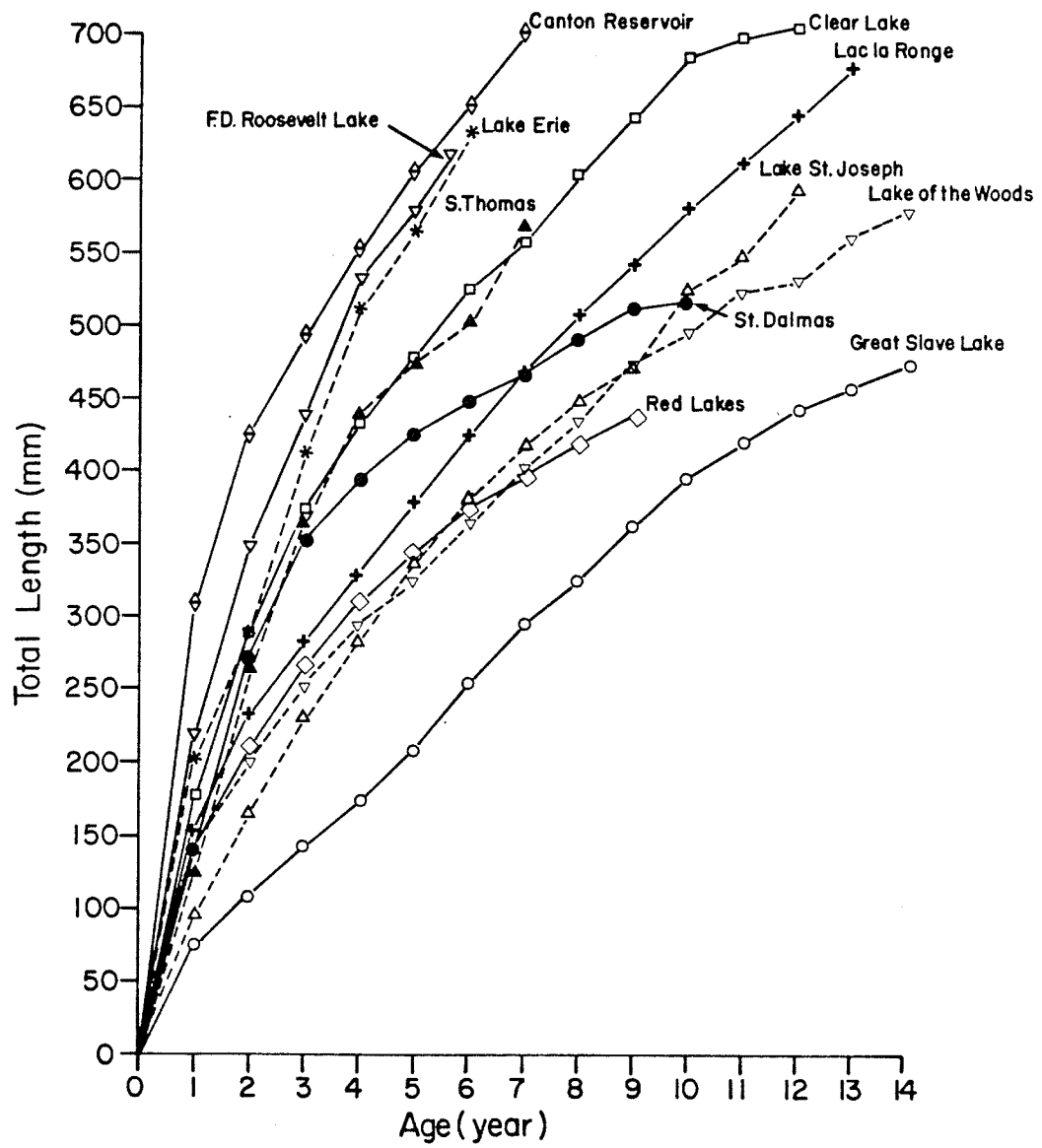


Figure 20. Back-calculated mean total lengths at age for the St. Dalmas and S. Thomas walleye populations, compared to those for walleye from selected non-saline North American lakes. Sources: All of: Canton Reservoir, Penn.; Clear Lake, Iowa; Lac la Ronge, Sask.; Lac St. Joseph, Ont.; Lake of the Woods, Minn.; Great Slave Lake, N.W.T.; Lake Erie; and F.D. Roosevelt Lake, Wash. are from Colby et al. (1979). Red Lakes, Minn. is from Smith (1977).



On both lakes, summer epilimnion temperatures in the 20-25C range provided theoretically optimal growth temperatures for these percids, particularly the walleye (Hokanson 1977). Although there were inter-lake stratification differences which produced seasonally variable temperature regimes, the effects on growth are probably minimal relative to other factors. This is suggested, for example, by similar dates of growth commencement. Inter-lake differences in proportions of perch and walleye with annuli formed were age , rather than temperature dependent, as both lakes had similar rates of water warming. These temperatures are comparable to those reported by others for growth commencement in perch (Coble 1965; Nakashima and Leggett 1975) and walleye (Parsons 1972).

Faster initial growth in St. Dalmas perch was demonstrated in 1978 and 1979 by the direct measurements of fry. This growth advantage may be attributed to the greater zooplankton biomass in St. Dalmas. Zooplankton are perch fry's principal dietary item (Maloney and Johnson 1954; Wong and Ward 1972; Noble 1975; Keast 1977), and fry growth is closely related to their availability (Noble 1975; Guma'a 1978), rather than to fry density (LeCren 1958; Pycha and Smith 1955; Noble 1975).

Inter-lake differences in back-calculated perch mean lengths at age 1 concurred with those directly measured from the fry in the latter part of their first growth year. Back-calculated growth histories further showed that older male and female St. Dalmas perch were consistently longer and heavier at all ages. However, instantaneous growth rates were faster for St. Dalmas perch only until ages 2-3 after which they were less than those of S. Thomas perch. Consequently, the larger weight and length of St. Dalmas perch at older ages occurred only because of this initial growth advantage. Schupp (1978) observed a comparable growth pattern between different walleye populations in a large Minnesota lake.

As with the fry, the growth advantage observed in St. Dalmas perch, up to ages 2-3, may relate to zooplankton availability. The diet of perch up to 96mm long (age 2) in Lake Opinicon - growth there is comparable to these study lakes (Fig. 19) - consisted predominantly of zooplankton, after which their diet shifted to progressively larger items (Keast 1977). Generally second year growth is also density independent (Alm 1946; LeCren 1958).

Examination of individual perch year classes indicated additional inter-lake back-calculated growth differences. In S. Thomas females greater than age 4, progressively younger year classes showed progressively

smaller mean lengths, within an age group. This was probably a consequence of declining growth rates, as there was little evidence of negative Lee's phenomena (Ricker 1969). A similar trend at all ages was observed by Grimaldi and Leduc (1973) in Lac St. Joseph perch. They attributed it to stunting that resulted from a continuously increasing perch density (but they could not demonstrate whether or not it may have resulted solely from negative Lee's phenomena). Absence of long term density data precludes a similar evaluation here. However, this growth trend was not observed in females (or males) less than 140-150mm, suggesting a size-related effect. Perch diets shift to a predominately piscivorous food source in this size range (Schneider 1972; Clady 1974; Keast 1977). If there were changes in this food source, and/or increased population densities of competing fishes - pike, walleye, burbot and larger perch - then this reduced growth may reflect the consequence of increased inter- and/or intraspecific competition.

