ANNUAL REPORT

OKLAHOMA DEPARTMENT OF WILDLIFE CONSERVATION

OKLAHOMA NONGAME FISHES

RESEARCH AND MANAGEMENT

[AREA 045]

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ANNUAL REPORT

State: Oklahoma

Project Title: Oklahoma Nongame Fishes Research and Management

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EXECUTIVE SUMMARY

Management of Oklahoma's native nongame (NNG) fishes is a new focus for the Department with the 2023 expansion of Area 45's focus to include Paddlefish and NNG fishes. Activities in the latter half of 2023 primarily included opportunistic collections of buffalofishes to provide specimens for a collaboration with Oklahoma State University on the morphology and genetics of Oklahoma buffalofishes. To date, 670 buffalofishes have been examined for morphology, age, sex, and genetic samples taken to determine levels of hybridization while providing a confirmation for species identification. Use of published morphological characters to differentiate Smallmouth and Black buffalofishes in Oklahoma has been problematic and our data demonstrate inconsistent results based on character(s) used. Collections are largely comprised of small sample sizes with highly variable age and size structure. However, we modeled population dynamics for an admixture of Smallmouth/Black buffalofishes collected from Grand Lake (n=138). Although this sample may be inadequate for robust interpretation, we found the age structure to span 2-41 years, recruitment to be episodic, and spawning interval to likely be non-annual (multiple years between spawns). We estimated annual mortality at 6%, however, a stronger understanding of fishing mortality is needed and data on exploitation are not currently available. Other samples, including 178 buffalofishes taken from a bowfishing tournament on Keystone Lake are in progress. A statewide management plan for NNG fishes is in development.

[1] Area 045 entered SFR funding on July 1, 2023. Some collections and activities described here occurred prior to July 1.

INTRODUCTION

Nongame fishes are officially defined in Oklahoma Title 29 by what they are not (§29-2-123). Whereas the definition of game fishes (§29-2-115) includes a qualifier that they are "normally sought after by sportsmen", this is accompanied by distinct list of at least 14 species or hybrids, which includes multiple nonnative species. Regardless of a species' emergent recreational or social status among sportsmen, "game fish" status is reserved only for those listed. Further, "sport fish" is not legally defined, however, many of Oklahoma's nongame fishes are undeniably *de facto* game or sport fishes, as recreational fisheries have existed for many decades. Examples include the Paddlefish, Flathead Catfish, Alligator Gar, and perhaps Hybrid Striped Bass. All these fishes are managed with bag or size limits, among other regulatory measures.

> §29-2-123. Nongame fish. "Nongame fish" are all fish not game fish.
>
> §29-2-115. Game fish. "Game fish" is a fish normally sought after by sportsmen, and includes only largemouth bass, smallmouth bass, white bass, spotted bass, black crappie, white crappie, northern pike, trout, sauger, saugeye, striped bass, walleye, blue catfish and channel catfish. Blue catfish and channel catfish are herein defined to mean "forked tail" catfish.

As of 2024, many native nongame (NNG) fishes are not collectively afforded any bag limits or protections, and this trends nationwide (Figure 1). For a regulatory summary of bag limits for select nongame fishes, see Appendix A. Several Oklahoma native nongame fishes are listed as Species of Greatest Conservation Need (SGCN, also known as Species of Special Concern). SGCN fishes are restricted to a daily bag limit of one (1) with mandatory reporting. Examples of NNG fishes falling under this SGCN bag limit regulatory umbrella include Shovelnose Sturgeon, Blue Sucker, American Eel, and others. Paddlefish and Alligator Gar are also SGCN fishes, however their individual species regulations are more restrictive (Table 1).

Oklahoma's aquatic biodiversity includes approximately 177 fish species, with 15 considered game fishes (when considering "trout" as a collective term to include both Rainbow and Brown), 5 considered threatened or endangered species, and 56 regarded as SGCN (Table 2). The remaining 101 species (57%) are other fishes that generally have no bag limits or harvest protections (Figure 2). In Oklahoma and other states, there is no clear regulatory distinction between NNG and nonnative invasive (NNI) fishes, particularly considering fishes deemed as naturalized (i.e., Common Carp and perhaps Grass Carp).

A number of Oklahoma's NNG fishes are targeted by various fisheries, including hook and line, snagging, spearing/gigging, noodling, and bowfishing. Snagging is primarily practiced in the pursuit of Paddlefish and this species/fishery is addressed separately in a Paddlefish annual report. Noodling is primarily practiced for catfishes, including the nongame Flathead Catfish, and these fisheries are considered by regional management personnel. Gigging and bowfishing are relatively under-studied methodologies in Oklahoma and nationwide, however a recent study was completed on gigging in northeast Oklahoma (Zentner et al. 2023) and two studies were completed on bowfishing in Oklahoma (York et al. 2022; Montague et al. 2023).

Figure 1. Table 2 from Rypel, et al. (2021) summarizing bag limit regulations for nongame fishes in all 50 states.

Table 2. Summary of rough fish regulations in the USA. If different bag limits existed by species, we report the lowest limit. Some states had regional- or ecosystem-specific regulations, but present here only statewide regulations.

State	Bag limits of over 10 fish per day	Unlimited bag limits	Possession limit	Term used	Largemouth Bass bag limit
Alabama	Y	Y	N	Nongame fish	10
Alaska	Y	Y	N	Other	-
Arizona	Y	Y	N	Other species	6
Arkansas	Y	Y	N	Rough fish	10
California	Y	Y	N	Other	5
Colorado	Y	Y	N	Game fish	5
Connecticut	Y	Y	N	Other	6
Delaware	Y	Y	N	Other	6
Florida	Y	Y	N	Nongame fish	5
Georgia	Y	Y	N	Other	10
Hawaii	–	–	–	Other	10
Idaho	Y	Y	N	Nongame fish	6
Illinois	Y	Y	N	Other	6
Indiana	Y	Y	N	Other	5
Iowa	Y	Y	N	Rough fish	3
Kansas	Y	Y	N	Other	5
Kentucky	Y	Y	N	Rough fish	6
Louisiana	Y	25	50	Nongame fish	10
Maine	Y	Y	N	Other	2
Maryland	Y	15	30	Other	5
Massachusetts	Y	Y	N	Other	5
Michigan	Y	Y	N	Other	5
Minnesota	Y	Y	N	Rough fish	6
Mississippi	Y	Y	N	Other	10
Missouri	Y	50	100	Nongame fish	6
Montana	Y	Y	N	Nongame fish	5
Nebraska	Y	Y	N	Nongame fish	5
Nevada[1]	Y	Y	N	Other	-
New Hampshire	Y	Y	N	Other	5
New Jersey	Y	25	N	Other	5
New Mexico	Y	Y	N	Other	5
New York	Y	Y	N	Other	5
North Carolina	Y	Y	N	Nongame fish	5
North Dakota	Y	Y	N	Nongame fish	3
Ohio	Y	Y	N	Forage fish	5
Oklahoma	Y	Y	N	Other	6
Oregon	Y	Y	N	Nongame fish	5–6
Pennsylvania	Y	50	N	Other	6
Rhode Island	Y	Y	N	Other	5
South Carolina	Y	Y	N	Other	5
South Dakota	Y	Y	N	Rough fish	5
Tennessee	Y	Y	N	Nongame fish	5
Texas	Y	Y	N	Other	5
Utah	Y	Y	N	Nongame fish	6
Vermont	Y	Y	N	Other	5
Virginia	Y	20	N	Nongame fish	5
Washington	Y	Y	N	Food fish	5
West Virginia	Y	Y	N	Other	6
Wisconsin	Y	Y	N	Rough fish	5
Wyoming	Y	Y	N	Nongame fish	6

[1]Bag limits in Nevada vary exclusively by region, but several rough fish taxa are unregulated, so they were listed as unlimited bag limit.

Table 1. List of select native nongame fishes of Oklahoma (taxonomically grouped) with conservation status, daily bag limit, and other details. SGCN fishes, unless otherwise regulated with a bag limit, are subject to a default daily limit of one (1) with mandatory harvest reporting.

Common Name	Scientific Name	Conserv. Status	Daily Bag Limit and other protections
Alligator Gar	*Atractosteus spatula*	SGCN	1, seasonal closure, mandatory reporting
Longnose Gar	*Lepisosteus osseus*		Unlimited
Shortnose Gar	*L. platostomus*		Unlimited
Spotted Gar	*L. oculatus*		Unlimited
Bigmouth Buffalo	*Ictiobus cyprinellus*		Unlimited
Smallmouth Buffalo	*I. bubalus*		Unlimited
Black Buffalo	*I. niger*	SGCN	1
River Carpsucker	*Carpiodes carpio*		Unlimited
Highfin Carpsucker	*C. velifer*		Unlimited
Quillback	*C. cyprinus*		Unlimited
Freshwater Drum	*Aplodinotus grunniens*		Unlimited
Flathead Catfish	*Pylodictus olivaris*		5
Black Bullhead	*Ameiurus melas*		Unlimited
Brown Bullhead	*A. nebulosus*	SGCN	1
Yellow Bullhead	*A. natalis*		Unlimited
Blue Sucker	*Cycleptus elongatus*	SGCN	1
Golden Redhorse	*Moxostoma erythrurum*		Unlimited
River Redhorse	*M. carinatum*		Unlimited
Shorthead Redhorse	*M. macrolepidotum*	SGCN	1
Goldeye	*Hiodon alosoides*		Unlimited
Mooneye	*H. tergisus*	SGCN	1
Skipjack Herring	*Alosa chrysochloris*		Unlimited
Alabama Shad	*A. alabamae*	SGCN	1
American Eel	*Anguilla rostrata*	SGCN	1
Paddlefish	*Polyodon spathula*	SGCN	1, annual limit 2, mandatory reporting, etc.
Shovelnose Sturgeon	*Scaphirhynchus platorynchus*	SGCN	1

Figure 2. Slide excerpted from American Fisheries Society annual meeting 2023 presentation titled- “The Complex Identities of ‘Other’ Fishes: How legal status and regulatory loopholes complicate the management and conservation of native, traditionally nongame fish species”.

