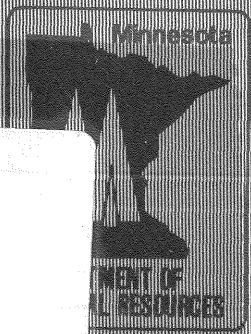Section of Fisheries
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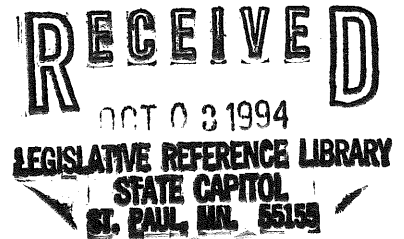NATURAL RESOURCES

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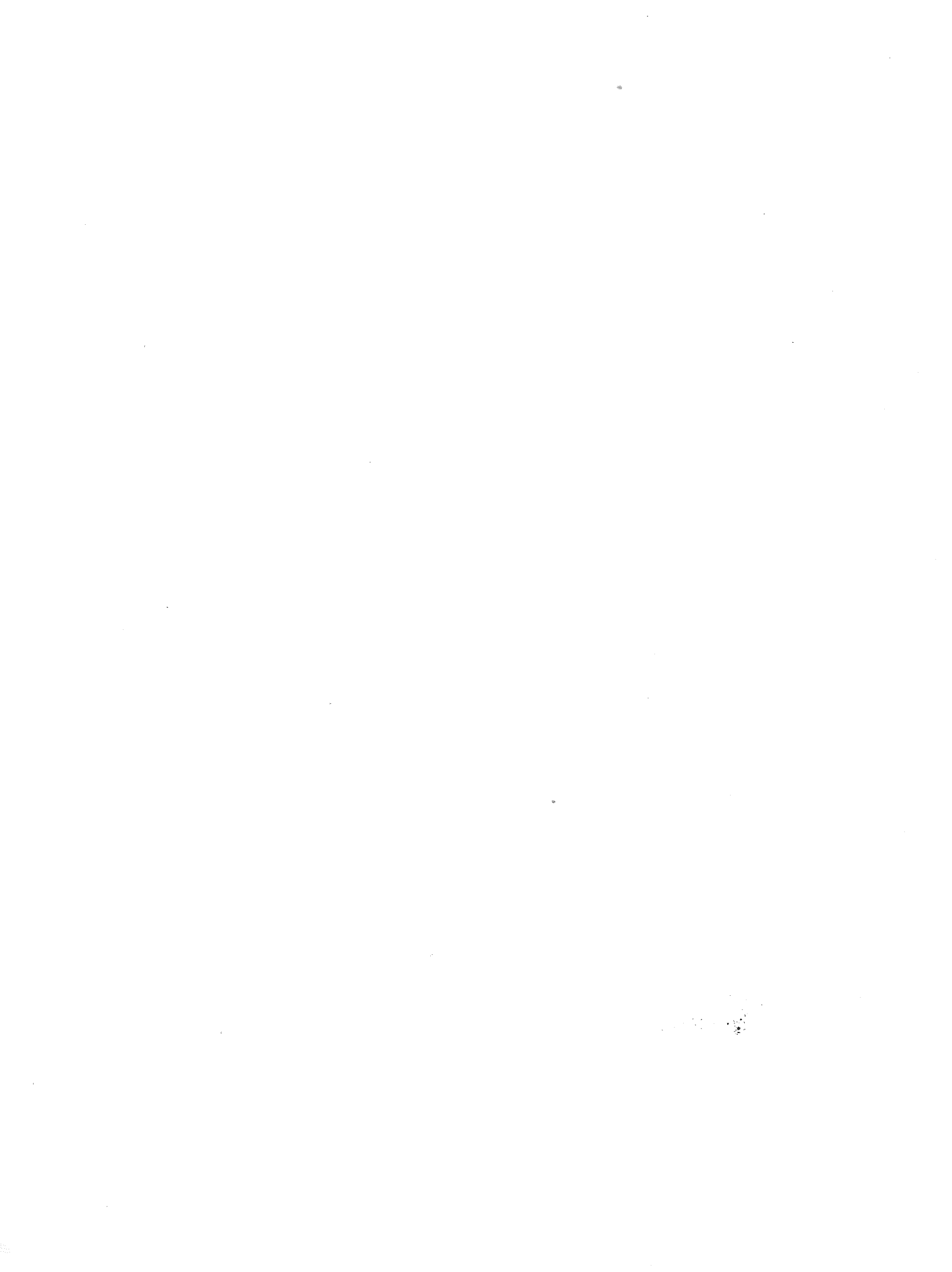
POPULATION DYNAMICS OF LARGE WALLEYE IN BIG SAND LAKE[1]

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Abstract. -- Walleye population parameters in Big Sand Lake, Hubbard County were estimated from 3 years of tagging and creel surveys. Estimated walleye biomass and annual yield were midrange of other North American walleye lakes. Large walleye ($\geq$550 mm) were exploited at lower annual rates than smaller walleye (38.4% for 350 to 549 mm males, 42.7% for 350 to 549 mm females, 13.5% for $\geq$550 mm males, and 25.2% for $\geq$550 mm females). Large walleye also had lower annual rates of natural mortality than small walleye (18.9% for 350 to 549 mm males, 14.5% for 350 to 549 mm females, 5.9% for $\geq$550 mm males, and 8.0% for $\geq$550 mm females). Voluntary releases of large walleye by anglers contributed to the lower exploitation rates. Although growth of Big Sand Lake walleye was slightly faster than walleye in other Minnesota lakes, the quality size structure was due to sustained growth rates at large sizes and low mortality rates. The experimental regulation allowing harvest of only one walleye greater than 508 mm had little effect on the walleye population in Big Sand Lake.

Introduction

Numbers of trophy walleye ($>$3.2 kg) in northwestern Minnesota lakes have declined in the past 20 years (Olson and Cunningham 1989). Increased fishing pressure and improved fishing gear have increased exploitation rates and reduced the numbers of walleye that survive to large sizes. Reduction in trophy walleye angling opportunities may contribute to increasing angler dissatisfaction. The importance of trophy angling opportunities for many Minnesota anglers was illustrated in an angler survey (Leitch and Baltezore 1987) where 48.4% of residents agreed to the statement "I fish so I can catch a trophy" (20.5% disagreed and 31.1% responded with no opinion).

The few lakes that still produce large walleye are becoming increasingly valuable. Big Sand Lake in Hubbard County is one of those lakes and provided the opportunity to study population dynamics of large walleye. Restoration of trophy walleye angling in other waters will be possible only after it is understood how walleye populations in lakes like Big Sand Lake function. The objective of this study was to examine population dynamics of walleye in Big Sand Lake by estimating parameters of growth, mortality, abundance and size-and-age structure.

Harvest of walleye in Big Sand Lake has possibly increased during the past several years,

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in part due to new angling techniques (trolling diving plugs at night) that are efficient in catching walleye suspended over deep water in summer. Public concern that this apparent increase in harvest would eventually reduce the numbers of large walleye in Big Sand Lake prompted implementation of an experimental regulation that allows harvest of only one walleye larger than 508 mm in a daily limit of six fish. The intent of the experimental regulation was to reduce the harvest of large walleye (≥ 508 mm). A secondary objective of this study was to evaluate effectiveness of this regulation.

Study Area

Big Sand Lake is a 672 hectare, hardwater (138 ppm total alkalinity) lake with a maximum depth of 41 m. Much of the lake (73%) is deeper than 4.6 m. Shallow water (less than 1.2 m) substrate is composed primarily of sand (60%), gravel (20%), and rock (15%), with the remaining 5% clay. Water quality is good with a secchi depth of 4.9 m (24 July 1989). Submerged vegetation is less abundant than in other area lakes. The lake thermally stratifies in summer and much of the hypolimnion remains oxygenated. The immediate watershed is 90% forested with conifers and mixed hardwoods, and most of the shoreline is developed with approximately 155 homes and cabins and 2 resorts. Fish species present include walleye *Stizostedion vitreum*, northern pike *Esox lucius*, muskellunge *Esox masquinongy*, largemouth bass *Micropterus salmoides*, smallmouth bass *Micropterus dolomieui*, bluegill *Lepomis machrochirus*, pumpkinseed *Lepomis gibbosus*, black crappie *Pomoxis nigromaculatis*, rock bass *Ambloplites rupestris*, white sucker *Catostomus commersoni*, cisco *Coregonus artedii*, yellow perch *Perca flavescens*, yellow bullhead *Ameirus natalis*, Johnny darter *Etheostoma nigrum*, log perch *Percina caprodes*, spottail shiner *Notropis hudsonius*, blacknose shiner *Notropis heterolepis*, and banded killifish *Fundulus diaphanus*. The lake is stocked in even-numbered years with walleye fingerlings intended to supplement natural reproduction.

