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

Final 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 the 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*) fishery. On-site angler surveys (1996-2001) found crappie and walleye to be the most highly sought species during the estimated 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 have observed this aging process in Sherman Reservoir 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) stated 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 the addition of 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. 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 (Colby et al. 1979). 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:

Adult Cove Abundance and Fidelity

Selection of control and experimental coves for this project was predicated by historic patterns of sedimentation. District fishery managers identified 3 coves to receive protection with the aquatic habitat project plan for Sherman Reservoir based on size, depth, documented crappie use and potential for shoreline erosion. Investigations of a reservoir map found control coves with similar characteristics and overall sizes for two of the protected coves (Figure 1). Coves were assigned names based on the color of tag that was employed to identify an individual crappie captured in a cove. Red, yellow and orange were designated as experimental coves, while green and pink were control coves. After the initiation of this project, fishery personnel decided to extend aquatic habitat protection efforts to the green cove based from the cost effectiveness of completing this task while the water was low and work crews were on-site.

Adult crappie (>150mm TL) were sampled from 2 stations in each experimental and control cove with single throat trap nets, with one lead line set from shore to an approximate depth of 1m. Trap nets were set Monday and checked daily each week (weather permitting) starting the first week of May for four consecutive weeks in 2004,

2005 and 2006. All crappie were measured (TL) and recorded to the appropriate 10-mm category. All adult crappie were examined for previous tags. If none were found a visible elastomer tag of a color representing the cove of capture was injected into the cutaneous tissue on the right ventral side of the mandible in 2004, left side in 2005, and under the jaw in 2006. Total number of crappie receiving marks and containing previous marks were recorded to provide catch per unit effort estimates for each cove, a multiple census population estimate for the reservoir, as well as each cove and estimates of cove fidelity within and between years. Significance for all tests were set at α=0.05 and standard error calculated for all means.

Larval Crappie Abundance

Larval crappie were collected by pushing paired 0.5m^2 plankton nets (750µm mesh) for 5 minutes at a speed of 0.5 m/s (similar to Sammons et al. 2001). These nets were mounted to the front of the boat with a metal frame and designed to sample approximately 0.5-m depth. Flow meters were placed at the mouth of each net to determine the volume of water sampled. Two stations were collected weekly for a total of 4 samples per cove per collection date. A similar sampling regime was established for both day and night hours. Sampling efforts began the second week of May and continued through the first full week of June in 2004, 2005 and 2006. Collected fish were preserved in 70% ethyl alcohol and returned to the lab for processing. All fish were identified to species, counted and measured (TL).

Entrainment

Irrigation release water was sampled weekly with a 1-m by 0.5-m rectangular net (1-mm mesh) and a 1.5-m by 2.5-m rectangular net (1-mm mesh) from the first week of June through the end of the irrigation release season (mid-September) in 2004 and 2005. A similar sampling regime was established for both day and night hours, as well as the top and bottom of released water. Each sample consisted of three separate 10-minute collections. A flow meter was attached to the mouth of each net during each deployment to determine the volume of water sampled. Collected fish were preserved in 70% ethyl alcohol for later processing. Each fish was identified to species, counted and measured (TL). Estimates of total fish loss were calculated for each species by extrapolating the density of fish captured to the total amount of water released. Information for day, night, surface, and sub-surface were calculated separately and combined for a total estimate. Records from Loup Basin Restoration District were used to determine the total amount of water released during daylight and night hours and geometric procedures were used to determine percentage of the released water held in sub-surface and surface areas of the irrigation canal. Significance for all tests were set at α=0.05 and standard errors calculated for all means.

Objective 2:

Adult Walleye Abundance and Fidelity

Walleye spawning activity was evaluated at four sampling sites (Figure 1) in 2007, 2008 and 2009. 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.

Adult walleye were collected from the sampling sites during March-April of 2007, 2008, and 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 the 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 were necessary because of gender specific gear bias (Koupal et al. 1997).

Collected walleye were measured (TL) and examined for previous tags. 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 relative 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 α=0.05 and standard errors calculated for all means.

Walleye Egg Deposition

Walleye eggs were collected from each sampling site during each season. Egg sampling disks were used to collect deposited eggs 4 times (weather permitting) during the spawning season from each site. Disks 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, 2008, and 2009. Egg densities from each season were compared using Kruskal-

Wallis. Significance for all tests was set at α=0.05 and standard errors calculated for all means.

Findings and Discussion

Objective 1:

Adult Cove Abundance and Fidelity

A total of 16,979 adult crappie (>150-mm TL) were collected from trap nets during 2004-2006 with the largest crappie in the 360-mm size category each season. A length frequency histogram comparing seasonal data is depicted in Figure 2. The mean catch per trap net night (CPUE) in selected coves was highest in 2004 (62.5±5.5) and slightly lower in 2005 (46.8±3.2) and 2006 (50.9±3.8) (Table 1). No significant differences were found between coves during the same year (p-value>0.05) and a different cove displayed the highest annual CPUE and lowest annual CPUE during each season of the project.

VIE tags were injected into 16,174 crappie during 2004-2006 and a total of 906 individuals were recaptured at least one time (Table 2). The cove fidelity for marked crappie ranged from 66-91% during the year of sampling and from 47-92% among years (Table 2). These mark recapture efforts allowed the opportunity to perform a closed population model for adult crappie at Sherman Reservoir. The population estimates were 62,078 (SE=37.8), 35,744 (SE=21.4) and 69,338 (SE=104.7) for 2004, 2005 and 2006, respectively.

