Fish Use of Habitats Across Four Seasons in a Borrow Pit

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Abstract - Many state agencies install different habitat structures composed of natural or artificial materials in an effort to enhance existing or replace lost fish habitat in lentic systems, including small impoundments and larger reservoirs. However, post-installation evaluations of these added structures are limited. The objective of this study was to compare fish use around recently-added Georgia cubes, existing submerged trees, and bare areas in a borrow pit. We also compared water quality parameters around structures. Fish counts and water quality were compared between the 3 habitats among 4 seasons. More fish were observed in fall and summer around all habitats and around cube complexes compared to the other habitats. No differences were noted in water quality between habitats. Overall, the results of this study show that fish use a novel, artificial structure more than existing natural habitats, and the addition of these habitats do not alter water quality.

Introduction

The practice of adding habitat structures to waterbodies to increase harvest dates as far back as the late 1700s in Japan (Meier 1989). In more recent years, a particular interest has focused on adding habitat structures into reservoirs, as these waterbodies are often devoid of or disconnected from habitat structure, such as vegetation or submerged trees (Miranda 2017). Excessive nutrient input and sedimentation in reservoirs can lead to reductions in reservoir surface area, depth, and volume (Minns et al. 1996, Miranda 2017), reducing littoral zones of emergent and submergent aquatic vegetation. Woody debris, frequently limiting in smaller impoundments and larger reservoirs, may undergo accelerated decomposition or be stranded in dry areas or along shallow margins (Krogman and Miranda 2016, Miranda 2017). In addition, increased habitat fragmentation and decreased water quality may result from lower reservoir elevations, increased sedimentation rates, and increased nutrient concentrations (Minns et al. 1996, Miranda 2017, Olds et al. 2011).

Additions of habitat structures could help to regain what has been lost in reservoirs over time and provide some benefits to fishes. Previous research has shown that habitat structures made of either natural (e.g., downed trees) or artificial (e.g., plastic-, metal-, or rubber-based) materials can provide spawning substrates for adult fishes (Feger and Spier 2010, Jones et al. 2015) and feeding habitat and cover for juvenile fishes (Baumann et al. 2016, Daugherty et al. 2014). These provisions may lead to increases in overall abundance of fishes that use these habitats. However, added habitat structures may also only serve to simply attract some fishes, potentially leading to overcrowding and stunted populations or increased angling vulnerability and overall decreases in population abundance due to overharvest (see Bolding et al. 2004 for a review).

Structures comprised of many different artificial materials and configurations have been tested over time and are designed differently depending on the target species and objectives for the fishery. Some previous research has compared performance of such structures to either

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control areas or habitats constructed of natural materials. Feger and Spier (2010) found higher relative abundance of *Micropterus salmoides* Lacepéde (Largemouth Bass) and *Lepomis macrochirus* Rafinesque (Bluegill) at sites with "fallen timber" imitation structures made of PVC pipe compared to control areas lacking any habitat structure. Performance of structures constructed from artificial material versus those composed of more natural materials may differ as well. For example, Richards (1997) found that angling catch per effort for both *Pomoxis nigromaculatus* Lesueur (Black Crappie) and Bluegill was nearly twice as high on evergreen tree structures compared to a fabricated sphere structure, though both habitats had much higher angler catches compared to bare areas. The decision to use structures constructed of artificial materials over natural materials may be based on the time goals of a habitat project. Habitats composed of woody materials will break down over time, and any added woody materials may need to be replaced every few years (Baumann et al. 2016), whereas artificial materials are expected to decompose at a much slower rate.