In contrast to S. Thomas, St. Dalmas perch had greater year class fluctuations in mean length at a given age. Of particular interest is the smaller size at any given age of the 1975-1978 year classes. For the abundant 1975 year class the smaller mean lengths at ages greater than one, compared to those of the 1974-1970 year classes, were only the result of poor first year growth since



subsequent length increments were comparable to those observed in these older year classes (Fig. 12). Additionally, although the 1975-1978 groups showed great variation in year class strength, their first year growth was similar. These results suggest that this 1975-1978 year class growth trend was related to the sustained effect of an extrinsic factor in early life, possibly to changes in food supply. Noble (1975) demonstrated that annual variations in Oneida Lake perch fry growth were dependent on the supply of Daphnia spp..

Sexual dimorphism in perch growth was observed in both populations. This is common and related to an earlier maturation and subsequent growth reduction of males relative to females (Thorpe 1977). However, growth divergence began at an earlier age in St. Dalmas, and coincided with the earlier maturation age of males there. Compared to S. Thomas males, this probably resulted from their initially faster growth rate, since such fish tend to mature earlier (Spangler et al. 1977).

The walleye 'pooled over sexes' mean length and weight growth curves indicated faster growth at age 1 in St. Dalmas, but by age 3 the trend clearly reversed, and more favourable growth was observed in S. Thomas. St. Dalmas walleye exhibited sexual dimorphism in growth by age 2. Whether this occurs at all, or at what age, or even in

which sex is highly variable for walleye and dependent on the specific situation (Colby et al. 1979). Therefore, since this factor could not be evaluated for S. Thomas walleye, the true extent of inter-lake growth differences after age 1 may have been obscured.

The decline in post age 2 St. Dalmas walleye growth, relative to S. Thomas and other populations, as suggested in Fig. 20, may represent a density-dependent response to intraspecific competition. In communities dominated by perch and walleye (Forney 1980), or even in the presence of an interspecific competitor like sauger (Swenson and Smith 1976), intraspecific walleye competition for perch prey determines and limits walleye growth. There is some indirect evidence to support this claim: The 1975-1977 St. Dalmas walleye year classes, which are not nearly as abundant as the older 1970-1972 ones, also showed longer mean lengths at age 2 and greater. Concurrent to this is the apparent abundance of perch in the very strong and, compared to older perch at the same age, smaller sized 1975 and 1977 year classes. The latter point suggests greater prey availability because walleye also prefer smaller sized prey items (Colby et al. 1979). Carlander and Whitney (1961) demonstrated year class specific growth rates in Clear Lake walleye that were inversely dependent on their relative year class strength.

The essential components for estimating fish production are biomass and growth (Chapman 1978). Fish biomass was greater in the more eutrophic St. Dalmas, and the estimates of biomass may have been an accurate index of fish production. However, as suggested for the St. Dalmas walleye, biomass and growth are inter-related (Weatherley 1966) and erroneous conclusions regarding fish productivity are possible if only the biomass variable is considered. Unfortunately, fish productivity could not be measured in either lake nor were estimates of pike growth possible, but two aspects suggest that fish productivity might be greater in St. Dalmas: First, biomass differences are significant, while those for growth, particularly in perch (which also comprised the greatest biomass on either lake) post age 2-3 were slight. Second, most fish production occurs in early life (Gerking 1962; Mathews 1971; Balon 1974; Vashro 1975) and it is during this period that St. Dalmas fish grew faster.

In summary, the two study lakes were quite different trophically despite their proximity and comparable size. Further research on such non-winterkill prairie lakes will probably reveal that this is not an exceptional result. After an exhaustive survey of winterkill prairie potholes Barica (1978) concluded that each water body must be treated as a special case, and generalizations regarding the prediction of lake trophy, and consequently 'productivity',

by morphometric and/or edaphic variables were all but impossible. Whether this will also be the case with non-winterkill saline lakes is unknown, pending more extensive multi-lake studies.

Inter-lake differences in fish biomass, community structure and early life growth rates were related to inter-lake differences in eutrophy. When compared to perch, walleye and pike inhabiting non-saline lakes, the population characteristics of biomass, age and year class structure, growth and other life history variables of such fish in these saline lakes were not exceptionally different. This does not mean that they were not somehow affected by the salinity concentration of their environment. It does suggest, however, that if there are saline related effects then they are minimal, relative to those related to other factors like lake trophy, temperature and food supply. Rawson and Moore (1944) found that in Saskatchewan lakes of comparable salinity levels, these study fishes were not adversely affected.

The innumerable saline prairie lakes represent a valuable recreational, agricultural and fisheries resource (Rawson and Moore 1944; Barica 1978). Conflicting resource demands on them are inevitable, while intensified agricultural practices will accelerate their eutrophication. Consequently, management decisions will be most effective when based on a comprehensive knowledge of their limnology and population ecology of their biota.

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## Appendix A:

Of the 633 St. Dalmas walleye for which age assignment on the basis of independent scale reading was possible, only 491 were used for the age and growth analyses. The remaining 142 were fish recaptured one or more times during the study. These samples were excluded from the analyses because they were not as reliably re-read as non-recaptured walleye, as shown below:

Sample Type	Number of Scales Re-Read	Number in Agreement	Percent Agreement
Non-recaptured	491	423	86.2
Recaptured once <sup>a</sup> .	142	110	77.5
Recaptured two or more times <sup>b</sup> .	32	19	59.4

a. Comparison made between first assigned age and the first recapture assigned age, only.

b. Comparison made between first assigned age and each assigned recapture age, for all recapture events  $\geq 2$ .

These results also indicated that re-reading agreement became progressively less reliable as the number of times recaptured increased.

In an additional analysis, all ageable samples were arbitrarily assigned to three year class groups:  $\geq 1974$ ; 1972, 1973;  $\leq 1971$ , and re-reading agreement of scale samples from recaptured and non-recaptured walleye was evaluated for each of these groups, as shown below.

Age Group By Year Class	Number of Scales Re-read		Percent in Agreement	
	Non-recaptures	Recaptures	Non-recaptures	Recaptures
$\geq 1974$	182	53	93.4	94.3
1973, 1972	96	28	84.4	82.1
$\leq 1971$	214	93	80.3	63.4

Not surprisingly, with increasing age, reliability of age determination for both non-recaptures and recaptures decreased.

But, re-aging agreement for 1971 and older recaptured walleye was considerably lower than for non-recaptures of the same age group. This was not the case with the two younger age groups.

