Relationships Among Catch, Angler Satisfaction, and Fish Assemblage Characteristics of an Urban Small Impoundment Fishery

Tomas J. Ivasauskas, *North Carolina State University Department of Applied Ecology, Box 7617, 127 David Clark Labs, Raleigh, NC 27695*

Wilson N. Xiong, *North Carolina State University Department of Applied Ecology, Box 7617, 127 David Clark Labs, Raleigh, NC 27695*

Augustin C. Engman, *North Carolina State University Department of Applied Ecology, Box 7617, 127 David Clark Labs, Raleigh, NC 27695*

Jesse R. Fischer, *North Carolina State University Department of Applied Ecology, Box 7617, 127 David Clark Labs, Raleigh, NC 27695*

Thomas J. Kwak, *U.S. Geological Survey, North Carolina Cooperative Fish and Wildlife Research Unit, North Carolina State University Department of Applied Ecology, Box 7617, 127 David Clark Labs, Raleigh, NC 27695*

Kirk R. Rundle, *North Carolina Wildlife Resources Commission, Nashville, NC 27856*

Abstract: Urban fisheries provide unique angling opportunities for people from traditionally underrepresented demographics. Lake Raleigh is a 38-ha impoundment located on the North Carolina State University campus in Raleigh. Like many urban fisheries, little is known about angler use and satisfaction or how angling catch rate is related to fish availability in Lake Raleigh. We characterized the recreational fishery and fish assemblage with concurrent creel and boat electrofishing surveys over the course of one year. In total, 245 anglers were interviewed on 68 survey days. On average, anglers spent 1.7 h fishing per trip and caught 0.385 fish h^{-1}. A large proportion of anglers (43.9%) targeted multiple species, whereas 36.5% targeted largemouth bass (*Micropterus salmoides*), 10.0% targeted panfish (i.e., sunfishes [*Lepomis* spp.] and crappies [*Pomoxis* spp.]), and 9.6% targeted catfish (*Ameiurus* spp. and *Ictalurus* spp.). Most anglers (69.4%) were satisfied with their experience, and overall satisfaction was unrelated to catch rate. Pulsed-DC boat electrofishing was conducted on 25 dates, and 617 fish were sampled. Angler catch rate was unrelated to electrofishing catch rate, implying that anglers' catch rate was independent of fish density or availability. Our results demonstrate that even minimally managed urban fisheries can provide high angler satisfaction, with limited dedication of management resources.

Key words: human dimensions, creel survey, electrofishing

Journal of the Southeastern Association of Fish and Wildlife Agencies 4:31–38

Over 60% of the approximately 33 million anglers in the United States live in urban areas (U.S. Fish and Wildlife Service and U.S. Census Bureau 2012), where lentic aquatic systems provide valuable cultural and recreational ecosystem services, including recreational fishing (Hunt et al. 2008). Urban recreational fisheries offer fishing opportunities to traditionally underrepresented groups of people, such as minorities, poor, elderly, or disabled anglers (Balsman and Shoup 2008). The convenience of urban fishing is further expected to encourage participation and retention of time-restricted anglers and anglers with children (Balsman and Shoup 2008, Hutt and Neal 2010). Therefore, promoting and improving urban fisheries is a means to bolster nationwide interest in recreational fishing and increase recreational fishing license sales (Balsman and Shoup 2008, Hunt et al. 2008). All state inland fisheries management agencies engage in actively managing urban fisheries, and dedicated urban fishing programs are common in the United States (Hunt et al. 2008). However, managers often lack information about the characteristics of anglers who utilize these fisheries.

Estimates of angling pressure, catch, and harvest rates are essential to effectively manage fisheries but have been studied less frequently in urban systems. Catch and harvest rates are relatively high following fish stockings on intensively stocked urban lakes and ponds (Lang et al. 2008, Meneau 2008, Schultz and Dodd 2008). However, catch-and-release fishing practices are also common in some urban fisheries (Emme and Buynak 2008). Due to higher human population densities and limited fishing opportunities in urban areas, angling pressure on urban lakes and ponds is often much higher on a per-hectare basis than on rural lentic systems, but the average trip length for urban anglers tends to be shorter (Cross et al. 1991, Arlinghaus and Mehner 2004, Lang et al. 2008, Meneau 2008). Thus, management of these systems offers challenges and opportunities that are often distinct from more traditional public waterbodies.

Factors affecting angler satisfaction in urban fisheries are important for effective fisheries management but have been the focus of few studies (e.g., Hutt and Neal 2010). Urban and non-urban anglers have both been observed to fish primarily for recreation (as opposed to sustenance), and both groups place high value on catching fish (Schramm and Dennis 1993, Arlinghaus et al. 2008). Some studies indicated that variation in urban angler satisfaction is driven by the catch-related aspects of fishing (Arlinghaus and Mehner 2004, Hutt and Neal 2010, Greiner et al. 2016); whereas, others suggested that fish catch is not essential for a satisfactory fishing experience in the urban context (Emme and Buynak 2008, Mauk 2015). Additional findings about urban angler satisfaction include generally high satisfaction among urban anglers, an emphasis on aesthetics, tolerance of noise from road traffic, and acceptance of fishing in close proximity to other anglers; further, satisfaction is contingent on the availability of amenities such as bathrooms or shelter facilities (Balsman and Shoup 2008, Hutt and Neal 2010, Mahasuweerachai et al. 2010, Greiner et al. 2016). Thus, urban anglers may have different expectations and desires than non-urban anglers, which should be reflected in management strategies.