Big Sand Lake is part of the Mantrap chain of lakes in Hubbard County (Figure 1). A
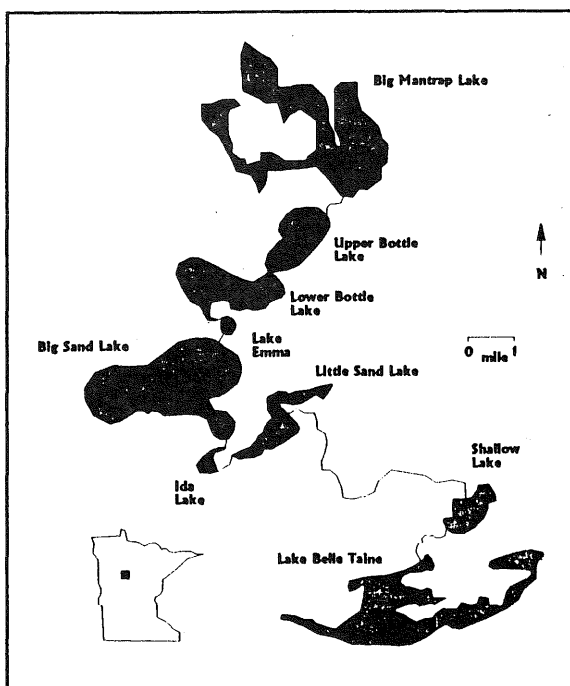
Figure 1. Map of the Mantrap Chain of Lakes in Hubbard County, Minnesota.

stream connects the lakes from Big Mantrap Lake to Lake Belle Taine. The stream ends at Lake Belle Taine with movement of water to the Crow Wing chain of lakes continuing as groundwater seepage out of Lake Belle Taine.

Walleye (and northern pike) may not be native to Big Sand Lake and the Mantrap Chain. The isolated nature of the watershed may have prevented movement of walleye and northern pike into the system. Long time residents recollect that the only predator fish species present in the Mantrap Chain in the early 1900s were smallmouth bass, largemouth bass, and muskellunge. Fuller's Tackle Shop Golden Book Fishing Contest Records (Olson and Cunningham 1989) had no contest entries for walleye or northern pike before the 1930s, however, many smallmouth and largemouth bass, and muskellunge were entered during that time.

Methods

Tagging

Walleye were captured in a pound net at the major inlet to Big Sand Lake during the spring spawning migrations in 1990 from 17

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April through 6 May, in 1991 from 23 April through 10 May, and in 1992 from 21 April through 8 May. Trap nets (19 mm bar measure) were also used to capture walleye in the lake. Serially numbered, plastic laminated, disc dangler tags were attached with 0.5 mm stainless steel wire to musculature between the dorsal fins. Total length and sex were recorded for all marked fish. All walleye marked were mature. Walleye were also marked in other lakes in the chain (Belle Taine, Little Sand, Emma, Upper and Lower Bottle) in the spring of 1990 to measure fish movement within the system. A public information program was developed in the area to enhance voluntary tag returns. The program consisted of posting signs at all public access points on the chain, preparing newspaper releases, and notifying all resorts and bait shops of the existence of tagged fish and the importance of returning angler-caught tags.

Tag Loss Estimation

Walleye captured during tagging operations in the springs of 1991 and 1992 were examined for tag loss. A lost tag was identified by prominent scarring of flesh around the tag insertion area. Bandow et al. (1993) tagged walleye with similar tags and observed distinct scars on walleye that were known to have lost tags (double tagged). Annual rate of tag loss for the first year (τ_1) was estimated by dividing the number of scarred fish observed in tagging operations in 1991 by the total number of recaptures (including scarred fish) of 1990 tagged fish observed in tagging operations in 1991.

Annual rate of tag loss from data for the second year (τ_2) was estimated by assuming that tag loss rate was constant and that 1990 tagged fish would have had twice the time to lose their tag as 1991 tagged fish (tag losses came from fish tagged in 1990 and 1991). The following equation was solved the for τ_2:

$$L_{92} = 2\,\tau_2\,R^*{}_{90} + \tau_2\,R^*{}_{91}\;;$$

where,

L_{92} = number of scarred fish observed in 1992 tagging operations;

$R^*{}_{90}$ = number of 1990 tagged fish recaptured during 1992 tagging operations (includes fish with lost tags);

$R^*{}_{91}$ = number of 1991 tagged fish recaptured during 1992 tagging operations (includes fish with lost tags).

Because the R^*'s include fish with lost tags, the number of scarred fish was apportioned to each R^* by the following equations:

$$R^*{}_{90} = R_{90} + L_{92}\,(2R_{90}/(2R_{90} + R_{91}));$$

$$R^*{}_{91} = R_{91} + L_{92}\,(R_{91}/(2R_{90} + R_{91}));$$

where,

R_{90} = number of 1990 tagged fish recaptured during 1992 tagging operations that retained their tag;

R_{91} = number of 1991 tagged fish recaptured during 1992 tagging operations that retained their tag.

Population Estimates

Spring population estimates of walleye in Big Sand Lake were made using the Petersen method, with corrections for migration (modified from Seber 1973; Equation 3.30):

$$N = \frac{(n_1 - \alpha n_1)\,n_2}{m_2} - \hat{a};$$

where,

N = population estimate;

n_1 = number of tagged fish extant (includes fish tagged in previous years, observed during tagging operations that year);

n_2 = number of fish examined for tags;

m_2 = number of recaptures (only recaptures from tagged fish known to be extant in that year were used);

α = estimated proportion of tagged fish lost to migration (αn_1 is equal to $-a_m$ of Equation 3.30 of Seber (1973));

$\hat{a}$ = net loss (or gain) of fish to the population from migration.

Variances were estimated using Equation 3.31 of Seber (1973).

The n_2 and m_2 values were from tagged and untagged fish examined in the creel survey for the first 23 to 26 days of the fishing season (12 May through 7 June in 1990, 11 May through 7 June in 1991, and 9 May through 7 June in 1992). Growth, recruitment, and tag loss were

assumed to be negligible during the time periods between tagging and recapture. Population estimates were calculated by size groups: 350 to 449 mm, 450 to 549 mm, and larger than 550 mm.

Mortality Rate Estimation

Total annual mortality rates were estimated from the annual exponential decline of angler reported tag returns using the regression method described by Ricker (1975). Walleye tagged in the spring of 1990 were used because they provided the longest series of annual angler reported returns (1990-1993). Tag returns were corrected for tag loss at monthly intervals. Migration of tags out of Big Sand Lake was estimated from tag returns of Big Sand Lake tagged fish caught from other lakes in the chain, which assumed equal survival rates throughout the chain. Although survival rate was not estimated for other lakes in the chain, casual observations indicated that fishing pressure was similar to Big Sand Lake, suggesting similar exploitation rates.

Exploitation rates were estimated from tagged walleye examined in the creel survey. Total number of tagged walleye harvested was estimated as the product of the proportion of tagged walleye observed during the creel survey and estimated total harvest. Only tagged walleye known to be extant for each year (newly tagged fish and previously tagged fish recaptured during that year's tagging operation) were used to estimate exploitation rate for that year. Annual natural mortality rate was estimated as the difference between exploitation rate and total mortality rate.

Age and Growth

Annual walleye length increments were estimated from changes in length of fish tagged in 1990 and recaptured during tagging operations in 1991, and from changes in length of fish tagged in 1991 and recaptured during tagging operations in 1992. Dorsal spines (second from the anterior of the fin - cut at the base of the spine) were collected during spring tagging operations in 1992 from at least 10 walleye of each sex per 25 mm group. Age distributions were expanded from subsamples using an age-length key. The Fraser-Lee Method (DISBCAL software, Frie 1982) was used for backcalculating lengths. Von Bertalanffy growth parameters were estimated using nonlinear regression (simplex method, Wilkinson 1992).