The original plan of having 2 control coves was altered as additional habitat work was conducted following the collection of preliminary data, but a baseline still exists that can be compared over time and one control cove remains. Catch of adult crappies among coves within a sampling year was similar; thus each cove displayed similar visitation patterns during the spawning season. The total number of crappie captured decreased each year, but this was due more to reduction in effort than a reflection of relative abundance.

Adult crappies displayed high cove fidelity within and among spawning seasons. This study found that more than 80% of adult crappies were captured in the same cove during the same spawning season, similar to results for bluegills (Paukert et al. 2004). Additionally, more than 70% of tagged adult crappies that were captured in subsequent years were in the same cove. Waters and Noble (2004) found a similar percentage of site fidelity with largemouth bass.

Crappies in Sherman Reservoir seek out specific coves within and between years, even when similar coves and substrate are available. Coves in reservoirs are susceptible to an accelerated aging process because of eroded soils, nutrients, and contaminants entering the reservoir from the watershed (Summerfelt 1999). The aging process changes a reservoir by decreasing depth, increasing turbidity, and resulting in more frequent algal blooms (Gablehouse 2000). As the years pass, spawning areas may be lost through the

aging process. Knowing that cohorts of the crappie population select specific coves over time and that the coves are susceptible to the aging process magnifies the need for habitat conservation efforts for specific coves used during spawning seasons.

Larval Crappie Abundance

Larval crappie were collected during daylight hours in 2004-2006 and additionally during dark hours in 2005-2006. A total of 18,210 larval crappie were collected, which resulted in an estimated 0.65±0.29 larval crappie/m^3 during day collections in 2004, 0.78±0.17/m^3 in 2005 and 0.47±0.08/m^3 in 2006. Night collections yielded 0.98±0.16/m^3 in 2005 and 2.27±0.53/m^3 in 2006. ANOVA comparisons of means for sample dates each year showed night samples collected the weeks of June 6, 2005 ($p<0.01$) and May 29, 2006 ($p<0.01$) had significantly higher larval crappie densities than day samples.

Crappie larvae ranged from 3 to 11-mm (TL) with a 2005 mean of 6.33-mm (±0.02) and a mean of 5.09-mm (±0.01) in 2006. Additionally, larval crappie were 316% more abundant in nighttime samples than day samples. The increased abundance of larval crappie in night samples was predominantly from individuals that were 9 to 11-mm (Figure 3), so some size disparity in day and night catches seems to exist. Other studies have found similar results regarding larval crappie collections (Lewis and Siler 1980, Holland and Sylvester 1983, Sammons and Bettoli 1998).

Multiple factors may contribute to the differences between daytime and nighttime collections including larval diel migrations, net avoidance, age of larvae, and changing reservoir conditions. A study by Van Den Avyle and Fox (1980) documented diel differences in gizzard shad that showed higher densities in surface collections at night than during the day. Net avoidance may also play a part in larval collections according to a study by Clark and Pearson (1980). They found, collectively, more larvae were sampled at night than during the day and suggested that larvae may be able to detect and avoid the net during the day, while detection of the net during the night may be limited. We recognize that nighttime sampling may have negative aspects including difficulties in navigation, undetectable net plugging, or artificial lights attracting or deterring larval fishes (Clark and Pearson 1980, Muth and Schmulbach 1984, St. John and Black 2004). However, based on our results, the additional information obtained from night sampling takes precedence over the possible difficulties associated.

The original intention was to determine relative abundance of larval crappie produced by cove as a means of assessing suitable habitat conditions through time. However, distribution of larval crappie may be impacted by wind and fish movement thus making the origin of nest location for captured larval crappie uncertain. As a result, crappie densities are reported as daily means rather than abundance by cove. Daily and seasonal densities of larval crappie do provide managers an opportunity to evaluate the use of day or night push nets for determining future year-class strength or to model abiotic and biotic conditions associated with variable larval production.

Entrainment

The small net collected 341 fish in 2004 and 792 in 2005. The large net collected 4,376 fish in 2005. These collections extrapolated to a total loss of 2,981,155 fish entrained in 2004 (small net estimate) of which 33% were crappie. The total estimated loss from small net collections in 2005 was 5,886,742 with crappie composing 18% of the total (Table 3). Collections from the large net estimated 10,948,609 entrained fish with 16% being crappie. Although these estimates of entrained crappie appear high, they are equivalent to the average fecundity of 22 female crappie (Scott and Crossman 1973), most likely having a minimal impact on the crappie population within this reservoir.

Densities of crappies released through irrigation discharge appeared to correlate with the amount of discharged water (Figure 4). The Wilcoxon analysis verified positive seasonal relationships between the density of crappies captured and the amount of water discharge in both 2004 and 2005 ($p<0.01$). Peak crappie loss occurred in late July to early August in both years, which is contrary to the observations of Moen and Dewey (1978), who found peak loss of crappie from DeGray Lake, Arkansas in late May and early June. However, during May and early June, Nebraska's irrigation season is just beginning, and flows range between 4.25 and 7.98 m^3/s compared with flow rates that ranged between 33.98 and 155.74 m^3/s in the Arkansas reservoir. The highest flows from Sherman Reservoir did not occur until late July and early August, when crappie entrainment also peaked. When mean weekly discharge increased by more than 8 m^3/s, the density of entrained crappies was significantly higher (ANOVA $p<0.05$) compared to periods with lower or stable discharge conditions. Thus, it appears that crappies are more vulnerable to entrainment when mean weekly discharge is increased by 8 m^3/s or more.