The observation that recaptured walleye, particularly older ones, were less reliably re-aged than non-recaptures may imply that the growth of these fish was also affected. Presumably, one factor that may have contributed to the poorer agreement among recaptures was that the handling and tagging

procedures interfered with the regular deposition of circuli at the scale's peripheral edge. False annuli are one possible consequence of this. This effect, or even the deposition of irregular circuli, could result in growth calculation errors either directly, or indirectly as a consequence of misaging, if those fish were used in the growth analyses. That growth rate may have been altered is supported by the observation that recaptured walleye, and again particularly the older ones, which were released in a period during the growth season immediately prior to recapture, generally showed either negative or no change in fork length between the two consecutive periods.

The observation that recaptured walleye were less reliably reaged, and at least the suspicion that their growth was also affected were sufficient reasons to exclude these samples from the age and growth analyses. Tagging has been shown to have both a negative effect on walleye growth (Mraz 1968), and no effect (Moenig 1975). Bagenal and Tesch (1978) cautioned that unless tagging can be shown to have no effect on growth then data of this type should not be used in growth estimation.

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## Appendix B:

Table 1. Monthly zooplankton biomass values from integrated samples collected in St. Dalmas<sup>a</sup>. and S. Thomas<sup>a</sup>. in 1978 and 1979.

Lake	Year	Date	Wet Weight (g)	Wet Weight/ Litre	Annual Mean Wet Weight/Litre
S. Thomas					
	1978				
		July 5	0.19	0.00449	
		August 3	0.15	0.00355	0.0042
		August 28	0.19	0.00449	
	1979				
		July 6	0.65	0.01537	
		July 25	0.36	0.00851	0.0104
		August 28	0.31	0.00731	
St. Dalmas					
	1978				
		July 5	1.06	0.01981	
		August 3	0.55	0.01028	0.0136
		August 28	0.58	0.01084	
	1979				
		July 6	0.59	0.01103	
		July 25	0.62	0.01159	0.0115
		August 28	0.64	0.01196	

<sup>a</sup>. Volume of integrated sampler: St. Dalmas - 53.52ℓ;  
S. Thomas - 42.30ℓ.

# Appendix C<sub>I</sub>:

This appendix presents results of the analysis of variance of log abundance (Table 1) and log biomass (Table 2) C.P.U.E. 1979 perch gill net data. Additionally, shown below are the results of tests of assumptions requisite for these analyses.

Both the relative abundance and relative biomass data sets were  $\log_{10}$  transformed. Normality was tested using the Kolomorgorov-Smirnov test statistic (PROC UNIVARIATE; Helwig and Council 1979) and a significance level of 0.05. Both transformed data sets were normally distributed: log abundance (n=96, D=0.063, pr>D = >0.15); log biomass (n=96, D=0.047, pr>D = >0.15).

The log transformation also ensured independence of the sample variances from the sample means. For log abundance, the log variance was independent of the log mean (d.f. 1 22, F = 1.07, pr>F = 0.312), with a slope of zero (estimate of b = 0.183, T for ( $H_0$ :b=0) = 1.04, pr>|T|= 0.312). For log biomass, the log variance was independent of the log mean (d.f. 1 22, F = 0.09, pr>F = 0.766), with a slope of zero (estimate of b = 0.034, T for ( $H_0$ : b=0) = 0.30, pr>|T|= 0.766).

Bartlett's  $\chi^2$  test for homogeneity of residual variances was non-significant for log biomass (d.f. = 23, pr> $\chi^2$  = 0.372); but rejected for log abundance (d.f. = 23,

Appendix C<sub>I</sub>:

Table 1. Results of factorial analysis of variance for  
1979 log C.P.U.E. relative abundance data.  
Main effects were entered in order of their  
relative biological value.

Source	d.f.	Sum of Squares	F-value	Pr>F
Lake	1	3.822	14.33	< 0.001
Period	5	1.433	1.06	0.391
Lake*Period	5	0.891	0.66	0.659
Time	1	0.064	0.23	0.629
Lake*Time	1	0.655	2.42	0.124
Period*Time	5	0.754	0.56	0.735
Lake*Period*Time	5	2.003	1.48	0.206
Error	72	19.484		
Total	95	29.166		

Appendix C<sub>I</sub>:

Table 2. Results of factorial analysis of variance  
for 1979 log C.P.U.E. relative biomass data.  
Main effects were entered in order of relative  
biological importance.

Source	d.f.	Sum of Squares	F-value	Pr>F
Lake	1	1.044	5.90	0.018
Period	5	1.174	1.33	0.262
Lake*Period	5	0.402	0.45	0.811
Time	1	0.149	0.84	0.361
Lake*Time	1	0.360	2.04	0.158
Period*Time	5	0.770	0.87	0.507
Lake*Period*Time	5	1.902	2.15	0.069
Error	72	12.746		
Total	95	18.548		



$\text{pr} > \chi^2 = 0.016$  ). However, since sample sizes are equal ( $n=4$ ) the effect of heterogeneous variances on the significance level are very slight (Glass et al 1972).

Appendix C<sub>II</sub>:

The 1979 log C.P.U.E. abundance data was analysed to test for significant differences in catchability of gill nets set parallel to shore in July versus right angles to shore in August. Because the TIME, and its interaction effects were non-significant (Appendix B<sub>I</sub>) gill sets from July and August not made during the formal sampling experiment were pooled into the data set. These sets were included primarily to increase the August sample size.

Since set angle was correlated with season, a preliminary analysis to test for seasonal effects was necessary. Set angle differences could be tested only if there were no significant seasonal trends in perch availability.

A factorial non-balanced analysis of variance (SAS User's Guide, PROC GLM, Helwig and Council 1979) using LAKE and PERIOD as main treatment effects was used to test for significant seasonal, that is PERIOD, differences (Table 1). The significant LAKE effect indicated a difference in log C.P.U.E. abundance between St. Dalmas and S. Thomas, while the non-significant PERIOD effect, using pooled over lakes means, indicated no seasonal trend in perch availability. Absence of a LAKE\*PERIOD interaction implied that the seasonal effect

Appendix C<sub>II</sub>:

Table 1. Results of factorial analysis of variance using all July and August log C.P.U.E. abundance data to test for significant PERIOD differences.

Source	d.f.	Sum of Squares	F-value	Pr>F
Lake	1	4.378	13.97	<0.001
Period	8	2.908	1.16	0.332
Lake*Period	8	1.919	0.77	0.634
Error	92	28.831		
Total	109	39.265		

was independent of the LAKE effect, and that there appeared to be no significant seasonal trend in perch availability within each lake. Therefore, log C.P.U.E. abundance catch data could be pooled by set angle.

Non-balanced analysis of variance, using LAKE and set ANGLE as main treatment effects, was used to test for the effect of set angle on log C.P.U.E abundance (Table 2). As above, the LAKE effect was observed. The non-significant ANGLE effect, and the LAKE\*ANGLE interaction, indicated that there was no difference in catch size between parallel and right angle sets within each lake.

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Appendix C<sub>II</sub>:

Table 2. Results of factorial analysis of variance comparing log C.P.U.E. abundance data of July parallel sets with right angle August sets.

Source	d.f.	Sum of Squares	F-value	Pr>F
Lake	1	3.497	11.25	0.001
Angle	1	0.603	1.94	0.167
Lake*Angle	1	0.018	0.06	>0.500
Error	106	32.954		
Total	109	39.265		

Appendix D<sub>I</sub>:

Table 1. Fork length (mm) at annulus formation for female S. Thomas perch collected during 1978 and 1989, showing back-calculated sizes, for separate growth years.

