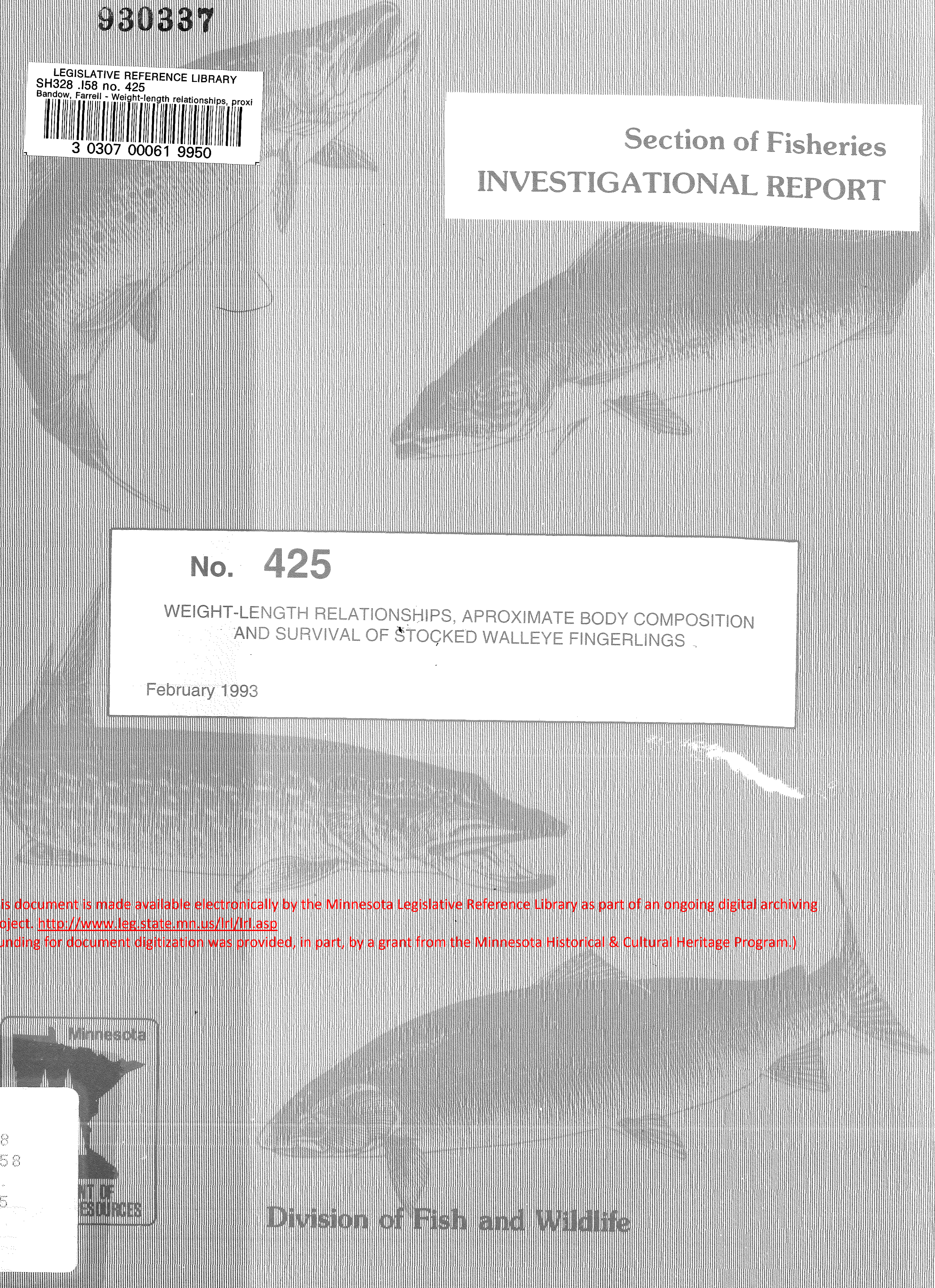

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WEIGHT-LENGTH RELATIONSHIPS, PROXIMATE BODY COMPOSITION, AND WINTER SURVIVAL OF STOCKED WALLEYE FINGERLINGS[1]

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Abstract.--Walleye fingerlings *Stizostedion vitreum* from stocks having different weight-length relationships were evaluated to determine how these relationships reflect proximate body composition, and how length and body composition influence winter survival. In three successive years (1987-89), fingerlings from two nursery stocks were sampled and released together in two drainable ponds without predators and in a lake with large predators. Weight-length regressions showed that the plumper of the paired stocks were, on average, 7 to 13% heavier at length. The plumper stocks survived better over winter in five of six pond trials and in all three lake trials. Disease, however, was a factor in fall 1988. The plumper stocks significantly exceeded the lighter stocks in mean length by 15 mm in 1987 and 8 mm in 1989, however, fish length did not appear to an important factor limiting survival. Elevations of fish weight-length regression lines increased over winter. Mortality of lighter fish could not be ruled out as a contributing factor, however, in four of the stocks, winter weight gains by undetermined numbers of walleye in the ponds were indicated by increases in numbers of positive residuals when spring weight-length coordinates were compared with fall regression lines.

Body components (water, ash, lipid) were measured for stocks before and after the winter of 1987-88. Although water accounted for 65-80% of body weight differences between stocks, the plumper fish were significantly richer in organic components, primarily protein. Winter weight gain was attributable largely to lipid deposition. Most of the information on ash free dry weight or energy content could be obtained from measured wet and dry weights.

Introduction

Walleye *Stizostedion vitreum* fingerling stocking is a major component of the Minnesota Department of Natural Resources' fish management program, but factors affecting post-stocking survival are poorly understood. Although size, expressed as the number of fingerlings per unit weight, is thought to influence survival, abundance of walleye fingerlings in nursery lakes and ease of harvest are the major criteria used in selection of nursery stocks to fill stock-

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ing quotas. Quotas are usually expressed as total fish weight per unit of water area, and thus indirectly address fish size, but the individual roles of fish length and body composition in survival are obscure.

For many temperate zone fishes, winter survival is strongly dependent upon length and energy reserves. This is often apparent with age-0 fish because they are small and have high specific metabolic rates. Smallmouth bass *Micropterus dolomieui* is one of the most thoroughly studied species, with key features being that fish cease feeding at cold temperatures (Munther 1970), shorter individuals have lower energy stores and deplete them at a higher rate, and fish die when AFDW reaches a critical level (also a function of length) (Oliver et al. 1979; Shuter et al. 1980; Shuter et al. 1989). Length related juvenile mortality also has been attributed to exhaustion of energy reserves in brook trout *Salvelinus fontinalis* (Hunt 1969) and Colorado squawfish *Ptychocheilus lucius* (Thompson et al. 1991). Length dependent winter mortality of age-0 fish has been reported for largemouth bass *Micropterus salmoides* (Toneys and Coble 1979; Adams et al. 1982; Newburg and Schupp 1986), and walleye (Forney 1966; Chevalier 1973). Length related winter mortality is not pervasive, however, because other factors such as body composition, winter duration, and predator-prey relationships interact. Toneys and Coble (1979) found no evidence of it in a largemouth bass population, and Priegel (1970) found none in a walleye population.

Walleye may have different patterns of winter survival than bass because they feed at lower temperatures (Galligan 1960; Kelso 1972), and may manage energy differently. Extensive knowledge of how length, weight-length relationships, and body composition influence juvenile walleye survival is needed for bioenergetic modeling to enrich understanding of year class development and improve stocking strategies. Objectives of this study were to document variations of weight-length relationships of fall walleye fingerlings, to determine how weight-length relationships reflect proximate body composition, and to evaluate how length, weight, and body composition influence winter survival of stocked walleye fingerlings.

Methods

Field Procedures

Each fall 1987-1989, two walleye fingerling nursery stocks were used for winter survival evaluation. Selection criteria were that stocks have similar mean lengths and parallel weight-length regression lines at different elevations. Stocks are identified by the names of summer nursery lakes in which they were reared, and the names identify cohorts only. The stocks were from Lone Tree and Rice Lakes in 1987, Clear and Mortenson Lakes in 1988, and Wintermute and Samantha Lakes in 1989.

As fingerlings were harvested from the selected nursery lakes in October and early November, they were marked, counted, and released in two separate 0.4 hectare drainable ponds (Table 1). Stocks were identified by removal of opposite paired fins, the pelvics in 1987 and 1989 and the pectorals in 1988. The fish were retained in the ponds until after marking was completed to minimize differential harvest and marking stress as variables affecting post-stocking survival. Retention time for various lots ranged from 5 to 34 d.