The majority of young-of-the-year (YOY) crappies entrained from Sherman Reservoir is likely a result of behaviors associated with life history. As larval crappie reach approximately 11 mm TL, they descend deeper in the water column (Overmann et al. 1980, Travnichek et al. 1996). This pattern of distribution makes larval crappies vulnerable to entrainment in bottom release structures during the summer. This is supported by our observations that the smallest crappies collected were 12 mm TL in 2004 and 11 mm TL in 2005.

This study increased our knowledge concerning entrainment loss from an irrigation reservoir. Entrainment loss is highly variable with much of the loss occurring in a pulse over a short time frame. Irrigation managers should try to avoid rapid increases in water discharge to help reduce entrainment of sportfish from irrigation reservoirs. Loss of YOY crappies varies within and between irrigation seasons, which may be driven by differences in year-class strength, timing of more intense releases, or other abiotic factors. Future studies should also investigate using an unbalanced design that would concentrate sampling efforts during periods of higher flow increases. The end result of this project was that the fish recovery system was not constructed for Sherman Reservoir.

Documents prepared from this objective include a thesis and 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 have been submitted with previous reports.

Objective 2:

Adult Walleye Abundance and Fidelity - Electrofishing

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 5). 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 4).

The electrofishing CPUE was significantly higher at site D than site A during the 2007 season ($p<0.01$) and 2008 season ($p<0.01$). During the 2009 season, the electrofishing CPUE at site D was significantly higher ($p<0.01$) than site A and site B (Table 4). Mean electrofishing CPUE at each sampling site did not differ between seasons (site A: $p=0.57$; site B: $p=0.99$; site C: $p=0.69$; site D: $p=0.40$) (Table 4).

Electrofishing catch rates indicate most male walleye were found along the dam (site D), with some males present on the adjacent mud flats (site B and site C) and a few males present in the upper portion of the reservoir (site A). The congregation of male walleye along rip-rap covered areas during the spawning season has been observed in other

reservoirs (Grinstead 1971, Weber and Imler 1974, Michaletz 1984 and Martin 2008). Male walleye may congregate along the dam because the rip-rap substrate is similar to the cobble/gravel substrate which they prefer (Roseman et al. 1996, Foust and Haynes 2007). Prior to the addition of the cobble substrate in Sherman Reservoir, the only other available substrate was mud (Katt 2009), which has been shown to be poor walleye spawning habitat (Johnson 1961).

The addition of cobble substrate did not change the distribution of male walleye significantly, but a 15% increase in electrofishing CPUE was observed during the 2008 season when the cobble was at the preferred spawning depth. However, low water levels in 2008 allowed only two weeks of sampling on the mud flat compared to four weeks in 2007 and five weeks in 2009. Although the 2009 electrofishing CPUE was more similar to the pre-cobble electrofishing CPUE, the water depth on the cobble exceeded the recommended depth for capture of spawning male walleye using electrofishing (Satterfield and Flickinger 1996), which may have affected the 2009 electrofishing CPUE on the cobble.

Adult Walleye Abundance and Fidelity – Gill Nets

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 5).

The mean gill net CPUE among the sampling sites did not differ ($p=0.36$) during the 2007 season (Table 5). During the 2008 season, the mean gill net CPUE at site D was significantly higher ($p=0.03$) than site A. No difference ($p=0.08$) 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 ($p=0.50$), site B ($p=0.90$), site C ($p=0.20$) and site D ($p=0.20$) (Table 5).

The gill net catch rates indicated spawning walleye were equally distributed among the dam (site D) and the mud flat (site B and site C) while few walleye were distributed in the upper portion of the reservoir (site A). This is in contrast with the distribution found using electrofishing, where most walleye were sampled along the dam. The contrasting distributions are likely due to gear bias as the gill nets used in this study are more efficient at capturing females while electrofishing is more efficient at capturing males (Koupal et al. 1997).

The distribution of adult walleye indexed using gill net CPUE did not differ significantly, but a 113% increase in gill net CPUE was observed on the cobble the second season it was available when the water level was ideal. Specifically, the gill net CPUE doubled from pre-cobble abundances at site C and site D. The catch rates were low enough with gill nets that meaningful comparisons cannot be made with this data and observed changes may be due to fluctuations in the population.

Adult Walleye Abundance and Fidelity - Fidelity

A total of 2,195 adult walleye were captured during the three sampling seasons and 2,104 were VIE tagged (Table 6). 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 7). Site fidelity within a season was 94% while site fidelity between years was 81%.

The high occurrence of site fidelity among marked walleye is consistent with other findings that showed walleye returned to the same location to spawn each year (Crowe 1962, Olson and Scidmore 1962, Olson et al. 1978). The results for site fidelity were greatly influenced by having 81% of tagged walleye being males captured along the dam.