Creel Survey

Roving creel surveys were conducted in 1990, 1991, and 1992, from opening day of the walleye fishing season through late September (Table 1). The surveys were stratified by 2 week pay periods, day type (weekday or weekend/holiday), and time of day (4 hour time blocks). Shifts within a pay period were first stratified by day type, then assigned by a two stage random sampling procedure (Snedecor and Cochran 1967), with days as primary units and time blocks as secondary units. Four time blocks, 0600-1000, 1000-1400, 1400-1800, and 1800-2200 hours, were used through 28 August in 1990, through 27 August in 1991, and through 25 August in 1992. Three time blocks 0800-1200, 1200-1600, and 1600-2000 hours were used after the same August dates in each

Table 1. Creel survey periods for Big Sand Lake, 1990-1992.

Period	1990	1991	1992
May	12 May - 5 June	11 May - 4 June	9 May - 2 June
June	6 June - 3 July	5 June - 2 July	3 June - 30 June
July	4 July - 31 July	3 July - 30 July	1 July - 28 July
August	1 August - 28 August	31 July - 27 August	29 July - 25 August
September	29 August - 25 September	28 August - 24 September	26 August - 22 September
Night	20 June - 28 August	5 June - 27 August	5 June - 25 August

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year. Each time block for each day type was sampled once per pay period. Three instantaneous counts of fishing boats were made during each shift at previously selected, random times from the center of the lake, where the entire surface of the lake could be observed. Estimated fishing pressure (boat-hours), within a day type and time block, was calculated by multiplying mean number of boats on the water in the time block by number of hours in the time block and by number of days of each day type in the pay period. Because only one day of each day type and time block was sampled for a pay period, two pay periods were combined to make variance estimates possible (Cochran 1977). Variance estimates for fishing pressure within a time period (two pay periods) and day type were calculated by ANOVA (two stage sampling, Snedecor and Cochran 1967), calculating a within-time block variance component and a between-time block variance component. A finite population correction was used to adjust the between-block variance component (Cochran 1977). Variances of fishing pressure for an entire fishing season were estimated by summing variances of all strata.

Angler interviews were conducted during each shift between instantaneous pressure counts. Party size, time fished, and numbers of fish caught and released were determined for each boat interviewed. Anglers were also asked to estimate time caught for each walleye and the length of each released walleye. All observed walleye were examined for tags and measured for total length. Weights were obtained from a subsample of fish. The second dorsal spine was collected from walleye in 1992.

A night shift (2200 to 0200 hours) was implemented from 20 June - 28 August 1990, 5 June - 27 August 1991, and 5 June - 25 August 1992. Night fishing during the excluded time periods was considered to be negligible. The night creel survey was access-based (at the one public access) and was stratified only by day type. All anglers returning to the public access during the shift were interviewed, thus direct measures of fishing pressure of boats launched at the public access were attained. Night fishing pressure from boats not using the public access was calculated from the estimated proportion of boats originating from areas other than the public access (determined from angler interviews conducted from 2100 to 2200 hours in the roving portion of the creel survey).

Time fished and numbers of fish caught by each interviewed party was partitioned into the 4 hour time blocks. Harvest and release rates (number of fish/boat hour) for each 4 hour time block in each time period were then calculated with variance estimates for ratio estimators (Cochran 1977). Harvest and released fish estimates were obtained by multiplying the appropriate catch rate by fishing pressure (boat hours) for the time period. Catch rates and fishing pressure in terms of angler hours were calculated by multiplying by mean party size. Catch rates presented in tables were simple ratios of estimated catch per estimated effort.

Results

Tag Returns

A total of 3,579 walleye were tagged in Big Sand Lake during the study (Table 2). Anglers returned 1,253 of the tags over the 4 years of study. The majority (94.4%) were caught in Big Sand Lake (Table 3). Little Sand Lake and Lake Emma produced most of the tagged returns not caught in Big Sand Lake. No tags were returned from Big Mantrap Lake. A dam at the outlet of Big Mantrap Lake prevents upstream movement of fish into the lake. Another 343 walleye were tagged in other Mantrap Chain lakes in the spring of 1990 and returns were primarily from the lake of origin or from lakes nearby in the chain (Table 4).

Table 2. Numbers of walleye tagged in Big Sand Lake in the springs of 1990, 1991, and 1992.

| Year | Previously untagged | Originally tagged in | | Total |
		1990	1991	
1990	1,509	-	-	1,509
1991	1,182	268	-	1,450
1992	888	135	163	1,186
TOTAL	3,579	403	163	4,145

Table 3. Location of tags returned by anglers and reported as harvested from walleye tagged in Big Sand Lake in the springs of 1990, 1991, and 1992.

Tagging year	Return year	Upper Bottle	Lower Bottle	Bottle[a]	Emma	Big Sand	Ida	Little Sand	Belle Taine	Unknown	Total	Number tagged
1990	1990		3	1	5	272	3	10		5	299	
	1991				2	157		2			161	
	1992	1				50		1			52	
	1993					31		1			32	
	Total	1	3	1	7	510	3	14		5	544	1,509
1991	1991				1	356	1	9			367	
	1992				1	79		6	2		88	
	1993					22					22	
	Total				2	457	1	15	2		477	1,182
1992	1992				2	179		10			191	
	1993				2	37		2			41	
	Total				4	216		12			232	888
TOTAL		1	3	1	13	1,183	4	41	2	5	1,253	3,579

[a] Angler did not specify Upper or Lower Bottle.

Table 4. Location of tags returned by anglers in 1990, 1991 and 1992 from walleye marked in the spring of 1990 in lakes in the Mantrap Chain other than Big Sand Lake.

Tagging location	Year	Upper Bottle	Lower Bottle	Bottle[a]	Emma	Big Sand	Ida	Little Sand	Belle Taine	Unknown	Total	Number Tagged
Inlet to Upper Bottle	1990	17		1							18	
	1991	5	3	1							9	
	1992										0	
	1993										0	
	Total	22	3	2							27	65
Inlet to Emma	1990	8	5	2	9	5	1				30	
	1991	2			1	3					6	
	1992		1	1							2	
	1993										0	
	Total	10	6	3	10	8	1				38	101
Inlet to Little Sand	1990					5	1	6			12	
	1991					1		1			2	
	1992										0	
	1993										0	
	Total					6	1	7			14	32
Outlet of Little Sand	1990					1	1	7	14	1	24	
	1991							1	7		8	
	1992							4	1		5	
	1993					1					1	
	Total					1	1	12	22	1	38	145
TOTAL		32	9	5	10	16	3	19	22	1	117	343

[a] Angler did not specify Upper or Lower Bottle

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Tag Loss

Twenty fish with tag loss scarring were identified in the spring of 1991. Annual rate of tag loss (τ_1) for 1991 data was estimated at 7.4% (20 scarred fish of the 272 recaptured fish from 1990 tags, which included scarred fish). Forty fish with tag loss scarring were identified in the spring of 1992. Annual rate of tag loss for 1992 data (τ_2) was estimated to be 8.0% ($R_{90} = 135$ and $R_{91} = 163$). The mean of the two estimates (weighted by number of scarred fish observed) was 7.8% (instantaneous rate of 0.0812).

Population Estimates

The estimated proportion of tagged fish lost to migration (α) were estimated for each year from the number of fish tagged in Big Sand Lake and reported from other lakes in the chain, divided by total number of reported recaptures (Table 3): $\alpha_{1990} = 0.0903$ (27 out of 299), $\alpha_{1991} = 0.0300$ (11 out of 367), $\alpha_{1992} = 0.0628$ (12 out of 191). Lack of population estimates of walleye in other lakes in the Mantrap Chain made an actual estimate of â (net loss or gain of fish into Big Sand Lake) impossible. However, because general magnitudes of fish movement in and out of Big Sand Lake were similar, â was assumed

to be zero (of walleye tagged in other lakes in the chain, 13.1% of 1990 recaptures were caught in Big Sand Lake (Table 4), and of walleye tagged in Big Sand Lake in 1990, 9.0% of 1990 recaptures were caught in other lakes in the chain (Table 3)).

Estimated spring populations of walleye longer than 350 mm in Big Sand Lake declined from 21,508 (32.0 fish/ha, 24.5 kg/ha) in the spring of 1990 to 7,120 (10.6 fish/ha, 13.6 kg/ha) in 1991 and then to 6,779 (10.1 fish/ha, 14.0 kg/ha) in 1992 (Table 5). The decline was a reflection of trends in the smaller size groups (primarily 350-449 mm), while the largest size group (≥ 550 mm) slightly increased in numbers. The large error associated with the small number of recaptures of the 350 - 449 mm size group in 1990 may have exaggerated the size of the 1990 population and the subsequent decline. The population of walleye ≥ 450 mm remained relatively stable.