Year Class	Sample Size	Age											Growth Year <sup>a</sup> .
		1	2	3	4	5	6	7	8	9	10	11	
1978	4	45											2
1977	13	46											1
	18	43	76										2
1976	38	47	76										1
	21	44	73	102									2
1975	14	46	77	104									1
	8	45	77	109	131								2
1974	26	43	72	96	125								1
	19	42	69	94	123	142							2
1973	36	44	69	98	124	144							1
	21	43	68	99	126	147	160						2
1972	11	45	73	101	129	149	165						1
	9	47	72	97	127	145	164	177					2
1971	31	51	76	102	128	149	166	180					1
	10	46	73	103	127	150	166	178	188				2
1970	42	47	74	99	127	150	168	181	191				1
	20	48	76	103	133	158	179	192	203	211			2
1969	12	45	76	104	129	154	173	189	199	207			1
	11	43	68	97	123	153	177	193	203	212	220		2
1968	7	42	71	103	136	158	181	195	204	212	219		1
	6	46	75	99	127	160	181	198	209	218	225	231	2
1967	1	53	80	112	139	175	187	196	202	207	215	220	1

a. July 1978 - June 1979 = 1; July 1979-Aug. 1979 = 2.

Appendix D<sub>I</sub>:

Table 2. Fork length (mm) at annulus formation for male S. Thomas perch collected during 1978 and 1979, showing back-calculated sizes for separate growth years.

Year Class	Sample Size	Age											Growth Year <sup>a</sup> .
		1	2	3	4	5	6	7	8	9	10	11	
1978	8	48											2
1977	11	45											1
	7	44	69										2
1976	37	46	73										1
	10	43	69	91									2
1975	6	45	73	95									1
	2	40	70	89	118								2
1974	13	43	68	92	113								1
	4	42	74	94	108	131							2
1973	8	47	73	96	115	128							1
	4	42	69	87	114	126	136						2
1972	6	44	64	85	106	121	134	143					2

<sup>a</sup>. July 1978 - June 1979 = 1; July 1979 - August 1979 = 2.

Appendix D<sub>I</sub>:

Table 3. Fork length (mm) at annulus formation for female St. Dalmas perch, collected during 1978 and 1979, showing back-calculated sizes for separate growth years.

Year Class	Sample Size	Age											Growth Year <sup>a</sup>
		1	2	3	4	5	6	7	8	9	10	11	
1978	7	56											2
1977	19	58											1
	32	57	90										2
1976	3	56	82										1
	2	54	74	109									2
1975	92	51	87	115									1
	58	50	87	113	147								2
1974	18	58	95	135	154								1
	32	59	96	136	157	181							2
1973	7	59	94	125	156	174							1
	6	56	97	131	156	174	194						2
1972	13	66	103	133	163	180	193						1
	8	65	97	127	157	180	193	208					2
1971	13	63	97	128	153	176	190	200					1
	13	65	103	133	162	182	197	206	218				2
1970	3	63	100	130	156	177	193	206	215				1
	10	64	104	130	157	178	192	201	208	221			2
1969	1	79	124	170	192	207	225	244	252	260			1

<sup>a</sup>. July 1978 - June 1979 = 1; July 1979 - Aug. 1979 = 2.



Appendix D<sub>I</sub>:

Table 4. Fork length (mm) at annulus formation for male St. Dalmas perch, collected during 1978 and 1979, showing back-calculated sizes for separate growth years.

Year Class	Sample Size	Age										Growth Year <sup>a</sup>	
		1	2	3	4	5	6	7	8	9	10		11
1978	8	57											2
1977	35	58											1
	10	54	86										2
1976	1	60	92										1
	4	56	81	102									2
1975	43	48	81	101									1
	32	47	79	98	121								2
1974	5	52	89	117	131								1
	1	50	87	109	127	147							2
1973	4	64	98	125	142	153							1
1972	2	63	100	121	142	158	168						1
	1	63	94	117	139	155	165	178					2
1971	8	61	93	110	132	147	157	164					1
	1	62	89	118	142	164	173	180	187				2
1970	1	49	70	109	135	157	173	183	187				1

<sup>a</sup>. July 1978 - June 1979 = 1; July 1979 - Aug. 1979 = 2.

Appendix D<sub>II</sub>:

Table 1 in Appendix D<sub>I</sub> compared mean fork lengths of female S. Thomas perch for the separate growth years. However, this may be inappropriate to show whether or not the apparent negative Lee's phenomenon, observed in the post age 5 fishes of this group, resulted solely from selective mortality for slower growing females. This is because a portion of the sample used to calculate mean lengths for the 1978 growth year was collected in May-June 1979, prior to annulus formation. Their inclusion with the 1978 July-August samples could mask the effects of selective mortality - that is, as systematic differences in the mean back-calculated fork lengths at an age within year classes - on growth, that would become apparent only over a sufficiently long temporal period. Consequently, the table shown here (Table 1) is calculated for S. Thomas females sampled between July-August 1978 and July - August 1979.

Sample sizes in 1978 were often small, consequently there are some underrepresented year classes (Table 1). Results indicate that although there is a tendency for trends within a given year class, for example the 1971 year class, this trend is not consistent across year classes suggesting the absence of negative Lee's phenomenon. If it were present then one would expect that for all or most year classes, the

Appendix D<sub>II</sub>:

Table 1. Fork length (mm) at annulus formation for S. Thomas female perch collected in separate sample years, for 1973 and older year classes.

Year Class	Sample Size	Age											Sample Year <sup>a</sup>
		1	2	3	4	5	6	7	8	9	10	11	
1973	13	44	69	97	123	142							1
	21	43	68	99	126	147	160						2
1972	2	45	71	100	129	144	165						1
	9	47	72	97	127	145	164	177					2
1971	14	55	80	105	131	152	170	182					1
	10	46	78	103	127	150	166	178	188				2
1970	12	48	75	102	130	152	170	185	195				1
	20	48	76	103	133	158	179	192	203	211			2
1969	3	49	82	107	133	160	181	196	204	211			1
	11	43	68	97	123	153	177	193	203	212	220		2
1968	6	46	75	99	127	160	181	198	209	218	225	231	2

a. July 1978 - August 1978 = 1; July 1979 - August 1979 = 2.

mean lengths of the post age 4 females from the 1979 samples within each year class would be consistently less at a given age than those calculated using the 1978 samples.

Appendix E<sub>I</sub>:

The purpose of this appendix is to discuss the validity of assumptions necessary for abundance estimation using mark-recapture methods. Only the St. Dalmas walleye and S. Thomas pike will be discussed in detail as catches of S. Thomas walleye were often too small to even form length-frequency by mesh size distributions.