While previous research has demonstrated that adding habitat structures constructed from artificial materials provides some benefits to both fish and anglers, questions remain as to which types of structures may work best to achieve particular outcomes (Jones et al. 2015, Minns et al. 1996). Further, many projects involving the addition of habitat may not involve evaluation post-habitat introduction (Bolding et al. 2004, Jones et al. 2015) or examine seasonal changes in fish use (Tugend et al 2002, but see Daugherty et al. 2014 as an example). Further, some reservoirs may be too large to add enough artificial structures to determine whether those structures provide benefits to fish populations. Thus, smaller impoundments, such as borrow pits, may provide opportunities to preliminarily evaluate fish use of added artificial structures and existing habitats before scaling up to larger reservoir projects in the future. Borrow pits are common features on Nebraska's landscape (Pauley et al. 2018) and may be important sources of fish diversity (Miranda et al. 2013) and recreational fishing opportunities (Schall et al. 2016, Schoenebeck et al. 2015). Many borrow pits have steep banks and little to no riparian zones; thus, these waters often have limited littoral area or coarse woody debris (Lusk et al. 2012). Therefore, we expected that the addition of structure would provide new habitat for fish to use. The objective of this study was to compare fish use around added structure (namely, Georgia cubes), existing submerged trees, and control (bare) areas across four seasons in one borrow pit pond in south central Nebraska.

Materials and Methods

This study was conducted in Pond 2 at Sandy Channel State Recreation Area, located in Buffalo County, Nebraska (Fig. 1). This waterbody was part of a larger study focused on fish use and survival associated with adding habitat structures constructed from artificial materials (L. Dietrich, University of Nebraska at Kearney, Kearney, NE, 2021, unpubl. data). For the purposes of this study, this waterbody was chosen due to the availability of existing habitat (woody debris and bare areas [control]) and recently added habitat structures constructed from artificial materials (Georgia cubes). Surface area is approximately 2.5 ha, and maximum, minimum, and mean depths are 5.2, 0.6, and 2.9 m, respectively. The fish community included Largemouth Bass, Bluegill, *Ictalurus punctatus* Rafinsque (Channel Catfish), and Black Crappie.

Three complexes of Georgia cubes were placed in the pond in mid-July 2020. Each complex was comprised of 3 individual cubes secured to each other with zip ties in a triangular, horizontal configuration (Fig. 2). Each cube was constructed using 1-m length polyvinyl chloride (PVC) pipe with 0.04-m diameter corrugated pipe suspended in the middle of the cube. The PVC of each cube was filled with 7 kg of small diameter (9.5 mm) gravel and punctured with at least 20 holes (1.27 cm diameter) to allow for water infiltration in order to sink the cubes and prevent drift. One of the 3 cubes was wrapped with 2.5-cm mesh chicken wire, and a second cube was wrapped with 5.1-cm mesh chicken wire. The third cube was not wrapped with any wire. The purpose of the mesh was part of a larger study to exclude predators from consuming smaller fishes (e.g., young-of-the-year Bluegill) using the cube structure. Each cube complex was set in depths between 2–5 m in a randomly selected location that was at least 15 m away from the other habitats to minimize influence on fish use of those habitats. Three areas of woody habitat (downed trees from the shoreline) and 3 bare areas (silt or small gravel, devoid of any vegeta-