The highest biomass of walleye in Big Sand Lake were in the larger size groups, with the exception of 1990 (Table 5). Biomass of walleye ≥ 450 mm was relatively stable ranging from 6,969 kg in 1990 to 8,402 kg in 1992. The largest size group of walleye (≥ 550) experienced an increase in biomass from 3,552 kg in 1990 to 6,058 kg in 1992.

Table 5. Spring population estimates (N) with standard errors (SE), mean weights within a size group, and biomass of walleye in Big Sand Lake for 1990 through 1992 (n_1= number of tagged fish extant - includes fish tagged in previous years observed during tagging operations that year, n_2= number of fish examined, m_2= number of recaptures from tagged fish known to be extant in that year).

Size group	n_1	n_2	m_2	N	SE	Mean Weight (kg)	Biomass (kg)
				1990			
350-449 mm	548	68	2	16,950	11,811	0.56	9,492
450-549 mm	525	58	9	3,078	944	1.11	3,417
≥ 550 mm	428	19	5	1,480	568	2.40	3,552
TOTAL				21,508	11,862		16,461
				1991			
350-449 mm	354	102	13	2,694	698	0.57	1,536
450-549 mm	664	81	24	2,201	378	1.10	2,421
≥ 550 mm	430	16	3	2,225	1,158	2.33	5,184
TOTAL				7,120	1,404		9,141
				1992			
350-449 mm	265	55	8	1,707	559	0.60	1,024
450-549 mm	550	50	11	2,343	625	1.09	2,344
≥ 550 mm	364	23	3	2,729	1,475	2.22	6,058
TOTAL				6,779	1,697		9,426

Table 6. Estimated total instantaneous mortality (Z) and annual survival (S) from angler reported returns of walleye tagged in 1990 from Big Sand Lake, returned from 1990 through 1993. Numbers in parenthesis are angler reported returns corrected for tag loss.

Sex or size group	Number of reported tags								Z	S
	1990		1991		1992		1993			
Males	235	(237.2)	131	(143.1)	37	(43.8)	23	(29.5)	0.744	0.475
Females	64	(66.5)	30	(32.7)	15	(17.8)	9	(11.5)	0.587	0.556
Both sexes 350-549 mm	251	(253.3)	136	(148.5)	35	(41.4)	19	(24.3)	0.831	0.436
Both sexes ≥ 550 mm	47	(47.3)	25	(27.3)	17	(20.2)	13	(16.7)	0.342	0.710
Males 350-549 mm	221	(223.1)	116	(126.8)	29	(34.3)	17	(20.3)	0.850	0.427
Females 350-549 mm	30	(30.2)	20	(21.8)	6	(7.1)	2	(2.6)	0.848	0.428
Males ≥ 550 mm	13	(13.1)	15	(16.4)	8	(9.4)	6	(7.7)	0.215	0.806
Females ≥ 550 mm	34	(34.3)	10	(10.9)	9	(10.6)	7	(9.0)	0.404	0.668

Mortality

Large walleye (≥ 550 mm) survived (Table 6) at a higher mean annual rate (71%) than walleye between 350 and 549 mm (44%). Females survived at higher rates (56%) than males (48%). However, the higher survival rate was probably size related and not sex related. Male walleye actually survived at higher rates than female walleye for fish in the larger size group. Small male and female walleye (350-549 mm) had the lowest mean annual survival rate (43%) and large males (≥ 550 mm) had the highest mean annual survival rate (81%).

Estimates of annual walleye exploitation rates ranged from 22-49% and averaged 34% (Table 7). Small female walleye consistently experienced the highest exploitation rates (mean 43%), while large male walleye consistently experienced the lowest (mean 14%). Within size groups, exploitation was consistently higher among females. Overall, the highest walleye exploitation rate was recorded in 1991 (49%) and the lowest in 1990 (22%).

Size distributions of tagged walleye harvested by anglers further illustrated the trends in exploitation rates by size (Table 8). Although these rates were minimum estimates because of nonreporting of tags, the trend was for lower exploitation rates of walleye larger than 550 mm for both males and females. Very large female walleye (≥ 750 mm) had high exploitation rates, although sample sizes were small. Few tags from large (≥ 550 mm) males were returned by anglers.

Table 7. Estimated exploitation rates for walleye in Big Sand Lake by sex, size and year.

	350-549 mm		≥ 550 mm		
	Males	Females	Males	Females	Total
1990	0.258	0.289	0.081	0.153	0.222
1991	0.561	0.619	0.132	0.326	0.486
1992	0.331	0.374	0.193	0.278	0.312
Mean	0.384	0.427	0.135	0.252	0.340

Estimates of mean annual natural mortality rates were similar for each sex and lower for large walleye: 18.9% for 350 to 549 mm males, 14.5% for 350 to 549 mm females, 5.9% for ≥ 550 mm males, and 8.0% for ≥ 550 mm females. Instantaneous natural mortality rates were respectively 0.281, 0.215, 0.066, and 0.097.

Age and Growth

Tagged female walleye had larger annual length increments than male walleye in both years (Figures 2 and 3). Annual increments of both sexes declined as a function of body size.

Annual length increments of tagged walleye were significantly larger in 1991 than in 1990 (Table 9). A square root transformation of annual increments was an acceptable fit to the data points in Figures 2 and 3 (distributions of residuals were normal and homoscedastic). A

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Table 8.   Length frequencies of Big Sand Lake walleye tagged in 1990, 1991, and 1992 and harvested by anglers the same year they were tagged and unadjusted exploitation rates (*u*).

Length (mm)	1990 Tagged	Retrnd.	*u*	1991 Tagged	Retrnd.	*u*	1992 Tagged	Retrnd.	*u*	Total Tagged	Retrnd.	*u*
						Males						
300-324	2	0	0.000	1	0	0.000	1	0	0.000	4	0	0.000
325-349	6	1	0.167	1	0	0.000	6	0	0.000	13	1	0.077
350-374	59	11	0.186	38	12	0.316	11	4	0.364	108	27	0.250
375-399	154	41	0.266	81	29	0.358	52	7	0.135	287	77	0.268
400-424	185	55	0.297	119	44	0.370	94	19	0.202	398	118	0.296
425-449	142	33	0.232	93	34	0.366	103	29	0.282	338	96	0.284
450-474	120	26	0.217	119	47	0.395	123	29	0.236	362	102	0.282
475-499	96	24	0.250	80	20	0.250	82	15	0.183	258	59	0.229
500-524	100	18	0.180	69	20	0.290	68	9	0.132	237	47	0.198
525-549	101	13	0.129	65	10	0.154	67	9	0.134	233	32	0.137
550-574	75	8	0.107	55	5	0.091	54	3	0.056	184	16	0.087
575-599	59	3	0.051	47	4	0.085	47	8	0.170	153	15	0.098
600-624	29	2	0.069	28	2	0.071	22	4	0.182	79	8	0.101
625-649	12	0	0.000	10	0	0.000	19	0	0.000	4	1	0.000
650-674	4	0	0.000	3	0	0.000	3	2	0.667	10	2	0.200
675-699												
700-724				1	0	0.000				1	0	0.000
725-749												
750-774												
775-799												
800-824												
TOTAL	1,144	235	0.205	810	227	0.280	752	138	0.184	2,706	600	0.222
						Females						
300-324												
325-349												
350-374				1	0	0.000				1	0	0.000
375-399												
400-424	4	2	0.500	6	3	0.500				10	5	0.500
425-449	4	2	0.500	16	8	0.500	5	4	0.800	25	14	0.560
450-474	17	4	0.235	41	12	0.293	21	6	0.286	79	22	0.278
475-499	24	7	0.292	84	29	0.345	63	15	0.238	171	51	0.298
500-524	30	8	0.267	119	48	0.403	67	16	0.239	216	72	0.333
525-549	37	7	0.189	87	27	0.310	59	8	0.136	183	42	0.230
550-574	27	3	0.111	68	21	0.309	54	9	0.167	149	33	0.221
575-599	23	2	0.087	36	10	0.278	43	5	0.116	102	17	0.167
600-624	15	3	0.200	24	4	0.167	25	8	0.320	64	15	0.234
625-649	33	4	0.121	20	2	0.100	18	5	0.278	71	11	0.155
650-674	49	8	0.163	36	4	0.111	16	1	0.063	101	13	0.129
675-699	50	6	0.120	46	4	0.087	23	2	0.087	119	12	0.101
700-724	19	1	0.053	29	3	0.103	24	3	0.125	72	7	0.097
725-749	18	4	0.222	13	2	0.154	6	0	0.000	37	6	0.162
750-774	9	1	0.111	11	3	0.273	6	4	0.667	26	8	0.308
775-799	6	2	0.333	2	1	0.500	3	0	0.000	11	3	0.273
800-824				1	0	0.000	1	0	0.000	2	0	0.000
TOTAL	365	64	0.175	640	181	0.283	434	86	0.198	1,439	331	0.230

plot of fitted increments illustrated the differences in growth for each sex and year (Figure 4). Walleye grew as much as 10 mm more in length in 1991 than in 1990. The increased growth rate in 1991 may have been a density dependent response related to the smaller population size.