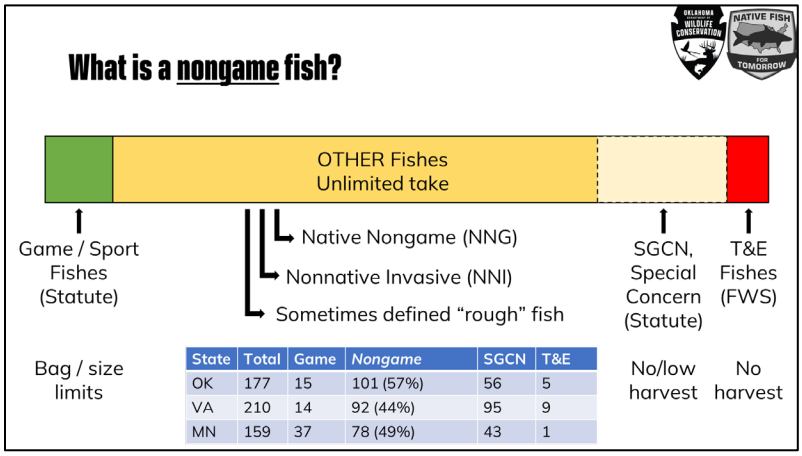


Table 2. List of 56 nongame fishes classified as Species of Greatest Conservation Need (SGCN) in Oklahoma. Excerpted from the ODWC Oklahoma Comprehensive Wildlife Conservation Strategy (ODWC 2016). Common names prefixed by an asterisk (*) are regarded as under the generalized purview of the Paddlefish and Nongame Program (Area 45), whereas the remainder are under the purview of the ODWC Streams Program (Area 05).

Common Name	SGCN Tot. Score	Tier	Selection Criteria
*Alabama Shad	11	II	2, 3, 4
*Alligator Gar	11	II	2, 3, 4
*American Eel	9	III	4
Arkansas Darter	13	I	1, 2, 3
Arkansas River Shiner	14	I	1, 3, 4
Arkansas River Speckled Chub	11	III	2, 3
*Black Buffalo	9	III	2
Blackside Darter	9	III	2
Blackspot Shiner	13	I	3, 4, 6
*Blue Sucker	11	II	2, 3
Bluehead Shiner	12	II	2, 3, 4, 6
Bluntface Shiner	11	II	2
*Brown Bullhead	9	III	2
Cardinal Shiner	12	II	6
Chub Shiner	11	II	6
Creole Darter	11	II	6
Crystal Darter	12	II	2, 3, 4
Cypress Minnow	9	III	2
Flathead Chub	9	III	2, 4
Goldstripe Darter	11	II	2
Harlequin Darter	9	III	2
Ironcolor Shiner	11	II	2, 4
Kiamichi Shiner	12	II	2, 3, 4, 6
Least Darter	12	II	4, 6
Leopard Darter	14	I	1, 3, 4, 6
Longnose Darter	14	I	2, 3, 4, 6
*Mooneye	9	III	2
Mountain Madtom	10	III	2
Neosho Madtom	14	I	1, 3, 4, 6
Orangebelly Darter	11	II	6
Ouachita Mountain Shiner	12	II	2, 3, 4, 6
Ozark Cavefish	13	I	1, 3, 4, 6
Ozark Minnow	11	II	6
*Paddlefish	9	III	3, 4
Pallid Shiner (Chub)	12	II	2, 3, 4
Peppered (Colorless) Shiner	14	I	2, 3, 4, 6
Plains Minnow	12	II	5
Plains Topminnow	10	III	2, 3
Prairie Speckled Chub	13	I	2, 3
Red River Pupfish	10	III	6
Red River Shiner	10	III	6
Redfin Darter	11	II	6
Redspot Chub	12	II	3, 6
Redspot Darter	10	III	6
River Darter	9	III	2
Rocky Shiner	12	II	3, 4, 6
Scaly Sand Darter	10	III	3
*Shorthead Redhorse	10	III	2
*Shovelnose Sturgeon	12	II	2, 3
Silverband Shiner	11	II	3
Southern Brook Lamprey	11	II	2
Spotfin Shiner	9	III	2
Sunburst (Stippled) Darter	12	II	6
Taillight Shiner	10	III	2
Wedgespot Shiner	11	II	6
Western Sand Darter	12	II	3, 4

While commercial fishing in Oklahoma remains legal in statute (§29-4-103), no commercial fishing permits have been issued since 1992. Prior to then, large total weights of numerous NNG fishes were taken annually. During the period 1961-1969, Mensinger (1971) reported that commercial harvests of buffalofishes (Bigmouth and Smallmouth) exceeded that of other species (carps, Flathead Catfish, Freshwater Drum, Paddlefish, River Carpsucker, White Bass, and gars). Commercial harvests were spread across 50-90 permits fishing 12 private or municipal lakes <500 acres and 19 reservoirs ≥500 acres with the largest annual harvest of buffalofishes occurring at Lake Texoma.

Although many of Oklahoma's native nongame fishes were historically seen to have commercial/economic value, this valuation has not been shared by anglers and the general public, resulting in these species being historically maligned, misunderstood, and in some cases, persecuted (Scarnecchia 1992; Rypel et al. 2021).

Additional harvest pressures on NNG fishes have been observed with the ascendence of sport bowfishing in recent decades (Scarnecchia and Schooley 2020). A recent boom in research focused on life history of nongame fishes has occurred in the last five years (Table 3). Some groundbreaking research on the revised longevity of Bigmouth Buffalo (Lackmann et al. 2019) forged a path for revised aging techniques and closer examination of many historically underappreciated fishes. Multiple studies in Oklahoma (Snow et al. 2020; Montague et al. 2023) found that longevity for several species was greater than previously known.

ODWC Fisheries Division has a standing committee focused on NNG fishes and comprised of members representing management regions and hatcheries. The Nongame Committee's focus is to provide a forum for the discussion, review, and facilitation of topics and actions relevant to Oklahoma's nongame fishes and the fisheries that target them. This includes, for example, regulatory changes and social media outreach.

With a few exceptions, management of native nongame fishes in Oklahoma and many other states has been nonexistent to date. However, ODWC has committed to living up to the Department mission by assigning value and dedicating resources towards the management of all native aquatic species, regardless of their legal status.

Table 3. Summary of life history knowledge for select native nongame fish species. Studies with validated ages are noted with an asterisk (*).

Common Name	Max. Age	Age at maturity (sex)	Irregular Recruitment	References [State/Prov.]
Bigmouth Buffalo	>100	10 (F)	Yes	(Lackmann et al. 2019, 2023b) [MN]
Smallmouth Buffalo	62			(Snow et al. 2020) [OK]
Black Buffalo	56			(Lackmann et al. 2019) [MN]
	54			(Montague et al. 2023) [OK]
Alligator Gar	68*			(Daugherty et al. 2020) [TX]
	95*			A. H. Andrews, NOAA Fisheries, pers. comm. [MS]
		5		(DiBenedetto 2009)[LA]
			Yes	(Buckmeier et al. 2013; Smith et al. 2020)
Longnose Gar	27			(McGrath et al. 2016) [VA]
	29			(Montague et al. 2023) [OK]
Quillback	44	8-9	Yes	(Lackmann et al. 2022b) [MN]
River Carpsucker	>45			(Lackmann et al. 2022b) [MN]
Paddlefish	29	8 (F)	Yes	(Scarnecchia and Schooley 2022) [OK]
	>60	16* (F)	Yes	(Scarnecchia et al. 2019) [MT, ND]
Bowfin	33		Yes	(Lackmann et al. 2022a) [MN]
Freshwater Drum	58*			(Davis-Foust et al. 2009) [WI]
Shorthead Redhorse	20			(Reid 2009) [ON]
Golden Redhorse	17			(Lackmann et al. 2023a) [MN]
Blue Sucker	42			(Radford et al. 2021) [IN, IL]

RESEARCH AND MANAGEMENT ACTIVITIES / METHODS

The first six months of the nongame program's existence included hiring of two technicians, acquiring equipment, performing fall sportfish management collections on multiple reservoirs, and performing annual Paddlefish winter gillnet collections. Nongame collections (primarily buffalofishes) have been opportunistic during other efforts.

