Assessment of Adult Crappie Abundance During the Spawning Season in Specific Coves, Larval Crappie Production, Entrainment, and Response to Artificial Walleye Spawning Substrate in Sherman Reservoir

Annual Performance Report

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Objectives

I. Estimate abundance of adult and larval crappie present in specific coves during spawning season and lost through water releases at Sherman Reservoir.

II. Determine the availability of spawning habitat and assess the functionality of artificial walleye spawning substrate in Sherman Reservoir.

Introduction

Sherman Reservoir is an off-stream irrigation storage impoundment for the Middle Loup River in South Central Nebraska. The United States Bureau of Reclamation completed Sherman Dam in 1962 and ownership of dam and water storage operations was transferred to the Loup Basin Reclamation District in 2002. At conservation pool (658.8 meters msl), Sherman Reservoir covers 1,151 ha with a maximum depth of 19 m. The capacity at conservation pool is approximately 8,520 ha-m, which is used to supply irrigation water for nearly 24,000 ha.

Regionally, Sherman Reservoir is a popular crappie (*Pomoxis spp*.) and walleye (*Sander vitreus*) fisher. On-site angler surveys (1996-2001) found crappie and walleye to be the most highly sought species for the estimated average of 87,600 hours of angling conducted between April and September of each year (Newcomb 2002). A high abundance and consistent recruitment drive the popularity of the crappie fishery, but walleye year-class strength is inconsistent. Consistent adult populations are unusual for crappie as they typically exhibit highly variable year-classes (Hooe 1991). The consistent recruitment in Sherman Reservoir is thought to be associated with lake water level patterns that minimize water level fluctuations and release during spawning and early development stages (Beam 1983; Mitzner 1991) and the presence of ample coves and embayments, which act as preferred spawning habitat sites (Mitzner 1991; Pope and Willis 1998).

As an artificial impoundment, Sherman Reservoir is susceptible to an accelerated aging process (Kimmel and Groeger 1986) due to increased soil erosion (Summerfelt 1999), increased watershed area to lake surface area ratio and phosphorus loading (Cooke et al. 1993). Most aging processes are the result of eroded soil, nutrients, and contaminants transported from the watershed to the lake. Increased input of eroded soil, nutrients, and contaminants from the watershed to the lake lead to increased turbidity, decreased depth, and more frequent algal blooms (Summerfelt 1999). Fisheries staff with the Nebraska Game and Parks Commission has observed this aging process in Sherman Reservior and become concerned for the perpetuity of critical cove habitat.

The concern for habitat in Sherman Reservoir has led to a proposed aquatic habitat project (AHP). The goals for this AHP are to restore and protect selected coves and points that are susceptible to shoreline erosion and siltation. Newcomb (2002) states that the protection of valuable coves and shoreline aquatic habitat is necessary to prevent

long-term decline in crappie populations. The collection of baseline information pertaining to the use of protected coves by spawning crappies and subsequent larval production would be valuable information for future comparisons.

Another component of the AHP is the construction of a fish recovery system in the tailwater canal. At Sherman Reservoir, the average annual water release is greater than 50% of reservoir volume. High reservoir flushing rates, especially during the late spring and early summer can negatively influence survival of crappie fry (Maciena and Stimpert 1998). Existing literature suggests that escapement loss, especially of larval fish, can be substantial for crappie (Moen and Dewey 1978), largemouth bass (Lewis et al. 1968), catfish (Louder 1958; Storck and Newman 1986), walleye (Walburg 1971; LeJeone 1988), and gizzard shad (Jensen et al. 1988; Smith and Brown 2002). Past salvage operations in the canal systems below Sherman Dam have documented hundreds of catfish, white crappie, and walleye. Unfortunately most of the entrained fish were not salvaged. However, the loss of great numbers of fish does not necessarily mean that populations within the reservoir were significantly impacted. Quantification of actual numbers of fish lost and species composition is essential for determining the economic benefit of constructing a fish recovery system.

A final component of the AHP is to add spawning substrate in an attempt to improve walleye recruitment. Sherman Reservoir is important to the NGPC as both a sportfishery and a broodstock for hatchery egg collections of this species. The success of these spawn-taking efforts is predicated on the abundance of adult walleye in Sherman Reservoir. To augment walleye populations in Sherman Reservoir, a maintenance stocking of 25-50 fingerlings per acre is provided every other year. However, the success of stocking at Sherman Reservoir may be limited as the average number of age-0 walleye caught in fall standardized gill net samples has been similar over the past 13 years between non-stocking years (1.70 per net night) versus stocking years (1.42 per net night). Thus it appears that Sherman Reservoir is most dependent on natural recruitment to maintain walleye populations.

Natural recruitment of walleye is highly erratic (Colby et al. 1979; Madenjian et al. 1996; Hansen et al. 1998). A variety of factors have been associated with strength of walleye year-classes including thermal and wind conditions (Koonce et al. 1977; Kallemeyn 1987); spring water levels (Kallemeyn 1987); water storage ratio (Willis and Stephen 1987); and prey availability (Koonce et al. 1977; Ritchie and Colby 1988). The walleye population in Sherman Reservoir is subject to these natural variations in recruitment, which could hinder the availability of adult walleyes for broodstock egg collection and natural production.

A potential bottleneck that can limit the development of natural recruitment could be the lack of appropriate spawning habitat. Walleye are broadcast spawners that offer no parental care (Scott and Crossman 1973), making them dependent on the quality of substrate. Spawning usually occurs in flowing water in streams or along wind swept shorelines in reservoirs that keep water in motion and provide clean substrate (Niemuth et al. 1962). Walleye concentrate the release of their eggs around rock or gravel, but sand,

silt, and vegetation also can be used (Niemuth et al. 1962; Prentice 1985). Additionally, walleye tend to demonstrate a homing tendency to a similar inlet or area for spawning (Olson and Scidmore 1962).

The availability of preferred spawning habitat at Sherman Reservoir is unknown. Collection of adult walleye during the spawn is concentrated by the dam face, which is covered in rip-rap. Other available habitat seems to be limited to silt/clay substrates as no gravel is known to be available in Sherman Reservoir. An additional concern to available habitat is the use of cement slurry to fortify rip-rap along the dam by the Loup Basin Reclamation District starting in the summer of 2004. The cement fills in interstitial spaces within the rip-rap, which reduces protection of fertilized walleye eggs.

The proposed AHP at Sherman Reservoir offers a unique opportunity for NGPC staff to assess the effectiveness of: 1) targeted habitat restoration; 2) efforts to assess the number of fish lost to irrigation release; and 3) the provision of 0.17 ha of cobble substrate for walleye spawning. An evaluation of project activities will be valuable to future projects supported by aquatic habitat funding. The collection of information pertaining to the use of protected coves by spawning crappies and subsequent larval production provides a baseline for future comparisons in protected and unprotected coves. Estimating entrainment can assist with predicting the impact of this fish loss on reservoir populations. Finally, evaluation of artificial spawning substrate will help determine the functionality and value of various substrates to walleye spawning and will assist with addressing bottlenecks in natural walleye recruitment that occur within reservoir systems throughout Nebraska.

Procedures

Objective 1:

Assessment of adult and larval crappie in selected experimental and control coves and irrigation release water was not scheduled for sampling work in 2009.

