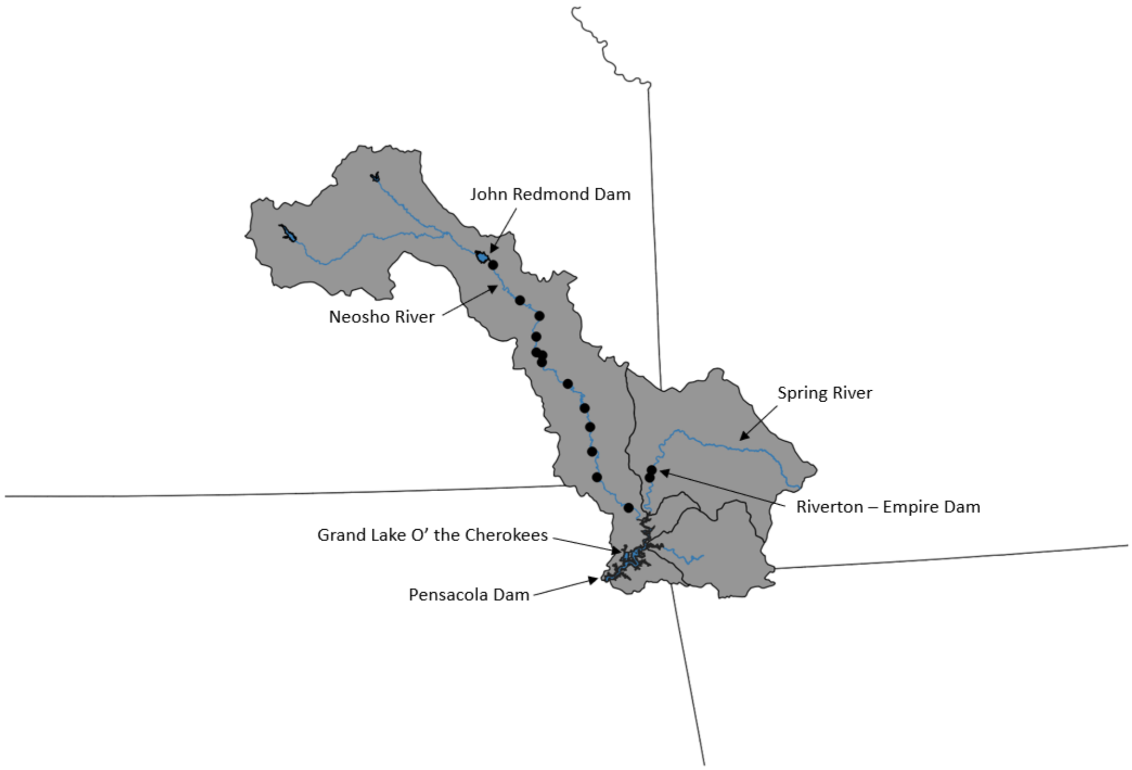
Project Title: Distribution and Population Demographics of Bighead Carp in the Neosho River-Grand Lake System to Inform Removal

Geographic Location: Map of Project Area (unlabeled dots indicate lowhead dam location):



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Participating Agencies: Oklahoma Department of Wildlife Conservation (ODWC), Missouri State University (MSU)

Statement of Need: Introduced invasive carps (bighead carp, black carp, grass carp, and silver carp) have become established in many portions of the Mississippi River Basin (Jennings 1998; Kolar et al. 2005). The feeding habits and population densities of invasive carps cause significant ecological harm where populations become established (Schrank et al. 2003; Irons et al. 2007; Sampson et al. 2009; Solomon et al. 2015; Phelps et al. 2017). The resulting diminished opportunity for fishing (recreational and commercial), boating, and other wildlife-associated recreation causes significant negative economic impact.

Bighead carp are occasionally captured within the Neosho River/Grand Lake system, but very little targeted sampling has occurred in either Kansas or Oklahoma. Existing bighead carp records are from a combination of public captures (primarily from paddlefish anglers) and incidental capture of bighead carp by ODWC while sampling for other fishes. Due to the limitations of the existing data, the distribution and abundance of bighead carp in the system is unknown.

This population of bighead carp also represents the only known population of either species of bigheaded carps in the United States to be potentially reproducing in a reservoir completely isolated from other populations. This provides a unique opportunity to learn about invasive carp and test ideas for removal or suppression in this type of system. Reservoir systems are incredibly important recreationally and economically in the United States. As invasive carp spread up Mississippi River tributaries and congregate below reservoir dams, the risk of introduction of invasive carp to these reservoirs increases; as does the need to learn more about how to manage invasive carp populations in reservoirs.

