# Abiotic Habitat Preferences of Age-0 Paddlefish In Lake Sakakawea, North Dakota During Late Summer

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Since the early 1990's, surface visual counts along transects have been conducted annually, allowing for estimates of relative abundance and year-class strength of age-0 paddlefish *Polyodon spathula* on the upper portions of Lake Sakakawea, North Dakota. This study focuses on the annual visual surface count data collected over an eleven year period from 2004-2014. More specifically it focuses on abiotic habitat factors (Secchi depth, water depth, and water temperature) and how they relate to age-0 paddlefish locations in late summer. Understanding habitat use during early life stages is imperative, yet to date, there is very limited knowledge available regarding the habitat preferences of young paddlefish. During this study fish were found to prefer Secchi depths between 10 and 60 cm, with the most productive range being at 30-40 cm. Water depths between 1 and 5 m produced the most age-0 sightings, while depths between 2-3 m had the highest frequencies of sightings. Certain temperature ranges, most notably 17-20 $^{o}$C and 22-25 $^{o}$C, were shown to be preferred by age-0 paddlefish also. Overall, the data from this study strongly suggests that significant relationships exist between age-0 paddlefish sightings and specific ranges of Secchi depths, water depths, and water temperatures. Future studies should focus on trying to correlate biotic factors, such as feeding activity and food availability, with the abiotic factors discussed in this study to achieve a broader understanding of young paddlefish habitat preferences during this vulnerable stage of life.

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**Introduction**

Since the early 1990's, surface visual counts along transects have been conducted annually, allowing for estimates of relative abundance and year-class strength of age-0 paddlefish *Polyodon spathula* on the upper portions of Lake Sakakawea (Fredericks and Scarnecchia, 1997). Surface visual counts are a very effective and practical method for monitoring juvenile paddlefish populations given the overall efficiency and the substantially smaller amount of time and effort required relative to other methods such as netting, trapping, or shocking (Fredericks and Scarnecchia, 1997). In addition, with surface visual counts there is no risk of mortality to the fish which is often not the case with other methods. This study focuses on annual visual surface count data collected over an eleven year period from 2004-2014. More specifically it focuses on the abiotic habitat factors such as, Secchi depth, water depth, and water temperature and how they relate to age-0 paddlefish abundance, this done in an attempt to determine if any distinct habitat preferences are shown by age-0 paddlefish.

Paddlefish have been shown to use a wide variety of habitats, yet habitat use generally varies annually and seasonally (Jennings and Zigler, 2009). Although understanding habitat use during early life stages is extremely important, relatively little is known about the habitat preferences and movements of juvenile paddlefish, especially age-0 fish, compared to what is known about adult fish (Hoxmeier and Devries, 1997; Phelps et al. 2009). The majority of the studies done on juvenile paddlefish have concentrated on feeding and growth (Michaletz et al., 1982; Hoxmeier and Devries, 1997; Kozfkay and Scarnecchia, 2002). Phelps et al. (2009) found that young paddlefish in the Mississippi River preferred areas with moderate current velocities (0.4-0.6 m/s), moderate depths (3-5 m), and sand substrate. Pitman and Parks (1994) observed that juvenile paddlefish in reservoirs prefer open water and tend to avoid littoral areas. Some studies also suggest that young paddlefish form large schools and suspend near the bottom of reservoirs and main channels of rivers (Ruelle and Hudson, 1977). Yet, due to habitat differences, paddlefish distribution and habitat use in rivers may be subjective to different factors than those from reservoir populations (Paukert and Fisher, 2001). In a similar study to this one, Kozfkay and Scarnecchia (2002) used surface visual counts on Fort Peck Lake, Montana to assess age-0 paddlefish relative abundance. They observed very little correlation between water transparency and age-0 paddlefish counts, but higher occurrences of age-0 paddlefish were noticed in areas with Secchi depths between 20 and 40 cm. Little information is available regarding temperature preferences of juvenile paddlefish, though some studies have shown that temperature may influence movement under certain conditions (Roush et al., 2003). Hoxmeier and Devries (1997) found that age-0 paddlefish growth rates were positively related to water temperature in the lower Alabama River, showing that water temperature may be a regulating factor in early-life stages of paddlefish.