Our primary efforts for collection of buffalofishes to date have contributed to a funded sub-award project with Dr. Guin Wogan, Oklahoma State University, examining the Genetic Identification and Estimation of Population Demographics for Oklahoma Buffalofishes. This partnership pairs the age and morphology (ODWC) of buffalofishes with the genetic speciation and characterization of hybridization (OSU) to determine the status and assemblage of the buffalofishes complex in Oklahoma reservoirs where they are targeted by bowfishers. Of specific interest is the detectable abundance of Black Buffalo (SGCN) among the more common and abundant Smallmouth Buffalo. Difficulties in visual identification of Black Buffalo have resulted in concerns that collateral harvest take of this rare species may be occurring among the unregulated and undocumented take of Smallmouth Buffalo due to similarity of appearance. Fisheries literature and personal communication with fisheries professionals within and without Oklahoma yield mixed opinions on the ability and accuracy of field species identification for these two species. It is unknown if the difficulty is a local phenomenon due to similarity/overlap of characters or if the species are hybridizing in the wild. As an example of problematic field identification techniques, Eddy and Underhill (1978) vaguely described Smallmouth Buffalo body depth as "back quite elevated" (p. 111), whereas Black Buffalo was described as "back not much elevated" (p. 112). Further, they described the mouth structures as similar between the species. However, Hubbs, et al. (2008) described several more complex measurements, which may be challenging in the field, especially for live specimens:

- Smallmouth Buffalo – SL > 5 times head width; "distance from the posterior tip of the maxillary to the front of the mandible less than eye length" (p. 25-26)
- Black Buffalo – SL < 5 times head width; "distance from the posterior tip of the maxillary to the front of mandible greater than eye length" (p. 25)

Field methodologies for buffalofishes collections include various collection techniques, most of which have been opportunistic bycatch during collections for other species or during dam operations or fish salvage efforts. To date, such collections have included the following:

- Chimney Rock Lake
    - May 2021 – large gillnets and electrofishing (targeted)
- Grand Lake
    - May 2021 – electrofishing (targeted)
    - December 2023 – large Paddlefish gillnets (bycatch)
- Heyburn Lake
    - September 2021 – tailwater drawdown, salvaged buffalofishes
- Hulah Lake
    - March 2023 – tailwater drawdown, salvaged buffalofishes
- Kaw Lake
    - December 2023 – large Paddlefish gillnets (bycatch)
- Keystone Lake
    - March 2023 – large Paddlefish gillnets (bycatch)
    - August 2023 – bowfishing tournament take (selected buffalofishes)
- Texoma Lake

    - November 2023, January 2024 – gillnets (community samples)
        - This ongoing collection is facilitated by South-Central Region in collaboration with Southeastern Oklahoma State University.
- Verdigris River
    - May 2022 – electrofishing (bycatch)
        - This collection was a collaboration between ODWC and the Ouachita Mountains Biological Station (OMBS, https://www.theombs.org/), resulting in the expansion of the known geographic range of Quillback (McAllister et al. 2023).

Each buffalofish was measured as follows in mm on a measuring board with the assistance of a metric measuring tape: total length (TL), standard length (SL), greatest pre-dorsal body depth (BD), and the longest dorsal fin ray (DFR). Weight was measured in kilograms on either a 4.5 or 18 kg capacity bench scale (whichever was appropriate) or a 113 kg hanging scale (when Paddlefish netting).

Fish were identified for sex by internal examination of the gonads. For females, gravidity was noted when eggs were present. In some pre-spawn collections, gonads and fat deposits were removed and weighed to calculate gonadosomatic index (GSI) and to assist in estimation of fecundity. Fish were externally examined for the presence of breeding tubercles and a tissue sample was removed from the pectoral or pelvic fin and preserved in 95% molecular grade ethanol for later genetic examination by OSU.

The nuchal hump was visually characterized as pronounced keel (P), moderate keel (M), or absent (A). All fish were *a priori* assigned to species by visual assessment (Bigmouth, Smallmouth, or Black) using several generalized rules of thumb (Table 4): 1) Fish with an anterior-facing mouth were recorded as Bigmouth, 2) Fish with a ventral-facing mouth and a pronounced keel were recorded as Smallmouth, and 3) Fish with a ventral-facing mouth and a moderate-to-absent keel were recorded as Black.

Hubbs, et al. (2008) suggested using the equation for depth index $D_i = {SL}/{BD}$ to differentiate between the two similar species Smallmouth and Black buffalofishes, with deeper-bodied Smallmouth Buffalo having a D_i = 2.2 – 2.8 and more elongate-bodied Black Buffalo having a D_i = 2.6 – 3.3. These overlapping ranges necessitated a more distinct breakpoint between the species, therefore we split the difference and used $D_i \leq 2.75$ for Smallmouth Buffalo. This index was calculated for each fish for which both SL and BD measurements were present.

Table 4. Rules of thumb for *a priori* visual identification of Oklahoma buffalofishes.

Species	Mouth orientation	Keel	SL/BD
Bigmouth Buffalo	Terminal	A-M	> 2.75
Smallmouth Buffalo	Ventral	P	≤ 2.75
Black Buffalo	Ventral	M	> 2.75

A priori visual species ID and D_i species ID were summarized and compared. Genetic species ID will be later determined by OSU to inform the levels of accuracy with field sex ID from morphology and characterize any hybridization of buffalofishes in Oklahoma.

Phillips and Underhill (1971) suggested utility of the length of the anterior dorsal fin rays to differentiate sexes for Smallmouth Buffalo, observing a significantly longer dorsal fin on females.

Therefore, dorsal fin length (relative to SL) was compared for sexes within species, as identified by D_i. Additionally, this metric was calculated and compared for D_i species within each stock.

Paired saggital otoliths were removed from each buffalofish for later age estimation. Preparation, mounting, sectioning, and aging of otoliths followed a combination of published literature (Long et al. 2023) and consultation with A. Lackmann at University of Minnesota, Duluth. Once all fish had been assigned ages, all population modeling was conducted using Fisheries Analysis and Modeling Simulator (FAMS). Vital rates of the population were calculated from length, weight, and age data. Total annual mortality was calculated using a weighted catch curve (number of individuals at each age) (Miranda and Bettoli 2007). Growth was modeled using the Von Bertalanffy growth equation using mean length at age data (von Bertalanffy 1938).

Other nongame projects are ongoing statewide, facilitated by various programs (Table 5). Area 45 aims to collaborate with other programs on any future nongame projects. A planning and coordination meeting is proposed between the Paddlefish and Nongame and the Streams programs to better define how these programs can work in tandem and reduce overlap in species or habitat focus.

Table 5. Summary of select projects occurring statewide related to native nongame fishes and not directly facilitated by Area 45.

Nongame Fish Species Studied	Principal Investigator(s)	Locality	Objective(s)
Skipjack Herring	ODWC Southeast Regional Management (Porter Office)	Arkansas River, R.S. Kerr Reservoir	Develop baseline life history information for the species (age and growth) in consideration for informing a managed fishery.
Blue Sucker	ODWC Durant Hatchery, US Fish and Wildlife Service	Lower Kiamichi River, Red River	Investigate rearing and captive propagation requirements for this and other SGCN fishes.
Golden Redhorse	ODWC Southwest Regional Management (Lawton Office)	Medicine Creek watershed, Wichita Mountains Wildlife Refuge	Revision of historical species distribution and abundance with new collections and additional localities.
Goldeye	OFRL (Norman Office) and South-Central Region Management (Durant Office)	Texoma Lake	Determine otolith aging precision for refinement of life history for the species.
Misc. (all species)	ODWC South-Central Region Management (Durant Office) and Southeastern Oklahoma State University	Texoma Lake Washita River arm upstream of Roosevelt Bridge	Examination of fish community impacts of reservoir siltation when compared to historical collections (Patton and Lyday 2008)
Misc. (gars, buffalofishes, carps)	ODWC Human Dimensions	Statewide	Examine and determine baseline social perceptions of native nongame fishes as we try to better communicate about these species (Figure 3).

Figure 3. Excerpts from the 2023 statewide angler survey with multiple questions related to social value and perception of native nongame fishes.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
One or more species of native nongame fish are important to my recreational fishing experience.	○	○	○	○	○
All native nongame fish species in Oklahoma should be subject to bag limits determined by the Wildlife Department.	○	○	○	○	○
One or more species of native nongame fish are desirable for human consumption.	○	○	○	○	○
Native nongame species are important to healthy ecosystems in Oklahoma.	○	○	○	○	○
All species of fish and wildlife should be used in beneficial ways (table fare, fertilizer, etc.) and not discarded as waste.	○	○	○	○	○

29. We are interested in your feelings (either positive or negative) in response to the following species of fish. First, we would like to ask about your feelings towards each of the following types of fish.