The sampling being conducted in this project will fill in knowledge gaps on invasive carp distribution in the Neosho-Grand Lake system, which supports Lower Mississippi River Strategy 2.4 [Implement contract surveillance or targeted invasive carp sampling to monitor the distribution and abundance of invasive carps. (National Goal 2)]. Due to suspected low bighead carp density in the system, the use of eDNA sampling is planned, which supports strategy Lower Mississippi River Strategy 2.5 [Use eDNA testing to guide early detection efforts. (National Goal 2)] Sampling will also occur in portions of the basin where it is unknown if bighead carp occur in line with Lower Mississippi River Strategy 2.6 [Use new technology and techniques to aid in the detection of invasive carps outside their known distribution. (National Goal 2)]

This project is planned as a stepping-stone to future work. Bighead carp density and reproduction are presumably low in the system, which potentially provides an opportunity to suppress or eradicate the population prior to densities and impacts increasing. This project is designed to provide guidance on how, where, and when to capture bighead carp in this system as well as provide insight into the number of fish that are present.

Project Objectives:

1. Identify locations of presence and upstream extent of bighead carp population within the Neosho River – Grand Lake system.
2. Collect baseline population demographic information including relative abundance, age and growth, and size structure.
3. Determine broadscale movements within the Neosho River system using otolith microchemistry.
4. Identify locations within the Neosho River – Grand Lake system for containment, removal, and/or eradication efforts.

Project Highlights:

- KDWP has contracted with MSU to complete project objectives.
- MSU crews have identified accessible sampling locations and have been actively collecting data within the Neosho River – Grand Lake system throughout 2021 and 2022.
- Fishing guides and anglers have increased reporting of bighead carp in the system in response to interest generated by the ongoing project.
- Sampling indicates that bighead carp are likely very rare in the Neosho – Grand Lake system.

- MSU will complete data analysis and provide final report by June 2023.

Methods: KDWP coordinates and serves in a guidance role. KDWP has contracted Missouri State University (MSU), who is conducting the project activities.

Objective 1.
Newly emerging protocols (implemented by USFWS) have been developed using eDNA that allow for quickly assessing the distribution and relative abundance of fishes. In cases where an individual species may be rare or difficult to detect using traditional fisheries sampling gear, eDNA provides a cost effective alternative for fisheries monitoring programs.

Invasive carp environmental DNA sampling is being conducted throughout the Neosho River-Grand Lake System [figure 1]. Sampling is in progress and will occur throughout the performance period May 2021-March 2023 at spatially selected sites throughout the system. This program is using existing eDNA protocols utilized by the USFWS. The program is using already "in place" infrastructure (i.e., existing eDNA collection and processing approaches) to analyze eDNA samples.

Furthermore, sampling for invasive carp is occurring at the same sites as above (at eDNA locations if feasible) using a defined compliment of gill nets, trammel nets, and electrofishing throughout the performance period. For each sample, fishes are identified, quantified (catch per unit effort) measured (to the nearest mm), and weighed (to the nearest gram) in the field. As a point of protocol, macrohabitat type (e.g., channel border, island, tailwater, tributary, main channel, backwater/embayment) and mesohabitat (e.g., water depth, velocity, substrate) is also recorded at each sampling site (allowing for quantification of habitat use).

Objective 2
Our goal is to collect as many bigheaded carp as possible throughout Neosho River-Grand Lake System from objective one above (including fish from anglers or other agency sampling). At time of collection, invasive carp are measured (total length; nearest mm for size structure Phelps and Willis 2013), weighed (nearest g), and otoliths removed for ageing (Seibert and Phelps 2013, Phelps et al. 2017). Invasive carp are also necropsied or externally viewed to determine sex (Wolf et al. 2018), reproductive potential (reproductive stages; Seibert et al. 2015 for a similar approach), total gonad weight, and egg counts. Stomach analysis will also be conducted to determine forage items and abundance. Using these population-level attribute data, the following will be constructed; length-frequency distributions, age-frequency distributions, condition (via length-weight regressions), sex ratios, fecundity, gonadosomatic index, and size structure index (proportional size distribution).

