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Changes in relative abundance of adult walleye and egg density following the addition of walleye spawning habitat in a midwest irrigation reservoir

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Abstract
Cobble substrate for walleye (Sander vitreus) spawning was added at Sherman Reservoir, Nebraska, in January 2008. We evaluated changes in relative adult walleye abundance and egg density in response to the cobble substrate and estimated site fidelity of adult walleye during the spawning seasons of 2007, 2008, and 2009. A 15% increase in electrofishing catch-per-unit-effort (CPUE) of adult walleye was observed on the cobble substrate the first season it was available (2008), but a 5% decrease in electrofishing CPUE was observed the second season (2009) compared to the 2007 season. While gill nets were not run during the first season the cobble was available, a 113% increase in gill net CPUE was observed the second season. During the first season the cobble was available, a 215% increase in egg density was observed, but no increase in egg density was found in the second season. Site fidelity of adult walleye within a spawning season was 94% and was 81% between seasons. These results indicate that the addition of the cobble substrate increased the relative abundance of adult walleye and density of eggs on the cobble substrate.

Keywords: *Sander vitreus*; walleye; spawning habitat evaluation; walleye spawning; spawning substrate; egg density

Introduction

Reservoirs are important fisheries in the lower Midwest where few natural lakes are present (Flickinger et al. 1999). In these reservoirs, stocking is often needed to introduce and establish desirable fish populations (Heidinger 1999). Walleye (Sander vitreus) is one common species introduced to reservoirs (Scott and Crossman 1973). However, natural reproduction of walleye is typically limited in reservoirs (Miranda 1999), and stocking is used to maintain these populations (Schlagenhaft and Murphy 1985; Johnson et al. 1988; Ellison and Franzin 1992).

One factor that may limit natural reproduction of walleye in reservoirs is the absence or limited availability of quality spawning substrate (Johnson 1961; Newburg 1975; Colby et al. 1979; Martin 2008). Since walleye are broadcast spawners (Priegel 1970; Jones et al. 2003) and provide no parental care (Roseman et al. 2006), egg survival is dependent on various environmental factors (Madenjian et al. 1996) including the substrate on which the eggs are spawned (Auer and Auer 1990). While most environmental conditions cannot be improved by management, the substrate on which walleyes spawn can be manipulated. Substrate improvements aimed at improving walleye reproduction usually involve the addition of cobble/gravel substrate as this is the preferred spawning substrate of walleye (Johnson 1961; Pitlo 1989; Roseman et al. 1996; Lowie et al. 2001; Foust and Haynes 2007) and has been shown to provide a higher egg hatching percentage compared to other substrate types (Johnson 1961; Corbett and Powles 1986; Jones et al. 2003).

Several studies have evaluated spawning habitat improvement projects (Johnson 1961; Weber and Imler 1974; Newburg 1975; Geiling et al. 1996; Dustin and Jacobson 2003) with varying results. Both Johnson (1961) and Newburg (1975) found that walleye egg deposition increased on the improved spawning areas but Geiling et al. (1996) found no evidence of increased egg deposition. Weber and Imler (1974) found that walleye were using the improved substrate but no significant changes in adult abundance were observed between the improved and unimproved areas. Dustin and Jacobson (2003) found adult walleye spawning on improved riffles but did not monitor changes in adult abundance or egg deposition following riffle improvement. The variety of results from previous studies indicates a need for additional evaluation of on-going spawning habitat improvements.

In Sherman Reservoir, Nebraska, walleye spawn on the rip-rap covered dam and on a shallow mud flat adjacent to the dam. In January 2008, 0.17 ha of cobble (Wentworth Scale, Cummins 1962) substrate was placed on the mud flat to increase the amount of quality walleye spawning habitat. The objectives of this study were to (1) assess changes in adult relative abundance following the addition of cobble substrate, (2) calculate site fidelity of spawning walleye in Sherman Reservoir, and (3) assess changes in egg deposition following the addition of cobble substrate.