The latter group's May estimate was statistically biased, negatively, on the order of 5% because the product of  $n_1 \times n_2$  (2.6) did not exceed the estimate of  $N$  (73) by at least a factor of 3-4 (Robson and Regier 1964). Because of small sample sizes formation of confidence intervals was not possible (Seber 1973). With respect to the validity of other assumptions (eg. random sampling, tagging mortality) it is assumed that the sampling procedures used to minimize their contribution to bias, for the other two groups, discussed below, also applied to the S. Thomas walleye population as it was subjected to comparable sampling and handling methodologies.

An important sampling assumption is that the population must be randomly or representatively sampled (Ricker 1975). During each mark-recapture period on a lake, fishing effort was allocated in approximately equal proportions to each of the four quadrats on that lake, with stations within quadrats also receiving representative effort.

Further, considering the intense allocation of effort, the possibility of failing to sample a geographically discrete subpopulation was likely minimal.

Another random sampling aspect is that of biased vulnerability of either different size, or age groups, to the sampling gear. Where feasible and warranted, both trap and gill nets were used for sampling, minimizing gear-specific effects. Length-frequency distributions were constructed for S. Thomas pike (Fig. 1) and St. Dalmas walleye (Fig. 2) showing trap net and gill net by mesh size, catches.

There is little evidence for gill net selection of pike because all three panels caught a comparable range of fish sizes and, generally, in the same proportions from any given length class (Fig. 1). The trap net frequency distribution is in good agreement with sizes caught by the gill nets. Those pike less than 500 mm were all recruited during August, and were also representatively sampled by each gill net mesh (Fig. 1).

Evaluation of St. Dalmas walleye catches (Fig. 2a, 2b) also suggests minimal size selective bias by the sampling gear. Trap net and gill net, by mesh size, May-June distributions (Fig. 2a) are very comparable, with the exception that different mesh sizes were somewhat differentially efficient at different length ranges. The August-September gill net catches, by mesh size, were also compatible

Fig. 1. Fork length - frequency distributions of S. Thomas pike, by trap net and gill net mesh size, caught throughout 1979.

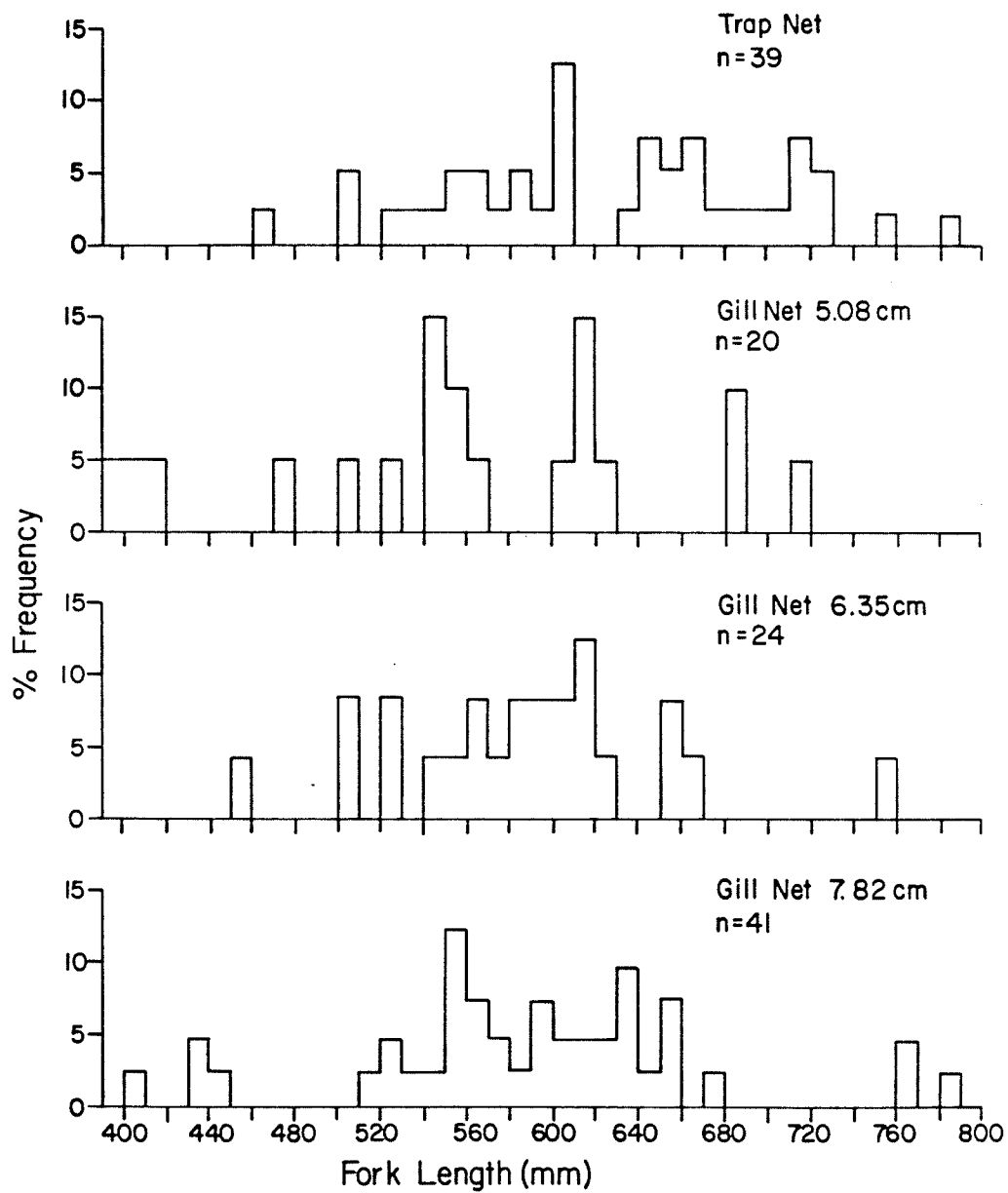
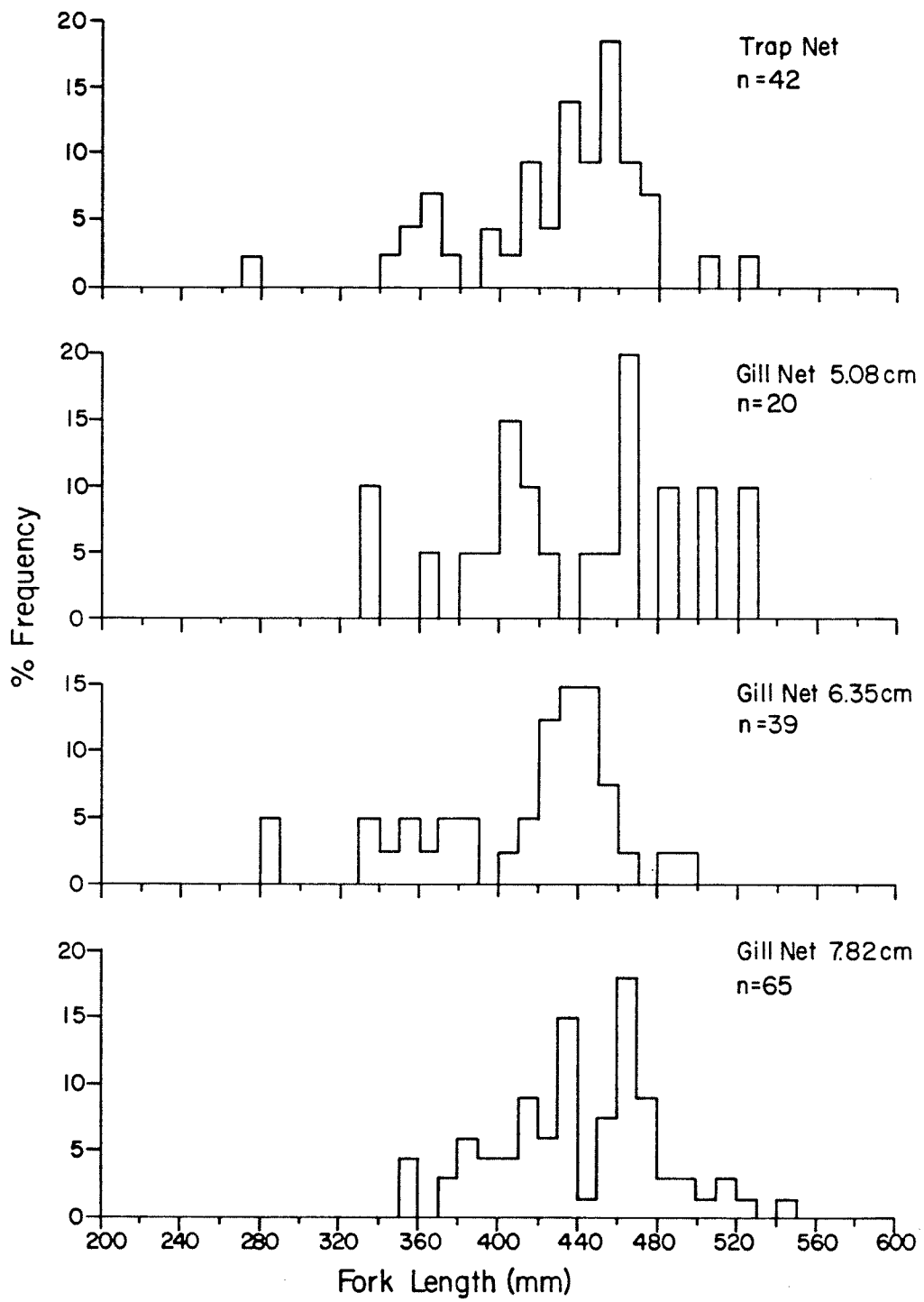