Site fidelity of spawning walleye may complicate the success of spawning habitat additions in lentic systems more than in lotic systems. For instance, in lotic systems spawning habitat can be added along known migration routes to spawning locations where walleye migrating up-stream will likely encounter the spawning habitat. Once the habitat is encountered, walleye may then choose to congregate on that habitat rather than continuing their migration up-stream. However, in lentic systems these migrations are not confined to a channel which reduces the likelihood of migrating walleye encountering the added habitat.

Walleye Egg Deposition

The highest egg density during each sampling season was observed at site D followed by site C, site B and site A (Table 8). Walleye egg densities ranged 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 ($p<0.01$) and 2009 season ($p<0.01$). In 2008, the egg densities at site C and site D were significantly higher than the egg density at site A ($p<0.01$). The egg density at site C was significantly higher than egg density at site A ($p<0.01$) during the 2009 season (Table 8).

There was no difference in egg density between seasons at site A ($p=0.08$), site B ($p=0.50$) or site D ($p=0.69$) (Table 9). The egg density at site C in 2008 was significantly higher ($p<0.01$) than it was in 2007 and 2009.

In Sherman Reservoir, the primary spawning area appears to be located on the dam, as the highest egg density was observed at this site during each season. Spawning does occur on the mud flat, but these egg densities were lower than those observed along the

dam. There appears to be little spawning activity in the upper portion of the reservoir as egg densities were minimal.

Egg density increased 215% the first season the cobble was available (2008), which indicates walleye began using the cobble substrate as soon as it was available; similar to observations by Johnson (1961). While it is unknown if changes in electrofishing CPUE and gill net CPUE are attributed to fluctuations in the population or reflect changes in spawning site selection, the increase in egg density on the cobble during 2008 did correspond with a decrease in egg density at site D during this season.

Although no increase in egg density was observed the second season the cobble substrate was available, differences in the water level pattern in the reservoir during the spawn may have influenced these results. Following the 2007 irrigation season, reservoir water levels were kept lower than normal so the cobble could be installed. During the spawning season of 2008, the reservoir was being filled, which eventually covered the cobble for the final two weeks of the spawning season. In 2009, the reservoir water level was stable but higher than anticipated which put the cobble substrate in water depths up to 3.8 m. Although walleye have been shown to spawn in water as deep as 5.0 – 6.0 m (Pitlo 1989, Fielder 2002), walleye in Sherman Reservoir appear to spawn in shallower water.

The addition of cobble increased the total area of spawning habitat by 125%. The total number of walleye eggs spawned in Sherman Reservoir appears to vary annually, as 174% more walleye eggs were spawned in 2009 at site C and site D compared to 2008. Serns (1982) also found the total number of walleye eggs spawned to vary annually in Escanaba Lake, Wisconsin. While variation in annual egg production is important, the percent contribution of site C to total egg production was of greater importance in this study. During 2008, 36% of the total egg production on these two areas came from site C while in 2009 only 8% of the total egg production came from site C.

The variation in total egg production may also have an effect on the total fry production based from hatching percentages associated with variable substrate. Egg densities from site C and site D in 2008 and 2009 were extrapolated to total egg production. At site C, the total area of cobble was measured following the completion of the reefs. On site D, the area of the rip-rap submerged in 0.5 to 1.5 m of water across the entire length of the dam was calculated. To estimate the total number of walleye fry produced from each site, literature values of hatching percentage on cobble (Johnson 1961) and rip-rap (Newburg 1975) were applied to the estimated total egg production on each site. During 2008, it was estimated that 78% of the total fry production from these areas came from site C while in 2009, 35% of the total fry production came from site C.

A thesis titled “Response of Walleye to the Addition of Spawning Substrate in a Nebraska Irrigation Reservoir” was submitted in previous reports. Findings from this project were 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. North American Journal of Fisheries Management.

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. Journal of Freshwater Biology.

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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Table 1. Number of adult crappie (≥ 150-mm TL) and mean catch per unit effort [CPUE (± 1 S.E.) number of fish per trap net night] collected in each sample cove during the 2004-2006 spawning seasons at Sherman Reservoir. In 2004, nets = 2, effort = 11. In 2005, nets = 2, effort = 13. In 2006, nets = 2, effort = 8.

	Cove	N	CPUE	Recaptures
2004				
	Red	1,423	65.5 + 14.6	72
	Green	1,713	74.6 + 11.7	135
	Pink	1,199	53.2 + 12.7	54
	Orange	1,637	72.7 + 13.1	50
	Yellow	1,069	46.6 + 7.1	41
	Total	7,041	62.5 + 5.5	352
2005				
	Red	1,066	42.9 + 10.3	80
	Green	985	39.6 + 9.4	101
	Pink	1,216	46.0 + 9.3	80
	Orange	1,454	58.3 + 10.9	105
	Yellow	1,147	47.3 + 10.9	57
	Total	5,868	46.8 + 3.2	423
2006				
	Red	866	54.1 + 8.6	35
	Green	822	51.4 + 13.5	29
	Pink	784	49.0 + 7.1	23
	Orange	797	49.8 + 8.4	29
	Yellow	801	50.0 + 5.4	15
	Total	4,070	50.9 + 3.8	131

Table 2. Adult crappie (≥ 150-mm TL) movement between coves during the 2004-2006 crappie spawning seasons at Sherman Reservoir. The "% Fidelity" column represents the percentage of tagged fish recaptured in their originally marked cove during a given year.