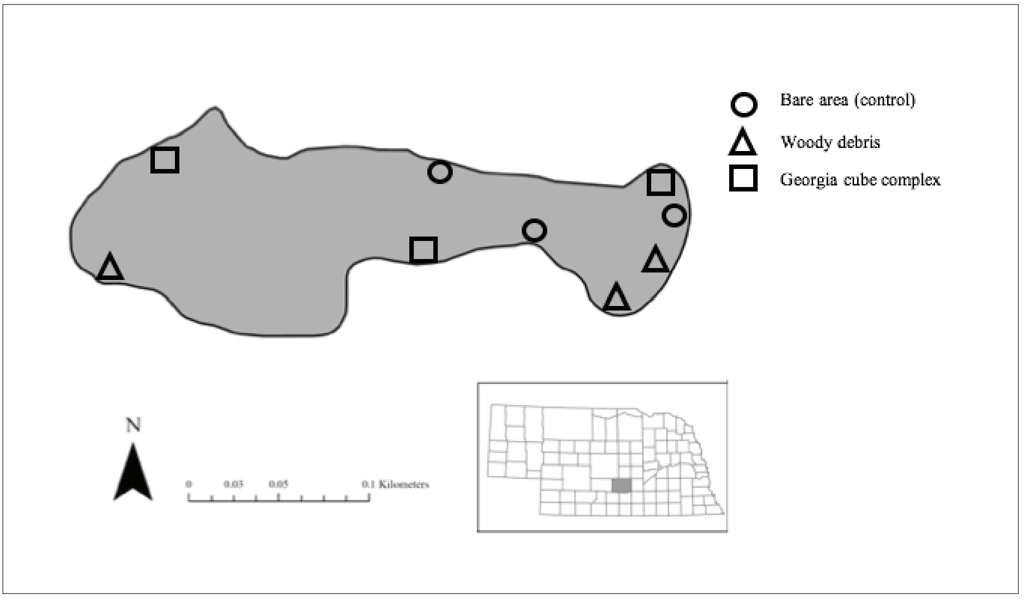

Figure 1. Locations of the sampled habitats within Pond #2 of Sandy Channel State Recreation Area (Buffalo County, NE, USA; shaded gray in lower right inset map). Georgia cubes were added in July 2020. Locations for woody debris (downed trees from the shoreline) and bare areas (silt or small gravel areas) were randomly selected from available habitats identified prior to the start of the study.

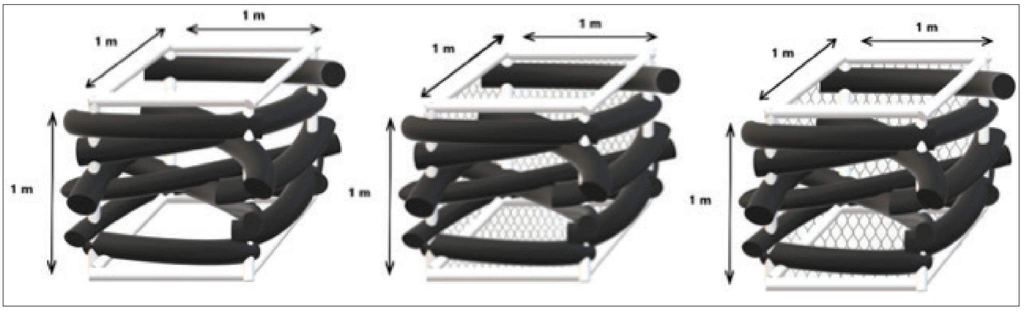

Figure 2. Schematics of the 3 Georgia cubes used to create 1 Georgia cube complex. The left panel represents the standard Georgia cube configuration as described by Jones et al. (2015). The middle and right panels represent Georgia cubes wrapped with 2.5- and 5.1-cm wire mesh, respectively. The addition of the mesh was part of a larger, related study of fish use and survival around Georgia cubes (L. Dietrich, University of Nebraska at Kearney, Kearney, NE, unpubl. data). The 3 cubes were tethered together horizontally in a triangular formation using zip ties.

tion or other habitat structure) of a surface area (3 m^2) with water depths similar to those of the Georgia cubes were randomly selected throughout the waterbody. The GPS coordinates were recorded at each site in order to revisit the same locations each season.

Sampling was conducted in fall (October 2020), winter (January 2021), spring (April 2021), and summer (July 2021). One day was selected around mid-month, and sampling occurred between 8:00 am and 1:00 pm to reduce influence of time of day on sampling. The first location to be sampled during each event was randomly selected, and sampling then proceeded in a counterclockwise direction around the lake until all habitats were sampled. Navigation to the sites was done by canoe during fall, spring, and summer sampling. A boat with an outboard motor was used during winter sampling in order to access sites covered by thin ice. Fish were observed at each habitat using an AquaVu Micro Revolution 5.0 Underwater Viewing System® pointed horizontally at each site at a standardized depth of 0.3 m from the substrate. The cord between the camera and the video receiver was strung into a 2 m long PVC pipe with a 90° elbow to allow for 360° camera rotation to visualize the selected habitat. The distance of the camera from the habitat depended on water clarity. If water clarity was diminished, the camera was placed closer to the structure to improve visualization. The camera rested in the water for 5 minutes to allow fish to recover from any potential disturbance (Baumann et al. 2016, Mayo and Jackson 2006). During the rest period, we measured pH with an Accumet® pH meter, conductivity (µS/cm) with an Oakton CTS Testr™, and temperature (°C) and dissolved oxygen (mg/L) with a YSI® multi-metric meter at the water surface on the opposite side of the boat from the camera. The Aqua-Vu® was then set to record for 5 minutes at each habitat. No motors were running during water quality sampling or fish observations. Video recordings were downloaded onto a laptop in the laboratory and watched by 2 independent viewers. Individual fish species identification was difficult due to water clarity; thus, the viewers recorded the total number of fish observed during the 5-minute period for a given habitat. If counts were inconsistent between the 2 viewers, both viewers reviewed the video again to come to a consensus.