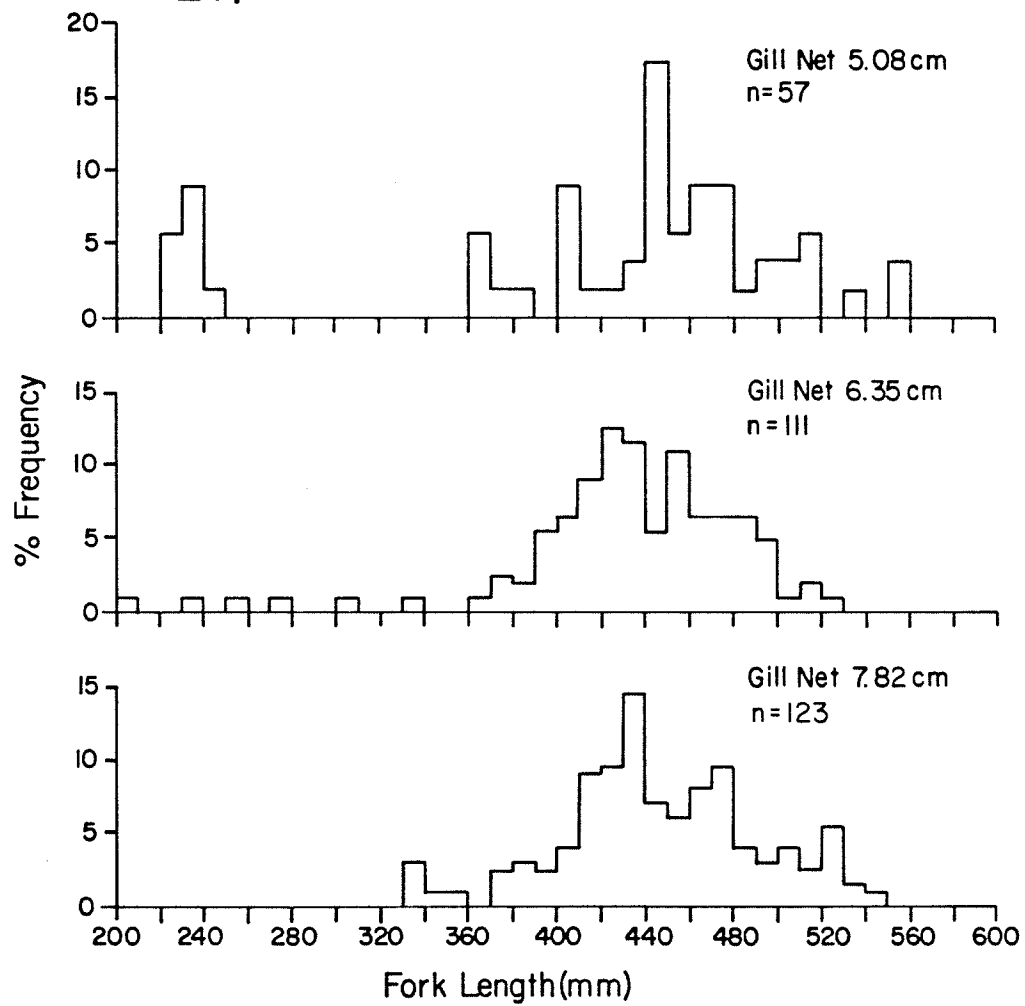


Fig. 2a) and 2b). Fork length-frequency distributions of St. Dalmas walleye, by trap net and gill net mesh sizes, for the May-June 1979 period: 2a), and for the August-September 1979 period: 2b).

2a)



2b)