	Cove	Marked	Recaptured	% Fidelity
2004				
	Red	1,348	72	81
	Green	1,600	135	79
	Pink	1,158	54	74
	Orange	1,593	50	86
	Yellow	1,032	41	88

	Cove	Marked	2004 Recapture	2004 % Fidelity	2005 Recapture	2005 % Fidelity
2005						
	Red	992	81	81	80	91
	Green	897	83	67	101	87
	Pink	1,143	81	70	80	84
	Orange	1,351	63	79	105	93
	Yellow	1,095	58	62	57	88

	Cove	Marked	2004 Recapture	2004 % Fidelity	2005 Recapture	2005 % Fidelity	2006 Recapture	2006 % Fidelity
2006								
	Red	837	28	61	77	61	35	80
	Green	801	28	68	77	78	29	66
	Pink	766	13	92	54	74	23	73
	Orange	771	17	88	33	91	29	90
	Yellow	790	15	47	51	57	15	73

Table 3. Estimated number of crappies (*Pomoxis* spp.) from the deployment of the small net that were lost through irrigation water discharge in 2004 and 2005 from Sherman Reservoir.

Year	*N*	Estimated crappie loss		
		Day	Night	Total
2004	137	230,371	767,950	998,321
2005	168	153,021	895,309	1,048,330

Table 4. 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 5. 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 6. 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 7. 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 8. 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}

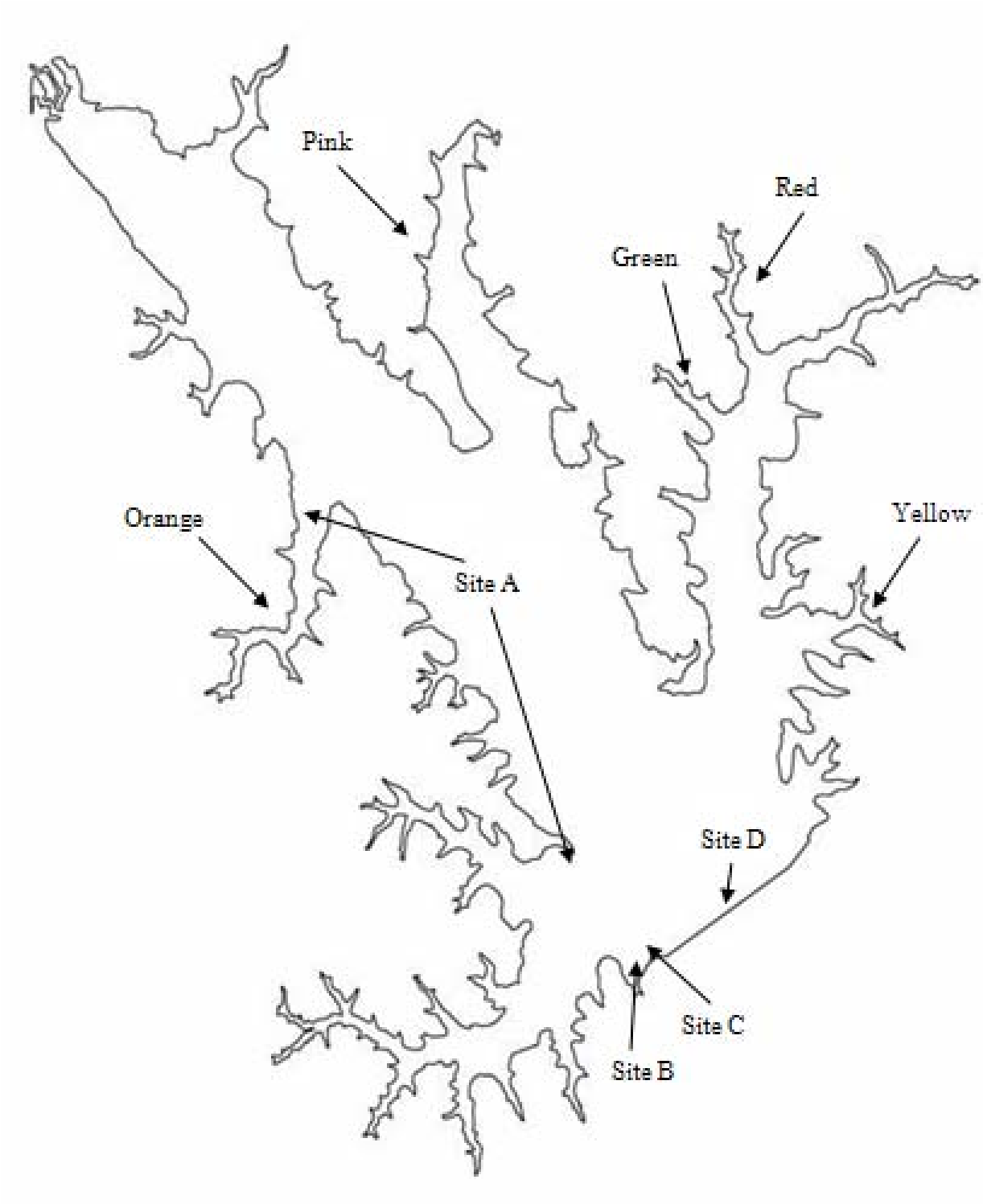

Figure 1. The sampling sites in Sherman Reservoir. Coves indicated by color were used for assessment of crappie populations. Sites designated by letters were used for walleye habitat assessment.