Objective 2:

Sampling Sites – Walleye spawning activity was evaluated at four sampling sites (Figure 1). Site A was located up reservoir where AHP structures were added. Low water levels prevented the added rip-rap from being available to spawning walleye. The substrate at site A was mud throughout the study. Site B and site C were located on a mud flat adjacent to the dam. Site B served as the control site on the flat and consisted of mud substrate throughout the study. Site C is where the cobble substrate was added, and the substrate was mud in 2007 and cobble in 2008 and 2009. Site D was located on the dam and consisted of rip-rap and cement slurry.

Abundance and Distribution of Adult Walleye on Added Spawning Substrate - Adult walleye were collected from the sampling sites selected for the walleye spawning project March-April of 2007-2009. Only sexually mature males and females were used for this

study. Walleye were collected with an electrofishing boat that is equipped with a 5,000-W generator and a Smith Root GPP Model 5 electrofisher. The unit pulsed DC standardized at a duty cycle of 40% and a square wave-form pulse rate of 80 Hz. Electrofishing collections consisted of ten minutes of effort on each sampling site or until habitat area was completely sampled and began approximately 30 minutes after sunset to maximize catch rate (Reynolds 1983). Each sampling site was sampled 5-7 times during the spawning season. Additional collections were made with gill nets constructed of monofilament nylon that measured 1.8 m deep and 61.0 m long with 5.1-cm mesh (bar measure). Gill net sets of 90-150 minutes in length were conducted on 3-7 separate occasions at each sampling site. Gill net efforts were repeated multiple times during the night as time and weather conditions permitted. Both capture methods are necessary as electrofishing is biased to collecting males and gill netting is biased towards collecting females (Koupal et al. 1997).

Collected walleye were measured (TL) and recorded to the appropriate 10-mm category. All walleye were examined for previous marks. If none were found, a visible implant elastomer (VIE) tag of a color representing each sampling site was injected with the method and process outlined by Fryda et al. (2006).

Estimates for abundance of walleye present based on catch per effort were made for each sampling season (2007-2009). Comparisons between years were made with a Kruskal-Wallis. Spawning site fidelity was calculated based on recaptured walleye. Significance for all tests was set at an alpha level of 0.05 and standard errors calculated for all means.

Abundance of Walleye Eggs on Added Spawning Substrate - Walleye eggs were collected from each sampling site selected for the walleye spawning project March-April of 2007-2009. A new gear, called egg sampling disks, was used to estimate walleye egg density at each of the sampling sites. The disks were evaluated in both the laboratory and field. Laboratory evaluations included estimating the egg recovery efficiency after multiple recovery procedures were conducted and estimating the recovery percentages of individual washers. Eggs were collected 4 times during the spawning season from each site. Discs were submerged in a tub filled with reservoir water and scrubbed vigorously twice. Water within the tubs was poured through a 500 μm sieve and eggs were extracted and immediately preserved in 5% formalin or counted depending on sample quantity.

Estimates of egg density at each sampling site were made for 2007-2009. Egg densities from each season were compared using Kruskal-Wallis. Significance for all tests was set at an alpha level of 0.05 and standard errors calculated for all means.

Assessment of Existing Spawning Habitat and Longevity of Added Spawning Substrate - Water temperatures and turbidity were collected for the entirety of each spawning season with a HOBO temperature unit set at each egg collection site. Additionally, flow meters assessed water movement over the substrate during variable wind speeds throughout the spawning season.

Existing spawning habitat was assessed through a substrate type and substrate firmness survey. The surveys took place during the summer of 2008 and all collected data was

entered into a Geographic Information System (GIS) to visually depict patterns in substrate type and substrate firmness throughout the reservoir.

Walleye egg hatchability from cobble and mud substrates was tested in the laboratory. Viable walleye eggs were obtained from Colorado, Nebraska and North Dakota. The eggs were allowed to incubate on the different substrate types until hatching. The percent of eggs hatched from each substrate type and from each lot of eggs was recorded.

Findings

Objective 1:

No additional sampling was conducted for this objective during 2009. A thesis was prepared and provided in previous annual reports. The thesis was titled "Adult abundance and larval production of crappie (*Pomoxis spp.*) and fish entrainment from a Nebraska Irrigation Reservoir". Four manuscripts have been accepted for publication in peer-reviewed journals based from this thesis. The citations for these manuscripts are:

Fryda, N.F., K.D. Koupal, and W.Wyatt Hoback. 2006. Estimate of crappie entrainment through water discharge from a Nebraska irrigation reservoir. Journal of Freshwater Ecology 21(4):693-697

Fryda, N.F., J.W. Laux, K.D. Koupal, and W.W. Hoback. 2007. Successful application of visible implant elastomer tags on crappie, *Pomoxis spp.*, without the use of anesthetic. Fisheries Management and Ecology 14:235-238

Fryda, N.F., K.D. Koupal, and W.W. Hoback. 2008. Abundance and cove fidelity of adult crappies during spawning seasons in a Nebraska irrigation reservoir. Pages 587-594 *in* M.S. Allen, S. Sammons and M.J. Maciena, editors. Balancing fisheries management and water uses for impounded river systems. American Fisheries Society Symposium 62, Bethesda, Maryland.

Fryda, N.F., K.D. Koupal, and W.Wyatt Hoback. 2008. Assessment of larval crappie (*Pomoxis spp.*) Abundance and Lengths in Day and Night Push Net Collections from Coves. Journal of Freshwater Ecology 23(4):529-535

Reprints or copies for any of these publications are available upon request.

Objective 2:

During the 2007 season, 574 adult walleye were collected with electrofishing from the sampling sites. In 2008, 669 adult walleye were collected and 866 walleye were collected during the 2009 season from the sampling sites. Collected walleye ranged from 290-mm to 570-mm (Figure 2). The catch-per-unit-effort (CPUE) among the sampling sites ranged from 2,997 ± 764 WAE/hr at site D in 2008 to 5 ± 3 WAE/hr at site A in 2008 (Table 1).

The electrofishing CPUE was significantly higher at site D than site A during the 2007 season ($p = 0.0006$, KW = 17.258) and 2008 season ($p < 0.0001$, KW = 28.255). During the 2009 season, the electrofishing CPUE at site D was significantly higher ($p < 0.0001$, KW = 29.524) than site A and site B (Table 1). Mean electrofishing CPUE at each sampling site did not differ between seasons (site A: $p = 0.5676$, KW = 1.133; site B: $p > 0.999$, KW = 3.512E-18; site C: $p = 0.6899$, KW = 0.7425; site D: $p = 0.4029$, KW = 1.818) (Table 1).

The total length (TL) distribution of male walleye collected from site D was significantly different than the TL distribution of male walleye collected from site C during each season, site B in 2009 and site A in 2007. No other significant differences were observed in TL distributions among the sampling sites (Table 2, Table 3).

A total of 30 adult walleye were collected with gill nets from the sampling sites during the 2007 season. Gill nets collected 20 adult walleye from the sampling sites during 2008 and 33 adult walleye during 2009. Collected walleye ranged from 370-mm to 750-mm. The gill net CPUE ranged from 1.4 ± 0.5 at site C in 2009 to 0.1 ± 0.1 WAE/hr at site A in 2008 and 2009 (Table 4).