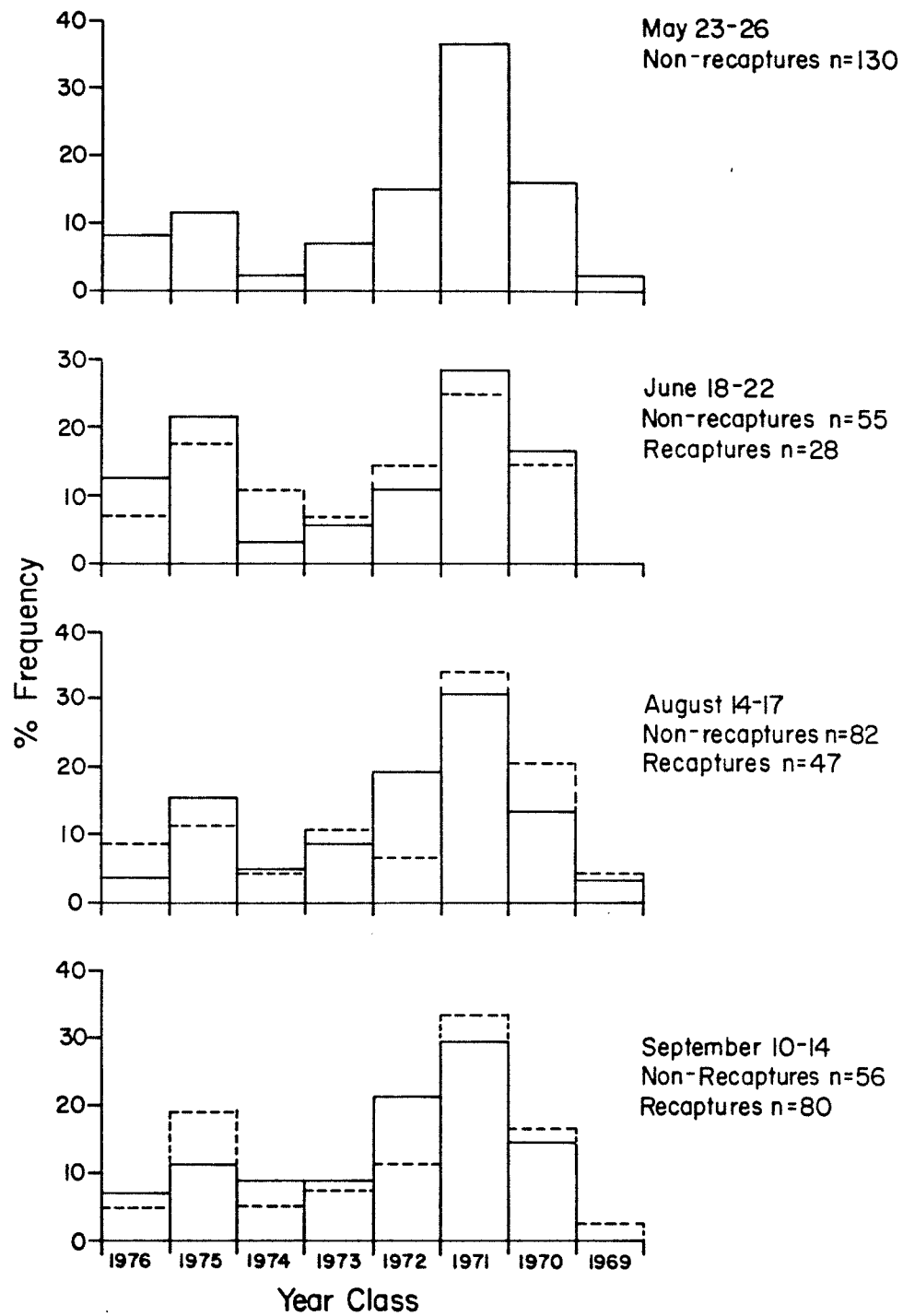


(Fig. 2b) with an excellent degree of overlap between mesh sizes. In this latter period recruited walleye were caught in both the 5.08 and 6.35 cm meshes, although predominately in the latter. Length-frequency distributions of St. Dalmas walleye captured in the July-August perch gill net gangs, which consisted of a different range of panel mesh sizes, were comparable to those observed in Fig. 2b, indicating that the absence of walleye in the 240-340 mm length range was not due to selection by the standard walleye gang.

The narrow range of gill net mesh sizes used may also warrent concern, however it is not a serious source of bias. This is suggested by the compatibility of trap net and standard gill net by mesh size length-frequency distributions for both S. Thomas pike (Fig. 1) and St. Dalmas walleye (Fig. 2a) in the May-June periods. Experimental catches in 1978, using a broader range of gill net meshes and extensive use of trap nets, substantiated this conclusion.

These results, and the analyses of seasonal walleye and pike length-frequency distributions in the RESULTS section indicates that sampling of each of the populations was not size biased. Minimal sampling bias by age for the St. Dalmas walleye is suggested in Fig. 3. The 1977 and 1978 year classes were not recruited until June and August, respectively, and therefore are not included. For

Fig. 3. Age-frequency distributions of St. Dalmas walleye caught during the mark-recapture periods in 1979, showing non-recaptured (—) and recaptured (--) groups for each age class.



both the non-recaptured and recaptured groups, the proportionate contribution of each year class to the within period total is similar between periods and with only a few exceptions does the relative ranking of year classes change between periods. Comparison of non-recaptured versus recaptured year classes, both within and between periods, further suggests minimal age bias selection.

A critical assumption in mark-recapture experiments is that of equal catchability of marked versus non-marked fish. Recapture data was sufficient only for the St. Dalmas walleye sample to conduct Pollock's (1975) chi-square test of equal catchability. This test is normally applicable to death only models. Although the full birth and death model was applied to the St. Dalmas data to account for the behavioural 'births' between May to June there was no evidence of further such recruitment past the June period, and since fish recruitment by growth was still excluded, it is reasonable to assume the absence of any type of recruitment past June. This is essentially a death only situation and consequently, Pollock's test may be applied to post June data to test for equal catchability of marks versus non-marks in the August 10-17 period, as shown on the following page:

Known number unmarked and alive in population		Known number marked and alive in population		$\chi^2$ Statistic	d.f.
Seen at i(S.1)	Not seen at i(N.1)	Seen at i(S.2)	Not seen at i(N.2)		
103	78	41	46	2.78	1

This test, which compares the proportion of marks in the August sample (i) to the proportion of marks in the population, with the  $H_0$ : the proportions are the same, was non-significant ( $\chi^2$  ( $\alpha = .05$ , d.f. 1) = 3.84), indicating that both marked and non-marked walleye were equally available to the gear during the August period. This would imply, assuming that a similar situation existed in the September period, that the June abundance estimate was not biased by failure of this assumption.

A similar measure of catchability, by the fishing gear, was provided by catch information from sport fishermen.. For S. Thomas pike, on June 27, 1979 a sportsman caught four pike, one (25%) of which was tagged. This concurred with the percent of tagged pike (21%) caught by trap and gill nets during the June 25-28 mark-recapture period. On St. Dalmas, the owner of the single cottage on the lake



reported that two (33%) of six fish caught between June 1 and June 19 were tagged. In the June mark-recapture period 23% of the total catch was tagged. Catches from this sportsman and another, between August 1 and August 18 - 8 tagged (47%) of 17 caught - were also in general agreement with the proportion of tagged walleye (29%) captured during the August 14-17 mark-recapture period.

An additional assumption of mark and recapture experiments is that there is equal mortality between marked and non-marked individuals. Sampling and handling procedures employed to minimize tagging mortality included termination of tagging when water temperature exceeded 19C (Kelso 1972; Schweigert 1976), and the use of an on-board floating sampling station which minimized handling stress, since fish spent very little time out of the lake. Regular shoreline patrols after each marking period were conducted and showed no carcasses post the May and June periods in S. Thomas. In St. Dalmas, there were no observed carcasses after the May and August periods, but two tagged and two non-tagged walleye were recovered in the post June period shoreline patrols. Robson's (1969) chi-square tests for initial tagging mortality did indicate some disproportionate mortality among St. Dalmas walleye released in the June period

Appendix E<sub>I</sub>:

Table 1. Robson's chi-square contingency table test for tagging mortality in St. Dalmas walleye.