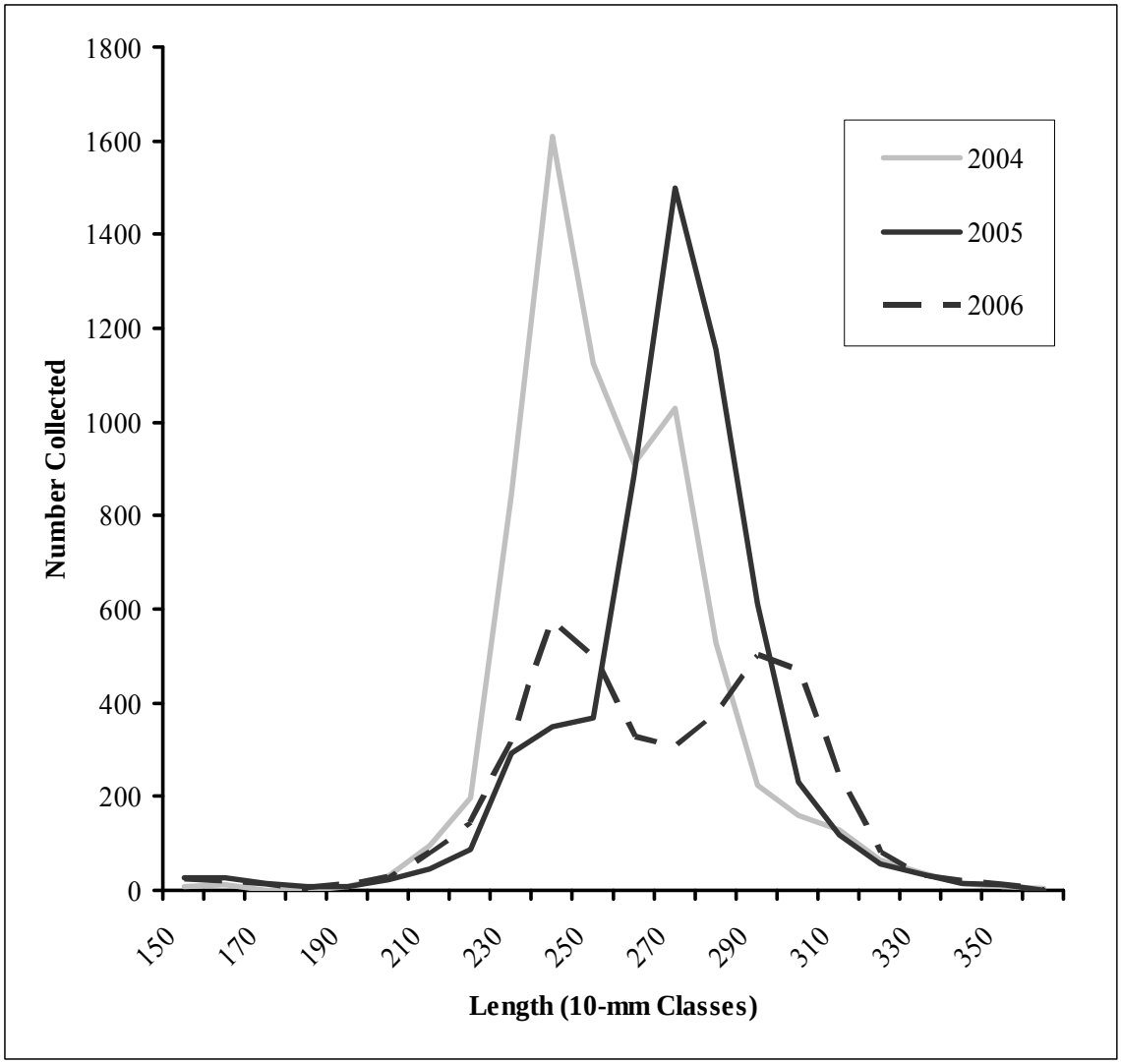

Figure 2. Length frequency histogram of adult crappie marked in 2004, 2005, and 2006 at Sherman Reservoir.