Surviving fish were recovered from the ponds in November and held temporarily in indoor raceways. They were hand counted, and most were stocked in Volney Lake, Le Sueur County, within 2 d. Volney Lake has a surface area of 115 hectares and maximum and mean depths of 20.4 and 6.6 m, respectively (Quade et al. 1977). Large predators were abundant in Volney Lake in 1987 as indicated by net catches that exceeded statewide medians for northern pike and walleye (Table 2).

The remaining fingerlings of each stock were measured for length and weight and apportioned to two raceways where they were retained 6-12 d for mortality assessments. They were then released and overwintered in two 0.4 hectare drainable ponds. Each pond received similar numbers of each stock. The following spring, the ponds were drained, and lengths and weights were obtained from the surviving yearlings.

Spring electrofishing was conducted in Volney Lake to sample the yearlings for mark-

Table 1. Summary of fall treatments of walleye nursery stocks.

		Marking and pond retention segment						Post-recovery mortality assessments					Final destination				
									Raceway 1		Raceway 2		Volney Lake		Ponds [a]		
Year	Nursery stock	Maximum water temp. (°C)	Marking time frame	Number marked	Pond recovery date	Number recovered	Post-marking survival (%)	Duration (d)	Number	Mortality (%)	Number	Mortality (%)	Date	Number	Date	Number pond 1	Number pond 2
1987	Lone Tree Lake	13	8 Oct-6 Nov	5,028	11 Nov	4,228	84.1	12	227	0.4	225	0.4	13 Nov	3,702	24 Nov	226	224
	Rice Lake	11	29 Oct-10 Nov	2,029	17 Nov	1,797	88.6	6	225	0.9	225	0.0	19 Nov	1,273	24 Nov	223	225
1988	Clear Lake	12	19-29 Oct	7,353	8 Nov	3,311	45.0	8	200	10.0	200	13.0	10 Nov	2,763	17 Nov	180	174
	Mortenson Lake	12	19-20 Oct	8,445	1 Nov	3,647	43.2	8	200	2.0	200	5.0	3 Nov	2,967	10 Nov	196	190
1989	Wintermute Lake	14	13-24 Oct	2,727	9 Nov	1,491	54.7	6	220	0.0	220	0.5 [b]	9 Nov	1,039	15 Nov	220	219
	Samantha Lake	15	11-24 Oct	16,256	7 Nov	4,842	29.8	8	220	0.5 [b]	220	0.5 [b]	8 Nov	4,252	15 Nov	219	219

[a] Pond 1 and pond 2 identify treatments and are not actual pond names.

[b] No observed mortality; cannibalism is presumed.

Table 2. Catch summary of standard overnight gill net and trap net surveys in Volney Lake, 25 June-7 July 1987.[a]

Species caught	Gill net sets (4) Mean number per set	Gill net sets (4) Mean weight per fish (g)	Trap net sets (4) Mean number per set	Trap net sets (4) Mean weight per fish (g)
Bowfin *Amia calva*	1.0	---	3.5	648
Northern pike *Esox lucius*	5.8	898	0.3	816
Carp *Cyprinus carpio*	1.5	2,496	---	---
Black bullhead *Ameiurus melas*	201.3	52	667.0	42
Yellow bullhead *Ameiurus natalis*	0.8	484	2.0	363
Green sunfish *Lepomis cyanellus*	0.3	154	---	---
Bluegill *Lepomis macrochirus*	1.3	107	18.3	52
Black crappie *Pomoxis nigromaculatus*	27.0	42	27.5	51
Yellow perch *Perca flavescens*	43.0	63	---	---
Walleye *Stizostedion vitreum*	7.5	1,007	1.0	987
Freshwater drum *Aplodinotus grunniens*	68.8	98	65.0	86

[a] Data from Minnesota Department of Natural Resources lake survey files.

recapture population estimates. Six samples were obtained in May 1988 and 1989. In 1990, sampling was conducted nine times in May and early June. Sampling began approximately 30 min after sundown, and the entire shoreline was traversed twice on most occasions. Except for the last outing each year, captured yearlings were placed in indoor raceways. The following morning, fin clips were evaluated, lengths and weights were obtained from each fish, the upper tip of the caudal fin of each was clipped, and they were returned to Volney Lake.

Twenty-five fingerlings from each of the Lone Tree Lake, Rice Lake, and Mortenson Lake stocks were sacrificed for proximate body composition analysis (Table 3). Also analyzed were 24 Lone Tree Lake yearlings and 25 Rice Lake yearlings recovered from the ponds in spring. Selection was not random, as effort was made to assure that length intervals were equally represented. The fish were wrapped individually in aluminum foil, live frozen in a chest packed with dry ice (-79°C), and transported to the University of Minnesota for storage at -20°C. Storage intervals preceding analyses were 98-434 d.

Analytical Procedures

Volney Lake population estimates were made by the modified Schnabel method (Ricker 1975). Confidence limits were derived by treating recaptures as Poisson variables. Confidence limits on survival rates were derived as direct extensions of population estimate limits.

Fish were measured to the nearest millimeter total length and weighed indoors to the nearest 0.1 g on a portable electronic balance. Balance accuracy was confirmed with standard weights at the start of each measurement session. Before weighing, the worker briefly placed the hand and fish on a damp sponge to eliminate dripping water, but made no effort to remove all moisture from the fish.

Water content was determined by drying finely diced, whole fish to constant weight at 80°C. Total lipids in approximately 2 g samples of mixed, dried, powdered fish were determined

Table 3. Total length summary of walleye fingerlings analyzed for proximate body composition.

		Total length (mm)			
Nursery stock	N	Minimum	Maximum	Mean	Standard deviation
Lone Tree Lake, fall	25	114	223	173	32.9
Lone Tree Lake, spring	24	145	225	185	25.5
Rice Lake, fall	25	125	244	180	34.7
Rice Lake, spring	25	125	230	172	30.7
Mortenson Lake, fall	25	128	171	149	11.8

by extraction with 160 ml of 2:1 chloroform-methanol solution for at least 18 h in a Soxhlet extraction apparatus (Folch et al. 1957; Flath and Diana 1985). The extract was filtered with a Buchner vacuum funnel, and the filtrate transferred to a separatory funnel and mixed thoroughly with 30 ml 0.8% aqueous KCl solution (Folch et al. 1957). When separation was complete, the chloroform-lipid layer was evaporated to approximately 15 ml under a fume hood. The solvent was then evaporated completely in a drying oven. Weights of samples and lipid recovered from them were used to calculate total body lipid. Ash content was determined by combusting approximately 2 g of the powdered fish at 550°C to constant weight. Wet and dry whole fish were weighed to 0.01 g; all other weight measurements were to 0.001 g. Ash free dry weight (AFDW) is a combination of organic body components, primarily lipid and protein. Elliott (1976) showed that water, fat, protein, and ash formed more than 99% of the live weight of brown trout *Salmo trutta*. Craig (1977) reported a range of 96.9-99.8% for European perch *Perca fluviatilis*. Ash and lipid free dry weight (ALFDW), primarily a protein component, was calculated as dry fish weight minus the combined weight of ash and lipid.

We could not compare composition of various walleye groups without reference to specific lengths because component weights varied with length at different rates. Groups were compared on the basis of predicted body weights and body component weights at the lower, middle, and upper lengths of the range common to both populations. Prediction models used were least-squares regressions of $\log_{10}$ transformed body and body component weights on $\log_{10}$total lengths (Table 4). Hypotheses tests were normal approximations of *t* tests. Small sample sizes of 24 and 25 fish may cast some doubt on inferences.

Body weight-length parameters of walleye overwintered in ponds and in Volney Lake samples were estimated by least-squares regression of $\log_{10}$weights (live fish weights) on $\log_{10}$total lengths. Differences between residual variances precluded analysis of covariance. Instead, tests for homogeneity of slopes and intercepts were done with Welch's *t* test on regression lines generated after independent variables were scaled by dividing them by the grand mean total length. Welch's *t* test does not assume equal residual variances. Intercepts of the scaled data are the elevations of the regression lines at about the grand mean length. Scaling was used for hypothesis testing only, and regression lines and parameter estimates displayed are for unscaled data.

Results

Weight-length Relationships

In all years, slopes of fingerling weight-length regression lines differed at the 10% significance level, but differences were small, and lines did not cross (Figure 1). Weight differences at the scaled intercepts represent averages and were 3.4, 2.5, and 0.84 g for 1987, 1988, and 1989, respectively. On a percent basis, the plumper stocks were 8.3, 13.3, and 7.0% heavier at the intercepts, respectively.

Mean total lengths differed significantly each fall (Table 5). Mean lengths of the plumper Lone Tree Lake stock in 1987 and the Wintermute Lake stock in 1989 exceeded those of their lighter counterparts. In 1988 the lighter Mortenson Lake stock exceeded the Clear Lake stock in mean length.