The Piedmont physiographic region in the southeastern United States is experiencing rapid urban expansion, which is projected to continue into the foreseeable future (Terando et al. 2014). Raleigh, North Carolina, is a large and growing metropolitan hub in this region with a population of nearly 500,000 as of July 2015. The North Carolina Wildlife Resources Commission (NCWRC) currently manages warmwater fisheries in eight small impoundments within the Raleigh area. The NCWRC actively encourages recreational fishing in these impoundments by working with community organizers to install appropriate amenities, improve access, and host community fishing events. However, angler satisfaction, fishing pressure, catch rates, and harvest rates are currently unknown for urban small impoundment fisheries in the area. The goal of our research was to better understand the fish and human dynamics of a Raleigh urban fishery to guide management strategies of urban fisheries in the region and contribute to the overall knowledge base of urban fisheries. The objectives of our study were to (1) describe characteristics and assess satisfaction of anglers, (2) estimate angler effort and catch rates in the fishery, (3) describe the fish assemblage in the impoundment, specifically near fishing areas, and (4) evaluate relationships between electrofishing catch rates and angler catch rates.

Study Area

Lake Raleigh is a 36-ha mesotrophic impoundment located on the Centennial Campus of North Carolina State University (NCSU) in Raleigh, North Carolina (Burkholder 1992). Constructed on Walnut Creek in 1900, the impoundment served as Raleigh's first and primary municipal water supply reservoir until 1927. In 1996, flooding associated with Hurricane Fran resulted in a failure of the dam, which was reconstructed in 2001 following sediment removal from the impoundment basin. The shoreline of Lake Raleigh is largely undeveloped and is primarily composed of hardwood and pine forest.

Fishing in Lake Raleigh was permitted beginning in 2007, from sunrise to sunset, on two handicap-accessible fishing piers and 150 m of designated shoreline. Fishing is prohibited from other shoreline areas, but is allowed from small non-motorized boats. Approximately 25 artificial fish habitats were situated within casting distance of piers and marked with buoys identifying their locations. These habitats utilized a design similar to one that was previously demonstrated to be superior for attracting fish in North Carolina impoundments (Baumann et al. 2016). Anglers can access Lake Raleigh through a variety of means: public parking is available, a major bus stop is located 0.4 km from the lake, and pedestrians or bicyclists may access the lake via the adjacent City of Raleigh Greenway. Small numbers of channel catfish (*Ictalurus punctatus*) have been infrequently stocked in Lake Raleigh (Wallace et al. 2011), but no other species have been stocked since reconstruction in 2001. Therefore, Lake Raleigh is currently managed as a self-sustaining warmwater fishery with largemouth bass (*Micropterus salmoides*), sunfish (*Lepomis* spp.), crappies (*Pomoxis* spp.), and various catfish species (*Ameiurus* spp. and *Ictalurus* spp.) as the primary gamefishes.

Methods

Angler Survey

An angler survey was designed and conducted using methods suggested by Pollock et al. (1994). The survey period was one year, from 6 December 2014 to 6 December 2015, and the survey schedule was established using a stratified random sample design. Strata were defined by season, day-type (weekday, holiday, or weekend), and time of day. The NCSU academic calendar was used to determine seasonality and holidays because we expected, a priori, that anglers would be primarily affiliated with the university. Equal effort was allocated to each of four seasons, where winter encompassed 6 December 2014–20 February 2015 and one survey conducted on 6 December 2015, spring encompassed 1 March 2015–9 May 2015, summer encompassed 10 May 2015–18 August 2015, and fall encompassed 19 August 2015–23 November 2015. Surveys were scheduled on approximately 12.5% of all weekdays and 25% of all holidays and weekend-days in each of the four seasons. This resulted in a total of 68 days with scheduled angler surveys. Survey shifts were conducted in the morning (beginning at sunrise) or afternoon (ending at sunset), randomly assigned within each day-type and season stratum, with equal effort allocated to each time period. The duration of shifts depended on seasonal daylight availability, as angling was only permitted during daylight hours. The shift length was 4 h for surveys conducted 1 November–25 January, 5 h for those conducted 5 February–4 May and 14 August–30 November, and 6 h for 11 May–1 August to reduce midday overlap of morning and afternoon angler surveys while ensuring complete coverage of daylight hours.

Angler surveys were conducted onsite using a standard questionnaire by creel clerks who were stationed at the boat ramp, which provided them with a vantage point for observing all pier- and bank-anglers and ensured interception of boaters who had completed trips. When possible, all anglers were intercepted for surveys at the end of their trip; all pier- and bank-anglers who stayed longer than the survey shift were interviewed prior to the end of the shift. Each member of an angler-party was interviewed separately. The survey addressed angler affiliation with NCSU, city of residence, fishing effort, choice of bait-type (i.e., live bait or artificial lures), targeted fishes, and whether they were fishing from a boat or not. Anglers who were not fishing from a boat (hereafter, collectively referred to as bank anglers) were also asked if their fishing effort was confined to the piers, the shoreline, or if they utilized both areas. Anglers were asked about the species of fish caught, released, and harvested. For the purposes of this study, species of fishes belonging to the genera *Lepomis* or *Pomoxis* were collectively referred to as panfish, species belonging to genera *Ictalurus* and *Ameiurus* were referred to as catfish, and largemouth bass and yellow perch (*Perca flavescens*) were each considered separately. Anglers were asked to individually rate satisfactions with their fishing experience and overall experience on a Likert-type scale as 'very dissatisfied,' 'dissatisfied,' 'neutral,' 'satisfied,' or 'very satisfied.'