The mean gill net CPUE among the sampling sites did not differ ($p = 0.3585$, KW = 3.223) during the 2007 season (Table 4). During the 2008 season, the mean gill net CPUE at site D was significantly higher ($p = 0.0323$, Mann-Whitney = 16.00) than site A. No difference ($p = 0.0831$, KW = 6.673) in mean gill net CPUE among the sampling sites was observed during the 2009 season. The mean gill net CPUE among seasons did not differ at site A ($p = 0.4993$, KW = 1.389), site B ($p = 0.9027$, $t = 0.1254$, $df = 10$), site C ($p = 0.1995$, $t = 1.399$, $df = 8$) and site D ($p = 0.2023$, KW = 3.196) (Table 4).

A total of 2,195 adult walleye were captured during the three sampling seasons of which 2,104 were VIE tagged (Table 5). In 2007, 583 adult walleye were VIE tagged from the sampling sites with 5 recaptures. During the 2008 sampling season, 677 adult walleye were VIE tagged at the sampling sites. There were 45 recaptures during this season, of which 32 were from the 2007 season and 13 were from the 2008 season. In 2009, 844 walleye were tagged and 86 recaptures were observed. Of these recaptures, 20 were from the 2007 season, 34 from the 2008 season and 32 from the 2009 season. Overall site fidelity was 86% (Table 6). Site fidelity within a season was 94% while site fidelity between years was 81%.

The egg recovery efficiency after multiple recovery procedures was evaluated in the laboratory (Table 7). After the first recovery procedure, 58 ± 2% of the eggs on the disk were recovered. The cumulative percent recovery after the second procedure was 75 ± 2% while after the third procedure it was 80 ± 2%.

Percent egg recovery of washers was also evaluated in the laboratory (Table 8). Two washers conducted the test with washer A having a recovery percent of 53 ± 3% and the recovery percent of washer B was 57 ± 3%. The recovery percentages did not differ (p =

0.35, t = 0.94, df = 52). Disk size did not influence the recovery percent for either washer (washer A: p = 0.97, f = 0.01, df = 26; washer B: p = 0.35, f = 0.94, df = 26).

The egg sampling disks were also evaluated in the field. The highest egg density during each sampling season was observed at site D followed by site C, site B and site A (Table 9). Walleye egg densities raged from 390 ± 225 eggs/m^2/spawn night at site D in 2009 to 0 ± 0 eggs/m^2/spawn night at site A in 2008. The walleye egg density at site D was significantly higher than the egg density at site A and site B during the 2007 season (p = 0.0002, KW = 19.302) and 2009 season (p < 0.0001, KW = 35.555). In 2008, the egg densities at site C and site D were significantly higher than the egg density at site A (p < 0.0001, KW = 21.313). The egg density at site C was significantly higher than egg density at site A (p < 0.0001, KW = 35.555) during the 2009 season (Table 9).

There was no difference in egg density between seasons at site A (p = 0.0846, KW = 4.939), site B (p = 0.4969, Mann-Whitney = 33.500) or site D (p = 0.6874, KW = 0.7496) (Table 9). The egg density at site C in 2008 was significantly higher (p = 0.0095, KW = 9.320) than it was in 2007 and 2009.

The observed egg viability at the sampling sites varied among and between seasons (Table 10). Egg viability estimates during the 2007 season ranged from 35% at site A to 84% at site D. In 2008, egg viability ranged from 0% at site A to 95% at site B while in 2009 egg viability ranged from 29% at site D to 81% at site C.

The disks were an effective gear as walleye eggs were sampled from each site during each season. Linear regression was used to test for a relationship between disk size and the number of eggs sampled on a disk. The size of a disk was not related to the number of eggs it sampled in 2008 (p = 0.80, f = 0.07, df = 73) or 2009 (p = 0.31, f = 1.04, df = 73) (Figure 3, Figure 4).

Each season displayed a unique water temperature pattern (Figure 5). In 2007, water temperatures gradually cooled during the spawning season. The water temperature remained fairly constant during 2008 while a warming trend was observed during the 2009 season.

Substrate samples were collected from 71 locations throughout the reservoir. Of these samples, 66 were classified as silt, 4 as boulders (rip-rap) and 1 as cobble (Figure 6). All of the sites classified as boulders were areas where rip-rap was added as shoreline protection. The only cobble available was that added during the AHP. All other substrate was found to be silt.

Substrate firmness varied throughout the reservoir, ranging from 0.0 to 35.6 cm (Figure 7). Shorelines exposed to open water of the northeast side of the reservoir generally consisted of firmer substrate than open water shorelines on the southwest side of the reservoir. Generally, the openings of coves were less firm than the backs of coves, but this trend did not apply to all coves.

Walleye eggs exhibited a higher percent hatch from cobble substrate than mud substrate with two of the three lots of eggs (Table 11). The walleye eggs from Colorado exhibited a significantly higher hatch percent (24.9%) on the cobble than the mud (0.1%) ($p = 0.0007$, Mann-Whitney = 63.5). No difference in hatch rate from the cobble (0.7%) and mud (1.2%) was observed in the Nebraska eggs ($p = 0.7518$, Mann-Whitney = 20.0). The hatch percent on the cobble (4.3%) was significantly higher than the hatch percent on the mud (0.5%) with the eggs from North Dakota ($p = 0.0335$, Mann-Whitney = 151.0).

A thesis titled "Response of Walleye to the Addition of Spawning Substrate in a Nebraska Irrigation Reservoir" has been completed and a digital copy is attached. All raw data collected for this project are included in the folder "Thesis" which has also been attached. Data collected during this project has been presented to the Nebraska Game and Parks Commission, Nebraska Chapter of the American Fisheries Society, North Central Division of the American Fisheries Society Walleye Technical Committee and at the 2008 Midwest Fish and Wildlife Conference. The following publications are anticipated:

Jordan D. Katt, Keith D. Koupal, Casey W. Schoenebeck and W. Wyatt Hoback. In review. Assessment of a new gear to sample walleye eggs. Fisheries Management and Ecology.

Jordan D. Katt, Keith D. Koupal, Brian C. Peterson, Casey W. Schoenebeck and W. Wyatt Hoback. In preparation. Field evaluation of added walleye spawning habitat in a Nebraska irrigation reservoir. North American Journal of Fisheries Management

Jordan D. Katt, Casey W. Schoenebeck and Keith D. Koupal. In preparation. Correlation of walleye electrofishing and gill net capture rates to walleye egg density in a Midwest irrigation reservoir. The Prairie Naturalist.

Jordan D. Katt, Keith D. Koupal and W. Wyatt Hoabck. In preparation. Walleye egg hatchability on mud and cobble substrates. Transactions of the Nebraska Academy of Science.

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Deviations from proposal

No significant deviation from the proposal occurred in 2009.

Program Plan

Our plan is to prepare manuscripts for publication in peer-reviewed journals and submit a final report by June 2010.

Table 1: Mean electrofishing CPUE (# WAE/Hr ± standard error) from each sampling site during each sampling season. Results of comparisons of mean electrofishing CPUE at each sampling site within a season are indicated by superscripts. Similar superscripts indicate the means were not significantly different (p=0.05). The comparison of mean electrofishing CPUE at a sampling site between seasons yielded no significant differences.