	Negative -2	-1	Neutral 0	+1	Positive +2
Gar	○	○	○	○	○
Trout	○	○	○	○	○
Black Bass	○	○	○	○	○
Buffalo	○	○	○	○	○
Carp	○	○	○	○	○
Catfish	○	○	○	○	○

30. Now, please respond with how you think other anglers you know feel about each of the following types of fish.

	Negative -2	-1	Neutral 0	+1	Positive +2
Gar	○	○	○	○	○
Trout	○	○	○	○	○
Black Bass	○	○	○	○	○
Buffalo	○	○	○	○	○
Carp	○	○	○	○	○
Catfish	○	○	○	○	○

RESULTS / DISCUSSION

To date, opportunistic collections of buffalofishes for our statewide morphology and genetics project have potentially yielded 670 samples likely representing all three species (Table 6). Although our confidence in identifying Bigmouth Buffalo is high (125 of 670 fish; 18.7%), an admixture of morphological traits makes confident species ID a challenge for Smallmouth and Black buffalofishes. This low confidence in visual identification of Black Buffalo (i.e., differentiation from Smallmouth Buffalo) has resulted in no fish labeled as Black Buffalo during visual inspection and measurement. However, *a posteriori* use of several morphological techniques on the remaining 545 fish not identified as Bigmouth Buffalo has yielded different, but inconsistent results. Through simple examination and classification of the nuchal keel, we identified 532 fish with pronounced keels (98%), 13 fish with moderate keels (2%), and none were absent. The D_i method, when used independently of keel, suggests that approximately a third (34%) of the 545 fish we visually identified as Smallmouth Buffalo could be Black Buffalo (27.8% of total catch).

Opportunistic collections have yielded highly variable sample sizes and size structure (Figure 4), which limits our interpretation of the catches. Therefore, only a few are reported in depth here.

Examination of anterior dorsal fin ray length in relation to standard length (DFR/SL*1000) for fish speciated based on D_i resulted in a significant difference (T-Test, $p=0.013$) between males and females for Grand Lake Black Buffalo only (Figure 5). However, when males and females were pooled, and despite small sample sizes, this character was significantly different for all three D_i species, when pairwise compared (T-Test, $p<0.05$). A re-analysis of this character will be warranted when genetic results confirm species ID.

As no morphological examination has yet been tested and verified to confidently differentiate Smallmouth from Black buffalofishes, we hereafter consider any fish not identified as a Bigmouth Buffalo to represent an admixture and we refer to them as Smallmouth/Black Buffalo except when describing species in terms of D_i. Genetic identification to species (or hybrid) is forthcoming but not currently available.

From Hulah Lake, a total of 79 fish were aged (Figure 6). Bigmouth Buffalo (n=46) ranged in age 4-39 years, with a large gap between one fish aged 28 years and the oldest aged 39. This gap could represent episodic recruitment; however, the low sample size warrants cautious interpretation of population dynamics. Smallmouth/Black buffalofishes (n=33) ranged in age 3-24 years. Given that the known lifespan of buffalofishes in Oklahoma far exceeds the maximum

ages observed in this collection, it is likely that sample sizes are inadequate for further interpretation.

From Grand Lake, a total of 138 Smallmouth/Black buffalofishes were collected and used for further analysis. Lengths ranged from 230 mm to 715 mm, and ages ranged from 2-41 years old (Figure 7). In the Grand Lake system, we see a wide range of lengths and ages collected which will necessitate a large sample to confidently evaluate this population.

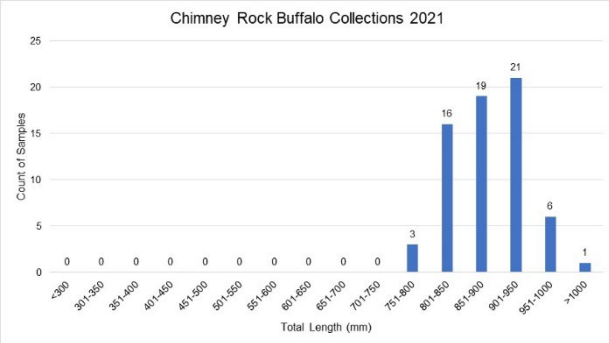
The age frequencies distribution indicates around 20% of the population is 2 or 3 years old. No individuals collected were age-0 or age-1. Failed detection of these cohorts is not necessarily evidence of lack of recruitment. Potentially these individuals are present in this population but are not yet recruited to the gear used (electrofishing). If early life data are needed, alternative sampling methods may need to be evaluated. The age frequency distribution also shows several missing year classes (4, 17, 20, 21) and several small year classes (12, 15, 19). Conversely, we see several large year classes that are making up a large portion of the population (3, 10, 23). Abiotic and biotic factors that may be driving these strong and weak year classes are unknown but can be evaluated in the future. Von Bertalanffy growth curve indicates fish are reaching asymptotic length around age-10 (Figure 8). At this age, the growth curve begins to flatten or asymptote, indicating most fish are reaching sexual maturity.

Table 6. Results of opportunistic collections of Oklahoma buffalofishes for genetics and morphology. Species is indicated here by visual assignment (V) or through implementation of body depth index (D_i).

Stock	Bigmouth Buffalo V. Count (%) [TL, Wt]	Smallmouth Buffalo V. Count (%) [TL, Wt] D_i Count (%) [TL, Wt]	Black Buffalo V. Count (%) [TL, Wt] D_i Count (%) [TL, Wt]	Total Samples
Chimney Rock	1 (1.5) [863, 13.45]	65 (98.5) [887, 13.9] 49 (74.2) [883, 14.0]	0 (0) [NA] 16 (24.2) [900, 13.8]	66
Grand Lake	9 (6.1) [687, 6.7]	138 (93.9) [475, 2.7] 54 (36.7) [399, 1.1]	0 (0) [NA] 84 (57.1) [526[2], 3.7]	147
Heyburn Lake (tailwater)	17 (100.0) [332, 0.51]	0 (0) [NA] 0 (0) [NA]	0 (0) [NA] 0 (0) [NA]	17
Hulah Lake (tailwater)	49 (59.8) [644, 4.8]	33 (40.2) [368, 1.5] 18 (22.0) [440, 1.3]	0 (0) [NA] 15 (18.3) [488, 1.7]	82
Kaw Lake	40 (100.0) [911, 15.5]	0 (0) [NA]	0 (0) [NA]	40
Keystone Lake	4 (2.2) [795, 10.6]	174 (97.8) [506, 2.2] 145 (81.5) [494, 2.0]	0 (0) [NA] 29 (16.3) [568, 2.8]	178
Texoma Lake	0 (0) [NA]	63 (100.0) [520, 2.5] 41 (65.1) [490, 2.2]	0 (0) [NA] 22 (34.9) [575, 3.0]	63
Verdigris River	5 (6.5) [586, 3.5]	72 (93.5) [355, 0.8] 52 (67.5) [322, 0.6]	0 (0) [NA] 20 (26.0) [440, 1.5]	77
Totals	125 (18.7)	545 (81.3) 359 (53.6)	0 (0.0) 186 (27.8)	670

Figure 4. Highly variable sample size and size structure of buffalofish collections from Oklahoma reservoirs.

[2] Two of these fish were not measured for total length and are excluded from the average length.