To estimate total fishing effort and the associated standard error, we used the formulas presented by Pollock et al. (1994). Point counts of anglers were conducted on each day that surveys were conducted. Any person who was holding, tending, or carrying a fishing rod (or multiple fishing rods) was counted as an angler; accompanying non-anglers were not counted. Point counts were conducted at the beginning, midpoint, and end of each scheduled survey-shift, and the instantaneous count of anglers for a given shift was estimated as the arithmetic mean of the three counts. Angler effort for each day was quantified as

$$\hat{e}_i = I_i * T_i,$$

where I_i is the instantaneous count of anglers and T_i is shift length (h) on survey day i. This was then expanded to total effort as

$$\hat{E} = \Sigma_{i=1}^{n} (\hat{e}_i / \pi_i),$$

where π_i represents the total probability of sampling each shift within the stratum. Standard error was calculated as

$$SE(\hat{E}) = \sqrt{N^2 * (s^2/n)},$$

where s^2 is the variance of effort observations, n is number of days sampled within a stratum, and N is the number of days available for sampling within that stratum.

Percentages were used to describe angler attributes pertaining to NCSU affiliation, residency in Raleigh, fishing techniques, species targeted, area fished, and satisfaction. The average trip length was evaluated across surveyed anglers with completed trips only. Catch rates and harvest rates were calculated as the total number of fish divided by the corresponding effort. Mean catch rates for boat and bank anglers were compared with a Kruskal-Wallis test, which was chosen because of the abundance of zeros (no catch) in the data. The relationship between overall satisfaction and catch rate was determined using the Wilcoxon-Mann-Whitney U test where the Likert rating for overall satisfaction was specified as the classification variable and angler catch rate was treated as the independent variable. The relationship between fishing satisfaction and catch rate was assessed using a similar procedure. All analyses were conducted using SAS (SAS Institute 2012). A type I error rate (α) of 0.05 was applied for all statistical tests.

Fish Assemblage Sampling

The near-pier fish assemblage of Lake Raleigh was sampled using pulsed-DC boat electrofishing during 2015. Electrofishing was conducted no more than four days prior to an angler survey during morning hours (0800–1100). A total of 25 boat electrofishing surveys occurred from 4 April to 16 October. On all sampling occasions, electrofishing occurred at three stations; west pier, east pier, and south shoreline. Fixed transects of approximately 75 m were sampled for 7 min at each station. At the piers, transects encompassed a short length of adjacent shoreline and sections parallel to all sides of the pier, which was representative of the areas in Lake Raleigh where bank angling was permitted. The shoreline transect was oriented parallel to the south shoreline, where bank fishing was prohibited. All sampled fish were identified to species (or for age-0 fish, to the lowest possible taxonomic designation), measured (total length, TL, mm), and released. Only fish exceeding the minimum stock lengths (TL) were reported. Proportional size distribution (PSD) was calculated for largemouth bass and for each individual species of panfish using the length categories and formulas given in Neumann et al. (2012). Catch-per-unit-effort (CPUE) was expressed as fish h^{-1}, and was reported by season, using the dates specified for the survey strata.

We assessed the relationship between fish densities that were available for bank anglers to catch (i.e., near the fishing piers) and angler catch rates. Mean electrofishing CPUE of gamefish was calculated using the two fishing piers on each electrofishing sample date. Mean angler catch rates were calculated for all corresponding days where at least one angler was surveyed. The relationship between mean electrofishing CPUE and mean angler catch rates was tested using linear regression. Electrofishing CPUE of largemouth bass and panfish was pooled by season for each pier and the south shoreline, and was compared using a repeated measures ANOVA model.

Results

Angler Survey

In this study, 245 anglers were interviewed over a 12-month period. Anglers reported fishing for a combined total of 362.9 h, with an overall mean completed trip length per angler of 1.7 h. The total angling effort at Lake Raleigh over the one-year study was estimated at 3236 angler h (SE = 1381). Effort was highest during the summer and lowest during the winter and was apportioned equally between weekdays (49%) and weekends (51%; Figure 1). The majority of angling (78%) took place during afternoon hours.

Most Lake Raleigh anglers (90%) were from Raleigh, but only 35% were affiliated with NCSU as students, faculty, or staff. Most Lake Raleigh anglers (62%) used artificial lures, 28% used live bait, and 10% used a combination of the two. Bank anglers composed 86% of all interviews; among them, 64% reported that they confined their fishing to piers, 15% to shoreline, and 21% reported utilizing both areas. Anglers fishing from boats tended to fish longer ($\chi^2 = 24.27$, df = 1, $P < 0.0001$) and have higher catch rates ($\chi^2 = 6.48$, df = 1, $P = 0.0109$; Table 1). Bank anglers most frequently fished for multiple species, whereas boat anglers most frequently targeted largemouth bass (Table 2).