Electrofishing Results			
Site	2007	2008	2009
A	10 ± 8^{a}	5 ± 3^{a}	11 ± 5^{a}
B	44 ± 13^{ab}	51 ± 3^{ab}	50 ± 17^{a}
C	119 ± 21^{ab}	137 ± 54^{ab}	113 ± 20^{ab}
D	$1{,}893 \pm 596^{b}$	$2{,}997 \pm 764^{b}$	$1{,}307 \pm 218^{b}$

Table 2: Summary of the mean total lengths (TL, mm) of adult male walleye sampled at each sampling site during the 2007 to 2009 spawning seasons at Sherman Reservoir.

Total Length Summary				
Year	Site	Mean TL	Range	n
2007	A	383 ± 9	330 - 448	11
	B	394 ± 6	354 - 450	17
	C	396 ± 4	350 - 493	68
	D	413 ± 2	298 - 557	471
2008	A	416 ± 12	376 - 472	9
	B	423 ± 7	350 - 540	21
	C	421 ± 3	339 - 519	100
	D	429 ± 1	343 - 585	545
2009	A	394 ± 21	344 - 446	5
	B	426 ± 8	333 - 500	31
	C	424 ± 4	391 - 574	115
	D	441 ± 1	315 - 534	705

Table 3: Results of the Kolmogorov-Smirnov test of length distributions of male walleye sampled at each sampling site during the 2007 to 2009 spawning seasons at Sherman Reservoir. Significance is indicated by *.

	Kolmogorov-Smirnov Test Results								
	2007			2008			2009		
Comparison	D-stat	p-value	df	D-stat	p-value	df	D-stat	p-value	df
A vs. B	0.321	0.470	28	0.429	0.162	30	0.433	0.337	35
A vs. C	0.233	0.635	79	0.346	0.234	109	0.383	0.494	120
A vs. D	0.459	0.019*	482	0.390	0.133	554	0.543	0.125	710
B vs. C	0.162	0.834	85	0.130	0.904	121	0.138	0.725	145
B vs. D	0.303	0.084	488	0.191	0.406	566	0.260	0.045*	735
C vs. D	0.235	0.003*	539	0.157	0.032*	645	0.196	0.001*	820

Table 4: Mean gill net CPUE (WAE/Hr ± Standard Error) from each sampling site during each sampling season. Results of comparisons of mean gill net CPUE at each sampling site within a season are indicated by superscripts. Similar superscripts indicate the means were not significantly different (p=0.05). The comparison of mean gill net CPUE at a sampling site between seasons yielded no significant differences.

Gill Net Results			
Site	2007	2008	2009
A	0.2 ± 0.1^{a}	0.1 ± 0.1^{a}	0.1 ± 0.1^{a}
B	0.7 ± 0.3^{a}	N/A	0.8 ± 0.3^{a}
C	0.6 ± 0.2^{a}	N/A	1.4 ± 0.5^{a}
D	0.4 ± 0.2^{a}	0.4 ± 0.2^{b}	1.0 ± 0.3^{a}

Table 5: The number of walleye sampled and tagged at each sampling site during a sampling season along with the number, site and season of previous capture of the recaptured walleye.

2007 Tag/Recapture Summary

Site	# WAE Sampled	# Tagged	2007 Recaptures				
			Total	A	B	C	D
A	15	13	0	0	0	0	0
B	28	26	0	0	0	0	0
C	79	70	0	0	0	0	0
D	482	474	5	0	0	0	5
Total	604	583	5	0	0	0	5

2008 Tag/Recapture Summary

Site	# WAE Sampled	# Tagged	2007 Recaptures					2008 Recaptures				
			Total	A	B	C	D	Total	A	B	C	D
A	13	13	0	0	0	0	0	0	0	0	0	0
B	17	17	0	0	0	0	0	1	0	0	0	1
C	92	91	2	0	0	0	2	1	0	0	0	1
D	567	556	30	0	1	3	26	11	0	0	0	11
Total	689	677	32	0	1	3	28	13	0	0	0	13

2009 Tag/Recapture Summary

Site	# WAE Sampled	# Tagged	2007 Recaptures					2008 Recaptures					2009 Recaptures				
			Total	A	B	C	D	Total	A	B	C	D	Total	A	B	C	D
A	12	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B	38	36	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0
C	131	121	1	0	0	0	1	8	0	0	4	4	0	0	0	0	0
D	721	682	19	2	0	0	17	25	0	0	2	23	32	0	0	1	31
Total	902	844	20	2	0	0	18	34	0	0	7	27	32	0	0	1	31

Table 6: Site fidelity percentages of recaptured walleye for each sampling site during each sampling season.

2007 Site Fidelity Results			
Site	# Tagged	2007 Recaptures	% Site Fidelity
A	13	0	N/A
B	26	0	N/A
C	70	0	N/A
D	474	5	100%

2008 Site Fidelity Results					
Site	# Tagged	2007 Recaptures	% Site Fidelity	2008 Recaptures	% Site Fidelity
A	13	0	N/A	0	N/A
B	17	0	N/A	1	0%
C	91	2	0%	1	0%
D	556	3	87%	11	100%

2009 Site Fidelity Results							
Site	# Tagged	2007 Recaptures	% Site Fidelity	2008 Recaptures	% Site Fidelity	2009 Recaptures	% Site Fidelity
A	5	0	N/A	0	N/A	0	N/A
B	36	0	N/A	1	0%	0	N/A
C	121	1	0%	8	50%	0	N/A
D	682	19	89%	25	92%	32	97%

Table 7: The mean egg recovery efficiency (± standard error) after three egg recovery procedures were conducted on a disk (n = 18). The egg recovery efficiency was calculated as the sum of eggs recovered after each recovery procedure divided by 100.

Egg Recovery Efficiency	
Procedure #	Cumulative % Recovered
1	58 ± 2
2	75 ± 2
3	80 ± 2

Table 8: The mean percent egg recovery (±standard error) from the egg sampling disks during each egg recovery procedure for each individual washer, the overall percent recovery for each individual washer and the mean number of eggs found in the tub for each individual washer (n = 9 for each washer). The percent egg recovery was calculated as the number of eggs available for recovery on the disk divided by the number of eggs recovered from the disk multiplied by 100. Superscripts indicate results of analysis with different letters indicating significant differences (p=0.05). Both the overall % recovery and the mean # eggs in tub were analyzed using ANOVA with a Tukey's post-test.

Percent Egg Recovery of Individual Washers					
Washer	Procedure 1 % Recovered	Procedure 2 % Recovered	Procedure 3 % Recovered	Overall % Recovery	Mean # Eggs in Tub
Washer A	68 ± 2	51 ± 4	41 ± 7	53 ± 3[a]	13 ± 3[a]
Washer B	64 ± 3	59 ± 4	51 ± 9	57 ± 3[a]	11 ± 2[a]
Washer C	53 ± 3	33 ± 5	23 ± 4	36 ± 3[b]	31 ± 4[b]

Table 9: Mean egg density (# WAE eggs/m^2/spawn night ± standard error) for each sampling site during each sampling season. Results of comparisons of mean egg densities at each sampling site within a season are indicated by superscripts. Similar superscripts indicate the means were not significantly different (p=0.05). The comparisons of mean egg densities at a sampling site between sampling seasons indicated one significant difference. The mean egg density at site C during the 2008 season was significantly higher (p=0.0094, KW stat=9.320) than the mean egg density at site C during the 2007 and 2009 seasons.