Chimney Rock Buffalo Collections 2021
Count of Samples
Total Length (mm)
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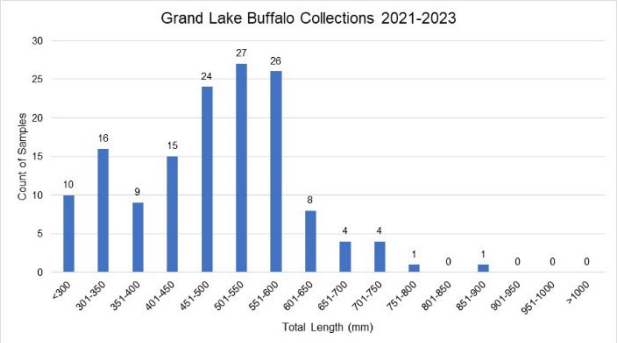
Grand Lake Buffalo Collections 2021-2023
Count of Samples
Total Length (mm)
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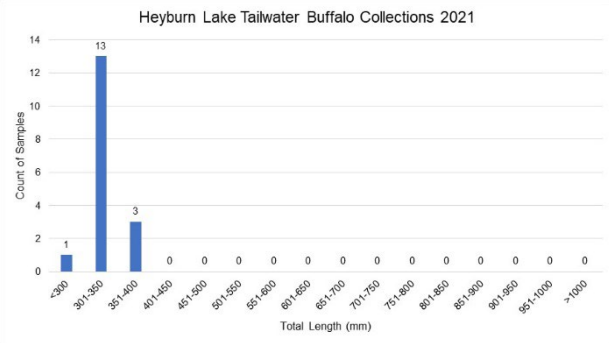
Heyburn Lake Tailwater Buffalo Collections 2021
Count of Samples
Total Length (mm)
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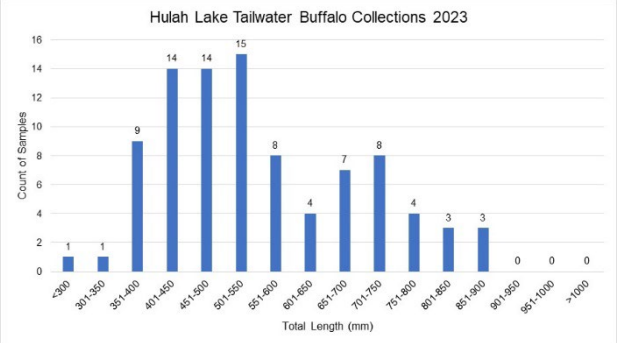
Hulah Lake Tailwater Buffalo Collections 2023
Count of Samples
Total Length (mm)
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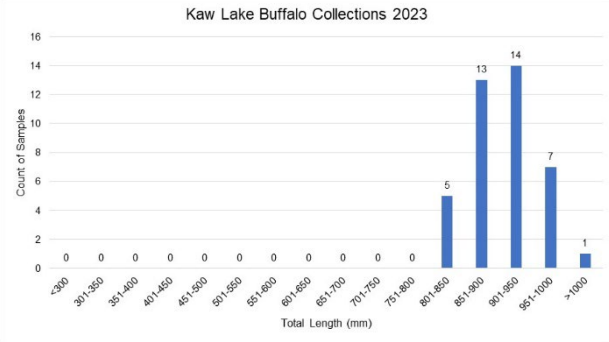
Kaw Lake Buffalo Collections 2023
Count of Samples
Total Length (mm)
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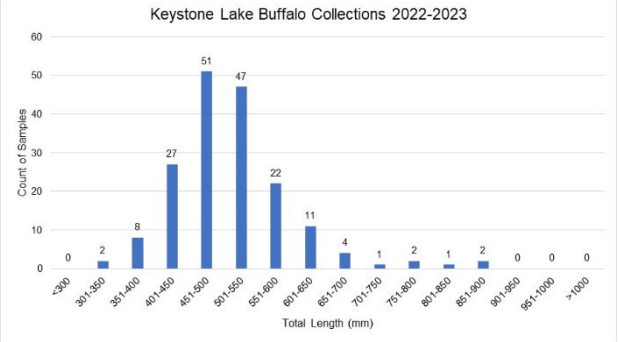
Keystone Lake Buffalo Collections 2022-2023
Count of Samples
Total Length (mm)
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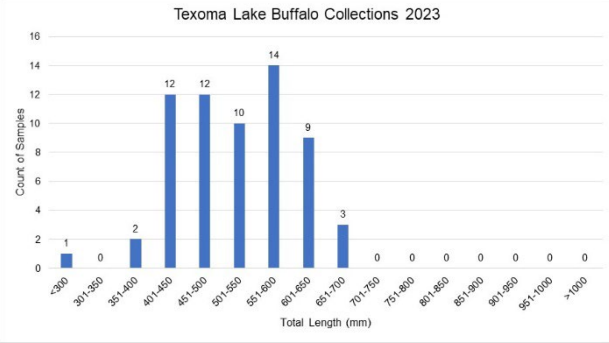
Texoma Lake Buffalo Collections 2023
Count of Samples
Total Length (mm)
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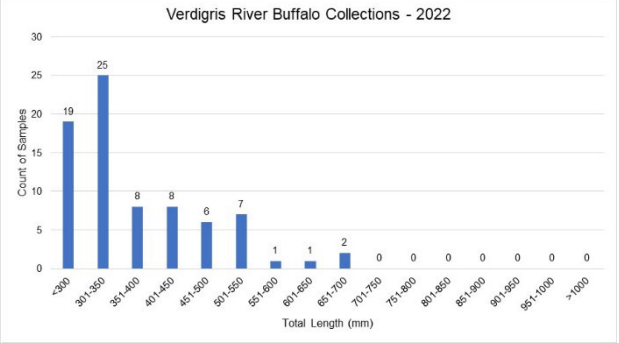
Verdigris River Buffalo Collections - 2022
Count of Samples
Total Length (mm)
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19 25 8 8 6 7 1 1 2 0 0 0 0 0 0 0

Figure 5. Examination of anterior dorsal fin ray length as a character for differentiating sexes in buffalofishes was found to result in a significant difference ($p<0.05$; indicated by an asterisk [*]) for Black Buffalo only. However, for pooled sexes, this character may be a reasonable differentiator for the three species.

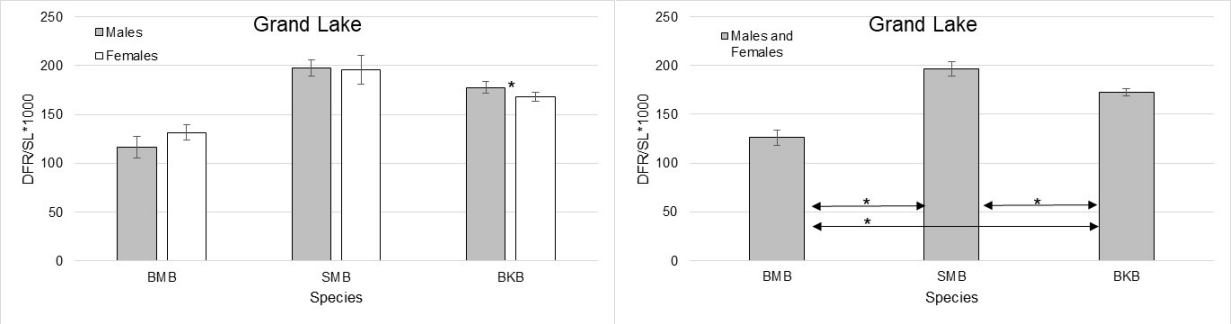


Figure 6. Preliminary age structure of 79 buffalofishes taken from Hulah Lake tailwater 2023.

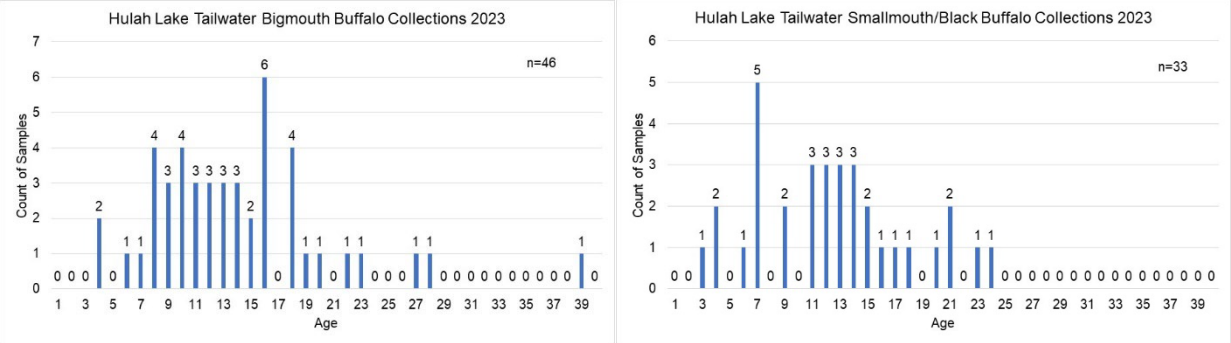


Figure 7. Age structure for Smallmouth/Black buffalofishes (n=138) from Grand Lake.

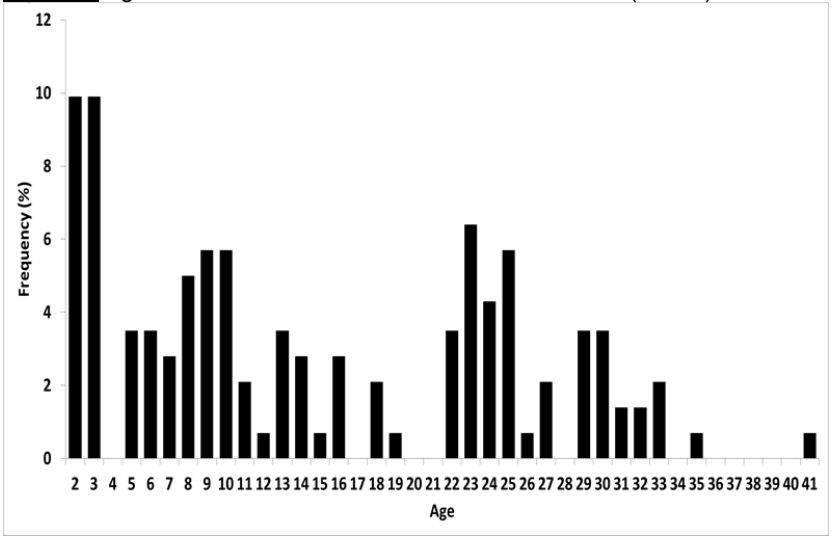
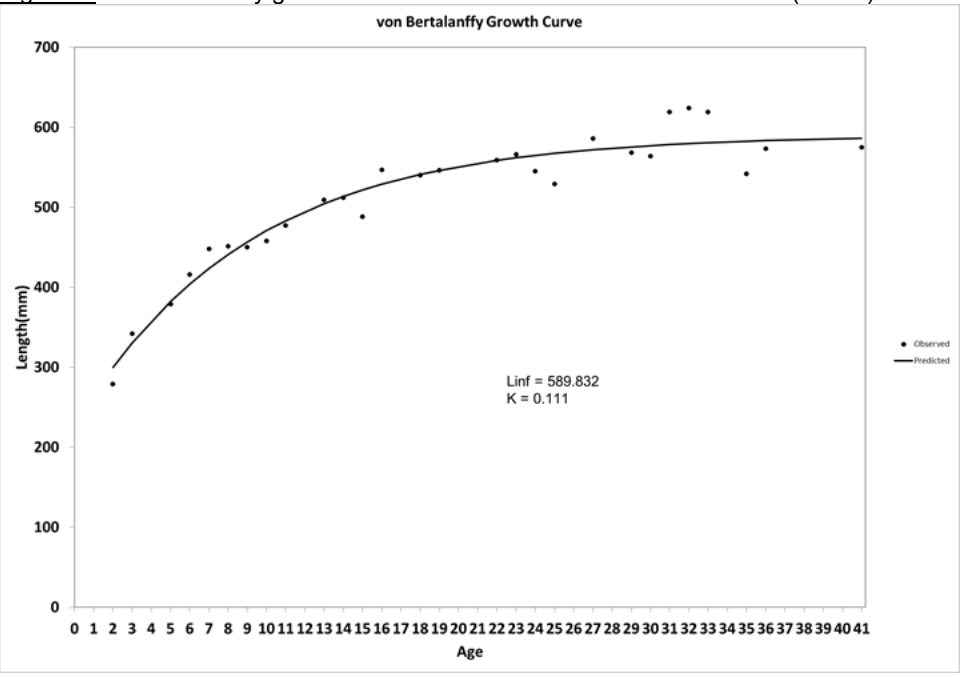