Fish count comparisons by habitat type and season were analyzed using a two-way ANOVA. The fish count data were transformed [$\log_{10}$(number of fish + 10)] to meet normality assumptions (Hubert and Fabrizio 2007). Differences of water quality measurements were compared between seasons by habitat type using a two-way analysis of variance (ANOVA). Post-hoc multiple comparisons of significant ANOVA results were performed using the Tukey's honestly significantly difference (HSD) test. All analyses were performed in SAS v.9.4 (2013). Significance was determined at $\alpha = 0.10$ for each test.

Results

A total of 287 fish were observed across all habitats and seasons during this study. Differences were noted in the number of fish between habitat types regardless of season ($F = 6.70$, df = 2, $P < 0.01$). Namely, more fish were found around Georgia cubes ($\bar{x} = 18.0$, SE = 7.1) than either woody or bare habitats; fish counts appeared similar between woody and bare habitats ($\bar{x} = 3.5$, SE = 2.1 and = 2.4, SE = 1.3, respectively, Fig. 3). More fish were observed in fall and summer ($\bar{x} = 16.3$, SE = 7.2 and $\bar{x} = 13.0$, SE = 7.2, respectively) than in winter or spring ($\bar{x} = 0.9$, SE = 0.4 and $\bar{x} = 1.7$, SE = 0.1, respectively) regardless of habitat ($F = 4.74$, df = 3, $P = 0.01$). No differences in fish counts were noted in the interaction between habitats and seasons ($F = 1.12$, df = 6, $P = 0.38$).

Dissolved oxygen varied between 5.04 and 10.02 mg/L across all seasons and habitat types ($\bar{x} = 8.11$, SE = 0.23) and tended to be lower in the summer and highest in the spring ($F = 81.07$, df = 3, $P < 0.0001$; Table 1). No differences were found in dissolved oxygen among habitat types ($F = 2.07$, df = 2, $P = 0.15$) nor in the interaction between habitat type and season ($F = 1.39$, df

= 6, $P = 0.26$). Similarly, conductivity was lowest in the summer but highest in the winter (1346 – 1461 µs/cm; = 1388.19, SE = 12.54; Table 1). Differences were only found between season ($F = 25.10$, df = 3, $P < 0.0001$). No differences were found in conductivity between habitat types ($F = 1.41$, df = 2, $P = 0.26$) or in the interaction between habitat type and season ($F = 0.34$, df = 6, $P = 0.91$). Water temperature varied from 2.7 to 26.0°C across seasons and habitat types ($\bar{x}$ = 13.38, SE = 0.12). The lowest temperatures were observed in the winter, and the highest were in the summer ($F = 13{,}170.00$, df = 3, $P < 0.001$; Table 1). There were no differences in temperature among habitat types ($F = 0.59$, df = 2, $P = 0.56$) or in the interaction between habitat type and season ($F = 0.59$, df = 6, $P = 0.73$). Lastly, pH was lower in fall and winter than in spring and summer ($F = 42.91$, df = 3, $P < 0.0001$; Table 1) and varied between 7.46 and 8.06 across all habitat types and seasons ($\bar{x}$ = 7.77, SE = 0.06). No differences in pH were found between habitat types ($F = 1.12$, df = 2, $P = 0.34$) nor in the interaction between habitat type and season ($F = 0.85$, df = 6, $P = 0.55$).