Backcalculated lengths of walleye sampled in 1992 showed similar growth differences by sex (Table 10). Female walleye were more than 100 mm longer (689 mm) than males (581 mm) by age 12. Von Bertalanffy parameters were estimated (from ages 1 to 15 years) to be $L_\infty = 770$ mm, $K = 0.190$, and $t_0 = 0.039$ for
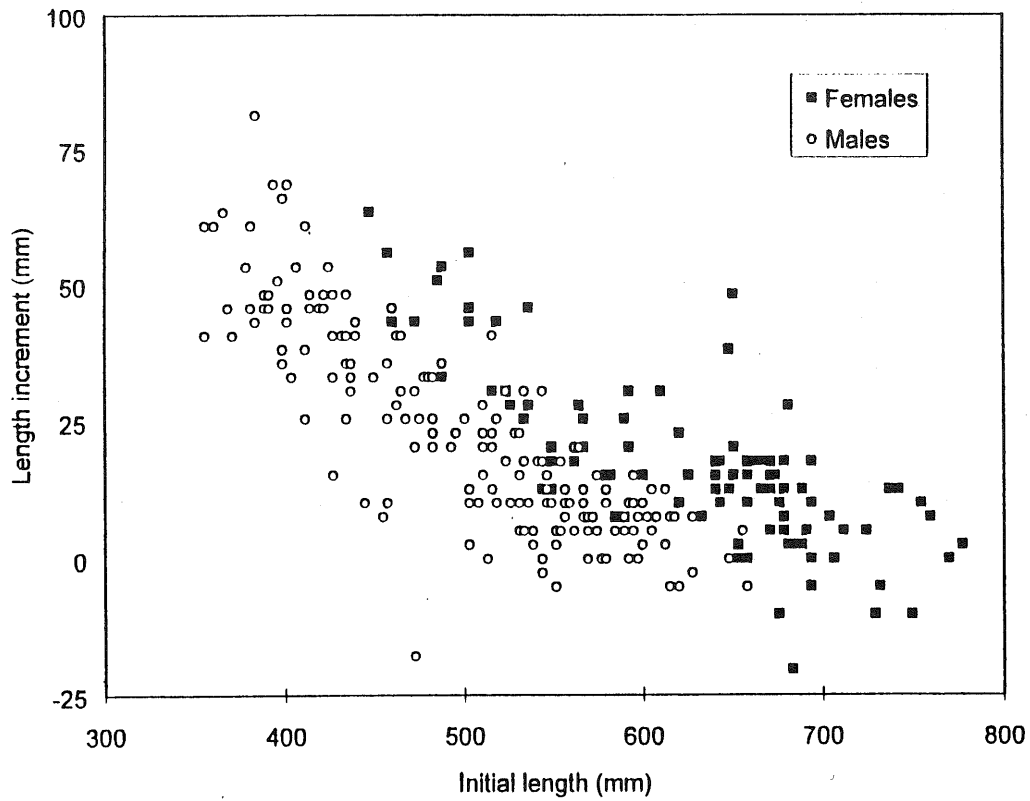
9

Figure 2. Increment in length of walleye tagged in 1990 and recaptured during tagging operations in 1991.
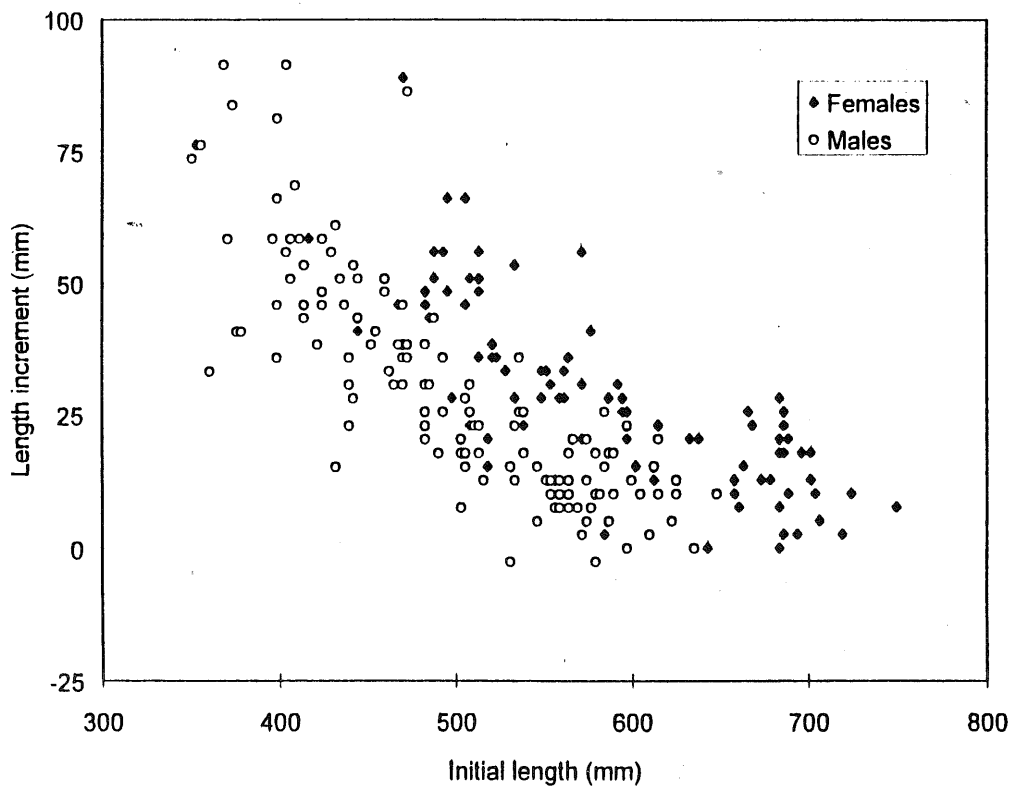

Figure 3. Increment in length for walleye tagged in 1991 and recaptured during tagging operations in 1992.

Table 9. ANCOVA table for the square root of annual length increments of walleye tagged in Big Sand Lake and recaptured during tagging operations one year later for growth years 1990 and 1991 (initial length was the covariate).

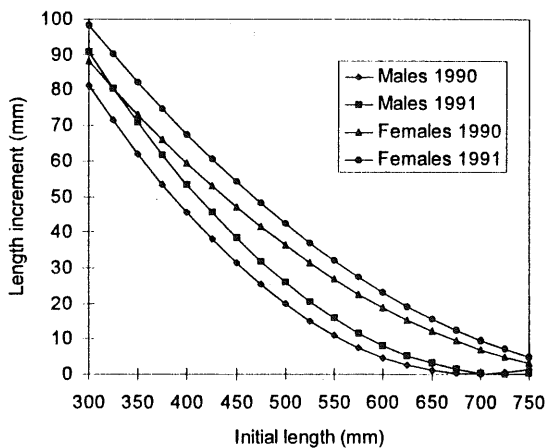| SOURCE	SS	DF	MS	F-RATIO	P
SEX	10.012	1	10.012	190.365	0.000
YEAR	0.936	1	0.936	17.792	0.000
SEX*YEAR	0.150	1	0.150	2.858	0.092
INITIAL LENGTH	45.162	1	45.162	858.676	0.000
ERROR	24.615	468	0.053		

Figure 4. Fitted annual increments of length for walleye in Big Sand Lake, 1990 and 1991.

females and $L_\infty = 627$ mm, $K = 0.234$, and $t_0 = 0.050$ for males.