Materials and methods

Study site

This study took place at Sherman Reservoir during March and April of 2007, 2008, and 2009. Sherman Reservoir is located near Loup City, Nebraska, and is an off-stream irrigation reservoir of the Middle Loup River. At conservation pool, the reservoir covers 1151 ha with a maximum depth of 11 m.

Three sampling sites (A, B, and C) were designated. Sites A and B were located on a mud flat near the southwest corner of the dam. Site A consisted of mud substrate. Site B was mud substrate in 2007 and is the site where the cobble substrate was placed in January of 2008. Site C was the face of the dam and consisted of riprap.

The cobble substrate was constructed as four reefs that averaged 56m in length by 8m in width. Each reef had a construction fabric base that was covered with 30 cm of cobble. They were constructed at an elevation approximately 0.5–1.5m below the 10-year mean April 1 reservoir elevation because this is the preferred depth for spawning walleye (Eschmeyer 1950; Johnson 1961; Grinstead 1971; McMahon et al. 1984). Low water levels during the 2008 winter caused the reefs to be unavailable for spawning until the final week of sampling. During 2009, water levels in the reservoir remained higher than average during the spawning season and the cobble was in 1.8–3.8m of water.

Walleye sampling

Adult walleye were sampled weekly using boat electrofishing at each of the sampling sites during March and April of 2007, 2008, and 2009. Electrofishing runs began approximately

30 min after sunset. The catch-per-unit-effort (CPUE) was expressed as walleye per hour of electrofishing. Adult walleye were also sampled using monofilament gill nets with 5.1 cm mesh (bar measure). Multiple net sets of 90–150 min duration were made throughout the night until all sampling sites had a minimum of two sets for the given week. The CPUE was extrapolated to the number of walleye captured per net-night, where a net-night equaled 12 h. Both sampling methods were used because of known sex-specific gear biases (Koupal et al. 1997).

All collected walleye were measured for total length, sexed, and assigned to one of three spawning condition categories- green, ripe, or spent (Satterfield and Flickinger 1996). Walleye classified as ripe were injected with visible implant elastomer (VIE) tags (Northwest Marine Technology, Inc.; Shaw Island, Washington), as ripe walleye were considered to be actively spawning at the location of capture. Site fidelity was subsequently calculated as the number of individuals recaptured from a sampling site divided by the total number of recaptures at that sampling site multiplied by 100.

Egg sampling

At each sampling site, 10 egg sampling disks were deployed at three randomly selected locations (30 disks at each site). The egg sampling disks ranged in diameter from 32 to 51 cm. Since the disks were of variable sizes, disks were assigned to sampling locations so that a similar amount of area was sampled at each site. Deployment, retrieval, and processing of the egg sampling disks are described in Katt (2009). During 2009, all viable eggs were taken to the laboratory where they were incubated, and the emerging fry were identified for verification of species. Of the roughly 2700 eggs collected, approximately 1000 hatched, and all the fry examined were identified as walleye.

The density of walleye eggs was calculated as the number of walleye eggs per square meter per spawn-night. The number of spawn-nights was factored into the density calculation because the amount of time between disk checks at each site varied throughout the three sampling seasons.

Data analysis

Two comparisons of walleye electrofishing CPUE, gill net CPUE, and egg density were made (1) among each sampling site within a season and (2) at a single sampling site between seasons. The electrofishing CPUE and egg density were compared using a Kruskal–Wallis test and a Dunn's post-test when significance was detected. The gill net CPUE in 2007 and 2009 were compared using ANOVA with a Tukey's post-test when significance was detected. Gill nets were not set at sites A and B in 2008 because of low water levels, so a Mann–Whitney test was used to compare the gill net CPUE among seasons at these sites. Significance was set at a=0.05 for all analyses.

Results and discussion

Electrofishing catch rates indicated that most male walleye were found along the dam (site C), with some males present on the adjacent mud flat (sites A and B) (Table 1). The congregation of male walleye along rip-rap covered areas during the spawning season has been observed in other reservoirs, such as Canton Reservoir in Oklahoma (Grinstead 1971), Lonetree Reservoir in Colorado (Weber and Imler 1974), Lake Francis Case in South Dakota (Michaletz 1984), and Red Willow and Enders Reservoirs in Nebraska (Martin 2008). Male walleye may congregate along the dam because the rip-rap substrate is similar to the

Table 1. Mean electrofishing CPUE, gill netting CPUE, and egg density during the 3 years of the study at site A (mud flat), site B (improved habitat), and site C (rip-rap on dam).