Weight-length regression line elevations rose significantly from fall to spring among all groups overwintered in ponds (Figure 2).

Table 4. Statistics of least-squares regressions of $\log_{10}$live body weight and $\log_{10}$body component weights on $\log_{10}$total length. Weight was measured in grams and length in millimeters.

		Dependent variables					
Walleye group/ Regression statistics	N	Live body weight	Water	Ash	Lipid	ALFDW	AFDW
Lone Tree Lake, fall	25						
Intercept		-6.190	-6.211	-8.423	-7.137	-7.285	-7.136
Slope		3.477	3.438	3.842	3.119	3.616	3.570
$s_{Y\|X}$		0.022	0.022	0.030	0.099	0.026	0.030
r^2		0.995	0.995	0.992	0.885	0.994	0.991
Lone Tree Lake, spring	24						
Intercept		-6.309	-6.300	-8.672	-7.718	-7.477	-7.329
Slope		3.535	3.482	3.955	3.486	3.700	3.668
$s_{Y\|X}$		0.022	0.022	0.023	0.066	0.028	0.030
r^2		0.990	0.990	0.992	0.917	0.985	0.983
Rice Lake, fall	25						
Intercept		-6.292	-6.228	-7.769	-9.886	-7.749	-7.807
Slope		3.504	3.428	3.537	4.309	3.799	3.845
$s_{Y\|X}$		0.021	0.019	0.029	0.142	0.032	0.040
r^2		0.995	0.996	0.992	0.874	0.991	0.986
Rice Lake, spring	25						
Intercept		-5.910	-5.865	-7.646	-8.033	-7.318	-7.249
Slope		3.347	3.279	3.494	3.582	3.616	3.614
$s_{Y\|X}$		0.033	0.034	0.027	0.098	0.033	0.040
r^2		0.985	0.984	0.991	0.893	0.987	0.981

Table 5. Summary of walleye fingerling body lengths and results of two sample t tests for equality of means. Unequal variances assumed.

	Total length (mm)					H_0: $\mu_1 = \mu_2$
Nursery stock	N	Minimum	Maximum	Mean	Standard deviation	P
			November 1987			
Lone Tree Lake	452	122	245	187	22.5	<0.001
Rice Lake	450	125	234	172	24.2	
			November 1988			
Clear Lake	398	118	175	143	8.4	<0.001
Mortenson Lake	400	129	176	149	8.0	
			November 1989			
Wintermute Lake	440	105	149	128	8.4	<0.001
Samantha Lake	440	105	148	120	6.7	

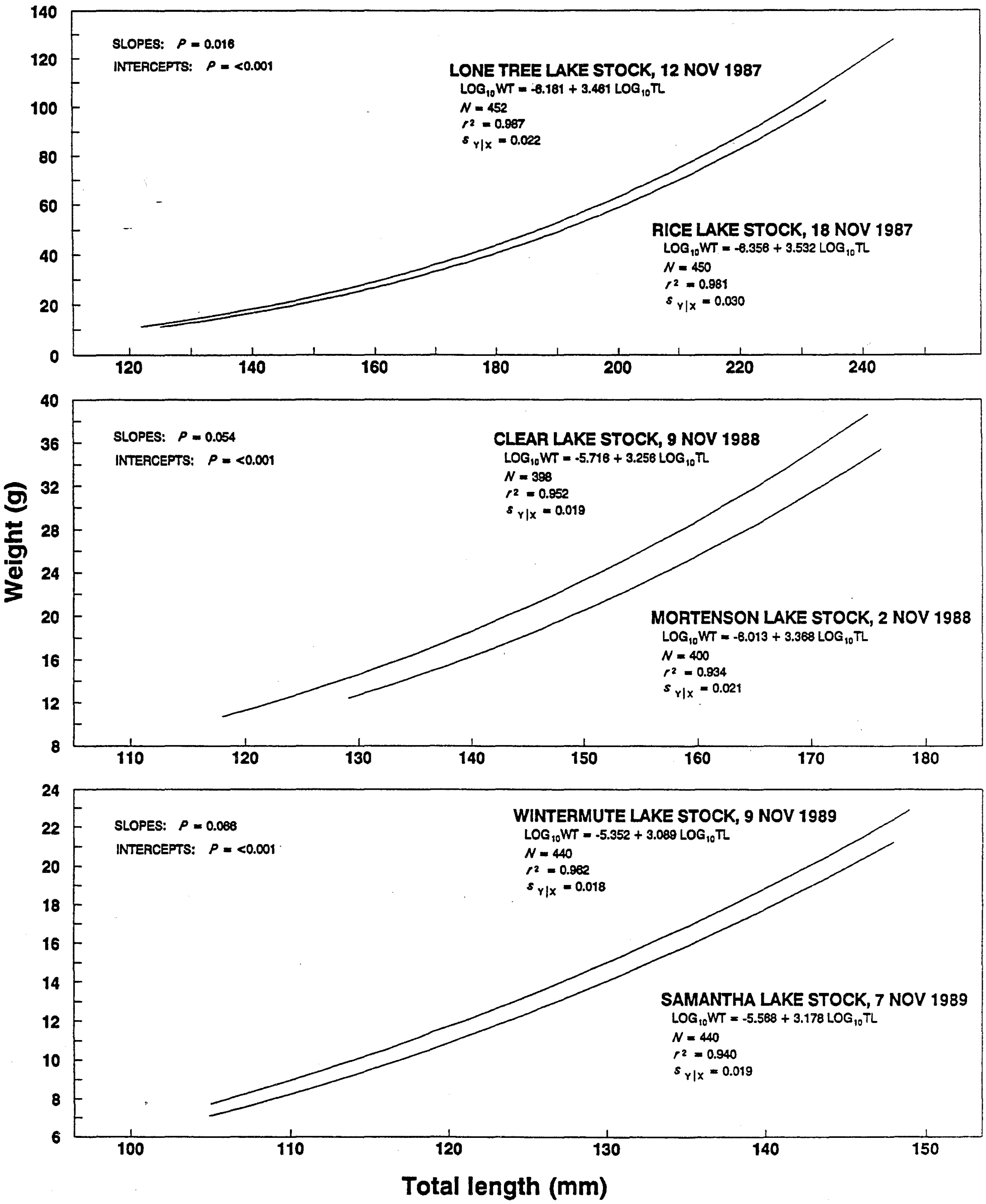

Figure 1. Walleye fingerling weight-length curves and results of Welch's t tests for equality of slopes and intercepts of scaled data. Lines were fitted by least-squares regression of $\log_{10}$ transformed variables.