Many males matured by age 4 (Table 11) at approximately 375 mm. Males at ages 4 through 8 comprised most of the spawning run in 1992 The oldest individuals were 18 years old. Females matured by age 5 or 6 at 475 mm (Table 12), with most fish between 5 and 11 years old and as old as 19 years.

Creel Survey

Fishing pressure on Big Sand Lake was consistent during the three years of the study (Table 13) with a mean of 28,002 angler-hours (41.7 angler hours/ha). The majority of pressure (63%) occurred in May and June and steadily declined throughout each summer. September pressure was very light. Night fishing comprised approximately 9% of total angler hours. Most (85%) pressure during all periods was directed at walleye. Nearly one-half (49%) of the anglers originated from the public access, 29% from resorts, and 22% from cabins on the lake.

Estimated annual walleye harvest in Big Sand Lake ranged from 2,206 fish in 1992 to 4,558 in 1991 (Table 14) with a mean of 3,512 (5.2 walleye/ha). Mean annual yield was estimated at 3,432 kg (5.1 kg/ha). Most (65%) walleye were harvested in May and June. Night fishing accounted for 25% of the harvested walleye. Access based anglers harvested the majority of the walleye (71%), while resort guests harvested 23% and cabin owners 6%. Mean size of harvested walleye for the 3 years was 452 mm and 0.98 kg. Night anglers caught (harvested and released) similar sized walleye (mean length of 417 mm) to day anglers (mean length of 442 mm). Most (77%) walleye harvested were smaller than 500 mm (Table 15). Anglers released 74% of walleye less than 350 mm and 39% of walleye larger than 550 mm. Only 8% of walleye between 375 and 524 mm were released. The majority (85%) of walleye releases greater than 508 mm were voluntary (Table 16) and not because of the experimental regulation (14%). Of all walleye caught (harvested and released) over 508 mm, only 4% were released because of the regulation.

Ages 4-7 dominated the walleye harvest in 1992 (Table 17). The oldest fish was 15 years old. Walleye catch rates (harvested and released fish per angler-hour) were highest in the night fishery with a mean of 0.34 and in May with a mean of 0.19 (Table 18). Catches of fish other than walleye, were low (Table 19). Smallmouth bass (mean annual harvest of 0.10 kg/ha) and northern pike (mean annual harvest of 0.19 kg/ha) were the most important predator species other than walleye. Few panfish (crappies, sunfish, rock bass and yellow perch) were harvested. Mean annual harvest was 0.11 kg/ha for all panfish species combined.

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Table 10. Backcalculated lengths at age of walleye tagged in Big Sand Lake in the spring of 1992.

Year-class	Age	N	Backcalculated length at age (mm)																	
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
									Males											
1991	1	0																		
1990	2	4	165	254																
1989	3	18	122	228	310															
1988	4	19	129	215	300	370														
1987	5	27	142	237	337	405	451													
1986	6	22	132	215	303	388	445	488												
1985	7	5	116	187	290	385	444	486	521											
1984	8	15	140	215	295	378	439	488	525	553										
1983	9	16	141	208	301	384	434	475	510	537	558									
1982	10	21	136	212	307	381	433	479	515	547	567	584								
1981	11	8	139	211	297	368	430	468	497	522	544	560	578							
1980	12	5	140	209	274	343	394	433	461	493	527	547	567	584						
1979	13	0																		
1978	14	3	124	205	280	355	404	450	479	508	531	552	571	584	600	613				
1977	15	2	96	159	262	341	391	417	451	481	505	531	552	569	586	603	615			
1976	16	0																		
1975	17	1	160	229	282	358	419	450	472	495	518	541	564	579	594	610	617	625	640	
Mean			135	218	306	382	437	476	507	535	553	569	571	581	594	609	616	625	640	
SE			2.0	3.0	3.7	3.9	3.9	4.0	4.5	4.4	4.9	5.5	6.9	9.2	11.0	11.4	6.1	0.0	0.0	
N		166	166	166	162	144	125	98	76	71	56	40	19	11	6	6	3	1	1	
1991	1	0							Females											
1990	2	0																		
1989	3	5	130	259	361															
1988	4	21	137	218	316	400														
1987	5	27	153	247	342	431	502													
1986	6	18	149	246	336	419	493	546												
1985	7	8	145	226	343	459	526	564	593											
1984	8	15	152	236	332	433	503	551	589	620										
1983	9	15	139	226	313	400	467	532	586	622	650									
1982	10	17	131	205	309	402	468	529	581	621	649	671								
1981	11	5	142	203	281	353	438	501	555	597	629	659	684							
1980	12	6	129	196	263	337	414	480	543	582	622	654	677	697						
1979	13	3	116	173	237	325	409	471	519	555	598	626	652	679	696					
1978	14	4	153	229	309	393	452	499	549	598	634	665	694	720	736	747				
1977	15	6	144	199	271	350	420	470	506	550	587	627	656	679	697	715	726			
1976	16	1	109	165	227	359	471	519	561	603	638	679	686	728	742	756	770	784		
1975	17	1	131	194	236	285	341	418	474	502	530	572	621	649	684	698	712	719	740	
1974	18	1	103	174	238	330	402	458	480	501	522	544	565	600	608	615	622	629	636	643
Mean			142	226	318	405	477	526	568	603	631	653	668	689	703	719	718	711	688	643
SE			2.0	3.0	4.1	4.7	5.2	5.3	5.0	5.1	5.6	5.9	7.9	9.0	11.7	13.2	17.5	44.9	52.2	0.0
N		153	153	153	153	148	127	100	82	74	59	44	27	22	16	13	9	3	2	1

Table 11. Age and length distributions of male walleye tagged in spring 1992 in Big Sand Lake.

Length group (mm)	Sample size	Subsample size	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
300-324	1	1				1																
325-349	6	5				1	3	2														
350-374	11	4				5	3	3														
375-399	52	4					52															
400-424	94	10					57	9	19	9												
425-449	103	9					23	57	23													
450-474	123	19					13	39	52	7	6		6									
475-499	82	10					8	24	25	25												
500-524	68	17						4	32	20	4	8										
525-549	67	17							8	31	4	12	8									
550-574	54	22							3	10		7	15	12	5			2				
575-599	47	16							3		3	6	9	14	9	3						
600-624	22	18									1	5	2	7	2	2			1			
625-649	19	12										1	3	6		2		3	2		2	
650-674	3	2												1	2							
675-699	0	0																				
700-724	0	0																				
725-749	0	0																				
750-774	0	0																				
775-799	0	0																				
800-824	0	0																				
TOTAL	752	166	0	0	0	7	159	138	165	102	18	39	43	40	18	11	0	5	3	0	2	0

Table 12. Age and length distributions of female walleye tagged in spring 1992 in Big Sand Lake.

Length group (mm)	Sample size	Subsample size	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
300-324	0	0																				
325-349	0	0																				
350-374	0	0																				
375-399	0	0																				
400-424	0	0																				
425-449	5	5					1	3		1												
450-474	21	7					9	6	6													
475-499	63	8						55	8													
500-524	67	8					8	42	17													
525-549	59	9						26	33													
550-574	54	12							27	27												
575-599	43	16							19	11	5	5	3									
600-624	25	16							6	5	6	5	3									
625-649	18	10								5	2	3	2	2	2		2					
650-674	16	12								1	1	6	3	3		1	2					1
675-699	23	16										6	4	10		2			1			
700-724	24	20											6	7	5	3		1	2			
725-749	6	5											2	1		1	1		1			
750-774	6	3														1	1	2	1		1	
775-799	3	2															1		1			
800-824	1	1																1				
TOTAL	434	153	0	0	0	0	18	132	116	50	14	25	23	23	7	8	5	4	6	0	1	1

Table 13. Angling pressure estimates (angler hours with SE in parenthesis) on Big Sand Lake from 1990 through 1992.

Month	1990		1991		1992	
May	13,190	(2,042)	12,527	(2,235)	12,525	(1,629)
June	4,085	(754)	5,364	(626)	5,573	(911)
July	7,005	(713)	3,752	(1,165)	3,933	(797)
August	1,842	(387)	1,890	(373)	2,554	(332)
September	651	(211)	630	(243)	662	(151)
Night	3,864	(183)	2,882	(58)	1,078	(121)
TOTAL	30,637	(2,340)	27,045	(2,638)	26,325	(2,066)

Table 14. Estimates of numbers of walleye caught (SE in parenthesis) in Big Sand Lake, 1990 through 1992.