Furthermore, the dynamic rate functions will be estimated using the following methods:
To determine the relative number of invasive carp that are entering (i.e., recruiting) the systems each year, the number of fish in each year class will be quantified. Ages derived from otoliths will be used to determine recruitment patterns. For each age class present throughout the Neosho River-Grand Lake System, we will quantify the relative strength or weakness of each cohort within each reach using the residual method. Specifically, positive residual values from the

regression would indicate a relatively strong year class while negative residuals would indicate weak year classes. Recruitment variability will be quantitatively analyzed using recruitment coefficient of determination. Mortality rates of the invasive carp in the Neosho River-Grand Lake System will be determined using a catch-curve approach. Catch curves will be generated by summing the number of fish caught per age class. These data will allow for the development of individual regression models to estimate instantaneous mortality. Instantaneous mortality rate (Z), which will be used to determine the total annual mortality ($A = 1- e^{-Z}$) for selected fishes from each river reach. Growth will be estimated for invasive carp by determining the mean length at age. Mean-length at age data will be incorporated into Fisheries Analysis and Modeling Simulator and will be used to model growth using a von Bertalanffy approach. The equation generated using the von Bertalanffy growth model is $Lt = L\infty(1-e(-K(t-t0))$; where, Length infinity ($L\infty$) is the theoretical maximum length that a fish can achieve, K is the growth constant or growth rate of the population, and t0 is the theoretical length at time zero (i.e., age 0).

Given the dynamic rate information (i.e., growth, mortality, maximum age, length-weight regression, natural mortality, and male to female ratios) obtained above, we will use the yield-per-recruit modeling option in FAMS (Slipke and Maceina 2014) to determine the relative exploitation rate to overfish the invasive carp population. FAMS uses the Jones (1957) modification of the Beverton– Holt equilibrium yield equation developed by Ricker (Ricker 1975). Within the modelling interface of FAMS, we will use both the yield-per-recruit (YPR) and the static spawning potential ratio (SPR) option. This modeling approach assumes fixed recruitment and all simulations will be started with an initial population size of 1,000 recruits. This will ultimately allow the evaluation of the relative influence of many exploitation rates simultaneously on the population (Slipke and Maceina 2014). Using FAMS, Yield-per- recruit (YPR) and spawning potential ratio (SPR) will be assessed for various exploitation rates in 5% intervals, (i.e., 5% – 95%) with invasive carp of varying target harvest lengths

Objective 3

Recent research has demonstrated that fishes that reside in the Upper Mississippi, Middle Mississippi, Ohio, Missouri, or Illinois rivers can be distinguished from one another using naturally occurring, river-specific chemical “signatures” present in fish otoliths, fin spines, and fin rays. Fish hard parts contain a permanent chronological record of the “signatures” representing environments an individual fish has occupied during its lifetime, enabling reconstruction of that fish’s environmental history through sub-sampling for isotopic and elemental analysis across the hard part (Carlson et al. 2017). This approach is currently being applied to identify natal environments and immigration patterns of adult invasive carps in the Illinois River, Missouri River, and Mississippi River.

We are in the process of using a similar approach as above to identify natal/nursery environment throughout the Neosho River, Spring River, and Grand River system and characterize movement patterns for all invasive carps collected throughout the system through analyses of trace elements or isotopes within fish hard parts. Fishes are being collected using a variety of gears, principally electrofishing, gill nets, angling, and trammel nets (see objective one). Fish hard parts (e.g., otoliths) are extracted from each fish (from objective one); one structure from each fish will be embedded in epoxy, sectioned, cleaned, and analyzed for trace elements or isotopic composition using mass spectrometry. Trace element or isotopic signature at the core will be used to identify natal environment for each fish via comparison with established signatures indicative of residency in each of the river segments listed above. Changes in elemental composition along the fish hard part will be used to infer frequency and timing of immigration into various river reaches from other river segments. Additional water samples will need to be collected overtime to bolster the water chemical library and ensure temporal consistency in water chemistry.

Objective 4
Using insight from information from the 3 objectives above, project participants will enter all data into a standardized database and share with all project partners. Discussions among partnering agencies will occur and an executive summary and final project report will be constructed to determine locations within the Neosho River – Grand Lake system for containment, removal, and/or eradication efforts. MSU will send regular updates to project partners as samples are processed, to inform the group of any new findings. These data will help inform managers of the current status of invasive carp populations in the Neosho River – Grand Lake system. Project partners will disseminate these findings to the basin planning committee, which will be used to guide the allocation of future management efforts to meet the needs of the LMR basin. An executive summary will be provided by June 2023.

Results and Discussion: This project is still in the data analysis phase of the project. The final report from MSU is contracted to be completed by June of 2023. Following are preliminary data summaries [tables 1-9].