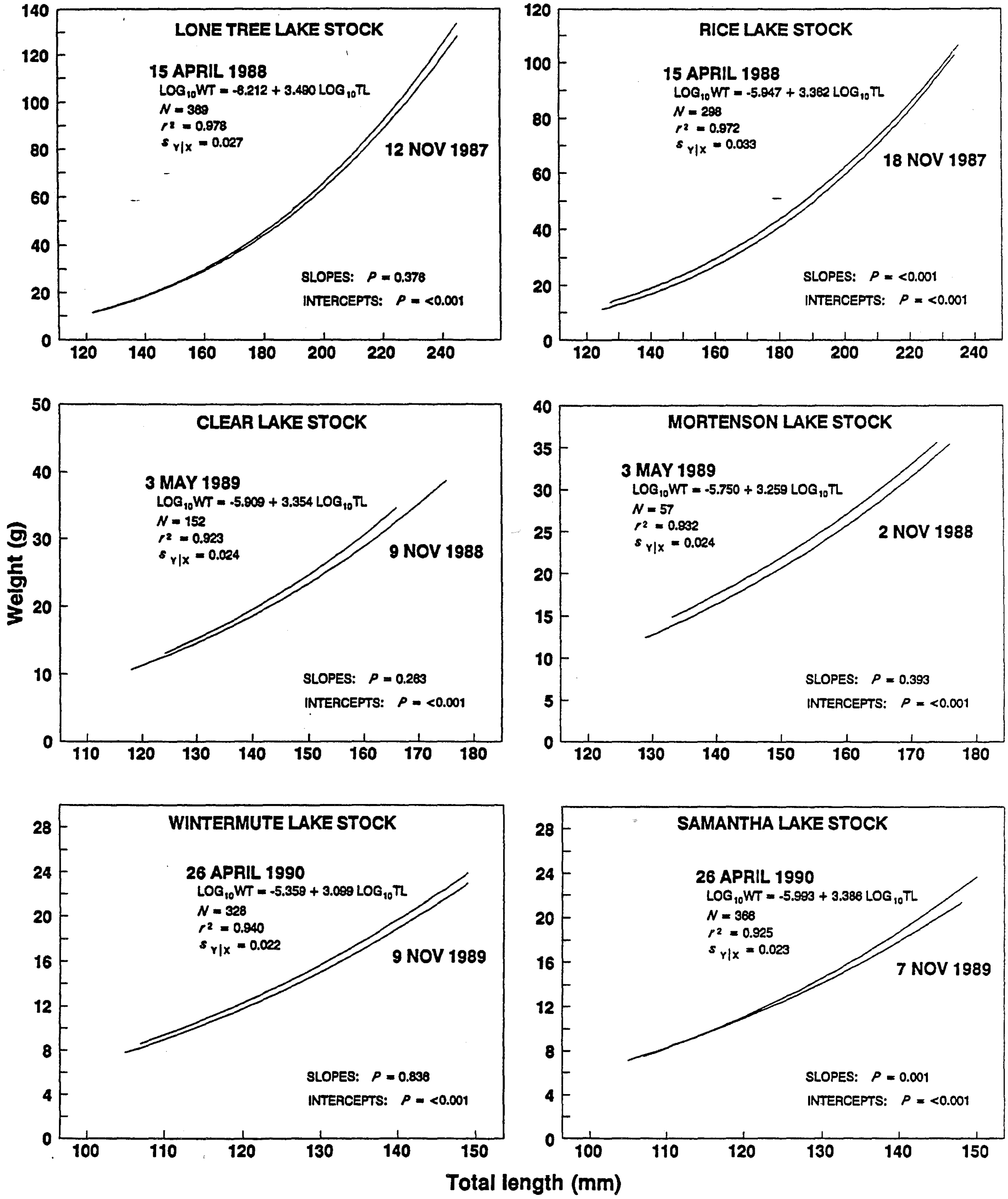

Figure 2. Weight-length curves of walleye fingerlings and pond-wintered yearlings, and results of Welch's *t* tests for equality of slopes and intercepts of scaled data. Lines were fitted by least-squares regression of $\log_{10}$ transformed variables. Fingerling regression statistics are shown in Figure 1.

Intercepts of scaled data increased 3.8% in the Lone Tree Lake stock, 7.1% in the Rice Lake stock, 4.3% in the Clear Lake stock, 6.2% in the Mortenson Lake stock, 3.6% in the Wintermute Lake stock, and 1.7% in the Samantha Lake stock. Slopes differed significantly from fall to spring in the Rice Lake and Samantha Lake stocks, but did not in the other stocks.

Greater mortality of lighter fish and individual weight gains could contribute to overwinter changes in weight-length regression lines. The influence of differential mortality, if any, is unknown, but individual weight gains did occur. They are shown by overwinter changes in weight-length coordinates relative to the fall weight-length regression lines (Table 6). With all stocks except the Clear Lake and Mortenson Lake fish (which were heavily infected with caudal peduncle disease when recovered from the ponds in fall), the number of positive residuals increased from fall to spring. Mortality acting alone could only reduce the number. The residual analyses revealed only that some fish gained weight. The number and magnitude of weight gains is unknown.

The weight gains of Wintermute Lake and Samantha Lake fish occurred primarily, if not solely, on invertebrate food. The wintering ponds were empty, except for some rainfall accumulation, for 6-11 d in 1987 and 53 d in 1988 before they were filled from an adjacent lake a few days before the walleye releases. It is unlikely that an appreciable number of potential forage fish survived passage through the pump, particularly at a time of year when most fish probably had moved offshore. Small increases in walleye mean length over winter refute cannibalism as an important factor (Table 7). In mid-January 1988, 19 L of fathead minnows *Pimephales promelas* were released in each pond with Lone Tree Lake and Rice Lake fish.

Spring weight-length regression lines from pooled Volney Lake electrofishing samples (spanning 2-4 weeks) also indicated overwinter elevation increases among all but the Rice Lake stock. However, they were disregarded as unreliable indicators of post-winter condition because analysis of covariance revealed at least one significant difference in adjusted means among sampling days each year (within stocks). Mean lengths generated from pooled spring data were similarly unreliable. Small but significant overwinter length increases in Volney Lake occurred in all but the Rice Lake stock (Table 7), suggesting that perhaps body length was a survival factor in that environment. However, large and significant variations in mean length from sample to sample in spring suggest sampling error was large and raise considerable doubt about the significance of overwinter changes.

Table 6. Distribution of weight-length coordinates about the fall weight-length regression lines for fingerlings released in the ponds in fall and survivors recovered in spring. Individual winter weight gains are indicated because they are the only mechanism that could cause increase in numbers of positive residuals between fall and spring.

Nursery stock	Location of weight-length coordinates relative to fall regression line	Number of fish: Fall releases	Number of fish: Spring recoveries	Number of fish: Net change
	Below	231	99	-132
Lone Tree Lk	Above	221	270	+ 49
	Total	452	369	- 83
	Below	218	41	-177
Rice Lake	Above	232	257	+ 25
	Total	450	298	-152
	Below	202	34	-168
Clear Lake	Above	196	118	- 78
	Total	398	152	-246
	Below	200	9	-191
Mortenson Lk	Above	200	48	-152
	Total	400	57	-343
	Below	225	73	-152
Wintermute Lk	Above	215	255	+ 40
	Total	440	328	-112
	Below	215	126	- 89
Samantha Lake	Above	225	240	+ 15
	Total	440	366	- 74

Proximate Body Composition

No major weight losses of walleye occurred during the storage time between sampling and analysis. Some weight loss was expected because not all excess water was removed from the live fish as they were weighed. While the number of fish showing weight losses (71) was nearly double the number showing weight gains (36), the decline in mean weight was small (42.1 to 42.0 g), and the difference was not significant in a two sample *t* test ($P = 0.98$). Weights of 17 fish did not change. Changes ranged from -3.0% to +2.6% (mean = -0.34%; SD = 1.00%). Analysis of covariance indicated that the regression lines of $\log_{10}$weights before and after storage on $\log_{10}$total lengths did not differ (slopes - $P = 0.86$; adjusted means - $P = 0.73$).

In each stock, percent water and percent ALFDW (~protein) had strong negative correlation, with r^2 values ranging from 0.41 to 0.91 (Table 8). Percent water also correlated negatively with percent lipid, but the association was weaker with r^2 values ranging from 0.12 to 0.57. Love (1970) characterized fatty fish as having an inverse relationship between water and lipid, and lean fish as having an inverse relationship between water and protein.

Percent water correlated negatively and percent ALFDW positively with total length, thus longer fish had a greater protein:water ratio. Among the Lone Tree Lake and Rice Lake fish, these relationships were weaker in spring than in fall. Lipid exhibited little correlation with total length, and ash showed strong correlation only among the Lone Tree Lake groups.

Table 7. Summary of walleye body lengths and results of two sample *t* tests for equality of means in fall versus spring. Unequal variances assumed.

		Total length (mm)				
						H_0: $\mu_{fall} = \mu_{spring}$
Stock/season	*N*	Minimum	Maximum	Mean	Standard deviation	*P*
Lone Tree Lake						
Fall	452	122	245	187	22.5	
Spring						
Ponds	369	123	245	189	21.5	0.139
Volney Lake	451	131	239	191	20.9	0.003
Rice Lake						
Fall	450	125	234	172	24.2	
Spring						
Ponds	298	127	235	176	23.0	0.073
Volney Lake	134	125	226	172	22.2	0.933
Clear Lake						
Fall	398	118	175	143	8.4	
Spring						
Ponds	152	124	166	144	8.3	0.154
Volney Lake	203	128	170	146	7.3	<0.001
Mortenson Lake						
Fall	400	129	176	149	8.0	
Spring						
Ponds	57	133	174	151	9.6	0.203
Volney Lake	27	143	166	153	6.2	0.010
Wintermute Lake						
Fall	440	105	149	128	8.4	
Spring						
Ponds	328	107	149	129	8.2	0.046
Volney Lake	92	112	155	135	8.6	<0.001
Samantha Lake						
Fall	440	105	148	120	6.7	
Spring						
Ponds	366	107	153	121	6.9	0.006
Volney Lake	222	108	154	127	8.9	<0.001

Table 8. Summary of regression relationships of body component weights (as a percent of wet weight) on percent water and total fish length. Coefficients of determination and probabilities of zero slope of regression are presented. Positive or negative slope is indicated by + or -. Probability ≤0.05 is indicated by an asterisk.