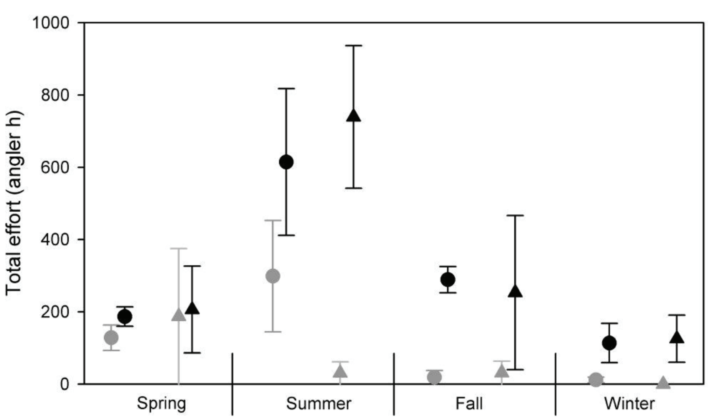

Figure 1. Estimates of total angler effort ($\hat{E}$) of the Lake Raleigh fishery from 6 December 2014 to 6 December 2015. Error bars indicate SE. Circles = weekends; triangles = weekdays; gray = morning; black = afternoon. Spring encompassed 1 March 2015–9 May 2015, summer encompassed 10 May 2015–18 August 2015, fall encompassed 19 August 2015–23 November 2015 and winter encompassed 6 December 2014–20 February 2015 and one survey conducted on 6 December 2015.

Table 1. Number surveyed, trip length, and catch and harvest rates (fish angler-h^{-1}) of bank- and boat-anglers at Lake Raleigh during each season from 6 December 2014 to 6 December 2015. Spring encompassed 1 March 2015–9 May 2015, summer encompassed 10 May 2015–18 August 2015, fall encompassed 19 August 2015–23 November 2015 and winter encompassed 6 December 2014–20 February 2015 and one survey conducted on 6 December 2015.

	Bank	Boat	Overall
Number of interviews	211	34	245
Spring	57	7	64
Summer	96	23	119
Fall	39	2	41
Winter	19	2	21
Trip length (h)	1.38	2.56	1.70
Spring	1.65	2.32	1.75
Summer	1.43	2.98	1.71
Fall	1.71	4.00	1.78
Winter	1.13	2.50	1.13
Catch rate, overall	0.351	0.513	0.385
Spring	0.371	0.929	0.433
Summer	0.452	0.413	0.445
Fall	0.214	0.625	0.234
Winter	0.095	0.000	0.086
Catch rate, largemouth bass	0.029	0.308	0.068
Spring	0.000	0.743	0.091
Summer	0.049	0.222	0.082
Fall	0.033	0.000	0.031
Winter	0.000	0.000	0.000
Catch rate, panfish	0.297	0.150	0.275
Spring	0.370	0.114	0.277
Summer	0.383	0.190	0.347
Fall	0.146	0.000	0.139
Winter	0.000	0.000	0.000
Catch rate, catfish	0.03	0.055	0.033
Spring	0.037	0.071	0.041
Summer	0.011	0.000	0.009
Fall	0.034	0.625	0.063
Winter	0.286	0.000	0.086
Harvest rate, overall	0.080	0.031	0.073
Spring	0.090	0.000	0.080
Summer	0.088	0.048	0.080
Fall	0.085	0.000	0.081
Winter	0.000	0.000	0.000

The mean angler catch rate was 0.385 fish h^{-1} (SD = 1.084). The point estimate of mean angler catch rate was highest during spring and lowest during winter (Figure 2). All anglers interviewed in January and February reported catching no fish. Anglers were typically content with their overall experience and fishing experience at Lake Raleigh (Table 3). The overall satisfaction of anglers was not related to their catch rate ($\chi^2 = 8.88$, df = 4, $P = 0.0642$), but fish-

Table 2. Percentage of anglers targeting various groups of fishes in Lake Raleigh in four seasons from 6 December 2014 to 6 December 2015. Spring encompassed 1 March 2015–9 May 2015, summer encompassed 10 May 2015–18 August 2015, fall encompassed 19 August 2015–23 November 2015 and winter encompassed 6 December 2014–20 February 2015 and one survey conducted on 6 December 2015.

	Largemouth bass	Panfish	Catfish	Multiple species
Overall	36.5	10.0	9.6	43.9
Bank-anglers	30.6	11.2	11.2	46.9
Spring	28.8	11.5	7.7	51.9
Summer	30.3	14.6	5.6	49.4
Fall	33.3	8.3	13.9	44.4
Winter	31.6	0.0	42.1	26.3
Boat-anglers	72.8	3.0	0.0	24.2
Spring	71.4	0.0	0.0	28.6
Summer	82.6	4.3	0.0	13.0
Fall	0.0	0.0	0.0	100.0
Winter	0.0	0.0	0.0	100.0

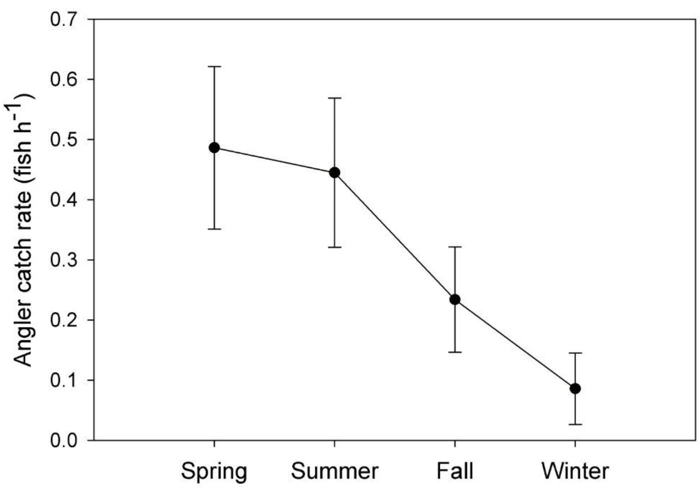

Figure 2. Mean seasonal catch rates (all species combined) among Lake Raleigh anglers interviewed from 6 December 2014 to 6 December 2015. Error bars represent SE. Spring encompassed 1 March 2015–9 May 2015, summer encompassed 10 May 2015–18 August 2015, fall encompassed 19 August 2015–23 November 2015 and winter encompassed 6 December 2014–20 February 2015 and one survey conducted on 6 December 2015.