Period	Number first captured in the $i^{\text{th}}$ sample and released		Number recaptured in the $i^{\text{th}}$ sample and released		$\chi^2$	pr> $\chi^2$
	Number seen later	Number not seen again	Number seen later	Number not seen again		
June 18-22	15	46	9	7	5.92	0.020
August 14-17	25	71	12	28	0.22	>0.500

(Table 1). However, Arnason and Baniuk (1978) found by use of simulation studies, that while this may bias survival estimates, those for abundance are robust to violation of this assumption. Therefore, abundance estimates are not unduely biased by tagging or handling mortality.

The last major assumption of mark-recapture experiments is that of negligible tag loss in marked fish. Tag loss is most effectively estimated by use of either double tags or permanent mutilations (eg. Robson and Regier 1966; Arnason and Mills 1981). Tags lost from fishes marked during this study produced an easily recognizable mutilation scar where the Floy tag had been injected. Tag loss of the type where the anchor remained, but the identifying streamer was gone, was also clearly recognized as such.

No tag losses were observed for either the walleye or pike in S. Thomas, captured during the June 25-28 recapture period, implying absence of tag loss bias in their respective Peterson abundance estimates.

Tag loss, observed in the St. Dalmas walleye population (Table 2) was generally about 5% of the marked subset sampled. Fish with losses cannot be identified as to their original release date precluding calculation of specific tag loss rates. Additionally, a number of

Appendix E<sub>I</sub>:

Table 2. Tag losses for St. Dalmas walleye during the 1979 mark and recapture season.

Period	Sample Size	Size of Marked Subset	Number and Type of Loss		Total Number Lost
			Scar	Anchor	
May 23-26	140	0	-	-	-
June 18-22	88	20	0	1	1
August 14-17	144	41	1	2	3
September 10-14	149	71	2	2	4

tagged walleye ( $n=112$ ) were released in 1978 (but not used to form any abundance estimates), and these individuals would contribute, at an unknown rate, to the pool of "tag lost" walleye sampled during 1979. This effect however, would result in an overestimate of the actual tag loss sustained by the pool of 1979 individuals used to form the abundance estimates (Table 2). Bias, as a consequence of tag loss, would therefore be overestimated. Further, Arnason and Mills (1981) have demonstrated that even in the presence of an unknown rate of tag loss, abundance estimates based on the full Jolly-Seber model remain unbiased. They further found the precision of these estimates, derived by the full model, will always be less than those from the death only model, as was observed here (see Appendix E<sub>II</sub>).

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Appendix E<sub>II</sub>:

Table 1. Estimate of population parameters (Arnason and Baniuk 1978) for St. Dalmas walleye in 1979.  
Top: Jolly-Seber death only analysis. Bottom: Jolly-Seber, full birth and death analysis.

Period (I)	AH(I) <sup>a</sup>	MH(I) <sup>b</sup>	NH(I) <sup>c</sup>	S(NH(I) N) <sup>d</sup>	PHI(I) <sup>e</sup>	S(PHI(I)) <sup>f</sup>	BH(I) <sup>g</sup>	S(BH(I)) <sup>h</sup>
1. May 23-26	-	-	624.17	45.60	>1.000	0.175		
2. June 18-22	0.236	184.51	811.84	128.94	0.684	0.138		
3. August 14-17	0.290	155.97	547.79	65.48	-	-		
4. September 10-14	0.480	-	-	-	-	-		
1. May 23-26	-	-	-	-	>1.000	0.183	-	-
2. June 18-22	0.236	179.12	759.13	196.78	0.693	0.146	46.46	120.13
3. August 14-17	0.290	163.58	564.74	107.27	-	-	-	-
4. September 10-14	0.480	-	-	-	-	-	-	-

a. Proportion of marks in population.

b. Estimated number of marks in population.

c. Estimated population size at time I.

d. Conditional standard error of population size estimate.

e. Estimate of survival rate between I, I+1.

f. Standard error of survival rate estimate.

g. Estimate of births entering between I, I+1. Full model only.

h. Standard error of estimate of births. Full model only.



Appendix F:

Table 1. Fork length (mm) at annulus formation for St. Dalmas walleye collected during 1978 and 1979, showing back-calculated sizes for separate growth years.

Year Class	Sample Size	Age										Growth Year <sup>a</sup>
		1	2	3	4	5	6	7	8	9	10	
1978	15	128										2
1977	2	130										1
	13	132	273									2
1976	17	150	270									1
	19	141	270	353								2
1975	54	129	281	352								1
	35	129	278	356	397							2
1974	14	127	255	336	378							1
	12	122	252	334	384	416						2
1973	15	137	253	333	386	417						1
	16	135	255	330	374	403	421					2
1972	30	134	257	335	382	410	429					1
	35	131	249	325	368	395	415	429				2
1971	79	140	255	329	371	400	421	435				1
	58	141	257	335	378	409	434	450	464			2
1970	38	142	257	332	376	405	428	444	456			1
	30	142	262	342	390	425	453	469	483	494		2
1969	5	134	262	343	387	415	434	450	461	471		1
	4	134	267	350	390	417	438	455	469	481	491	2

<sup>a</sup>. July 1978 - June 1979 = 1; July 1979 - Sept. 1979.

Appendix F:

Table 2. Fork length (mm) at annulus formation for S. Thomas walleye collected during 1978 and 1979, showing back-calculated sizes for separate growth years.

Year Class	Sample Size	Age										Growth Year <sup>a</sup>
		1	2	3	4	5	6	7	8	9	10	
1977	2	103										1
	9	108	246									2
1976	1	135	268									1
1975	1	114	253	347	399							2
1974	1	136	269	352	409							1
	1	128	257	353	417	443						2
1973	17	127	258	354	419	453						1
	17	121	251	347	416	449	474					2
1971	1	141	307	372	432	473	494	512				1
1969	1	143	243	361	462	517	550	568	581	592	598	2

<sup>a</sup>. July 1978 - June 1979 = 1; July 1979 - Aug. 1979 = 2.

## Appendix G:

In order to make growth comparisons with other studies, which generally present lengths as total rather than fork, total length - fork length relationships were developed by linear regression on  $\log_{10}$  transformed data for the perch and arithmetic data for the walleye. For perch, lake-specific relationships were calculated using data collected in 1978. For walleye, only a St. Dalmas relationship was calculated, also using 1978 data. This relationship was applied to both walleye populations, since total length-fork length conversion ratios are generally similar, regardless of the population (Colby et al. 1979). These relationships with sample size, S.E. of b, and  $r^2$  in square brackets are:

## Perch:

## St. Dalmas:

$$\log (T.L.) = 0.024 + 0.998 \log (F.L.); [276, 0.003, 1.00]$$

## S. Thomas:

$$\log (T.L.) = 0.029 + 0.995 \log (F.L.); [273, 0.001, 1.00]$$

## Walleye:

## St. Dalmas:

$$T.L. = -5.660 + 1.065 F.L.; [61, 0.012, 0.99]$$

## Literature Cited

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