		Nursery stock and season					
Variables	Coefficient of determination/ probability	Lone Tree Lake fall (n=25)	Lone Tree Lake spring (n=24)	Rice Lake fall (n=25)	Rice Lake spring (n=25)	Mortenson Lake fall (n=25)	Groups combined (n=124)
Ash and water	r^2	0.360 -	0.392 -	0.038 +	0.102 -	0.019 -	0.021 -
	P	0.002 *	0.001 *	0.354	0.119	0.506	0.106
Lipid and water	r^2	0.118 -	0.270 -	0.567 -	0.402 -	0.537 -	0.374 -
	P	0.092	0.009 *	<0.001 *	0.001 *	<0.001 *	<0.001 *
ALFDW and water	r^2	0.776 -	0.753 -	0.912 -	0.852 -	0.410 -	0.556 -
	P	<0.001 *	<0.001 *	<0.001 *	<0.001 *	0.001 *	<0.001 *
AFDW and water	r^2	0.837 -	0.931 -	0.958 -	0.925 -	0.936 -	0.929 -
	P	<0.001 *	<0.001 *	<0.001 *	<0.001 *	<0.001 *	<0.001 *
Water and total length	r^2	0.525 -	0.347 -	0.601 -	0.506 -	0.297 -	0.297 -
	P	<0.001 *	0.003 *	<0.001 *	<0.001 *	0.005 *	<0.001 *
Ash and total length	r^2	0.610 +	0.761 +	<0.001 +	0.045 +	0.011 -	0.192 +
	P	<0.001 *	<0.001 *	0.982	0.307	0.623	<0.001 *
Lipid and total length	r^2	0.089 -	0.005 -	0.174 +	0.051 +	0.030 +	0.002 -
	P	0.147	0.740	0.038 *	0.278	0.405	0.590
ALFDW and total length	r^2	0.641 +	0.305 +	0.619 +	0.625 +	0.501 +	0.416 +
	P	<0.001 *	0.005 *	<0.001 *	<0.001 *	<0.001 *	<0.001 *
AFDW and total length	r^2	0.239 +	0.159 +	0.527 +	0.473 +	0.329 +	0.184 +
	P	0.013 *	0.054	<0.001 *	<0.001 *	0.003 *	<0.001 *

On average, compared to a Rice Lake fingerling of the same length, a 125 mm Lone Tree Lake fingerling was 11% heavier and contained 9% more water, 2% less ash (not significant), 79% more lipid, 21% more ALFDW, and 24% more of the organic components combined (AFDW) (Table 9). A 174 mm Lone Tree Lake fingerling was 10% heavier and contained 9% more water, 7% more ash, 20% more lipid, 13% more ALFDW, and 14% more AFDW. A 223 mm Lone Tree Lake fingerling was 9% heavier and contained 10% more water, 16% more ash, 11% less lipid (not significant), 8% more ALFDW, and 6% more AFDW (low significance).

Inorganic body components accounted for much of the difference in body weight between the two stocks, and the magnitude was size dependent. Water accounted for 65% of the difference in 125 mm fish to 80% in 223 mm fish. Ash did not differ significantly in 125 mm fish but accounted for 3 and 7% of the weight differences in 174 and 223 mm fish, respectively. Accordingly, organic body components accounted for less of the difference in longer fish. ALFDW accounted for 27% of the weight difference in 125 mm fish and 16% in 223 mm fish. Lipid accounted for 9% in 125 mm fish, 3% in 174 mm fish, and had an insignificant role in 223 mm fish.

Comparison of fall and spring models suggest lipid deposits accounted for a large part of the individual weight gains noted previously in Lone Tree Lake and Rice Lake walleye. The Lone Tree Lake regressions showed body weight gains between fall and spring, but it was insignificant in 145 mm fish (Table 10). All body component weights increased over winter, but only lipid showed statistically significant change. The lipid gains increased with fish length, ranging from 65% in a 145 mm fish to 92% in a 223 mm fish. Lipid accounted for 43 and 34% of the body weight gains in 184 and 223 mm fish, respectively.

The Rice Lake regression models showed overwinter increases in body weight and all body component weights in 125 and 178 mm walleye (Table 11). Lipid was the only variable that changed significantly across the entire common length range. Lipid gains were most important in small fish (opposite the trend in the Lone Tree Lake fish), ranging from 114% in 125 mm fish to 37% in 230 mm fish. Body weight increased 13% in 125 mm fish and 7% in 178 mm fish. Water increased 12 and 6%, ash 9 and 6%, and ALFDW 12 and 4%, respective-

Table 9. Live body weight and body component weights predicted from least-squares regression of $\log_{10}$ transformed variables of Lone Tree Lake and Rice Lake walleye in fall 1987 (Table 4). Total lengths represented are the minimum, midpoint, and maximum of the longest range common to both population samples. Equalities of predicted weights between stocks were tested using normal approximation of *t* tests.

	Minimum TL (125 mm)			Midpoint TL (174 mm)			Maximum TL (223 mm)		
	Predicted weight	$H_0: \hat{Y}_1 = \hat{Y}_2$		Predicted weight	$H_0: \hat{Y}_1 = \hat{Y}_2$		Predicted weight	$H_0: \hat{Y}_1 = \hat{Y}_2$	
Variable/ stock	(g)	*z*	*P*	(g)	*z*	*P*	(g)	*z*	*P*
Body weight									
Lone Tree Lake	12.62			39.86			94.44		
Rice Lake	11.38			36.25			86.49		
Disparity	1.24	3.76	<0.01	3.61	6.70	<0.01	7.95	3.80	<0.01
Water									
Lone Tree Lake	9.95			31.02			72.79		
Rice Lake	9.14			28.39			66.45		
Difference	0.81	3.31	<0.01	2.63	6.67	<0.01	6.34	4.16	<0.01
% of body wt. disparity	65.3			72.9			79.7		
Ash									
Lone Tree Lake	0.43			1.53			3.98		
Rice Lake	0.44			1.43			3.44		
Difference	-0.01	0.80	0.42	0.10	3.73	<0.01	0.54	4.71	<0.01
% of body wt. disparity	-0.8			2.8			6.8		
Lipid									
Lone Tree Lake	0.25			0.71			1.53		
Rice Lake	0.14			0.59			1.71		
Difference	0.11	3.63	<0.01	0.12	2.33	0.02	-0.18	0.85	0.40
% of body wt. disparity	8.9			3.3			-2.3		
ALFDW									
Lone Tree Lake	1.99			6.57			16.12		
Rice Lake	1.65			5.80			14.88		
Difference	0.34	4.88	<0.01	0.77	6.52	<0.01	1.24	2.57	0.01
% of body wt. disparity	27.4			21.3			15.6		
AFDW									
Lone Tree Lake	2.24			7.29			17.69		
Rice Lake	1.80			6.41			16.63		
Difference	0.44	4.74	<0.01	0.88	5.54	<0.01	1.06	1.63	0.10
% of body wt. disparity	35.5			24.4			13.3		

Table 10. Live body weight and body component weights predicted from least-squares regression of $\log_{10}$ transformed variables of Lone Tree Lake walleye in fall 1987 and spring 1988 (Table 4). Total lengths represented are the minimum, midpoint, and maximum of the longest range common to both population samples. Equalities of predicted weights between seasons were tested using normal approximation of *t* tests.

	Minimum TL (145 mm)			Midpoint TL (184 mm)			Maximum TL (223 mm)		
Variable/ season	Predicted weight (g)	$H_0: \hat{Y}_1 = \hat{Y}_2$ *z*	*P*	Predicted weight (g)	$H_0: \hat{Y}_1 = \hat{Y}_2$ *z*	*P*	Predicted weight (g)	$H_0: \hat{Y}_1 = \hat{Y}_2$ *z*	*P*
Body weight									
Fall	21.14			48.41			94.44		
Spring	21.51			49.94			98.54		
Disparity	-0.37	0.70	0.48	-1.53	2.03	0.04	-4.10	1.66	0.10
Water									
Fall	16.57			37.59			72.79		
Spring	16.79			38.49			75.16		
Difference	-0.22	0.55	0.58	-0.90	1.58	0.11	-2.37	1.29	0.20
% of body wt. disparity	59.5			58.8			57.8		
Ash									
Fall	0.76			1.90			3.98		
Spring	0.75			1.92			4.12		
Difference	0.01	0.53	0.59	-0.02	0.67	0.50	-0.14	1.13	0.26
% of body wt. disparity	-2.7			1.3			3.4		
Lipid									
Fall	0.40			0.84			1.53		
Spring	0.66			1.50			2.94		
Difference	-0.26	5.83	<0.01	-0.66	9.97	<0.01	-1.41	6.83	<0.01
% of body wt. disparity	70.3			43.1			34.4		
ALFDW									
Fall	3.40			8.04			16.12		
Spring	3.31			8.00			16.29		
Difference	0.09	0.84	0.40	0.04	0.29	0.77	-0.17	0.34	0.73
% of body wt. disparity	-24.3			-2.6			4.1		
AFDW									
Fall	3.80			8.90			17.69		
Spring	3.97			9.51			19.26		
Difference	-0.17	1.29	0.20	-0.61	3.19	<0.01	-1.57	2.45	0.01
% of body wt. disparity	45.9			39.9			38.3		

ly. Water accounted for 74% of the overwinter body weight gain in a 125 mm fish and 72% in a 178 mm fish. Lipid accounted for 11 and 15%, respectively, and ALFDW accounted for 13 and 10%, respectively. Together, the organic components accounted for 23 and 25% of the weight gains of Rice Lake fish, respectively.