Table 3. Percentage of anglers interviewed from 6 December 2014 to 6 December 2015 that were Very Satisfied (VS), Satisfied (S), Neutral (N), Dissatisfied (DS), and Very Dissatisfied (VDS) with their overall and fishing experiences.

	VS	S	N	DS	VDS
Overall Satisfaction	20.5	48.9	24.9	4.4	1.3
Bank-anglers	20.5	47.2	26.7	4.1	1.5
Boat-anglers	21.2	60.6	15.2	3.0	0.0
Fishing Satisfaction	8.7	55.0	21.4	13.1	1.8
Bank-anglers	9.7	51.3	23.1	13.9	2.1
Boat-anglers	3.0	78.8	12.1	6.1	0.0

ing satisfaction was related to overall catch rate ($\chi^2 = 17.46$, df = 4, $P = 0.0016$).

Lake Raleigh angler residency, effort, satisfaction, and catch were compared to available results from six larger impoundments in North Carolina (Table 4). In comparison to these, Lake Raleigh had a higher percentage of local anglers, relatively high angler satisfaction, and the lowest catch rates. On a per-hectare basis, Lake Raleigh received a comparable amount of pressure to some larger more intensively managed fisheries.

Fish Assemblage

A total of 617 gamefish exceeding the minimum stock length were sampled from 4 April to 16 October 2015 (Table 5). The PSD of largemouth bass was 78 and the PSDs of the various panfish species ranged from 7–44 (Table 6). For largemouth bass, CPUE did not differ among stations ($F = 0.88$, df = 70, $P = 0.4182$) but was related to season ($F = 3.18$, df = 70, $P = 0.0475$; Figure 3). Conversely, CPUE of panfish differed significantly among stations ($F = 17.69$, df = 70, $P < 0.0001$) but not among seasons ($F = 0.33$, df = 70, $P = 0.7222$; Figure 3).

Of the 25 dates when electrofishing was conducted, anglers were encountered and angler catch rates were calculated for 22

Table 4. Results of angler surveys conducted at various North Carolina impoundment fisheries. All metrics were estimated over a one-year period. NR = Not reported.

		Size	*Angler effort*		Trip length	Local	Catch rate	Satisfied
Fishery	Year(s)	(ha)	(angler h)	($h\ ha^{-1}$)	(h)	(%)	($fish\ h^{-1}$)	(%)
Lake Raleigh	2014–2015	36	3236	89.9	1.7	90	0.39	69
Cheoah Reservoir[a]	1998–1999	249	11685	46.9	5.3	52	0.54	59
Santeetlah Lake[a]	1998–1999	1160	55788	48.1	5.3	79	0.57	58
Harris Lake[b]	1997–1998	1600	188948	118.1	5.1	NR	0.90	24
Lake James[c]	1997–1998	2634	226254	85.9	NR	57	0.58	27
Lake Gaston[d]	2007–2008	8215	335562	40.8	NR	24	0.85	41
Lake Matamuskeet[e]	2014	16314	202338	12.4	NR	16	1.13	NR

a. Yow et al. 2002
b. Jones et al. 2000
c. Yow 2005
d. Rundle et al. 2009
e. Dockendorf et al. 2015

Table 5. Gamefish sampled from Lake Raleigh by boat electrofishing from 4 April to 16 October 2015. Sample size (N) included fish that exceeded the minimum stock length. Catch-per-unit-effort (CPUE) is expressed as fish h^{-1}, and associated SE is given in parentheses.

Common name	Scientific name	N	CPUE
Black Bass			
Largemouth bass	*Micropterus salmoides*	82	9.1 (1.3)
Panfish			
Bluegill	*Lepomis macrochirus*	234	29.8 (2.6)
Redear sunfish	*Lepomis microlophus*	93	14.5 (1.6)
Warmouth	*Lepomis gulosus*	68	7.7 (1.0)
Black crappie	*Pomoxis nigromaculatus*	50	5.7 (1.2)
Green sunfish	*Lepomis cyanellus*	18	1.9 (1.1)
White crappie	*Pomoxis annularis*	7	0.8 (0.4)
Catfish			
Brown bullhead	*Ameiurus nebulosus*	7	0.9 (0.3)
Yellow bullhead	*Ameiurus natalis*	4	0.4 (0.2)
Black bullhead	*Ameiurus melas*	2	0.1 (0.1)
Channel catfish	*Ictalurus punctatus*	1	0.1 (0.1)
White catfish	*Ameiurus catus*	1	0.1 (0.1)
Perch			
Yellow perch	*Perca flavescens*	47	5.8 (1.3)

Table 6. Proportional size distributions (PSD) of largemouth bass and panfish species collected in electrofishing samples from 4 April to 16 October 2015 from Lake Raleigh. Only species where at least 50 individuals were collected are reported.