Discussion

Our results showed that fish began using the Georgia cube structures within 3 months of setting the complexes in this particular pond. Rapid colonization of fishes on added structures constructed from artificial materials has been found in other marine and aquatic studies. For example, Edwards and Clark (1993) found that adult reef fish were attracted to artificial reef structures within hours of their placement in the Maldives. Colonization of fish on added cinder blocks, tires, and brush bundles were noted as early as 4 hours after final introductions of habitat into a wildlife refuge pond in Maine (Moring and Nicholson 1994). Colonization may follow a successional pattern. For example, Paxton et al. (2018) found that colonization of a new artificial reef in Onslow Bay, North Carolina, began as early as 2 weeks post-deployment, starting with schooling, pelagic, planktivorous fish; demersal fishes colonized weeks or months later. Other factors that may influence colonization rates of new habitat may include the distance of fish to new habitat, ecological species traits, and the availability of existing habitat (Stoll et al. 2014). Given this, the observed colonization in our study is expected. Fish in our study lake tended to be more pelagic (Black Crappie, Bluegill, and Largemouth Bass; Hrabik et al. 2015). Further, the area of the borrow pit we studied is likely smaller than the home range of these fish, and habitat may have been limiting prior to the addition of the Georgia cubes. Thus, fish may have been seeking new habitat and would have been able to locate these novel structures relatively easily.

Though only a single day was used to represent a season, we did note seasonal differences in fish use across all habitat types in this study as more fish were observed at all sites in summer and fall compared to winter and spring. These results may be related to water temperatures as epi-

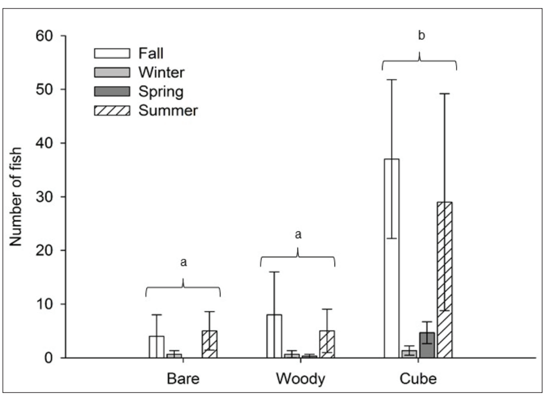

Figure 3. Mean fish counts by habitat type and season in Sandy Channel Recreation Area, Pond #2. Error bars represent one standard error. Letters denote significant differences in overall mean fish counts between habitat types based on results of a two-way analysis of variance of transformed count data ($\log_{10}$[number of fish + 10]).

Table 1. Mean water quality parameters at each habitat type by season. One measurement of each parameter was taken at the surface at each habitat type (n = 3 locations per type). Numbers in parentheses represent one standard error.

Parameter	**Habitat type**	**Fall**	**Winter**	**Spring**	**Summer**	**Overall mean**
DO (mg/L)	Bare	7.59 (0.09)	9.04 (0.07)	9.50 (0.30)	5.61 (0.42)	7.93 (0.47)
	Woody	8.11 (0.25)	8.53 (0.31)	9.38 (0.49)	6.26 (0.06)	8.07 (0.37)
	Georgia cube	7.99 (0.28)	8.89 (0.14)	9.71 (0.26)	6.71 (0.26)	8.43 (0.37)
Conductivity (µS/cm)	Bare	1351 (4)	1445 (36)	1372 (11)	1347(18)	1379 (15)
	Woody	1396 (17)	1461 (24)	1377 (6)	1355 (6)	1397 (14)
	Georgia cube	1376 (0)	1457 (7)	1373 (7)	1348 (15)	1384 (13)
Water temperature (°C)	Bare	13.9 (0.1)	3.0 (0.2)	10.7 (0.2)	25.9 (0.3)	13.4 (2.5)
	Woody	14.0 (0.1)	3.1 (0.1)	10.7 (0.2)	26.0 (0.1)	13.5 (2.5)
	Georgia cube	14.0 (0.1)	2.7 (0.1)	10.7 (0.2)	26.0 (0.1)	12.2 (2.5)
pH	Bare	7.46 (0.13)	7.64 (0.04)	7.87 (0.04)	7.99 (0.06)	7.74 (0.07)
	Woody	7.58 (0.03)	7.54 (0.03)	7.90 (0.07)	8.01 (0.09)	7.76 (0.07)
	Georgia cube	7.51 (0.02)	7.63 (0.02)	8.03 (0.04)	8.06 (0.11)	7.77 (0.07)