The objectives of this study were to (1) determine if a relationship exists between abiotic habitat variables (Secchi depth, water depth, and water temperature) and the abundance of age-0 paddlefish in late summer and (2) determine if habitat preferences exist and try to explain these preferences with available literature.

## Methods

### *Study Area/Background*

The study was conducted on Lake Sakakawea, a main-stem impoundment of the Missouri River located in western North Dakota. Created by the closure of Garrison Dam in 1953, the reservoir encompasses an area of roughly 156,000 ha and is 270 km long when at full pool (Fredericks and Scarnecchia, 1997; Firehammer and Scarnecchia, 2006). Lake Sakakawea supports one of the few self-sustaining, harvestable populations of paddlefish in the United States (Fredericks and Scarnecchia, 1997). Paddlefish in this reservoir are referred to as the Yellowstone-Sakakawea stock and inhabit an area extending from Garrison Dam in central North Dakota upriver through Lake Sakakawea to the confluence of the Yellowstone and Missouri Rivers. Then up the Yellowstone River to the diversion dam at Intake, Montana, and up the Missouri River to the tailwaters of Fort Peck Dam near Fort Peck, Montana (Scarnecchia et al., 2007).

Fish from the Yellowstone-Sakakawea stock rear in Lake Sakakawea and when sexually mature (age 15-18 for females, 8-10 for males), migrate upriver through the reservoir headwaters and into the Yellowstone and Missouri Rivers to spawn in the spring and early summer (Scarnecchia et al., 1996; Firehammer and Scarnecchia, 2006; Scarnecchia, 2007; Miller and Scarnecchia, 2008). After hatching, larval paddlefish move downriver into the reservoir headwaters where they will remain during their first summer, reaching fork-lengths of 150-250 mm by late summer and selectively feeding on invertebrates, primarily *Leptodora kindtii* (Fredericks, 1994). After their first year paddlefish become filter-feeders, feeding on a much wider variety of zooplankton and other invertebrates (Michaletz et al., 1982; Fredericks, 1994.)

### *Surface Visual Counts*

This study focuses on annual visual surface count data collected over an eleven year period from 2004-2014. Throughout this period transects ranged from river mile 1494 to river mile 1539, with 6 to 10 transects being run each year. Transects ranged from 0.6 to 4.5 km in length. Given the nature of Lake Sakakawea the number and locations of transects run was heavily dependent on reservoir water levels. There were multiple years during the study period where reservoir elevation fluctuated by three to nearly five meters between consecutive years, making certain areas inaccessible on a year to year basis. Counts were performed once a week for six consecutive weeks from late July through early September each year. A GPS with fixed endpoints for each transect was used to ensure accurate duplication. The boat was driven along each transect at a constant speed of around 8 km/h. When paddlefish encounter turbulence or pressure waves from the boat they are generally driven to the surface, allowing them to be easily counted (Kozfkay and Scarnecchia, 2002). Paddlefish were counted by two observers, each looking off one side of the boat. Fish were only counted within an estimated 10 m of either side of the boat. Age was estimated visually by observing the lengths of the fish [age-0 = < 200 mm BL (body length), (Kozfkay and Scarnecchia, 2002)].

Water temperature, cloud cover, and wave height were observed and recorded at the start of each transect. Cloud cover was described as clear, partly cloudy, or cloudy. Wave heights were categorized as 0 (0-0.30 m), 1 (0.30-0.61 m), 2

(0.61-0.91 m), or 3 (0.91 m). Water depth and Secchi depth readings were taken at three equally spaced intervals along each transect.

### *Data Analysis*

A Pearson's Chi-Square Test was run on the data describing the frequencies of age-0 paddlefish sightings at varying Secchi depths, water depths, and water temperatures using Program R. This was done to obtain $x^2$ critical values, degrees of freedom, and p-values in an attempt to determine if the actual number of sightings is independent of the total number of transects without a sighting. Finding low p-values would suggest that the actual number of age-0 sightings was strongly independent of the expected variables and that a relationship does exist between the probabilities of age-0 paddlefish sightings and differences in Secchi depth, water depth, and water temperature.