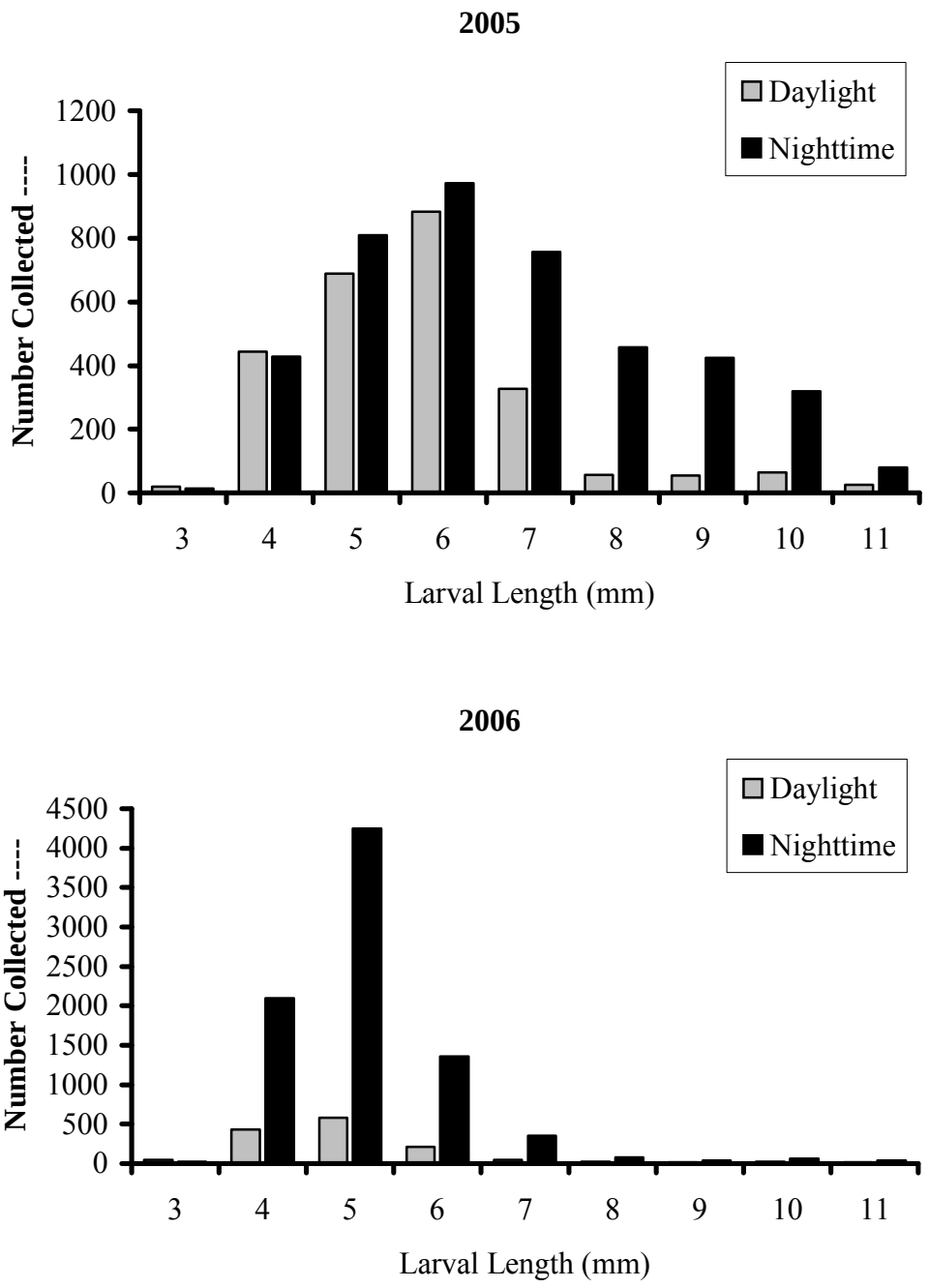

Figure 3. Length comparison of larval crappies collected in 2005 and 2006 during daylight and nighttime samples from Sherman Reservoir.