Egg Density Results			
Site	2007	2008	2009
A	3 ± 3^{a}	0 ± 0^{a}	1 ± 1^{a}
B	9 ± 5^{a}	2 ± 1^{ab}	8 ± 2^{ab}
C	26 ± 11^{ab}	82 ± 17^{b}	26 ± 3^{bc}
D	158 ± 63^{b}	103 ± 17^{b}	390 ± 225^{c}

Table 10: The percent viable eggs sampled at each site during each season. The * indicates the viability percentage influenced by egg processing procedures.

2007 Viable-Dead Egg Results				
Site	Total # Eggs	Total # Viable Eggs	Total # Dead Eggs	% Viable Eggs
A	212	74	138	35%
B	677	488	189	72%
C	2,058	1,694	364	82%
D	6,337	5,308	1,029	84%
2008 Viable-Dead Egg Results				
Site	Total # Eggs	Total # Viable Eggs	Total # Dead Eggs	% Viable Eggs
A	2	0	2	0%
B	22	21	1	95%
C	2,807	2,601	206	93%
D	7,380	6,861	519	93%
2009 Viable-Dead Egg Results				
Site	Total # Eggs	Total # Viable Eggs	Total # Dead Eggs	% Viable Eggs
A	95	55	40	58%
B	720	273	447	38%
C	2,436	1,974	462	81%
D*	30,852	8,912	21,940	29%

Table 11: The percent walleye egg hatch from cobble and mud substrates during laboratory trials. Results from comparisons between percent hatch from each substrate type are indicated by superscripts. Similar superscripts indicate no significant difference was observed.

Walleye Egg Hatchability Summary		
	Mud	Cobble
Colorado	0.1 ± 0.1^{a}	24.9 ± 6.2^{b}
Nebraska	1.2 ± 1.2^{a}	0.7 ± 0.4^{a}
North Dakota	0.5 ± 0.5^{a}	4.3 ± 1.9^{b}

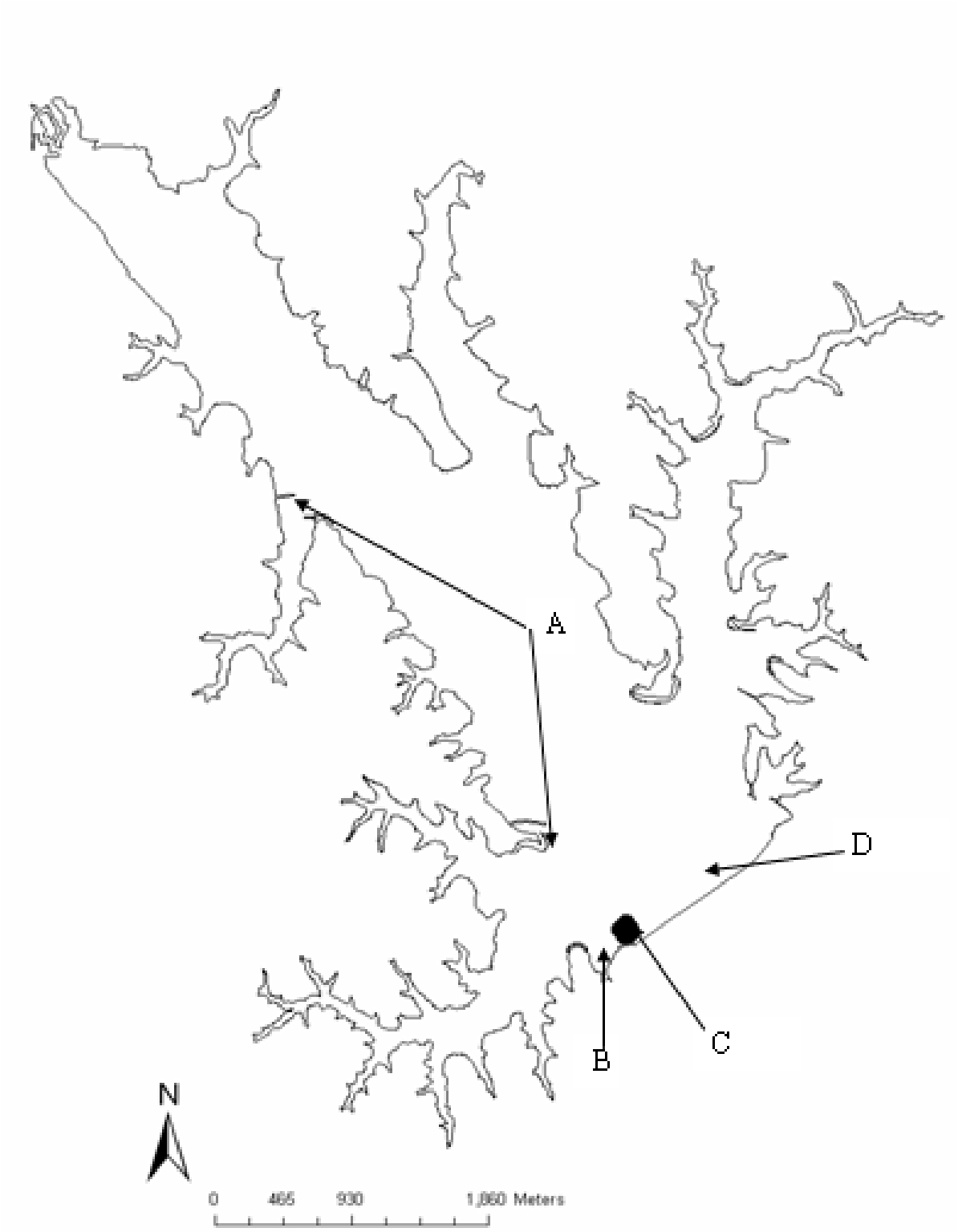

Figure 1: The sampling sites in Sherman Reservoir. Site A and site B were both mud substrate throughout the study, site C was mud substrate during 2007 and was cobble substrate during 2008 and 2009. Site D was rip-rap during 2007 and 2008 and was cement slurry with scattered rip-rap during 2009.