Month	1990		1991		1992	
			Harvested			
May	1,570	(278)	2,344	(485)	1,538	(251)
June	333	(65)	715	(145)	388	(96)
July	208	(73)	361	(171)	164	(48)
August	226	(63)	52	(32)	26	(10)
September	10	(9)	12	(11)	7	(6)
Night	1,425	(77)	1,074	(58)	83	(14)
TOTAL	3,772	(311)	4,558	(538)	2,206	(274)
			Released			
May	433	(140)	884	(277)	384	(91)
June	424	(100)	93	(88)	130	(43)
July	151	(64)	51	(35)	54	(22)
August	35	(16)	22	(13)	5	(8)
September	10	(9)	12	(11)	3	(4)
Night	578	(35)	116	(12)	0	(0)
TOTAL	1,631	(188)	1,178	(294)	576	(103)

Table 15. Length distributions of walleye measured during creel surveys on Big Sand Lake from 1990 through 1992.

Length (mm)	Harvested				Released				Percent released
	1990	1991	1992	Total	1990	1991	1992	Total	
200-224					7	1	3	11	100.0
225-249					2	0	2	4	100.0
250-274					20	3	4	27	100.0
275-299	3	5	0	8	6	0	0	6	42.9
300-324	4	6	2	12	42	30	3	75	86.2
325-349	13	13	2	28	7	2	3	12	30.0
350-374	35	36	4	75	17	7	2	26	25.7
375-399	32	51	12	95	7	3	0	10	9.5
400-424	40	66	28	134	0	5	0	5	3.6
425-449	50	35	33	118	8	3	1	12	9.2
450-474	43	38	20	101	6	10	3	19	15.8
475-499	26	38	19	83	1	0	1	2	2.4
500-524	20	32	19	71	3	2	0	5	6.6
525-549	13	15	12	40	0	5	3	8	16.7
550-574	7	15	10	32	2	6	5	13	28.9
575-599	5	6	6	17	4	4	9	17	50.0
600-624	3	7	4	14	2	4	4	10	41.7
625-649	2	2	4	8	1	1	2	4	33.3
650-674	3	0	1	4	2	1	1	4	50.0
675-699	0	1	3	4	2	2	1	5	55.6
700-724	3	1	0	4	0	1	0	1	20.0
725-749	2	0	0	2	1	0	0	1	33.3
750-774					0	0	1	1	100.0
775-799	2	1	0	3					0.0
TOTAL	306	368	179	853	140	90	48	278	24.6

Table 16. Numbers of walleye greater than 508 mm, examined by the creel clerk, that were harvested legally, harvested illegally, released voluntarily, and released because of the special regulation.

	Year		
	1990	1991	1992
Harvested legally	51	73	49
Harvested illegally	0	1	1
Released voluntarily	12	22	23
Released because of regulation	4	3	2

Table 17. Age distribution of walleye harvested from Big Sand Lake and measured during the creel survey in 1992.

Age	Number
2	2
3	8
4	41
5	33
6	21
7	10
8	3
9	4
10	3
11	1
12	1
13	
14	1
15	1
TOTAL	129

Table 18. Estimated walleye catch rates (number per hour) in Big Sand Lake, 1990 through 1992.

Month	1990	1991	1992
		Harvested	
May	0.119	0.187	0.123
June	0.082	0.133	0.070
July	0.030	0.096	0.042
August	0.123	0.028	0.010
September	0.015	0.019	0.011
Night	0.369	0.373	0.077
TOTAL	0.123	0.169	0.084
		Released	
May	0.033	0.071	0.031
June	0.104	0.017	0.023
July	0.022	0.014	0.014
August	0.019	0.012	0.002
September	0.015	0.019	0.005
Night	0.150	0.040	0.000
TOTAL	0.053	0.044	0.022

Discussion

The quality size structure of walleye in Big Sand Lake was the result of low mortality rates of large fish and sustained growth rates. Exploitation rates of large walleye (≥ 550 mm) were considerably lower than for smaller walleye. Although releases of large walleye partially ex-

plain the lower exploitation rates, large walleye were less vulnerable to anglers. Serns and Kempinger (1981) and Payer et al. (1987) also found larger walleye to be less vulnerable to angling. Compared to exploitation rates estimated for other populations of walleye in Minnesota, Big Sand Lake exploitation rates were midrange (Table 20). The majority of the exploitation pressure in Big Sand Lake was centered on smaller walleye, similar to many of the traditional walleye lakes in Minnesota. Natural mortality rates of large walleye were also lower than for small walleye. Natural mortality rates for walleye in Big Sand Lake were within the 5-30% range reported by Ney (1978). Natural mortality rates of large walleye were similar to the 4.8% estimated by Olson (1957). Mean biomass (17.4 kg/ha) and annual harvest (5.1 kg/ha) were midrange of North American walleye biomasses and harvests (Carlander 1977). Growth rates of Big Sand Lake walleye were faster at early ages than those in some of Minnesota's important walleye waters (Table 21). Big Sand Lake walleye maintained or slightly increased their growth rate advantage at larger sizes and older ages then other walleye populations.

Good habitat and abundant forage in Big Sand Lake may be the reason for the lower exploitation rates and sustained growth of large walleye. An abundance of deep water, with an oxygenated hypolimnion, provides habitat for a

Table 19. Estimates of fish other than walleye caught in Big Sand Lake, 1990 through 1992. Mean weight (kg) is of harvested fish.

Species	1990			1991			1992		
	Harvested	Released	Mean weight	Harvested	Released	Mean weight	Harvested	Released	Mean weight
Smallmouth bass	195	299	0.75	59	342	0.63	34	172	0.60
Largemouth bass	0	17	-	0	28	-	0	4	-
Northern pike	139	152	1.02	56	99	2.19	31	20	3.57
Muskellunge	0	10	-	0	8	-	0	0	-
Rock bass	87	495	0.29	94	356	0.31	19	66	0.25
Black crappie	14	20	0.74	0	0	-	67	0	0.42
Sunfish	77	97	0.18	283	25	0.28	24	82	0.16
Yellow perch	455	NE	0.08	289	NE	0.15	17	NE	0.13
White sucker	22	44	NE	0	0	-	0	0	-

NE = not estimated

Table 20. Unadjusted annual rates of exploitation based on voluntary reports of tagged walleye in Minnesota.

Lake	Year(s)	Source	Tag	Size, sex	Exploitation Rate
Vermillion	1940	Carlander 1941	jaw tags	mature fish	0.050
St. Louis River Estuary	1980-82	Osborn et al. 1991	T-bar anchor	mature fish	0.081
Sallie	1954	Olson 1955	jaw and opercle tags	mature fish	0.093
Winnibigoshish	1937-39	Stoudt and Eddy 1939	jaw tags	mature fish	0.102
Lake of the Woods (MN waters)	1982	Payer et al. 1987	disc dangler	≥ 279 mm males, ≥ 330 mm females	0.137[a]
Cass, Andrusia, Big Wolf	1971-75	Strand 1980	disc dangler	mature females	0.158
Big Sand	1990-92	this study	disc dangler	mature females	0.222
Big Sand	1990-92	this study	disc dangler	mature males	0.230
Winnibigoshish	1975-1977	Osborn et al. 1985	T-bar anchor and disc dangler	mature males	0.231
Cass, Andrusia, Big Wolf	1971-75	Strand 1980	disc dangler	mature males	0.260
Winnibigoshish	1975-1977	Osborn et al. 1985	T-bar anchor and disc dangler	mature females	0.261
Many Point	1955-57	Olson 1957	fin clip	≥ 356 mm	0.269
Otter Tail	1983	Schreiner 1987	disc dangler	mature fish	0.279

[a] sport fishing only

Table 21. Backcalculated lengths (mm) at age of walleye in Minnesota.