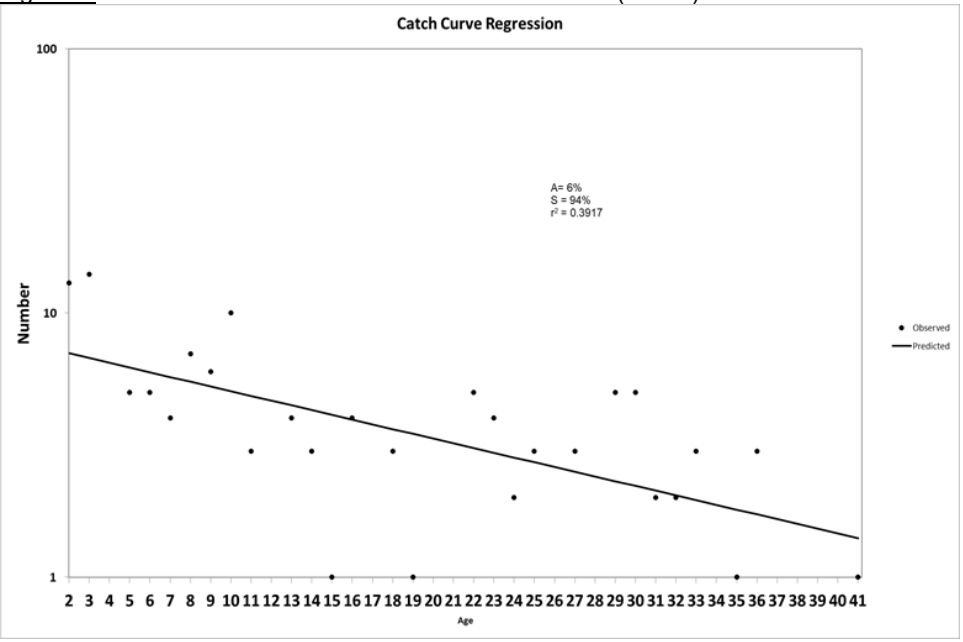
Figure 8. Von Bertalanffy growth curve for Smallmouth/Black buffalofishes (n=138) from Grand Lake.



We observed that female Grand Lake Smallmouth/Black buffalofishes were gravid at 520 mm or greater (generally classified as stage 3 – maturing or stage 4 – mature). However, a large portion of the females collected of this size or greater were nongravid during the time of collection. This may be a strong indication that these fish may not be spawning annually. Gonadal recrudescence (or renewal) for buffalofishes is not well-studied, however in studies of Paddlefish, the rate of recrudescence may vary across latitudes, across stocks within the same species, or even within the lifespan of an individual fish (with shorter inter-spawning intervals [i.e., more rapid recrudescence] observed in older fish at prime reproductive potential) (Scarnecchia et al. 2007, 2019). Additional data on fecundity and gonadal recrudescence will be essential in determining accurate estimations of buffalofishes' resilience to exploitation. However, the little evidence we have from the Grand Lake Smallmouth/Black Buffalo stock indicates that we would be prudent to consider modeling various multi-year spawning intervals when examining the potential population impacts of exploitation on Oklahoma's buffalofishes.

Total annual mortality of Smallmouth/Black buffalofishes in Grand Lake was estimated at 6% (Figure 8). Instantaneous rates of mortality are low in this population- including both natural and fishing mortality. Further evaluation discerning natural and fishing mortality are needed to better understand the fishery. A stronger understanding of mortality is needed to set harvest limits based on maximum sustainable yield.

Figure 8. Catch Curve for Smallmouth/Black buffalofishes (n=138) from Grand Lake.



FUTURE EFFORTS AND MANAGEMENT RECOMMENDATIONS

Collections in 2024 and beyond: While opportunistic collections of buffalofishes have provided much valuable information about these species, contributing to an assessment of morphology and genetics, in order to adequately assess the status, distribution, and sustainability of NNG fisheries in Oklahoma, more data are needed. In order to meet demands for species/stock-level management of NNG fishes in Oklahoma reservoirs, localized assessments will be required with larger sample sizes. Short of developing intense sampling plans for collecting these data as the result of our own efforts, we hope to continue salvaging specimens from bowfishing take to best address data inadequacies and to maintain direct relevance to the sport most often targeting these species. Acquisition of tournament-shot fish will provide large volumes of specimens which will likely be adequate for assessment of age and growth, continuation/expansion of our buffalofish morphology and genetics project, and better fine tune our estimates of mortality and exploitation.

Regulatory strategies for management of nongame fishes: At present, only a select number of NNG fishes in Oklahoma are afforded any sort of regulatory protection (Table 1). However, as emerging fisheries such as sport bowfishing and “carp” angling (which, in practice, targets carps, buffalofishes, and carpsuckers), plus other fisheries such as gigging, pressure these NNG stocks, we have an obligation to ensure that the fishery opportunities provided to our license holders are responsible and sustainable. Numerous challenges are realized when an expanding fishery (e.g., bowfishing) targets a group of NNG fishes with high conservation value (i.e., long lifespans, irregular recruitment) and no regulatory limitations on take. These challenges are confronted in recent, but long overdue literature on the sport, it’s need for management, and the barriers to funding (Scarnecchia and Schooley 2020; Scarnecchia et al. 2021), although these concepts are not new ones (Scarnecchia 1992). Fundamentally, any hunting or fishing opportunities overseen by the Department should be managed for sustainability. However, a low social value stigma associated with many NNG fishes has been historically applied to these fish. As a result, there has been a historical reluctance to expend attention, effort, or funding on their behalf. Modern fisheries science prioritizes healthy

ecosystems and aquatic communities rather than a focus on cultivating a few species (perhaps nonnative) that are favored by anglers. NNG fishes are valued for their roles in the fishery community (as predator, forage, etc.) or for the ecosystem services they provide (e.g., as hosts to freshwater mussels, see Appendix B). The conservation value of NNG fishes would conflict with their eradication or removal- whether it be willful through overfishing or negligent through lack of regulatory oversight.

A substantial regulatory proposal package was submitted in 2023 with the objective to set an example by assigning value to NNG fishes. The proposed changes would prohibit the shoot and immediate release of NNG fishes by bowfishing. This practice is currently prohibited in 42 states, but is only quasi-legal in Oklahoma through an enforcement loophole. Use of Oklahoma's native wildlife as targets with no intent to retain the usable parts (e.g., edible flesh), essentially amounts to sport wounding or killing and is in stark conflict with the fundamental tenets of the North American Model of Wildlife Conservation. Typically, state statutes prevent the wanton waste of wildlife or wildlife parts. However, Oklahoma Title 29 creates a conflict by protecting an angler's rights to return fish remains to a reservoir and there is not clear differentiation between a filleted carcass and a perforated (wounded or dead) whole fish. Our research removed all doubt that a high fraction (87%) of fish shot with a bow and arrow die within 5 days (60% dead within 12 hours) and the sport cannot be responsibly practiced as shoot and release (Montague et al. 2023).

A second major component of the regulatory proposal was comprised of an aggregate daily limit of 10 NNG fishes for all methods. This proposal was justified not as a solution to overharvest of any particular species, but as a demonstrative move by the Department to assign social value to a suite of NNG species. Fish and wildlife species with a daily bag limit are viewed as inherently more valuable. Our statewide bowfishing survey results (York et al. 2022) indicated that only a small fraction of bowfishers (13%) would be impacted by the bag limit. Additional psychological impacts of applying a bag limit to an unregulated fishery were considered (i.e., the "Limit Syndrome" as described by Evans (1971)). In the absence of a harvest limit, the benchmark of success (Fox 1975) for a bowfishing trip is individually defined. Through implementation of a harvest limit, any person harvesting over that limit would now be impacted by the limit, however someone harvesting below the limit may now be inspired to fish more because the limit is perceived as a benchmark of success. Proximity to the daily limit has been demonstrated as correlated to angler satisfaction in studies with game fishes (Cook et al. 2001). Therefore, responsible selection of a limit must consider multiple factors. A range of limits were modeled to examine the harvest impacts of inspiring enhanced effort and harvest for bowfishers typically harvesting below the new limit. The limit of 10 was ultimately selected because it impacted few bowfishers while being robust to enhanced pressure of limit-seekers. Selection of larger daily limits ran the risk of increasing harvest by moving the benchmark of success far enough to create an imbalance between harvest reduction of bowfishers above the limit and enhanced harvest of bowfishers below the limit.