limnetic temperatures tend to be colder than hypolimnetic waters following fall turnover in north temperate lakes (Cole 1994). During warmer spring months, many fishes, such as centrarchids (e.g., Largemouth Bass, Bluegill, and *Lepomis cyanellus* Rafinesque [Green Sunfish]), move into the littoral zone to reproduce and feed (Hall and Werner 1977, Hatzenbeler and Bozek 2000, Keast et al. 1978). Fish distributions by season may also be influenced by changes in other water quality measurements. For example, fish may move away from areas of lower dissolved oxygen during certain times of the year (Hasler et al. 2009, Matthews et al. 1985). Fish use of all habitats in our study was highest when dissolved oxygen was generally lower (i.e., summer) compared to colder months, but none of our measures of dissolved oxygen were below critical thresholds for fish (< 5.0 mg/L; Doudoroff and Shumway 1970). Thus, the influence of water quality on seasonal use of fish structures may not have played a role in this single-year study. However, more sampling within a season is needed to capture the variability in water quality parameters.

Surprisingly, fish use was significantly higher in our novel Georgia cube complexes compared to existing habitat (trees). Research comparing fish use of artificial versus more natural habitat in marine waters has shown varying results. For example, Carr and Hixon (1997) found that fish abundance and species richness were higher on translocated natural compared to artificial reefs of similar area in the Caribbean Sea near Exuma, Bahamas. In contrast, Baumann et al. (2016) found that Georgia cubes deployed in two North Carolina reservoirs held more fish than evergreen trees and that fish use of evergreens decreased over time as the trees decomposed. Habitats composed of natural materials may provide more complexity for feeding and cover by fish compared to artificial structures, but structures of artificial materials may be designed to provide at least some similar structural complexity (Daugherty et al. 2014, Hunter and Sayer 2009). In our study, the Georgia cubes may have actually provided more cover and interstitial spacing than the existing tree habitats. Many of the downed trees in this waterbody were large (> 6 m height) but only partially submerged; thus, the trees may not have provided as much coverage for fish as possible. In addition, the trees had fallen into the water from the shore at different times. One site included a fairly new fallen tree (within 2 months prior to the study) while trees at the other sites had been there for a much longer period of time as noted by their degradation (little to no bark on the trunk, broken branches, etc.). Future research should continue to evaluate fish use of all structures to determine any longer-term changes in fish use as decomposition, degradation, or sedimentation of structures composed of natural or artificial materials progresses over time.

Another reason for differences in fish use of different habitats may be related to some other aspects of water quality that we did not measure as part of our study, including but not limited to measures of productivity or concentrations of potentially toxic substances. The influence of added habitat on lower trophic responses has been only minimally studied to date (Sass et al. 2019). Smokorowski et al. (2006) found that chlorophyll *a* concentration was higher among older, decaying coarse woody habitat than in newly added woody structure. Some concerns have been raised regarding potential leachates from artificial materials used to create habitat structure (Bolding et al. 2004, Gualtieri et al. 2005, Nelson et al. 1994), which could negatively impact fish use of such structures. In the one year of this study, the water quality parameters we measured did not differ among habitat types or appear to influence fish use of habitats. Thus, it appears that neither existing nor added habitats change water quality compared to the control (bare) sites, at least during the course of this study. However, other water quality parameters such as chlorophyll *a*, phosphorous, or contaminates may need to be measured in the future.

In all, the results of our study showed that fish were attracted to and used a novel, artificial structure more than existing habitat and that the additions of these habitats do not alter water quality, at least in the short term. Structures composed of artificial materials may last longer than those made of natural materials as the latter may experience decomposition over time

(Baumann et al. 2016). Evaluations of fish use of habitat can inform fisheries managers when planning habitat additions in small impoundments and reservoirs where habitat may be limiting. Further information is needed on the long-term changes in fish populations and their use across all habitat types, as well as the longevity of these benefits to assist in the planning and evaluation of habitat management plans.

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