Tables and Figures:

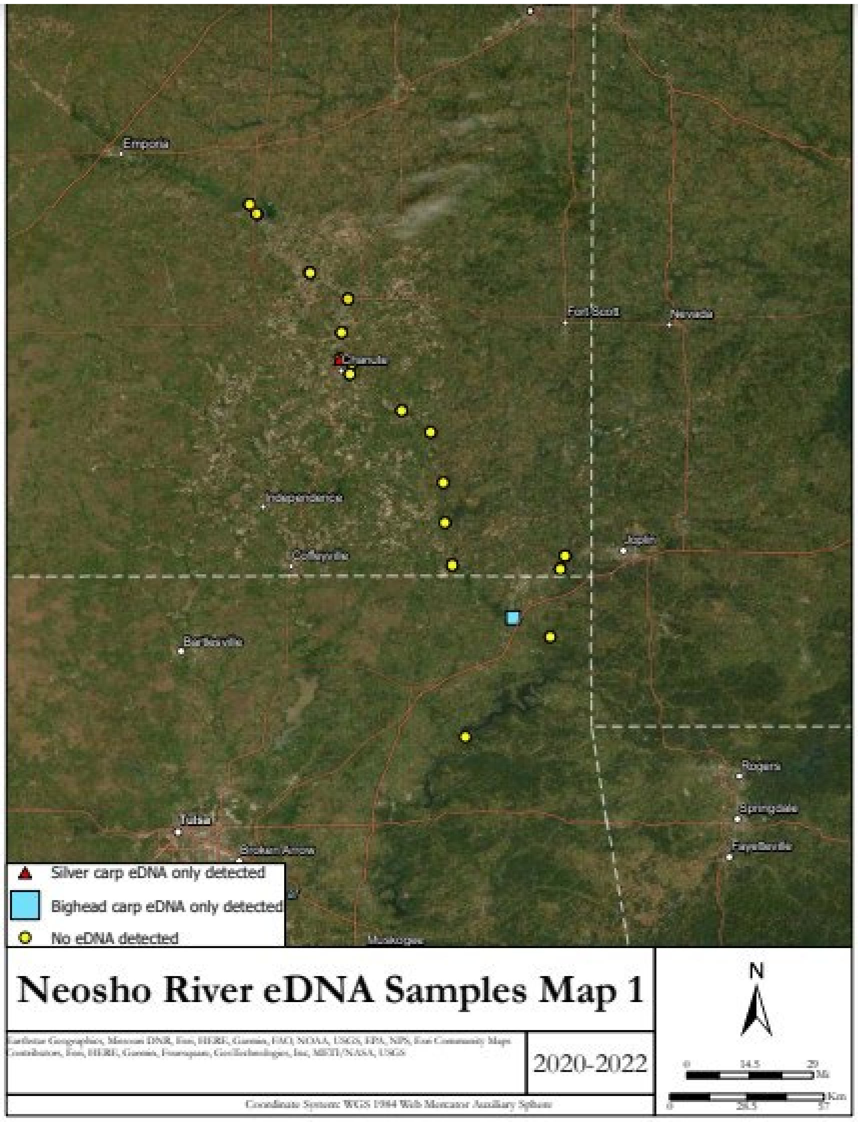

Figure 1. *Map of eDNA sampling locations and preliminary results from samples collected 2020-2022.*

Table 1. Netting effort, catch, and CPUE from community sampling on the Neosho River from 2021-2022.

	Neosho River			
	Spring 2022	Summer 2021-2022	Fall 2021-2022	Total
Netting Effort				
Overnight Gill Sets	6	2	–	8
Short-term Gill Sets	–	38	27	65
Overnight Mini Gill Sets	4	2	–	6

Short-term Mini Gill Sets	–	24	18	42
Hoop Sets	4	28	18	50
Modified Fyke Sets	4	26	17	47
Mini Fyke Sets	8	53	42	103
Total Samples (Sets)	26	173	122	321
Netting Catch				
Overnight Gill	148	83	–	231
Short-term Gill	–	120	113	233
Overnight Mini Gill	10	18	–	28
Short-term Mini Gill	–	14	13	27
Hoop	8	44	22	74
Modified Fyke	6	79	100	185
Mini Fyke	228	4,122	6,334	10,684
Total (N)	400	4,480	6,582	11,462
Total Species	21	39	38	44
Netting CPUE (fish/net)				
Overnight Gill	24.7 (5.2)	41.5 (6.5)	–	28.9 (4.8)
Short-term Gill	–	3.2 (0.6)	4.2 (0.7)	3.6 (0.4)
Overnight Mini Gill	2.5 (1.0)	9.0 (7.0)	–	4.7 (2.4)
Short-term Mini Gill	–	0.6 (0.2)	0.7 (0.3)	0.6 (0.2)
Hoop	2.0 (2.0)	1.6 (0.3)	1.2 (0.6)	1.5 (0.3)
Modified Fyke	1.5 (0.6)	3.0 (1.0)	5.9 (1.4)	3.9 (0.8)
Mini Fyke	28.5 (9.4)	77.8 (34.5)	150.8 (74.9)	103.7 (35.3)