Species	PSD
Largemouth bass	78
Black crappie	44
Bluegill	7
Redear sunfish	22
Warmouth	10

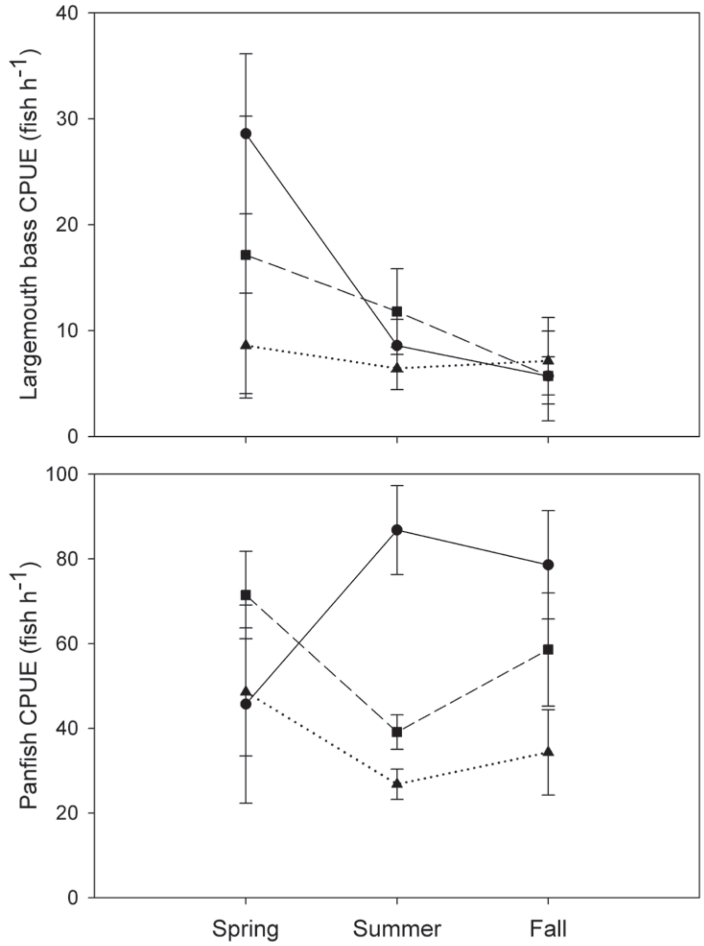

Figure 3. Mean electrofishing catch rates of largemouth bass and panfish across three seasons at each of three sampling stations on Lake Raleigh. East pier = dotted line and triangles; West pier = dashed line and squares; South shoreline = solid lines and circles. Error bars represent SE. Spring encompassed 4 April 2015–9 May 2015, summer encompassed 10 May 2015–18 August 2015, and fall encompassed 19 August 2015–16 October 2015.

corresponding occasions. On three occasions, electrofishing was conducted but no anglers were encountered during the paired angler survey. Average daily angler catch rates were unrelated to electrofishing catch rates at the piers ($t = -1.27$, df = 21, $P = 0.2181$).

Discussion

Characteristics of Lake Raleigh urban anglers were distinct from anglers that utilize other North Carolina fisheries in many respects. When compared with anglers of larger rural impoundments in North Carolina, a higher proportion of Lake Raleigh anglers were local and fished for shorter durations. Fishing 'close-to-home' and taking short fishing trips are typical findings of prior studies that have characterized urban anglers (Arlinghaus and Mehner 2004, Lang et al. 2008). The majority of anglers at Lake Raleigh fished from piers or from the bank, whereas the majority of recreational fishing in North Carolina's larger impoundments is conducted from boats (e.g., Yow et al. 2002). Bank fishing at urban small impoundments is often facilitated by designed access points; whereas, access to bank fishing in other settings can be difficult or unsafe (Yow et al. 2002, Arlinghaus and Mehner 2004).

Compared to other systems in North Carolina, angler catch rates on Lake Raleigh were low, but overall and fishing satisfaction was high for Lake Raleigh anglers. This result appears to contrast with some prior findings, which indicate that urban angler satisfaction was related to the catch-related aspects of fishing (Arlinghaus and Mehner 2004, Hutt and Neal 2010, Greiner et al. 2016). However, satisfaction with the catch-related aspects of fishing is dependent upon angler expectations (Hampton and Lackey 1975).

Thus, Lake Raleigh anglers may have low catch-related expectations, making them satisfied with their fishing experience despite low catch rates. Unlike some other urban fisheries, Lake Raleigh is minimally managed, with infrequent supplemental stockings and no fish feeders; therefore, the gamefish assemblage comprised self-sustaining populations of native warmwater species. Anglers who are aware of the lack of management practices may anticipate low catch rates. Similarly, the prior fishing experiences of the interviewed anglers are unknown, and if most Lake Raleigh anglers mainly fish at Lake Raleigh or other lakes with low catch rates, then we presume that they would have low catch-related expectations for fishing.

Our observation of greater levels of overall satisfaction than fishing satisfaction indicates that the non-catch-related aspects of the fishing experience also contributed to a positive experience for Lake Raleigh anglers. Familiarity is one factor that has been shown to be a predictor of angler satisfaction on urban and community fishing lakes (Greiner et al. 2016). High levels of familiarity can be expected for Lake Raleigh anglers, who were 90% local. Since it is on-campus and maintained by NCSU, Lake Raleigh is safe, scenic, and accessible, with many amenities required by anglers (e.g., bathroom access, sitting areas, garbage receptacles). All of these features have been shown to contribute to satisfactory experiences for urban anglers (Balsman and Shoup 2008, Hutt and Neal 2010, Mahasuweerachai et al. 2010, Greiner et al. 2016). Although we did not ask anglers about specific, non-fishing related aspects of their experience, several anecdotally commented that they simply enjoyed being outdoors and having the opportunity to fish close to their home. This underscores the importance of urban small impoundments and their fisheries, which can be a valuable cultural and natural resource even when management intensity and catch rates are low.