				Lake			
Age	Lake of the Woods[a] 1983-84	Cass[b] 1990	Leech[c] 1985-90	Winnibigoshish[d] 1990	Mille Lacs[e] 1983-90	Kabetogoma[f] 1990	Big Sand[g] 1992
				Males			
1	140	147	155	127	137	132	135
2	213	229	239	216	216	213	218
3	284	295	307	292	282	277	305
4	335	351	356	348	343	351	381
5	378	381	391	399	394	411	437
6	411	427	419	439	429	450	478
7	432	450	439	488	460	465	508
8	452	465	455	536	485	493	536
9	500				498	508	554
10	508				526	521	569
11						531	572
12							582
				Females			
1	145	147	157	132	140	132	142
2	218	226	244	221	221	226	226
3	290	297	318	307	290	302	318
4	343	358	373	373	358	368	406
5	389	409	422	414	424	434	478
6	429	457	457	457	475	480	526
7	455	498	485	645	518	531	569
8	508	544	490		544	564	605
9	554	569			574	594	630
10	538	599			602	612	653
11	602	627				625	668
12	622					648	688
13	632						704
14	645						719

[a] Payer et al. 1987
[b] Boe 1991
[c] Haukos 1991
[d] Albert 1991
[e] Bruesewitz 1991
[f] Eibler 1991
[g] This study

large population of small cisco that, along with an abundant yellow perch population, provide large walleye with a good forage base. In addition, the deep water may provide a refuge for larger walleye and the high water clarity may make them more difficult to catch. Although the night fishery that developed on Big Sand Lake provided a way to catch these deep water walleye in summer, it contributed only 25% of total harvest, which did not suggest an excessive level of harvest. Also, night anglers did not catch larger walleye than day anglers.

The experimental regulation of one walleye over 508 mm had little effect on the Big Sand Lake walleye population. Only 4% of walleye caught larger than 508 mm were released because of the regulation. Voluntary releases of walleye larger than 508 mm were considerably higher than releases because of the regulation. Although the creel survey used primarily incomplete interviews (regulation releases would have been higher in completed bags), it is doubtful that regulation releases were significant. A 1992 creel survey of Little McDonald Lake (Tables 22-24) in Otter Tail County (a lake similar to Big Sand Lake in morphology, chemistry and reputation for large walleye), with a design identical to the Big Sand Lake creel survey, estimated a voluntary release rate of 25.0% for walleye larger than 508 mm, which is similar to

Table 22.   Estimates of angling pressure, walleye catch and catch rates from Little McDonald Lake, Otter Tail
              County in 1992 (SE in parenthesis).

Month	Angler hours		Numbers of fish				Catch per hour	
			Harvested		Released		Harvested	Released
May	1,204	(355)	48	(27)	14	(11)	0.040	0.012
June	2,538	(477)	102	(34)	30	(15)	0.040	0.012
July	4,087	(499)	165	(44)	44	(21)	0.040	0.011
August	2,313	(434)	218	(59)	174	(57)	0.094	0.075
September	1,600	(279)	44	(22)	13	(10)	0.028	0.008
Night	636	(45)	90	(12)	63	(8)	0.142	0.099
TOTAL	12,378	(933)	667	(89)	338	(65)	0.054	0.027

the Big Sand Lake. Size limits were not in effect on Little McDonald Lake, which suggests that the voluntary release of large walleye was occurring independently from any indirect influence of the one over 508 mm regulation.

Although exploitation rates of small walleye were high in some years (greater than 50% in 1991), the existing size structure of walleye in Big Sand Lake appears to be sustainable. Walleye abundance in Big Sand Lake declined over the study period, but the decline was in the smallest (350-449 mm) size group. The population of larger walleye was relatively stable. Apparently, angling impacted the population of smaller walleye more than the larger walleye. Also, length and age distributions of walleye collected during the 1988 spawning run by the Park Rapids Management Area from an identical trap at the inlet to Big Sand Lake (Tables 25,26) suggested that no significant changes in the size structure occurred from 1988 through 1992. Records from the Fuller's Tackle Shop Golden Book Fishing Contest (Olson and Cunningham 1987) indicate that the population of trophy walleye in Big Sand Lake, is on a upward trend, after a large peak of entries in the 1940s and a sharp decline in the 1950s (Figure 5).

Although the existing population structure appears to be sustainable, evidence exists that the size structure of Big Sand Lake walleye was better in the past. Of 16 spawning runs in Minnesota sampled from 1939 through 1942, Big Sand Lake had the largest sizes of walleye (Carlander 1942). In 1942, mean length of Big Sand Lake walleye was 546 mm for males (com-

pared to 462 mm in 1990-1992) and 627 mm for females (compared to 556 mm in 1990-1992). Although actual length distributions were not presented, Carlander (1942) calculated a statistic where 90% of males were larger than 452 mm (compared to only 56% in 1990-1992) and 90% of females were larger than 592 mm (compared to only 38% in 1990-1992).

Management Implications

Although the existing walleye size structure in Big Sand Lake appears to be sustainable, historical evidence (Carlander 1942) and the occurrence of high exploitation rates in some years, suggest that it could be improved. A regulation that protects walleye through the size range with the highest exploitation rates (375-525 mm) appears to have the best chance of increasing numbers of large walleye. The current one over 508 mm experimental regulation had little effect on the population of walleye in Big Sand Lake and should be discontinued.

Table 23. Length distributions of walleye measured during the creel survey on Little McDonald Lake in 1992.

Length (mm)	Harvested	Released
200-224		1
225-249		1
250-274		2
275-299	3	7
300-324	2	14
325-349	10	5
350-374	9	2
375-399	10	
400-424	5	1
425-449	15	
450-474	4	
475-499	5	
500-524	8	
525-549	5	
550-574	3	
575-599		2
600-624	2	
625-649	1	1
650-674		2
675-699		
700-724		
725-749	1	1
TOTAL	83	39

Table 24. Estimated catch and mean weight (kg) of harvested fish, other than walleye, from Little McDonald Lake in 1992.

Species	Number of fish Harvested	Released	Mean weight
Largemouth bass	640	841	0.50
Northern pike	352	1,184	0.84
Rock bass	8	8	0.25
Black crappie	207	44	0.20
Sunfish	446	706	0.49
Yellow perch	4	NE	0.11

NE = not estimated

Table 25. Length distributions of Big Sand Lake walleye captured during the spawning run in 1988 (Minnesota DNR files) and from 1990-1992 (this study).

Length (mm)	Males 1988	1990	1991	1992	Females 1988	1990	1991	1992
305-329	4	2	1	2				
330-355	30	13	6	6			1	
356-380	117	80	44	16				
381-405	147	160	89	63	1		1	
406-431	133	182	115	100		4	7	1
432-456	51	147	121	112	4	11	18	9
457-482	54	111	99	119	18	17	52	30
483-507	25	102	83	65	14	27	94	75
508-532	31	98	59	79	10	31	116	61
533-558	18	91	67	60	14	33	94	53
559-583	17	75	57	50	12	26	51	53
584-609	10	50	37	46	13	22	31	40
610-634	6	24	21	23	22	18	21	21
635-659		8	9	10	21	45	29	18
660-685		1	1	1	3	49	40	19
686-710					8	37	45	22
711-736			1		11	22	20	20
737-761					7	13	9	6
762-786					2	8	0	3
787-812					2	2		3
813-837							1	
TOTAL	643	1,144	810	752	162	365	640	434

Table 26. Age distributions of walleye captured at the inlet to Big Sand Lake during the spawning run in 1988[a].

Age	Males	Females
2	2	
3	36	
4	379	26
5	95	20
6	47	17
7	39	45
8	13	18
9	5	2
10	6	
11	16	12
12	2	4
13		6
14	3	3
15		4
16		1
17		2
18		1
TOTAL	643	161

[a] Minnesota DNR files.
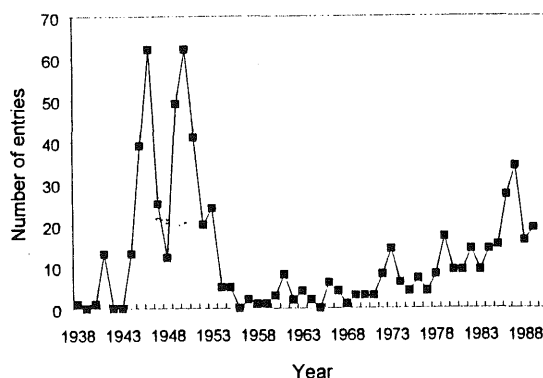
Figure 5. Number of trophy (>3.18 kg) walleye entries from Big Sand Lake, 1932-1989, in the Fuller's Golden Book Fishing Contest (Olson and Cunningham 1987).

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