	Electrofishing CPUE (fish/h)			Gill-netting CPUE (fish/net-night)			Egg density (eggs/m^2/spawn-night)		
Year	Site A	Site B	Site C	Site A	Site B	Site C	Site A	Site B*	Site C
2007	44^{a}	119^{ab}	1893^{b}	8^{a}	8^{a}	5^{b}	9^{a}	26^{a}	158^{b}
2008	51^{a}	137^{a}	2997^{b}	–	–	12	2^{a}	82^{a}	103^{a}
2009	50^{a}	113^{a}	1307^{b}	9^{a}	17^{a}	12^{a}	8^{a}	26^{b}	390^{b}

Notes: Similar alphabets (a and b) indicate that the means are not significantly different.
* Indicates that a significant difference was found at that site between seasons.

cobble/gravel substrate which they prefer (Johnson 1961; Pitlo 1989; Roseman et al. 1996; Lowie et al. 2001; Foust and Haynes 2007). Prior to the addition of the cobble in Sherman Reservoir, the only other available substrate was mud (Katt 2009), which is poor walleye spawning habitat (Johnson 1961).

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 2 weeks of sampling on the mud flat (sites A and B) compared to 4 weeks of sampling in 2007 and 5 weeks in 2009. Although the 2009 electrofishing CPUE was more similar to the pre-cobble electrofishing CPUE (2007), 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. Further, the changes in electrofishing CPUE during the 2008 and 2009 seasons may be a result of natural fluctuations in the walleye population rather than changes in spawning habitat selection, as the electrofishing CPUE at site C followed a similar increase/decrease pattern as site B during this study.

Gill netting

The gill net CPUE doubled from pre-cobble abundances at sites B and C, but no significant differences were detected between sites within a season or at a site between seasons (Table 1). The gill net catch rates indicated spawning walleye were equally distributed among the dam (site C) and the mud flat (sites A and B) which is in contrast with the distribution found using electrofishing. The contrasting distributions are likely due to gear bias as the gill nets used in this study (5.1 cm bar mesh) 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. However, these changes may also be due to fluctuations in the population, as a similar pattern of increase in gill net CPUE was observed at site C.

Site fidelity

Site fidelity within a season was 94% while site fidelity between seasons was 81% (Table 2). These results are similar to other findings that show walleye returned to the same location to spawn each year (Crowe 1962; Olson and Scidmore 1962; Olson et al. 1978). Site fidelity was influenced by the high number of male walleye captured and tagged along the dam, as 81% of all tagged male walleye came from this location.

Table 2. Total number of walleye tagged at each site and total recaptures by site.

Site	Number tagged	Site A	Site B	Site C
A	79	0	1	1
B	282	0	4	8
C	1712	1	6	113

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 up-stream migration. However, in lentic systems, these migrations are not confined to a channel which likely reduces the likelihood of migrating walleye encountering the added habitat. Therefore, in lentic systems, spawning habitat additions should be placed near areas where some spawning activity already occurs for the habitat to be utilized (Dustin and Jacobson 2003). Further, spawning habitat additions in lentic systems may not be immediately utilized due to high site fidelity.

Egg sampling

Site C had the highest egg density compared to the other sites during each season (Table 1).Walleye egg density at site B was significantly higher during the 2008 sampling season compared to the 2007 and 2009 seasons. 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 which is similar to observations by Johnson (1961) in Lake Winnibigoshish, Minnesota. 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 suggests actual changes in spawning habitat use since a decrease in egg density was observed at sites A and C during this season.

Although no increase in egg density was observed in 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 that the cobble could be installed. During the spawning season of 2008, the reservoir was being filled, which eventually covered the cobble for the final 2 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 5.0–6.0m (Pitlo 1989; Roseman et al. 1996; Fielder 2002), walleye in Sherman Reservoir appear to spawn in shallower water.

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