Lipid as a percent of dry weight in Lone Tree Lake fish was 5.7-11.1% in fall and 9.7--17.0% in spring. Means were 8.3% (SD = 1.62%) and 13.3% (SD = 1.51%), respectively, and differed significantly in a two sample *t* test ($P < 0.001$). In Rice Lake fish, ranges were 4.5-12.4% in fall and 8.3-14.7% in spring. Means were 7.8% (SD = 2.22%) and 11.6% (SD = 1.80%), respectively and differed significantly in a two sample *t* test ($P < 0.001$). It appears that lipid deposition played an important role in individual weight gains over winter. However, the degree of deposition is unknown because greater mortality of lean fish could have influenced the results.

Body weight-length regressions reflected differences of body composition between Lone

Table 11. Live body weight and body component weights predicted from least-squares regression of $\log_{10}$ transformed variables of Rice Lake walleye in fall 1987 and spring 1988 (Table 4). Total lengths represented are the minimum, midpoint, and maximum of the longest range common to both population samples. Equalities of predicted weights between seasons were tested using normal approximation of *t* tests.

	Minimum TL (125 mm)			Midpoint TL (178 mm)			Maximum TL (230 mm)		
	Predicted weight	H_0: $\hat{Y}_1 = \hat{Y}_2$		Predicted weight	H_0: $\hat{Y}_1 = \hat{Y}_2$		Predicted weight	H_0: $\hat{Y}_1 = \hat{Y}_2$	
Variable/ season	(g)	*z*	*P*	(g)	*z*	*P*	(g)	*z*	*P*
Body weight									
Fall	11.38			39.26			96.38		
Spring	12.86			41.98			99.00		
Disparity	-1.48	3.37	<0.01	-2.72	3.65	<0.01	-2.62	0.78	0.43
Water									
Fall	9.14			30.69			73.88		
Spring	10.24			32.64			75.63		
Difference	-1.10	3.20	<0.01	-1.95	3.40	<0.01	-1.75	0.69	0.49
% of body wt. disparity	74.3			71.7			66.8		
Ash									
Fall	0.44			1.55			3.83		
Spring	0.48			1.64			4.02		
Difference	-0.04	2.02	0.04	-0.09	3.22	<0.01	-0.19	1.45	0.15
% of body wt. disparity	2.7			3.3			7.3		
Lipid									
Fall	0.14			0.65			1.95		
Spring	0.30			1.07			2.68		
Difference	-0.16	4.64	<0.01	-0.42	6.22	<0.01	-0.73	2.20	0.03
% of body wt. disparity	10.8			15.4			27.9		
ALFDW									
Fall	1.65			6.32			16.74		
Spring	1.84			6.60			16.67		
Difference	-0.19	2.48	0.01	-0.28	1.98	0.05	0.07	0.11	0.92
% of body wt. disparity	12.8			10.3			-2.7		
AFDW									
Fall	1.80			6.99			18.73		
Spring	2.14			7.68			19.40		
Difference	-0.34	3.30	<0.01	-0.69	3.54	<0.01	-0.67	0.72	0.47
% of body wt. disparity	23.0			25.4			25.6		

Tree Lake and Rice Lake fingerlings, however they were imperfect indicators of trends in protein content. When all analyzed fish were combined ($N = 124$), slopes of body weight-length regression and ALFDW weight-length regression differed (Welch's *t* test, $P = 0.001$). Slopes of the body weight model and the organic component (AFDW) model also differed ($P = 0.007$). For these reasons, energy content, measured as $\text{kJ}\cdot(\text{g dry weight})^{-1}$, would be correlated with percent water and length. Assuming the ALFDW component is entirely protein ($23.6\ \text{kJ}\cdot\text{g}^{-1}$) and the lipid component is highly unsaturated fats ($36.2\ \text{kJ}\cdot\text{g}^{-1}$) (Brafield 1985), we calculate a mean energy content of $20.89\ \text{kJ}\cdot\text{g}^{-1}$. The value differed among stocks, yet much of the variation in these samples is associated with percent water and length [Energy content ($\text{kJ}\cdot\text{g}^{-1}$) = 74.072 - 0.533 percent water - 5.350 $\log_{10}$total length; $R^2 = 0.53$; $s_{Y|X} = 0.477$].

Winter Survival

Overall, the plumper stocks exhibited higher winter survival than their lighter counterparts. The plumper Lone Tree Lake and Clear Lake stocks survived better in the ponds during the first two winters of the study (Table 12). However, during the 1989-90 winter, the lighter Samantha Lake stock survived better in one pond than the Wintermute Lake stock did.

Caudal peduncle disease influenced survival of the 1988 year class. Poorer survival of the lighter Mortenson Lake stock was expected because most of those fish exhibited the disease, and, while it was widespread among the Clear Lake fish, it was less severe. Fall plumpness, if it reflects fitness, may have been a factor governing severity of the disease. Many Mortenson Lake fingerlings were also infected with *Neascus sp.*.

Table 12. Numbers of walleye fingerlings released in the ponds in fall, numbers recovered in spring, and winter survival rates.

Nursery stock	Number released	Number recovered	Percent survival
		1987 year-class	
Lone Tree Lake			
Pond 1	226	187	83
Pond 2	224	182	81
Ponds combined	450	369	82
Rice Lake			
Pond 1	223	149	67
Pond 2	225	149	66
Ponds combined	448	298	67
		1988 year-class	
Clear Lake			
Pond 1	180	113	63
Pond 2	174	39	22
Ponds combined	354	152	43
Mortenson Lake			
Pond 1	196	43	22
Pond 2	190	14	7
Ponds combined	386	57	15
		1989 year-class	
Wintermute Lake			
Pond 1	220	203	92
Pond 2	219	141	64
Ponds combined	439	344	78
Samantha Lake			
Pond 1	219	198	90
Pond 2	219	172	79
Ponds combined	438	370	84

Survival estimates from Volney Lake in all years favored the plumper stocks (Table 13). Spring population estimates indicated that in Volney Lake, unlike in the ponds, the Wintermute Lake stock fared better than the Samantha Lake stock; 79% survival compared to 54% survival, respectively. Relative abundance of Wintermute Lake fish in Volney Lake electrofishing samples was higher than the population estimate indicates. Additional population estimates made by apportionment of a single estimate, derived from combined samples of the two stocks, according to capture ratios yields 94% survival of Wintermute Lake fish and 56% survival of Samantha Lake fish. Chi square analysis indicated that the overwinter change in relative abundance (release ratios compared to spring capture ratios) of the two stocks was highly significant. The change in relative abundance favoring Lone Tree Lake fish over Rice Lake fish was small.

Discussion

With one exception, winter survival of stocked walleye fingerlings was better among the plumper of the paired stocks. However, in two of the three years, the plumper stock had greater mean length in the fall (Table 5). The importance of 8-15 mm differences relative to survival probably was small in the ponds where large predators were absent. Winter mean length increases within stocks in the ponds were small (1-3 mm), indicating that fish length had little effect on survival (Table 7).

Importance of length related mortality in Volney Lake, where large predators were abundant, did not appear to be large either. Pooled spring samples showed small, but significant, overwinter mean length increases of 3 to 7 mm in five of the six stocks. However, high variability of mean lengths between samples within stocks raises considerable doubt about the significance of those apparent length gains. In Oneida Lake, Forney (1966) observed overwinter increases in mean length of walleye fingerlings of

Table 13. Fall walleye releases and spring electrofishing results in Volney Lake, results of 2 x 2 contingency table χ^2 tests for equality in ratios of the number of individuals per stock in fall releases and spring samples, and estimates of yearling populations and winter survival rates. 95% confidence limits in parentheses.