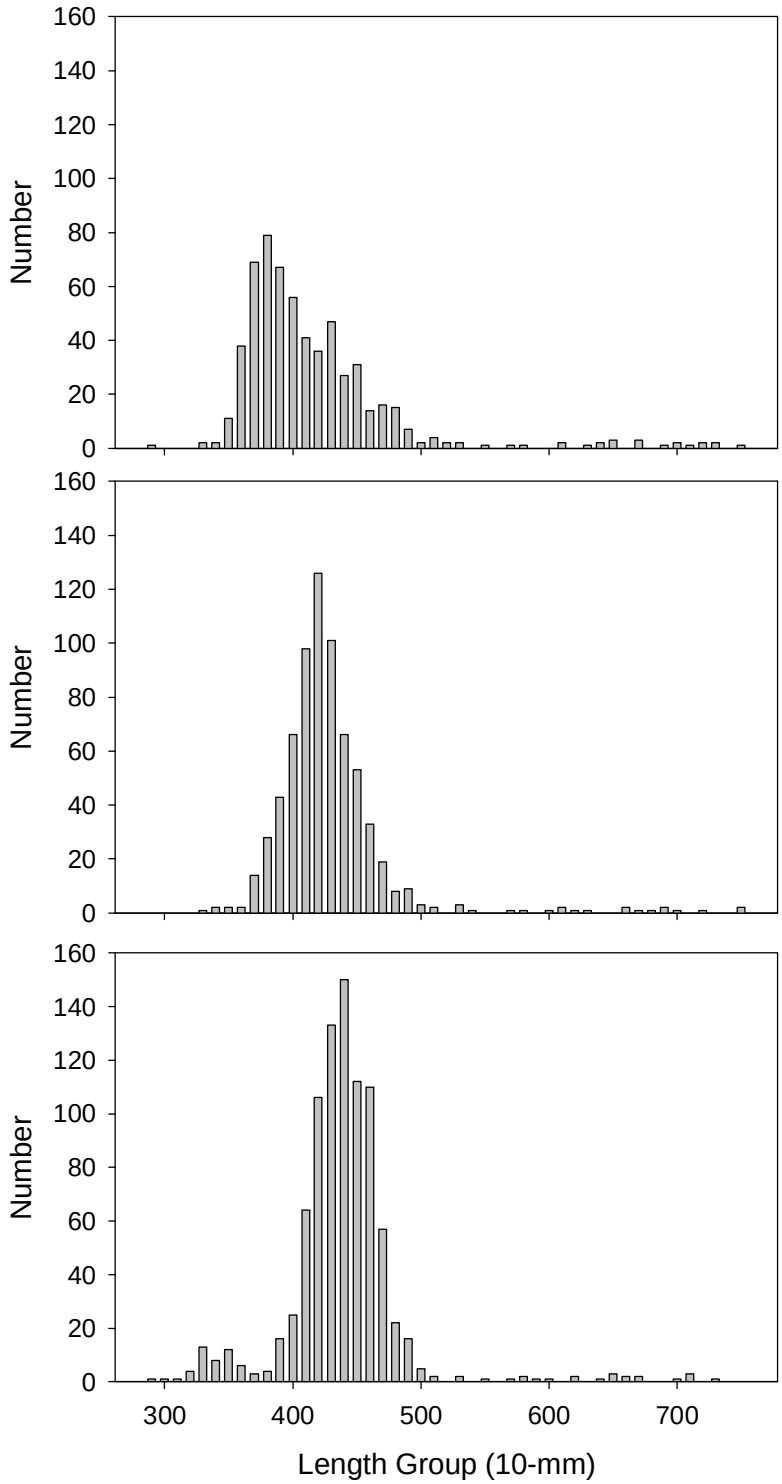

Figure 2: Length frequency histograms of all adult walleye sampled by season.

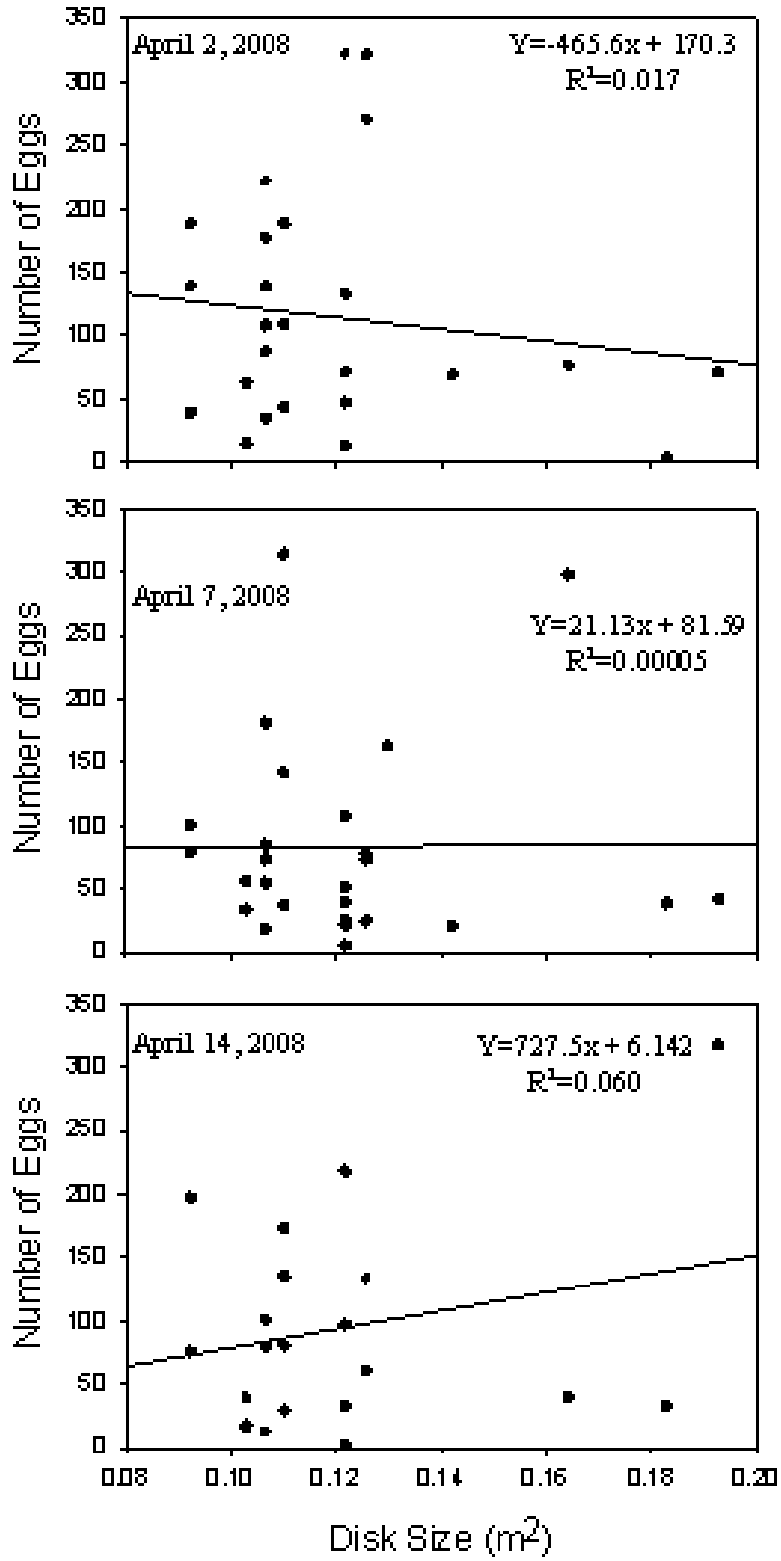

Figure 3: Linear regression from the 2008 field season shows no relationship between egg sampling disk size and the number of walleye eggs sampled per disk.