Nearly half of Lake Raleigh anglers were non-selective in their fishing, indicating a conspicuous lack of specialization. Creel clerks noted that some anglers also indicated a lack of knowledge of appropriate techniques for catching fish in Lake Raleigh, which may have contributed to the overall low catch-rates. However, similar to most fisheries, Lake Raleigh anglers probably represented a variety of motivations, expectations, and skill levels. For example, anglers fishing from boats achieved higher catch rates than those fishing from piers or from the bank. The greater catch rate for anglers in boats could be attributed to higher skill level or their ability to access habitats and areas of the lake that receive less fishing pressure.

The lack of relation between electrofishing and angler catch rates implied that angler catch was independent of fish density or availability. Panfish had a low catch rate by anglers, despite the high relative abundance in the sampled fish assemblage. The high proportion of small panfish in the assemblage may not be vulnerable to angling, as size-selectivity on panfish is common among anglers due to the use of large-sized hooks and gape limitations (Miranda and Dorr 2000, Cooke et al. 2005). Although relatively few anglers reported targeting panfish exclusively, many of the anglers that were fishing for multiple species included panfish as a potential target. Angler catch rates of largemouth bass by bank anglers were also low, despite the relatively high proportion of directed effort for this species. Electrofishing catch rates of largemouth bass indicated limited availability near the fishing piers; this, combined with concentrated angling, may have potentially resulted in reduced vulnerability to catch (Anderson and Heman 1969, Siepker et al. 2006). Therefore, angler behavior, limited angling locations, and tackle size may have contributed to low angling catch rates on Lake Raleigh.

The onsite surveys applied in our study proved to be an effective means to characterize the Lake Raleigh fishery and the anglers that use it. Although this study provided insights into the satisfaction levels of users of urban small impoundments, it did not address angler motivations or expectations. Future surveys in North Carolina and other states should examine motivations of anglers choosing to fish at urban small impoundments, given other regional options. Many universities have on-campus fisheries, yet the literature lacks any comprehensive studies of users of such resources. This study indicates that urban fisheries on university campuses can provide recreational opportunities for both university-affiliated anglers and the greater urban community. Furthermore, even minimally managed urban fisheries like Lake Raleigh can provide high angler satisfaction and societal benefit with limited dedication of management resources.

Acknowledgments

We thank James Wehbie and Spencer Gardner for field work assistance. This manuscript benefitted from comments given by three anonymous reviewers and the associate editor, Steve Sammons. Brian Irwin also provided a constructive manuscript review. The North Carolina Cooperative Fish and Wildlife Research Unit is jointly supported by North Carolina State University, North Carolina Wildlife Resources Commission, U.S. Geological Survey, U.S. Fish and Wildlife Service, and Wildlife Management Institute. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Literature Cited

Anderson, R.O. and M.L. Heman. 1969. Angling as a factor influencing the catchability of largemouth bass. Transactions of the American Fisheries Society 98:317–320.

Arlinghaus, R., M. Bork, and E. Fladung. 2008. Understanding the heterogeneity of recreational anglers across an urban-rural gradient in a metropolitan area (Berlin, Germany), with implications for fisheries management. Fisheries Research 92:53–62.

——— and T. Mehner. 2004. A management-orientated comparative analysis of urban and rural anglers living in a metropolis (Berlin, Germany). Environmental Management 33:331–44.

Balsman, D. M. and D. E. Shoup. 2008. Opportunities for urban fishing: developing urban fishing programs to recruit and retain urban anglers. Pages 31–40 *in* R. T. Eades, J. W. Neal, T. J. Lang, K. M. Hunt, and P. Pajak, editors. Urban and community fisheries programs—development, management, and evaluation. American Fisheries Society, Symposium 67, Bethesda, Maryland.

Baumann, J. R., N. C. Oakley, and B. J. McRae. 2016. Evaluating the effectiveness of artificial fish habitat designs in turbid reservoirs using sonar imagery. North American Journal of Fisheries Management 36:1437–1444.

Burkholder, J. M. 1992. A study of water quality in Lake Raleigh. Project 50165, Report UNC-WRRI-92-264. North Carolina State University, Raleigh, North Carolina.

Cooke, S. J., B. L. Barthel, C. D. Suski, M. J. Siepker, and D. P. Phillip. 2005. Influence of circle hook size on hooking efficiency, injury and size selectivity of bluegill with comments on circle hook conservation benefits in recreational fisheries. North American Journal of Fisheries Management 25:211–219.

Cross, T. K., T. J. Polomis, and R. A. Davis. 1991. Use of channel catfish to create an urban fishery in Lions' Lake, Mankato, Minnesota. Minnesota Department of Natural Resources, Division of Fish and Wildlife, Section of Fisheries, Investigational Report 407, St. Paul, Minnesota.

Dockendorf, K. J., K. M. Potoka, and C. D. Thomas. 2015. Lake Mattamuskeet creel survey, 2014. North Carolina Wildlife Resources Commission, Federal Aid in Sport Fish Restoration, Project F-108, Final Report, Raleigh, North Carolina.

Emme, K. A. and G. L. Buynak. 2008. Year-one evaluation of Kentucky's urban fishing program. Pages 333–346 *in* R. T. Eades, J. W. Neal, T. J. Lang, K. M. Hunt, and P. Pajak, editors. Urban and community fisheries programs—development, management, and evaluation. American Fisheries Society, Symposium 67, Bethesda, Maryland.