				H_0: fall ratio = spring ratio			
Nursery stock	Number of fingerlings released in November	Number captured in spring	Number of marked recaptures	Continuity adjusted χ^2	P	Yearling population estimate	Percent survival
			1988				
Lone Tree Lake	3,702	589	37	1.28	0.26	3,518 (2,571-4,951)	95 (69-100)
Rice Lake	1,273	182	13			868 (522-1,538)	68 (41-100)
			1989				
Clear Lake	2,763	304	27	201	<0.01	1,257 (876-1,872)	45 (32-68)
Mortenson Lake	2,967	43	7			81 (42-170)	3 (1-6)
			1990				
Wintermute Lake	1,039	100	4	17.2	<0.01	825 (368-2,063)	79 (35-100)
Samantha Lake	4,252	244	9			2,310 (1,276-4,619)	54 (30-100)

11, 19, and 20 mm in the 1962-64 year classes, respectively. Similarly, Chevalier (1973) observed a 16 mm increase over winter in the 1969 year class in Oneida Lake. They attributed those increases to size-selective mortality. Chevalier (1973) noted that lengths of most juvenile walleye ingested by adult walleye were less than the mean length of the juvenile population, suggesting size-selective predation. In contrast, Priegel (1970) did not observe overwinter length increases of walleye fingerlings in Lake Winnebago.

Santucci and Wahl (1990) found that first year survival of stocked fall walleye fingerlings in Ridge Lake strongly favored the longer groups where mean length disparities of approximately 70 mm existed. Kempinger and Carline (1977) reported that, despite a wide range (unspecified) in mean lengths of fall fingerlings in Escanaba Lake, length and survival to age 3 were not related.

Mortality during the first winter following stocking in Volney Lake appeared to be less important than mortality the following year in limiting eventual recruitment to the sport fishery. Except with the diseased 1988 fingerlings, first winter survival was high compared with survival between ages 1 and 2. This was particularly true of the 1987 year-class for which estimated survival to age 1 was nearly 90%. Spring population estimates of the 1987 and 1988 year-classes at age 2, however, showed high mortality between ages 1 and 2, and less than 10% survival from fingerling releases to age 2. Kempinger and Carline (1977), on the other hand, estimated 42 and 49% overwinter survival of fall fingerlings from the 1958 and 1959 year-classes in Escanaba Lake, respectively. Survival of the 1958 year-class from age 1 to age 2 was 61%. The large sizes of Lone Tree Lake and Rice Lake yearlings (1987 year-class) did not appear to give them an advantage during their second year in Volney Lake compared to the Clear Lake and Mortenson Lake yearlings (1988 year-class) during their second year (Tables 7 and 14).

Reviews of walleye stocking evaluations by Laarman (1978) and Ellison and Franzin (1992)

Table 14. Population and survival estimates of the 1987, 1988, and 1989 cohorts of walleye released in Volney Lake. 95% confidence limits are in parentheses. The Lone Tree and Rice Lake stocks comprise the 1987 cohort, the Clear Lake and Mortenson Lake stocks comprise the 1988 cohort, and the Wintermute Lake and Samantha Lake stocks comprise the 1989 cohort.

Year-class	Number of fingerlings released in November	Age-1 electrofishing samples			Age-2 electrofishing samples			Survival rate age-1 to age-2
		Number captured	Number of marked recaptures	Population estimate and survival rate to age-1	Number captured	Number of marked recaptures	Population estimate and survival rate to age-2	
1987	4,975	771	50	4,452 (3,394-5,975) 89.5% (68.2-100%)	112	9	488 (270-977) 9.8% (5.4-19.6%)	11.0% (4.5-28.8%)
1988	5,730	347	34	1,301 (939-1,858) 22.7% (16.4-32.4%)	78	9	234 (129-468) 4.1% (2.3-8.2%)	18.0% (6.9-49.8%)
1989	5,291	344	13	3,355 (2,016-5,946) 63.4% (38.1-100%)				

revealed highly variable results. A variety of well known biological factors, such as size of length disparities, availability of suitable forage, and densities of predators, alternate prey, and competitors, undoubtedly contributed to the variability. Body composition is likely an important variable also, but knowledge of how it varies and relates to walleye survival is inadequate. In this study, the plumper Lone Tree Lake fingerlings were of superior quality than Rice Lake fingerlings. Although water largely accounted for body weight differences (65-80%), Lone Tree Lake fingerlings were significantly richer in organic components, primarily protein, than Rice Lake fingerlings of similar length.

Fall energy reserves seem to be less important to age-0 walleye than to age-0 black bass, which are inactive at temperatures that occur in ice covered lakes and do not feed (Johnson and Charlton 1960; Munther 1970; Warden and Lorio 1975). In temperate climates, they rely heavily on energy reserves during winter, and shorter individuals with high specific metabolic rates frequently exhaust their reserves and starve to death (Oliver et al. 1979; Shuter et al. 1980; Adams et al. 1982; Shuter et al. 1989). In contrast, walleye continue to feed at winter temperatures, although at reduced levels (Galligan 1960; Kelso 1972). Age-2 to age-6 walleye fed only at maintenance levels at winter temperatures in the laboratory (Kelso 1972) and depleted stored energy over winter in West Blue Lake (Kelso 1973). In this study, age-0 walleye gained weight during winter largely through lipid deposition. Greater mortality of lighter fish could not be discounted as partly causing the rise in elevations of weight-length regression lines from fall to spring, but in four of the stocks, individual winter weight gains in the ponds were indicated by overwinter increases in numbers of positive residuals when spring weight-length coordinates were compared with fall regression lines. This perhaps is possible for juvenile walleye because, unlike adults, they do not expend energy during winter preparing for spawning.

Percent ALFDW had a positive relationship and percent water a negative relationship with length of the juvenile walleye, while percent lipid showed little correlation. Accordingly, the calculated energy content ($kJ \cdot g^{-1}$) and the ratio of organic to inorganic content increased with length. Thus, comparing mean percent protein or mean percent water in walleye fingerling stocks is a meaningless exercise unless the stocks exhibit similar mean lengths and variances about the mean. This is also true with the Fulton condition factor unless slopes of population weight-length regressions are 3 (Cone 1989).

For many applications AFDW measurement will render sufficient detail to evaluate quality of walleye fingerlings. The relative ease of measuring AFDW provides an attractive alternative to expensive and labor intensive protein or lipid analysis. AFDW represents all organic body components combined, but primarily lipid and protein. In walleye fingerlings, which are lean fish, AFDW largely reflects protein, as differences in lipid content were relatively small. Calculated energy content was related to percent water and length, so energy estimates could be improved by reference to easily measured covariates, provided the relationship is tested on additional stocks and lengths (energy content cannot increase indefinitely with length).

The high correlation found between percent AFDW and percent water among the five analyzed walleye groups (Table 8) suggests that most of the information on AFDW can be obtained from measurement of dried fish weights. This would eliminate having to combust the dried fish. The least-squares regression model developed from the combined fingerling and yearling walleye groups is percent AFDW = 93.0628 - 0.9607 percent water; $N = 124$; $r^2 = 0.929$; $s_{Y|X} = 0.300$.

Walleye fingerling data to test the model, other than those used in model development, were unavailable, however. Following Weisberg (1985), the estimated average prediction error of the model is 0.305%. This compares favorably to square roots of the average squared fitting errors of the five walleye groups individually that ranged from 0.224 to 0.333%. These similarities indicate that prediction errors of about 0.3% can be expected--if the model represents juvenile walleye in general.

For each fish, estimated AFDW was calculated from body weights and the percent AFDW predicted by the model. Summary statistics of measured and estimated AFDW by walleye group are compared in Table 15. Differences between measured and estimated AFDW ranged

Table 15. Summary statistics of measured and estimated AFDW. Estimated AFDW was derived from the model percent AFDW on percent water.

Walleye group/ Parameter	Measured AFDW (g)	Estimated AFDW (g)	Disparity (sign ignored)	Percent disparity (sign ignored)	Number of estimated weights larger than measured weights	Number of estimated weights smaller than measured weights
Lone Tree Lake, fall					13	12
Mean	8.28	8.34	0.109	1.45		
Minimum	1.62	1.55	0.001	0.01		
Maximum	17.70	18.02	0.362	4.26		
Standard deviation	5.02	5.13	0.108	1.05		
Lone Tree Lake, spring					10	14
Mean	10.55	10.58	0.096	0.95		
Minimum	3.90	3.84	0.001	0.01		
Maximum	18.70	19.14	0.440	2.64		
Standard deviation	5.03	5.13	0.101	0.70		
Rice Lake, fall					16	9
Mean	8.79	8.84	0.097	1.50		
Minimum	1.75	1.74	0.010	0.08		
Maximum	21.18	21.20	0.484	5.48		
Standard deviation	5.92	5.94	0.099	1.32		
Rice Lake, spring					14	11
Mean	7.86	7.88	0.086	1.31		
Minimum	2.46	2.43	0.003	0.06		
Maximum	18.18	17.98	0.275	4.65		
Standard deviation	4.93	4.93	0.072	1.20		
Mortenson Lake, fall					5	20
Mean	4.04	4.00	0.047	1.08		
Minimum	2.16	2.14	0.001	0.01		
Maximum	7.03	6.92	0.248	4.54		
Standard deviation	1.23	1.21	0.054	1.03		

from 0.01 to 5.48%. AFDW was underestimated on 80% of the Mortenson Lake fish, while numbers of underestimates and overestimates were more similar in the other groups. In total, estimated values exceeded measured values in 58 cases compared to 66 cases when the opposite occurred. Within walleye groups, regressions of measured and estimated $\log_{10}$AFDW on $\log_{10}$total length were compared by analysis of covariance (Table 16). With all groups, large probabilities indicate that lines derived from measured and estimated AFDW do not differ.