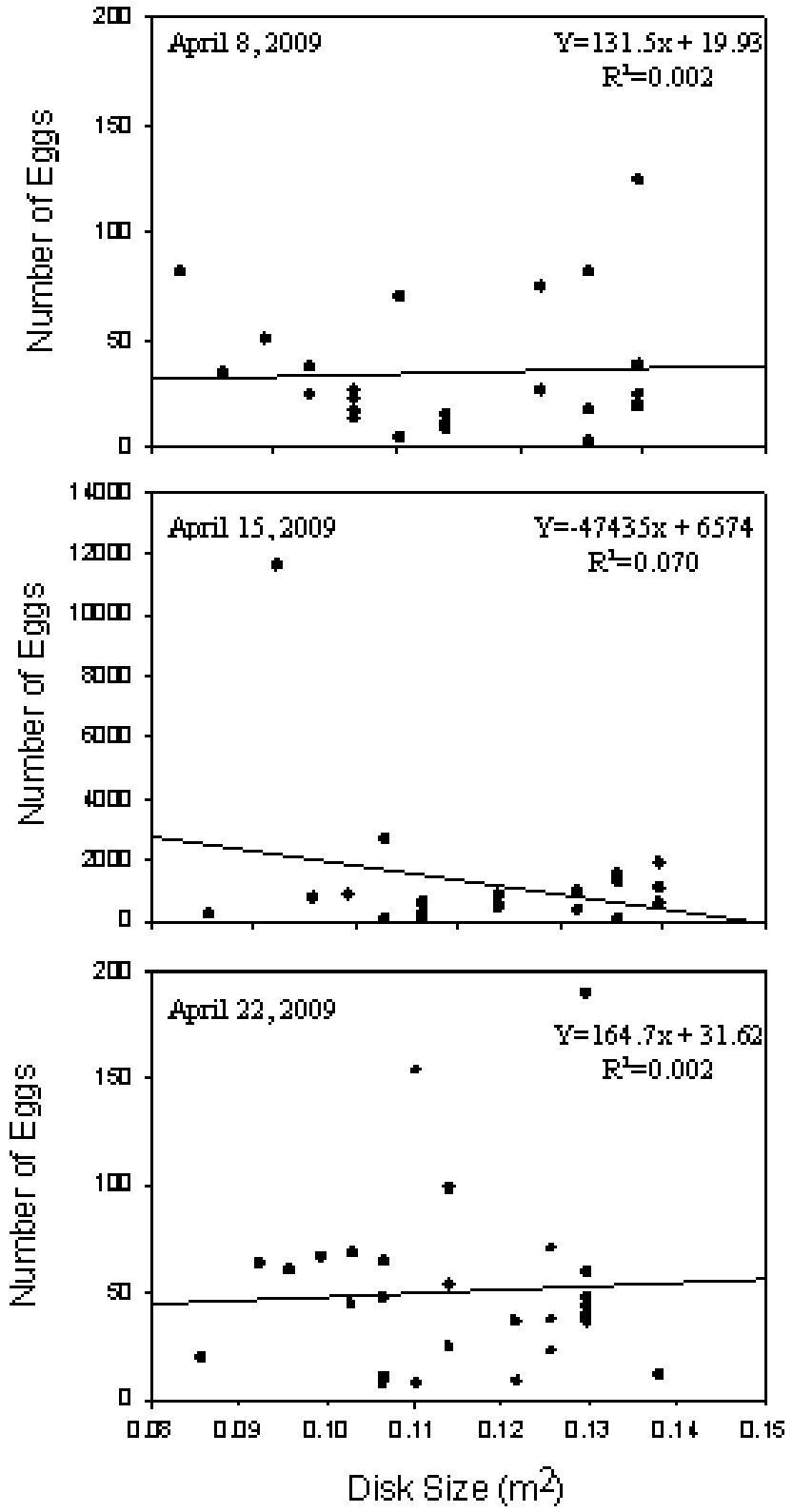

Figure 4: Linear regressions from the 2009 field season shows no relationship between egg sampling disk size and the number of walleye eggs sampled per disk.

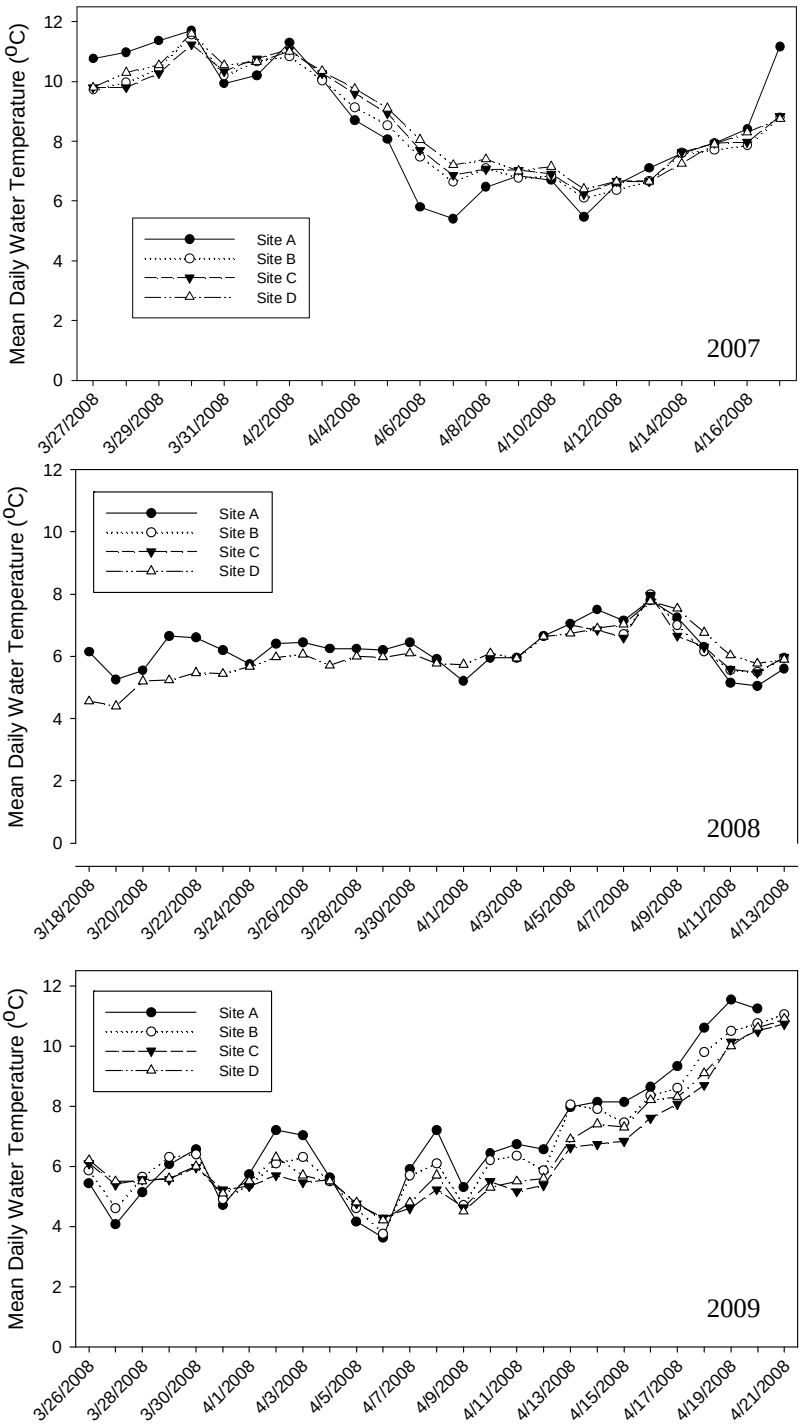

Figure 5: The average daily water temperature at each sampling site by season.