Greiner, M. J., D. O. Lucchesi, S. R. Chipps, and L. M. Gigliotti. 2016. Community fisheries in eastern South Dakota: angler demographics, use, and factors influencing satisfaction. Human Dimensions of Wildlife 21:254–263.

Hampton, E. L. and R. T. Lackey. 1975. Analysis of angler preferences and fisheries management objectives with implications for management. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 29:310–316.

Hunt, K. M., H. L. Schramm, T. J. Lang, J. W. Neal, and C. P. Hutt. 2008. Status of urban and community fishing programs nationwide. Pages 177–202 *in* R. T. Eades, J. W. Neal, T. J. Lang, K. M. Hunt, and P. Pajak, editors. Urban and community fisheries programs—development, management, and evaluation. American Fisheries Society, Symposium 67, Bethesda, Maryland.

Hutt, C. P. and J. W. Neal. 2010. Arkansas urban resident fishing site preferences, catch related attitudes, and satisfaction. Human Dimensions of Wildlife 15:90–105.

Jones, T. W., W. J. Collart, D. Hinshaw, and S. Van Horn. 2000. Harris Lake creel survey, 1997–98. North Carolina Wildlife Resources Commission, Division of Inland Fisheries, Raleigh.

Lang, T. J., J. W. Neal, and C. P. Hutt. 2008. Stocking frequency and fishing quality in an urban fishing program in Arkansas. Pages 379–390 *in* R. T. Eades, J. W. Neal, T. J. Lang, K. M. Hunt, and P. Pajak, editors. Urban and community fisheries programs—development, management, and evaluation. American Fisheries Society, Symposium 67, Bethesda, Maryland.

Mahasuweerachai P., T. A. Boyer, D. M. Balsman, and D. E. Shoup. 2010. Estimating demand for urban fisheries management: an illustration of conjoint analysis as a tool for fisheries managers. North American Journal of Fisheries Management 30:1339–1351.

Mauk, R. J. 2015. Angler catch, harvest, and characteristics at Neighborhood Fishin' Program lakes. Texas Parks and Wildlife Department, Inland Fisheries Division. Management Data Series No. 288, Austin, Texas.

Meneau, K. 2008. The St. Louis Urban Fishing Program. Pages 227–238 *in* R. T. Eades, J. W. Neal, T. J. Lang, K. M. Hunt, and P. Pajak, editors. Urban and community fisheries programs—development, management, and evaluation. American Fisheries Society, Symposium 67, Bethesda, Maryland.

Miranda, L. E. and B. S. Dorr. 2000. Size selectivity of crappie angling. North American Journal of Fisheries Management 20:706–710.

Neumann, R. M., C. S. Guy, D. W. Willis. 2012. Length, weight, and associated indices. Pages 637–676 *in* A. V. Zale, D. L. Parrish, and T. M. Sutton, editors. Fisheries Techniques. 3rd edition. American Fisheries Society, Bethesda, Maryland.

Pollock, K. H., C. M. Jones, and L. T. Brown. 1994. Angler survey methods and their applications in fisheries management. American Fisheries Society, Special Publication 25, Bethesda, Maryland.

Rundle, K., B. Collart, and B. McRae. 2009. Lake Gaston creel survey, 2007–2008. North Carolina Wildlife Resources Commission, Federal Aid in Sport Fish Restoration, Project F-23, Final Report, Raleigh, North Carolina.

SAS Institute, Inc. 2012. SAS system for linear models. Release 9.4. Cary, North Carolina.

Schramm, H. L. and J. A. Dennis. 1993. Characteristics and perceptions of users and nonusers of an urban fishery program in Lubbock, Texas. North American Journal of Fisheries Management 13:210–216.

Schultz, R. D. and B. J. Dodd. 2008. Characteristics of an Iowa put-and-take rainbow trout fishery and associated economic benefits. Pages 391–401 *in* R. T. Eades, J. W. Neal, T. J. Lang, K. M. Hunt, and P. Pajak, editors. Urban and community fisheries programs—development, management, and evaluation. American Fisheries Society, Symposium 67, Bethesda, Maryland.

Siepker, M. J., K. G. Ostrand, and D. H. Wahl. 2006. Effects of angling on feeding by largemouth bass. Journal of Fish Biology 69:783–793.

Terando, A. J., J. Costanza, C. Belyea, R. R. Dunn, A. McKerrow, and J. A. Collazo. 2014. The southern megalopolis: using the past to predict the future of urban sprawl in the Southeast U.S. PloS one 9:e102261.

U.S. Fish and Wildlife Service, and U.S. Census Bureau. 2012. 2011 National survey of fishing, hunting, and wildlife-associated recreation. U.S. Government Printing Office, Washington, D.C.

Wallace, B. C., D. M. Weaver, and T. J. Kwak. 2011. Efficiency of baited hoop nets for sampling catfish in southeastern U.S. small impoundments. Pages 581–588 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society Symposium 77, Bethesda, Maryland.

Yow, D. L. 2005. Lake James creel survey, 1997–1998. North Carolina Wildlife Resources Commission, Federal Aid in Fish Restoration, Project F-24, Raleigh, North Carolina.

———, C. S. Loftis, and E. Ganus. 2002. Creel surveys of Santeetlah, Cheoah, Calderwood, and Chilhowee Reservoirs, 1998–1999. North Carolina Wildlife Resources Commission, Federal Aid in Fish Restoration, Project F-24, Raleigh, North Carolina.