To examine the utility of estimated AFDW further, the "measured" and "estimated" lines described in Table 16 for each walleye group were compared to similarly derived lines of the other groups by analysis of covariance to determine if statistical inferences made from "measured" and "estimated" data differed (Table 17). Only in one instance would inferences differ at the 5% significance level. With the Lone Tree Lake stock versus the Rice Lake Stock in fall, the hypothesis of equal slopes would be rejected in one case but not in the other. Rejection would occur in both cases at the 10% level. At the 1% level, all inferences would be the same. Although test results with model construction data were favorable, a model must be validated with data unrelated to its development to be functional.

Body composition analysis is not practical in most instances, but weight-length data should be acquired for a random sample of each nursery stock as an integral part of walleye stocking programs. Analysis of weight-length data is a cost-effective way to evaluate walleye nursery stocks and guide apportionment of fingerlings harvested from them. Weight-length relationships reflected structural differences in the Lone Tree Lake and Rice Lake fingerlings. Flath and Diana (1985) noted that wet weight is usually a good indicator of total energy content in lean fish. Weight based stocking quotas (eg. kg/hectare) incorrectly assume that survival from stocking to entry into the sport fishery is directly proportional to individual fingerling weight. Although, rigid guidelines cannot be established from the results of this study, knowledge of weight-length relationships and length distributions should help managers achieve more pre-

Table 16. Parameters of least-squares regressions of $\log_{10}$measured and $\log_{10}$estimated AFDW on $\log_{10}$total length, and results of hypotheses tests for equality of variances, slopes, and adjusted means. Measured weights are from laboratory analysis and estimated weights are derived from the model percent AFDW on percent water. Units are grams and millimeters.

Walleye group/ Derivation of AFDW	Regression parameters				Analysis of covariance		
	Intercept	Slope	r^2	$s_{Y\|X}$	Parameter	F	P
Lone Tree Lake stock, fall					Residual variances	1.115	0.398
Measured	-7.136	3.570	0.991	0.030	Slopes	0.486	0.489
Estimated	-7.291	3.640	0.992	0.029	Adjusted means	<0.001	0.995
Lone Tree Lake stock, spring					Residual variances	1.042	0.462
Measured	-7.329	3.668	0.983	0.030	Slopes	0.258	0.614
Estimated	-7.496	3.741	0.984	0.030	Adjusted means	0.003	0.959
Rice Lake stock, fall					Residual variances	1.340	0.244
Measured	-7.807	3.845	0.986	0.040	Slopes	0.016	0.901
Estimated	-7.768	3.829	0.989	0.035	Adjusted means	0.096	0.758
Rice Lake stock, spring					Residual variances	1.331	0.249
Measured	-7.248	3.614	0.981	0.040	Slopes	0.011	0.918
Estimated	-7.279	3.629	0.986	0.034	Adjusted means	0.015	0.902
Mortenson Lake stock, fall					Residual variances	1.082	0.426
Measured	-7.454	3.700	0.949	0.030	Slopes	0.009	0.923
Estimated	-7.405	3.676	0.952	0.029	Adjusted means	0.206	0.652

Table 17. Results of hypotheses tests for equality of parameters in regressions of $\log_{10}$AFDW on $\log_{10}$total length for various walleye group combinations. Results with measured AFDW are compared to results with estimated AFDW.

Walleye group combinations/ Parameters	Analysis of covariance			
	AFDW measured		AFDW estimated	
	F	*P*	*F*	*P*
Lone Tree Lake stock, fall vs. Rice Lake stock, fall				
Residual variances	1.739	0.096	1.448	0.191
Slopes	5.201	0.027	3.082	0.086
Adjusted means	28.492	<0.001	33.494	<0.001
Lone Tree Lake stock, fall vs. Mortenson Lake stock, fall				
Residual variances	1.007	0.493	1.023	0.478
Slopes	0.450	0.506	0.039	0.845
Adjusted means	13.383	0.001	15.300	<0.001
Rice Lake stock, fall vs. Mortenson Lake stock, fall				
Residual variances	1.752	0.093	1.415	0.206
Slopes	0.402	0.529	0.555	0.460
Adjusted means	10.628	0.002	7.949	0.007
Lone Tree Lake stock, spring vs. Rice Lake stock, spring				
Residual variances	1.722	0.104	1.348	0.244
Slopes	0.124	0.727	0.663	0.420
Adjusted means	15.183	<0.001	15.614	<0.001
Lone Tree Lake stock, fall vs. Lone Tree Lake stock, spring				
Residual variances	1.016	0.486	1.054	0.450
Slopes	0.600	0.443	0.702	0.407
Adjusted means	9.683	0.003	8.471	0.006
Rice Lake stock, fall vs. Rice Lake stock, spring				
Residual variances	1.026	0.476	1.020	0.482
Slopes	2.621	0.112	2.644	0.111
Adjusted means	14.173	<0.001	17.207	<0.001

dictable and consistent results, or it can be applied in the treatment of priorities.

The peduncle disease problems with the Mortenson Lake and Clear Lake fingerlings in November 1988 suggest that the disease could have catastrophic but unrecognized effects on walleye stocking programs. Optimum temperatures for coldwater disease outbreak are 4-10 °C, while the bacterial pathogens are inactive at temperatures above about 12 °C (Pacha and Ordal 1970; Post 1987). Water temperatures were mostly above 10 °C when the Mortenson Lake and Clear Lake fish were harvested from the nursery lakes, marked, and released in ponds, and peduncle disease was not apparent. It was severe, however, when the fish were recovered from the ponds in November long after water temperatures had fallen below 10°C. Most walleye fingerling harvesting and stocking statewide is done when water temperatures are such that the coldwater disease is unobtrusive. Marking undoubtedly added to capture stress of fish in this study, but the results emphasize need to minimize handling stress.

Management Implications

With one exception in a pond, plumper stocks survived better over winter than lighter stocks. Mean length differences of 8 and 15 mm gave no apparent survival advantage to plumper stocks in predator-free ponds, and they did not appear to be of great importance in the lake with an abundance of large predators.

Mortality during the first summer after stocking may limit contribution to the sport fishery more than winter mortality of fingerlings. Except with the diseased Mortenson Lake fingerlings, winter survival in Volney Lake was high among all stocks compared with survival among the 1987 and 1988 year-classes from age 1 to age 2. Individual weight gains by undetermined numbers of fish occurred over winter, and evidence suggested that lipid deposits were a major reason. The appearance of peduncle disease in November 1988 after the ponds had cooled below 10°C suggested that the disease could have catastrophic and unrecognized effects on walleye stocking programs and emphasizes need to minimize handling stress.

Weight based stocking quotas incorrectly imply that post-stocking survival is directly proportional to individual fingerling weight. On average, Lone Tree Lake fingerlings were plumper at length and contained significantly more water and protein than Rice Lake fingerlings. Although water accounted for 65-80% of the weight differences at length between the stocks, weight-length regressions reflected superior quality in the Lone Tree Lake fish. For this reason, and the simplicity of the procedure, weight-length relationships of all fingerling stocks should be measured routinely. Stock plumpness should be evaluated with regression rather than Fulton's condition factor, which is usually length biased.

Direct analysis of the four major body components (water, ash, lipid, and protein) provides the best measure of fingerling quality, however, this is impractical during routine management activities. The next best procedure, direct analysis of organic components combined (AFDW), involves combustion of dried fish and eliminates the more specialized and technically difficult procedures of lipid extraction and/or protein analysis. AFDW is a good measure of walleye quality, because it is largely protein in lean fishes. Strong inverse correlations between percent water and percent AFDW indicated that wet and dry weights may provide reasonable estimates of AFDW, thus eliminating the combustion step. However, this relationship has not been confirmed with other walleye fingerling data.

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