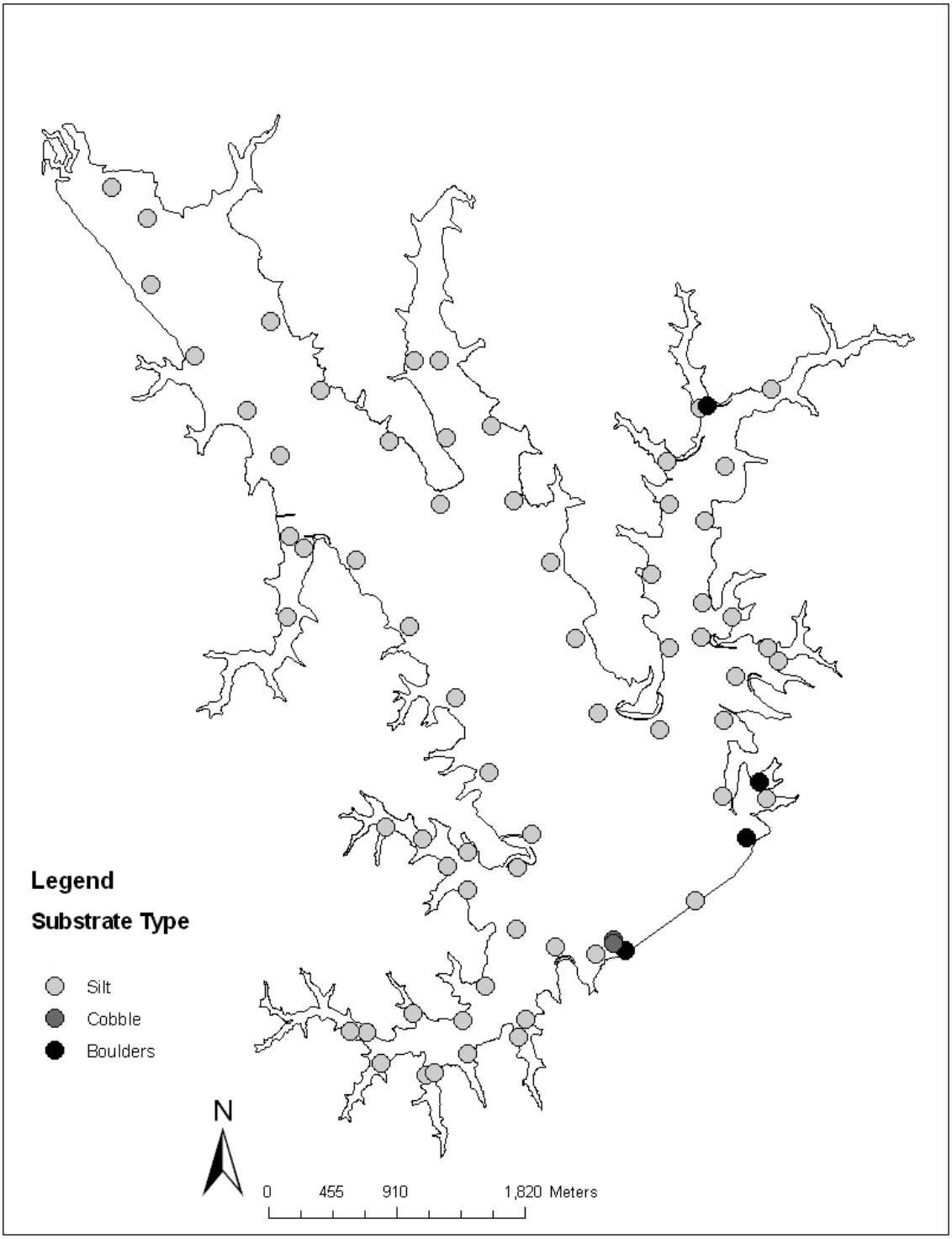

Figure 6: Map of the substrate types found in Sherman Reservoir during the walleye spawning season.

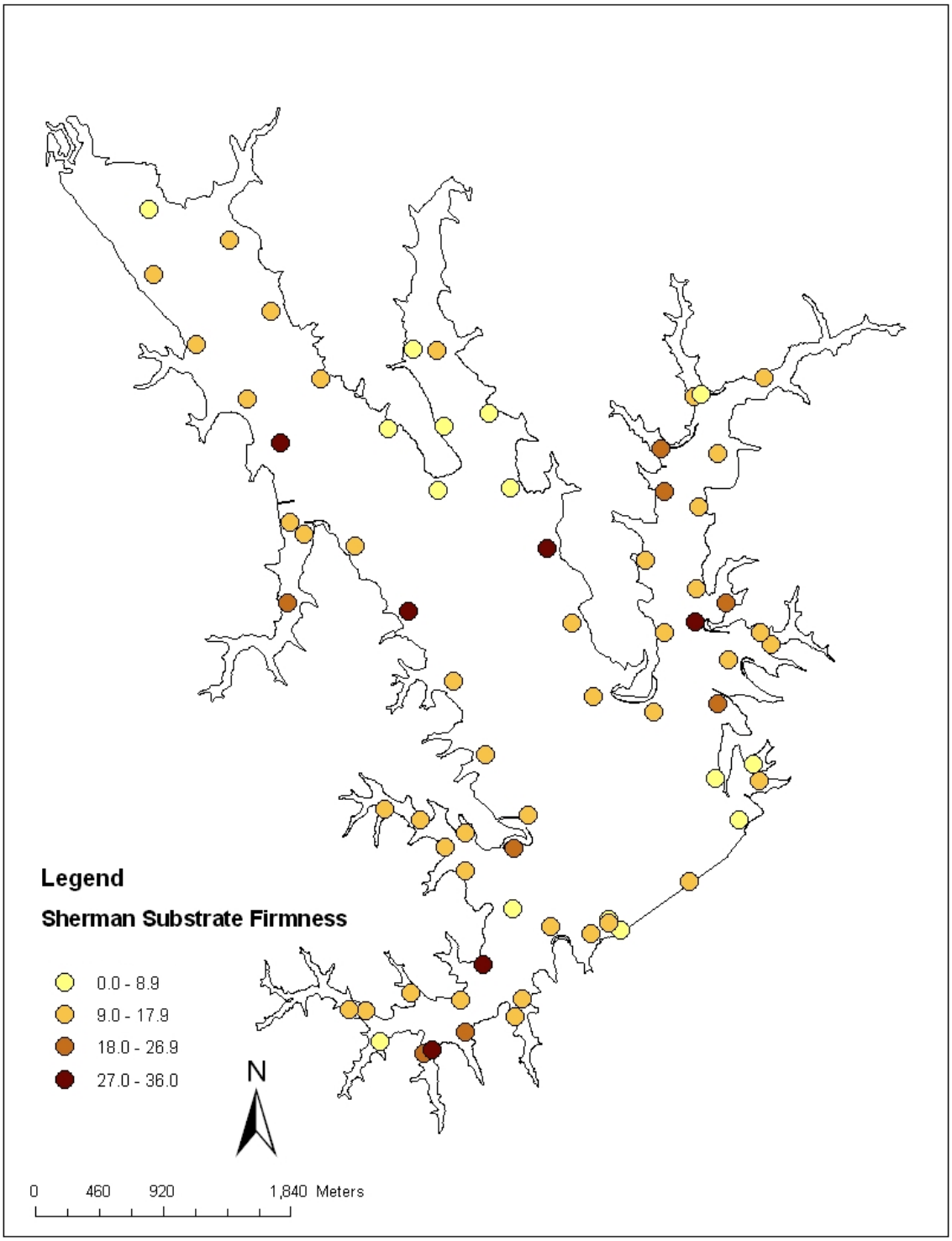

Figure 7: Map of the substrate firmness (recorded in cm) of Sherman Reservoir during the walleye spawning season.