Table 2. Netting effort, catch, and CPUE from community sampling on the Spring River from 2021-2022.

	Spring River			
	Spring 2022	Summer 2021-2022	Fall 2021-2022	Total
Netting Effort				
Overnight Gill Sets	6	–	–	6
Short-term Gill Sets	–	12	6	18
Overnight Mini Gill Sets	4	–	–	4
Short-term Mini Gill Sets	–	8	4	12
Hoop Sets	4	5	4	13
Modified Fyke Sets	4	6	4	14
Mini Fyke Sets	8	12	8	28

Total Samples (Sets)	26	43	26	95
Netting Catch				
Overnight Gill	73	–	–	73
Short-term Gill	–	33	25	58
Overnight Mini Gill	3	–	–	3
Short-term Mini Gill	–	3	1	4
Hoop	9	5	6	20
Modified Fyke	14	61	38	113
Mini Fyke	154	818	71	1,043
Total (N)	253	920	141	1,314
Total Species	29	34	25	42
Netting CPUE (fish/net)				
Overnight Gill	12.2 (4.6)	–	–	12.2 (4.6)
Short-term Gill	–	2.8 (1.7)	4.2 (1.6)	3.2 (1.2)
Overnight Mini Gill	0.8 (0.5)	–	–	0.8 (0.5)
Short-term Mini Gill	–	0.4 (0.2)	0.3 (0.3)	0.3 (0.1)
Hoop	2.3 (1.1)	1.0 (0.3)	1.5 (0.7)	1.5 (0.4)
Modified Fyke	3.5 (2.4)	10.2 (3.8)	9.5 (4.1)	8.1 (2.1)
Mini Fyke	19.3 (13.2)	68.2 (31.2)	8.9 (2.6)	37.3 (14.5)

Table 3. Electrofishing effort, catch, and CPUE from community sampling on the Spring River from 2021-2022.

	Spring River			
	Spring 2022	Summer 2021-2022	Fall 2021-2022	Total
Electrofishing Effort				
Samples (runs)	8	23	13	44
Electrofishing hours	2.0	5.8	3.3	11.0
Electrofishing Catch				
Total (N)	450	1,955	2,112	4,517
Total Species	35	44	48	52
CPUE (fish/hr)	225.0 (21.8)	340.0 (58.4)	649.9 (99.1)	410.6 (48.3)

Table 4. Electrofishing effort, catch, and CPUE from community sampling on the Neosho River from 2021-2022.

	Neosho River			
	Spring 2022	Summer 2021-2022	Fall 2021-2022	Total
Electrofishing Effort				
Samples (runs)	30	85	57	172
Electrofishing hours	7.5	21.3	14.3	43.0
Electrofishing Catch				
Total (N)	4,316	2,496	3,578	10,390
Total Species	36	33	43	47
CPUE (fish/hr)	575.5 (387.4)	117.5 (9.2)	251.1 (68.4)	241.6 (71.6)

Table 5. Netting effort and catches of Grass Carp on the Neosho River from 2021-2022.

	Spring 2022	Summer 2021-2022	Fall 2021-2022	Total
Netting Effort				
Overnight Gill Sets	6	2	–	8
Short-term Gill Sets	–	38	27	65
Overnight Mini Gill Sets	4	2	–	6
Short-term Mini Gill Sets	–	24	18	42
Hoop Sets	4	28	18	50
Modified Fyke Sets	4	26	17	47
Mini Fyke Sets	8	53	42	103
Total Samples (Sets)	26	173	122	321
Netting Catch				
Overnight Gill	–	–	–	–
Short-term Gill	–	1	–	1
Overnight Mini Gill	–	–	–	–
Short-term Mini Gill	–	–	–	–
Hoop	–	–	–	–
Modified Fyke	–	–	–	–
Mini Fyke	–	–	–	–
Total (N)	–	1	–	1
CPUE (fish/net)	0.00 (0.00)	0.02 (0.02)	0.00 (0.00)	0.01 (0.01)

Table 6. Netting effort and catches of Grass Carp on the Spring River from 2021-2022.