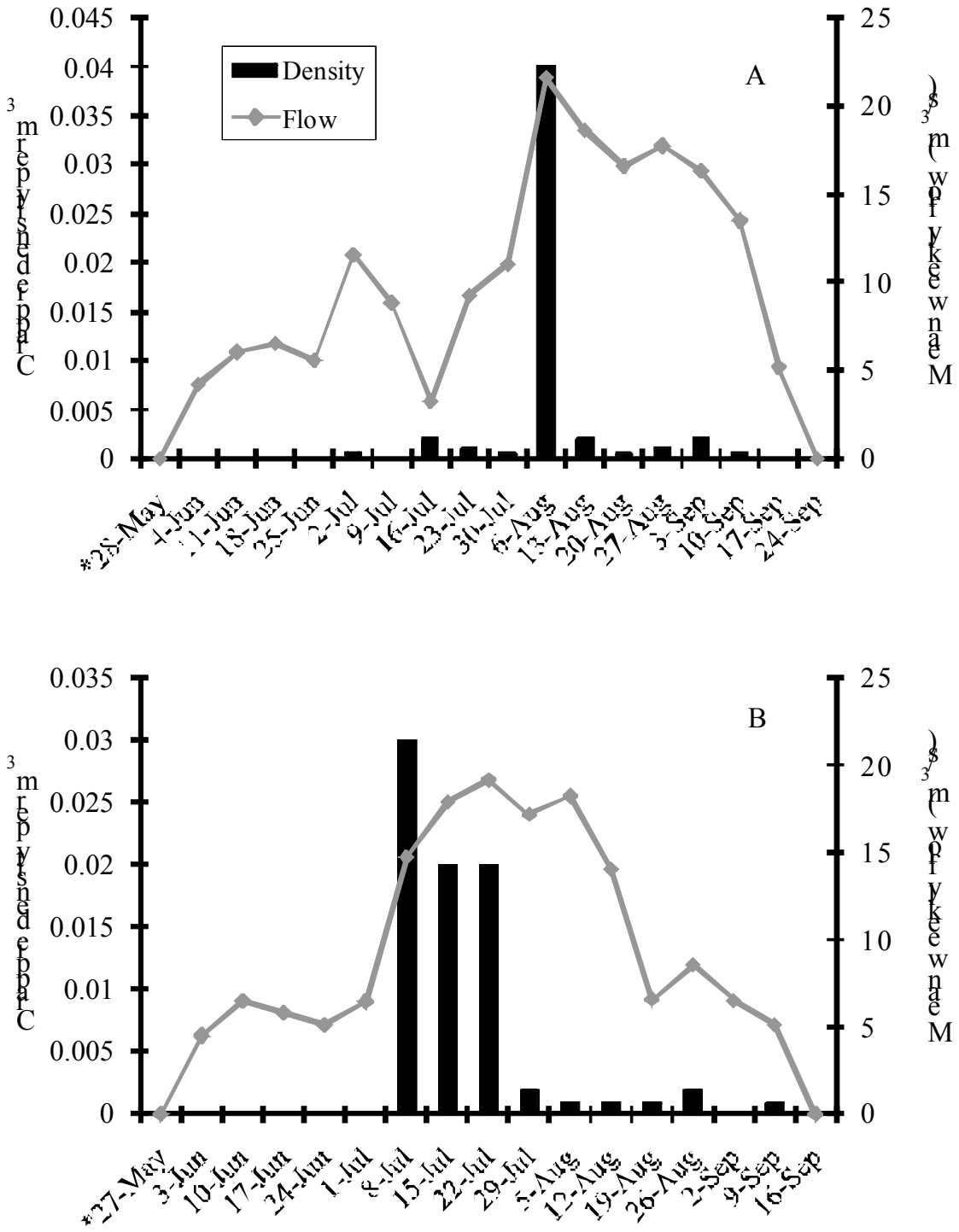

Figure 4. Weekly mean water release and crappie entrainment during the 2004 (A) and 2005 (B) irrigation seasons at Sherman Reservoir.

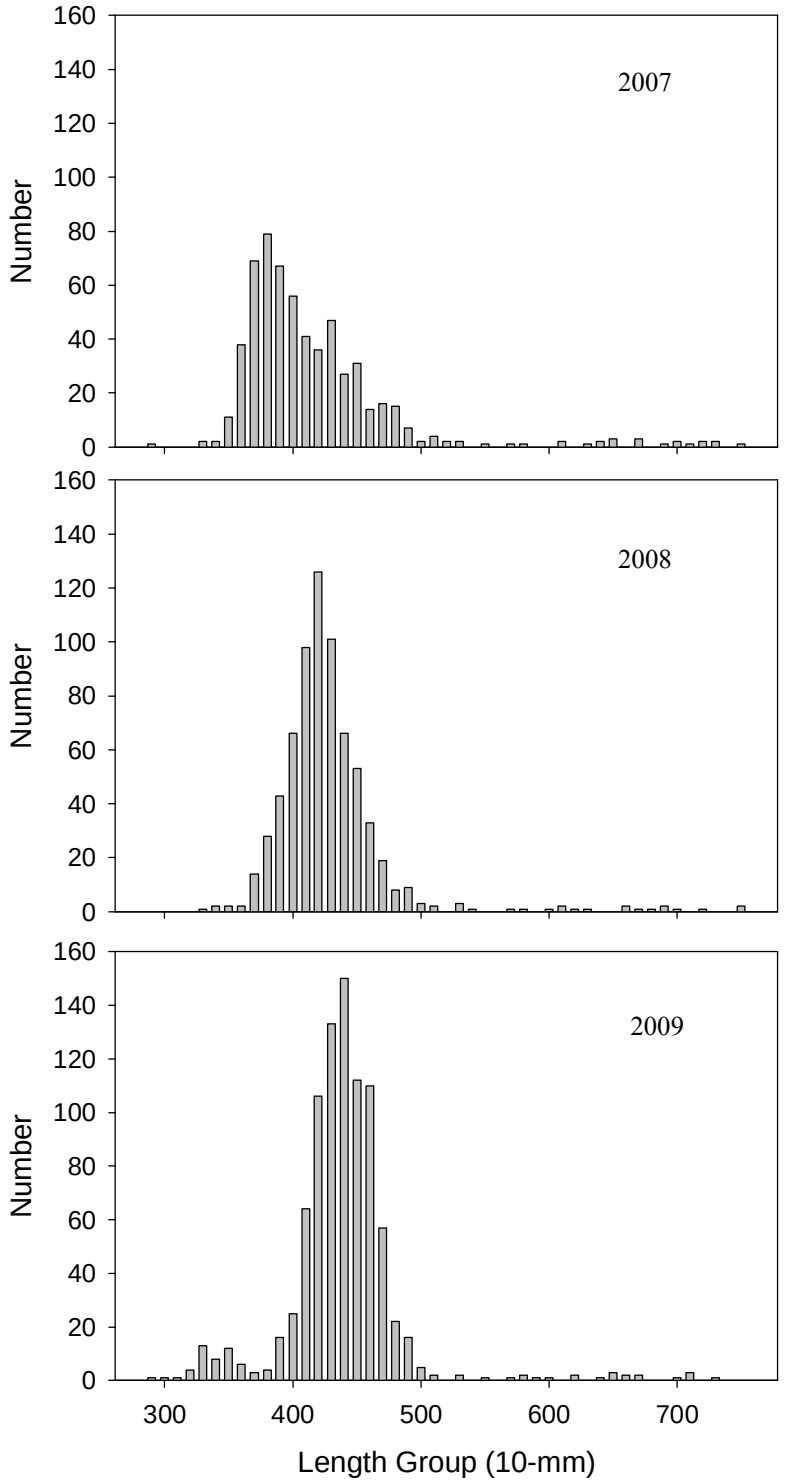

Figure 5. Length frequency histograms of all adult walleye sampled in 2007, 2008 and 2009.