Additional components to the rule change proposals related to NNG fishes and bowfishing concerned a revised definition of bowfishing equipment, an alignment of the possession limit with the daily bag limit, and some clarifications on fish carcass disposal.

Outreach, social media, and human dimensions: ODWC, with the assistance of the Nongame Fishes Committee and our program, continues to be a leader among agencies advocating for the appreciation of NNG fishes. November 2023 saw another successful installment of the popular #GarWeek on social media platforms. This year's objective was to feature the nexus between gars and other NNG fishes that have low social value, but high conservation value.

While statewide angler surveys have typically reflected low rankings for NNG fishes among the more popular game fishes and NNG fishes have been held in relatively low social regard among anglers (York et al. 2022), social media campaigns have been shown to be effective at fostering goodwill on behalf of our quirky native nongame fishes such as the gars when the messaging is delivered by the Department- a passionate and authoritative source.

Management plan for nongame fishes: Though our program is in it's infancy, as is the generalized focus on management of NNG fishes, we would benefit from the development of a plan for the statewide management of these fishes. It is likely that there is significant overlap with the fundamental hypotheses and objectives featured in the Oklahoma Paddlefish Management Plan (Scarnecchia et al. 2013). Using the Paddlefish plan as a blueprint (simply substituting "native nongame fishes"), we reveal a meaningful outline for a future NNG management plan-

A Comprehensive Plan for the Management of Native Nongame Fishes in Oklahoma
Oklahoma Department of Wildlife Conservation (modified from Scarnecchia, et al. 2013)

Philosophy and fundamental hypotheses

1. Oklahoma's NNG fishes are irreplaceable species of historical, recreational, commercial, and aesthetic significance.
2. Maintaining natural habitat conditions and numbers of wild fish adequate to sustain natural reproduction, growth and survival are critical to the long-term survival of the species.
3. Benefits from NNG resources should accrue to the entire public, rather than to just a few individuals or groups.
4. Sustainable recreational harvest and non-harvest fishing opportunities are desirable at the level appropriate within the productive capacity of the stocks.
5. The management plan for harvest and habitat should lead to sustainability of the resource and be matched to the life history of the species.
6. High-quality data is critical to stock assessment and sustainable management; fish harvest should be a key source of necessary data.
7. Goals, objectives, and actions, including management regulations and monitoring, should be as uniform as practicable among the stocks but remain sensitive to stock-specific and location-specific fisheries constraints and conditions.
8. A thorough knowledge of the stock-recruitment relationship and factors affecting year class strength should be high priorities for stock assessment.
9. The plan for Oklahoma NNG stocks and harvest management units need not be consistent with, but should not be detrimental to, broader (regional or national) NNG conservation and management goals and activities. The plan should strive for consistency with other in-state and regional fisheries management plans.
10. Evaluation, regulation, enforcement, information, and education are keys to the success of the plan and should be assessed annually for effectiveness.

Goals for NNG management in Oklahoma

1. Provide a basis for cooperative, coordinated management of Oklahoma NNG fishes in consultation with the appropriate federal agencies and Native American Tribes.
2. Provide for an orderly, equitable, and sustainable recreational fishery for NNG fishes and a harvest consistent with the productive capacity of the stocks. This goal should include similar regulations between in-state harvest areas and between states, to the extent possible.
3. Develop and maintain a standardized database for stock assessment and yield forecasting.
4. Maintain and enhance existing NNG fish habitat and obtain additional information to better define and provide for NNG habitat requirements.
5. Conduct research necessary for successful long-term management.
6. Integrate and define the role of artificial propagation and stocking in the successful long-term management.
7. Increase public awareness of NNG fishes and their habitat requirements.
8. Incorporate public acceptance and compliance with the regulatory framework established for long-term management.

LITERATURE CITED

von Bertalanffy, L. 1938. A Quantitative Theory of Organic Growth (Inquiries on Growth Laws. II). Human Biology 10(2):181–213.

Buckmeier, D. L., N. G. Smith, and D. J. Daugherty. 2013. Alligator Gar Movement and Macrohabitat Use in the Lower Trinity River, Texas. Transactions of the American Fisheries Society 142(4):1025–1035.

Cook, M. F., T. J. Goeman, P. J. Radomski, J. A. Younk, and P. C. Jacobson. 2001. Creel Limits in Minnesota: A Proposal for Change. Fisheries 26(5):19–26.

Daugherty, D. J., A. H. Andrews, and N. G. Smith. 2020. Otolith-Based Age Estimates of Alligator Gar Assessed Using Bomb Radiocarbon Dating to Greater than 60 Years. North American Journal of Fisheries Management 40(3):613–621.

Davis-Foust, S. L., R. M. Bruch, S. E. Campana, R. P. Olynyk, and J. Janssen. 2009. Age Validation of Freshwater Drum using Bomb Radiocarbon. Transactions of the American Fisheries Society 138(2):385–396.

DiBenedetto, K. C. 2009. Life history characteristics of Alligator Gar, Atractosteus spatula, in the Bayou Dularge area of southcentral Louisiana. Louisiana State University.

Eddy, S., and J. C. Underhill. 1978. How to Know the Freshwater Fishes, 3rd edition. WCB/McGraw-Hill, Boston, Massachusetts.

Evans, G. B. 1971. The upland shooting life1st ed. Knopf, New York.

Fox, A. C. 1975. Effects of traditional harvest regulations on bass populations and fishing. Pages 393–398 *in* R. H. Stroud and H. Clepper, editors. Black Bass biology and management. Sport Fishing Institute, Washington, D.C.

Hubbs, C., R. J. Edwards, and G. P. Garrett. 2008. An Annotated Checklist of the Freshwater Fishes of Texas, with Keys to Identification of Species, 2nd edition. Texas Academy of Science.

Lackmann, A. R., A. H. Andrews, M. G. Butler, E. S. Bielak-Lackmann, and M. E. Clark. 2019. Bigmouth Buffalo Ictiobus cyprinellus sets freshwater teleost record as improved age analysis reveals centenarian longevity. Communications Biology 2(1):197.

Lackmann, A. R., E. S. Bielak-Lackmann, M. G. Butler, and M. E. Clark. 2022a. Otoliths suggest lifespans more than 30 years for free-living bowfin *Amia calva*: Implications for fisheries management in the bowfishing era. Journal of Fish Biology 101(5):1301–1311.

Lackmann, A. R., E. S. Bielak-Lackmann, R. I. Jacobson, A. H. Andrews, M. G. Butler, and M. E. Clark. 2023a. Harvest trends, growth and longevity, and population dynamics reveal traditional assumptions for redhorse (*Moxostoma* spp.) management in Minnesota are not supported. Environmental Biology of Fishes.

Lackmann, A. R., E. S. Bielak-Lackmann, R. I. Jacobson, M. G. Butler, and M. E. Clark. 2022b. Otolith allometry informs age and growth of long-lived Quillback Carpiodes cyprinus. Environmental Biology of Fishes 105(8):1051–1064.

Lackmann, A. R., J. Sereda, M. Pollock, R. Bryshun, M. Chupik, K. McCallum, J. Villeneuve, E. S. Bielak-Lackmann, and M. E. Clark. 2023b. Bet-hedging bigmouth buffalo (*Ictiobus cyprinellus*) recruit episodically over a 127-year timeframe in Saskatchewan. Canadian Journal of Fisheries and Aquatic Sciences 80(2):313–329.

Long, J. M., R. A. Snow, D. E. Shoup, and J. B. Bartnicki. 2023. Validation and Comparison of Age Estimates for Smallmouth Buffalo in Oklahoma Based on Otoliths, Pectoral Fin Rays, and Opercula. North American Journal of Fisheries Management 43(3):618–627.

McAllister, C. T., E. M. Leis, D. G. Cloutman, and H. W. Robison. 2023. New Geographic Distribution Record for Quillback, *Carpiodes cyprinus* (Cypriniformes: Catostomidae) in the Verdigris River (Arkansas River drainage) of Northern Oklahoma.

McGrath, P. E., E. J. Hilton, and J. A. Musick. 2016. Population Demographics of Longnose Gar, *Lepisosteus osseus,* from the Tidal Rivers of Virginia. Copeia 104(3):738–745.

Mensinger, G. C. 1971. Oklahoma Commercial Fisheries Harvest Summary 1961-1969. Proceedings of the Oklahoma Academy of Sciences 51:23–28.