## Results

The proportion (frequency) of transects with age-0 paddlefish sightings was shown to be influenced by differences in Secchi depth ($x^2$ = 33.8, df = 6, p-value < 0.01), water depth ($x^2$ = 30.4, df = 6, p-value < 0.01), and water temperature ($x^2$ = 21.3, df = 9, p-value = 0.01). Paddlefish were more likely to occur at Secchi depths between 10 and 60 cm, with the highest frequencies found at Secchi depth categories 30-40 cm (0.52), 40-50 cm (0.48), and 10-20 cm (0.48) (Figure 1A). No age-0 paddlefish were ever observed in areas with Secchi depths over 97.3 cm. Water depths between 1 and 5 m produced the highest number of sightings, with the most productive depths at 2-3 m (0.58), 1-2 m (0.45), and 4-5 m (0.45) (Figure 1B). No age-0 paddlefish were sighted at depths over 9.5 m. Fish also seemed to prefer specific water temperature ranges over others. Higher frequencies of age-0 sightings occurred at temperature ranges 17-20 $^{o}$C and 22-25 $^{o}$C, while the temperature categories 15-16 $^{o}$C (0.8), 22-23 $^{o}$C (0.51), and 23-34 $^{o}$C (0.51) showed the highest frequencies of age-0 sightings overall (Figure 1C).

Higher frequencies of age-0 sightings tended to coincide with higher frequencies of available habitat within all three habitat variable types. Though, Secchi depth and water temperature seemed to show the highest correlation. Frequencies of available habitat were found by dividing the number of measurements taken in each category (i.e. Secchi depths of 20-30 cm) by the total number of measurements for each habitat type. No significant trends could be found linking cloud cover and wave height to age-0 paddlefish abundance.

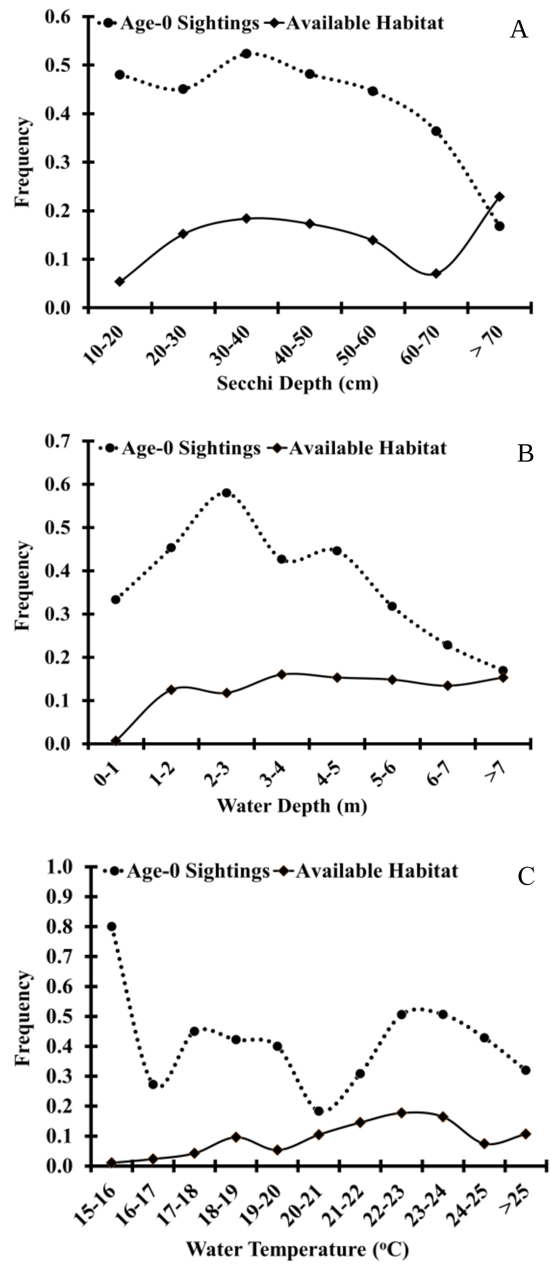


Figure 1.- Proportion of transects with age-0 sightings in comparison to frequency of available habitat. Graph (A) refers to Secchi depth (cm), (B) water depth (m), and (C) water temperature (°C).