	Spring 2022	Summer 2021-2022	Fall 2021-2022	Total
Netting Effort				
Overnight Gill Sets	6	–	–	6
Short-term Gill Sets	–	12	6	18
Overnight Mini Gill Sets	4	–	–	4
Short-term Mini Gill Sets	–	8	4	12
Hoop Sets	4	5	4	13
Modified Fyke Sets	4	6	4	14
Mini Fyke Sets	8	12	8	28
Total Samples (Sets)	26	43	26	95
Netting Catch				
Overnight Gill	–	–	–	–
Short-term Gill	–	–	–	–
Overnight Mini Gill	–	–	–	–
Short-term Mini Gill	–	–	–	–
Hoop	–	–	–	–
Modified Fyke	–	–	–	–
Mini Fyke	–	–	–	–
Total (N)	–	–	–	–
CPUE (fish/net)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)

Table 7. Invasive carp electrofishing effort and catches from the Neosho River 2021-2022.

	Spring 2022	Summer 2021-2022	Fall 2021-2022	Total
Electrofishing Effort				
Samples (runs)	64	85	79	228
Electrofishing hours	16.0	21.3	19.8	57.0
Electrofishing Catch				
Total (N)	1	2	4	7
CPUE (fish/hr)	0.06 (0.06)	0.09 (0.07)	0.20 (0.10)	0.12 (0.05)

Table 8. Invasive carp electrofishing effort and catches from the Spring River 2021-2022.

	Spring 2022	Summer 2021-2022	Fall 2021-2022	Total
Electrofishing Effort				
Samples (runs)	22	23	13	58
Electrofishing hours	5.5	5.8	3.3	14.5
Electrofishing Catch				
Total (N)	2	1	7	10
CPUE (fish/hr)	0.36 (0.25)	0.17 (0.17)	2.15 (1.07)	0.69 (0.28)

Table 9. Sampling location, season and method of acquisition, total length (mm), body mass (kg), sex, and age of Grass Carp specimens obtained via netting and electrofishing at John Redmond Reservoir, the Neosho River, and the Spring River, Kansas from 2021–2022.

Site	Season	Method	Total Length (mm)	Body Mass (kg)	Sex	Age
John Redmond Reservoir	Spring 2022	Day Electrofishing	923	10.2	F	19
John Redmond Reservoir	Spring 2022	Day Electrofishing	213	0.1	I	2
Neosho River						
Burlington	Summer 2021	Day Electrofishing	890	–	M	22
Iola	Fall 2021	Day Electrofishing	895	–	F	14
Iola	Fall 2021	Day Electrofishing	876	–	M	37
Iola	Fall 2021	Day Electrofishing	852	–	–	–
Chanute 2	Summer 2021	Short-term Gill Netting	854	–	F	16
Chanute 2	Spring 2022	Day Electrofishing	840	6.5	F	21
Chanute 2	Fall 2022	Day Electrofishing	980	10.4	F	11
Oswego	Summer 2022	Day Electrofishing	983	9.4	F	11
Spring River						
Baxter Springs	Fall 2021	Day Electrofishing	1,049	–	M	42
Baxter Springs	Fall 2021	Day Electrofishing	864	–	M	17
Baxter Springs	Fall 2021	Day Electrofishing	960	–	F	24
Baxter Springs	Fall 2021	Day Electrofishing	892	–	M	17
Baxter Springs	Fall 2021	Day Electrofishing	930	–	M	25

Baxter Springs	Fall 2021	Day Electrofishing	874	–	F	–
Baxter Springs	Spring 2022	Day Electrofishing	921	9.4	M	13
Baxter Springs	Spring 2022	Day Electrofishing	904	–	M	19
Baxter Springs	Summer 2022	Day Electrofishing	847	6.1	M	18
Baxter Springs	Fall 2022	Day Electrofishing	1,092	11.9	M	15

Recommendations: Continue and complete this project as scheduled. Opportunistically collect additional data from bighead carp collected by others (fishermen, ODWC paddlefish crews, etc.) in the Neosho – Grand Lake system. Due to the low number of bighead carp encountered, consider alternative (e.g. telemetry study of bighead and/or grass carp) and novel (e.g. targeting and snagging bighead carp with live imaging sonar technology) approaches for collecting additional fish and data to better understand and manage the bighead carp in the Neosho River – Grand Lake system.

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