## Discussion

Prior to this study very little data existed on the habitat preferences of juvenile paddlefish, especially age-0 fish (Hoxmeier and Devries, 1997; Phelps et al. 2009). Most studies on juvenile paddlefish have focused solely on feeding and growth (Michaletz et al., 1982; Hoxmeier and Devries, 1997; Kozfkay and Scarnecchia, 2002). While conducting surface visual counts for paddlefish on Fort Peck Lake, Montana Kozfkay and Scarnecchia (2002) observed age-0 paddlefish using a wide range of Secchi depths, yet slightly higher occurrences were found in areas with Secchi depths between 20 and 40 cm. This was somewhat consistent with the results of this study where age-0 paddlefish utilized a wide range of Secchi depths and the highest frequencies of sightings were observed at Secchi depths between 30 and 40 cm. While Secchi depths under 60 cm were greatly preferred, the reason behind this is still somewhat unclear. Higher food availability in areas with lower Secchi depths may provide a substantial link. Given that paddlefish have a poorly developed visual system (Hussakof 1910), Wilkens et al. (1997) suggested that paddlefish rely on their rostrum to electrically sense prey. This electrosensory ability may also be an important dynamic in determining the day to day movements and habitat preferences of paddlefish. Whether a Secchi depth measurement is an accurate way to predict locations of age-0 paddlefish is yet to be seen, there certainly is some strong evidence suggesting it may be a key factor affecting paddlefish location.

Water depth was also shown to strongly influence age-0 paddlefish locations. Fish in this study preferred water depths between 1 and 5 m, with the highest frequency of sightings occurring at depths between 2 and 3 m. Phelps et al. (2009) observed similar results when they found that young paddlefish in the Mississippi River preferred areas with moderate depths between 3-5 m. Yet, distribution and habitat preferences of paddlefish in rivers is likely different than those found in reservoirs due to habitat differences (Paukert and Fisher, 2001). In rivers, paddlefish tend to inhabit areas near current breaks and eddies (Southall and Hubert et al. 1984; Zigler et al. 1999). While, in reservoirs, paddlefish prefer open water and avoid littoral areas (Pitman and Parks 1994). The reason why fish were more readily found in areas of moderate depth (2-3 m) could be attributed to a variety of factors. More suitable water temperatures or higher food availability could be plausible explanations, yet other habitat conditions could also be at play, such as flow rates or lower rates of predation.

Water temperature seemed to play a slightly lesser role in the locations of age-0 paddlefish than either Secchi depth or water depth, though at times fish did select for certain temperature ranges, most notably temperatures between 17-20 $^{o}$C and 22-25 $^{o}$C. Hoxmeier and Devries (1997) found that age-0 paddlefish growth rates were positively related to water temperature in the lower Alabama River, showing that water temperature may be a regulating factor in early-life stages of paddlefish. Crance (1987) observed that optimum temperatures for adult paddlefish were between about 12-24 $^{o}$C. In Keystone Reservoir, Oklahoma Paukert and Fisher (2000) found that adult male paddlefish selected more moderate temperatures during summer and avoided the highest available water temperatures. Fish also selected different temperature ranges on different consecutive days. Although this study did not focus on adult paddlefish, the results are similar to the findings of Paukert and Fisher (2000). Additionally, based on the findings of Hoxmeier and Devries (1997), more attention should be given to water temperature in future studies, especially during the spring, assuming that temperature may be a regulating factor in early life stages of paddlefish.

In conclusion, the data from this study provides strong evidence to suggest that significant relationships exist between age-0 paddlefish sightings and specific ranges of Secchi depths, water depths, and water temperatures. Yet, considering the limited knowledge currently available on age-0 paddlefish, further study is warranted on the subject. More specifically, seasonal movements and locations of fish may be more closely related to feeding activities, food availability, or other biotic factors rather than the abiotic factors discussed in this study. Future research focused on relating biotic and abiotic factors to the locations of young paddlefish should provide a much greater understanding of this species in its most vulnerable stage of life.

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