Miranda, L. E., and P. W. Bettoli. 2007. Mortality. Pages 229–277 *in* C. S. Guy and M. L. Brown, editors. Analysis and interpretation of freshwater fisheries data. American Fisheries Society, Bethesda, Maryland.

Montague, G. F., J. D. Schooley, D. L. Scarnecchia, and R. A. Snow. 2023. Bowfishing shoot and release: High short-term mortality of nongame fishes and its management implications. North American Journal of Fisheries Management 43(4):962–983.

ODWC. 2016. Oklahoma Comprehensive Wildlife Conservation Strategy: A Strategic Conservation Plan for Oklahoma's Rare and Declining Wildlife. Page 422. Oklahoma Department of Wildlife Conservation, Oklahoma City.

Patton, T., and C. Lyday. 2008. Ecological Succession and Fragmentation in a Reservoir: Effects of Sedimentation on Habitats and Fish Communities. Pages 147–167 *in* M. S. Allen, S. Sammons, and M. J. Maceina, editors. Balancing Fisheries Management and Water Uses for Impounded River Systems. American Fisheries Society, Symposium 62, Bethesda, Maryland.

Phillips, G. L., and J. C. Underhill. 1971. Distribution and Variation of the Catostomidae of Minnesota. Occasional Papers of the Bell Museum of Natural History 10:1–45.

Radford, D. S., A. R. Lackmann, C. J. Moody-Carpenter, and R. E. Colombo. 2021. Comparison of Four Hard Structures Including Otoliths for Estimating Age in Blue Suckers. Transactions of the American Fisheries Society 150(4):514–527.

Reid, S. M. 2009. Age, growth and mortality of black redhorse (*Moxostoma duquesnei*) and shorthead redhorse (*M. macrolepidotum*) in the Grand River, Ontario. Journal of Applied Ichthyology 25(2):178–183.

Rypel, A. L., P. Saffarinia, C. C. Vaughn, L. Nesper, K. O'Reilly, C. A. Parisek, M. L. Miller, P. B. Moyle, N. A. Fangue, M. Bell-Tilcock, D. Ayers, and S. R. David. 2021. Goodbye to "Rough Fish": Paradigm Shift in the Conservation of Native Fishes. Fisheries 46(12):605–616.

Scarnecchia, D. L. 1992. A Reappraisal of Gars and Bowfins in Fishery Management. Fisheries 17(5):6–12.

Scarnecchia, D. L., B. D. Gordon, J. D. Schooley, and A. A. Nealis. 2013. A Comprehensive Plan for the Management of Paddlefish in Oklahoma. Oklahoma Department of Wildlife Conservation, Oklahoma City.

Scarnecchia, D. L., L. F. Ryckman, Y. Lim, G. J. Power, B. J. Schmitz, and J. A. Firehammer. 2007. Life History and the Costs of Reproduction in Northern Great Plains Paddlefish (*Polyodon spathula*) as a Potential Framework for Other Acipenseriform Fishes. Reviews in Fisheries Science 15(3):211–263.

Scarnecchia, D. L., and J. D. Schooley. 2020. Bowfishing in the United States: History, Status, Ecological Impact, and a Need for Management. Transactions of the Kansas Academy of Science 123(3–4).

Scarnecchia, D. L., and J. D. Schooley. 2022. Trophies, Technology, and Timescape in Fisheries Management, as Exemplified through Oklahoma's World Record Paddlefish *Polyodon spathula*. Fisheries 47(9):381–394.

Scarnecchia, D. L., J. D. Schooley, K. M. Backes, A. Slominski, S. Dalbey, and Y. Lim. 2019. Paddlefish Life History: Advances and Applications in Design of Harvest Management Regulations. Pages 1–27 *in* J. D. Schooley and D. L. Scarnecchia, editors. Paddlefish: Ecological, Aquacultural, and Regulatory Challenges of Managing a Global Resource. American Fisheries Society, Bethesda, Maryland.

Scarnecchia, D. L., J. D. Schooley, A. R. Lackmann, S. J. Rider, D. K. Riecke, J. McMullen, J. E. Ganus, K. D. Steffensen, N. W. Kramer, and Z. R. Shattuck. 2021. The Sport Fish Restoration Program as a Funding Source to Manage and Monitor Bowfishing and Monitor Inland Commercial Fisheries. Fisheries 46(12):595–604.

Smith, N. G., D. L. Buckmeier, D. J. Daugherty, D. L. Bennett, P. C. Sakaris, and C. R. Robertson. 2020. Hydrologic Correlates of Reproductive Success in the Alligator Gar. North American Journal of Fisheries Management 40(3):595–606.

Snow, R. A., M. J. Porta, and D. M. Bogner. 2020. Examination of the Current Oklahoma State. Proc. Okla. Acad. Sci. 100:16–21.

York, B., J. D. Schooley, and D. L. Scarnecchia. 2022. Oklahoma Bowfishing Values and Perspectives toward Nongame Fishes and Their Management. North American Journal of Fisheries Management 42(4):1020–1040.

Zentner, D., D. Shoup, and S. K. Brewer. 2023. Effects of sucker gigging on fish populations in Oklahoma scenic rivers. U.S. Fish and Wildlife Service, Cooperator Science Series.

Appendix A. Regulatory Summary for Select Nongame Fishes

Daily bag limits for select nongame fishes in select states.

Species of Greatest Conservation Need (SGCN) are shaded in orange. Aggregate bag limits are shaded in green. The designation *NA* is used when a species is not found in a state (according to the species distribution map) and any uncertainties are noted with a question mark (?).

Native Nongame Species	OK	TX	MO	AR	NM	NE	CO	LA	AL	MS	IA	IL	TN	OH	WI	MN	VA	KS	Dist. MAP
Alligator Gar	1	1	20	1	*NA*	*NA*	*NA*	unlim	1	2	*NA*	1	0	0	*NA*	*NA*	*NA*	*?*	LINK
Longnose Gar	unlim	unlim	20	unlim	unlim	unlim	*NA*	unlim	unlim	unlim	unlim	unlim	unlim	?	unlim	10	1 or 5	unlim	LINK
Shortnose Gar	unlim	unlim	20	unlim	unlim	unlim	*NA*	unlim	unlim	unlim	unlim	unlim	unlim	0	unlim	10	?	unlim	LINK
Spotted Gar	unlim	unlim	20	unlim	unlim	unlim	*NA*	unlim	unlim	unlim	unlim	unlim	unlim	0	unlim	10	?	unlim	LINK
Bigmouth Buffalo	unlim	unlim	20	unlim	unlim	unlim	*NA*	25	unlim	unlim	unlim	unlim	unlim	unlim	unlim	unlim	exotic	unlim	LINK
Smallmouth Buffalo	unlim	unlim	20	unlim	unlim	unlim	*NA*	25	unlim	unlim	unlim	unlim	unlim	unlim	unlim	unlim	exotic	unlim	LINK
Black Buffalo	1	unlim	20	unlim	unlim	unlim	*NA*	25	unlim	unlim	unlim	unlim	unlim	unlim	0	unlim	exotic	unlim	LINK
River Carpsucker	unlim	unlim	20	unlim	unlim	unlim	*NA*	unlim	unlim	unlim	unlim	unlim	unlim	unlim	unlim	unlim	20	unlim	LINK
Quillback	unlim	unlim	20	unlim	unlim	unlim	*NA*	unlim	unlim	unlim	unlim	unlim	unlim	unlim	unlim	unlim	20	unlim	LINK
Highfin Carpsucker	unlim	unlim	20	unlim	unlim	unlim	*NA*	unlim	unlim	unlim	unlim	unlim	unlim	unlim	unlim	unlim	20	unlim	LINK
Freshwater Drum	unlim	unlim	20	unlim	unlim	unlim	*NA*	25	unlim	unlim	unlim	unlim	unlim	unlim	unlim	unlim	20	unlim	LINK
Paddlefish	1	0	2	2	*NA*	2	*NA*	2	0	2	2	2	2		0	0	*NA*	2	LINK
Bowfin	unlim	unlim	20	unlim	unlim	0	*NA*	unlim	unlim	unlim	unlim	unlim	unlim	unlim	unlim	unlim	1 or 5	?	LINK
Links to Regs:	LINK	LINK	LINK	LINK		LINK	LINK	LINK	LINK	LINK	LINK	LINK	LINK	LINK	LINK	LINK	LINK	LINK	

Appendix B. Ecosystem services of Oklahoma's Nongame Fishes – Mussel Hosts

Oklahoma's native nongame fishes are host to many freshwater mussels, some of which are imperiled (red shading indicates endangered and yellow shading indicates threatened). The right three columns contain mussel species hosted by taxonomic grouping of similar species (gars, buffalofishes, and carpsuckers).

Data are summarized from the Illinois Natural History Mussel database
https://fms19.naturalhistorysurvey.org/fmi/webd/Freshwater%20Mussel%20Host%20Database

Imperiled status of mussels is derived from US Fish and Wildlife species status listings https://ecos.fws.gov/ecp/report/species-listings-by-tax-group?statusCategory=Listed&groupName=Clams&total=120

Mussel Common Name	Longnose Gar	Shortnose Gar	Spotted Gar	Alligator Gar	Florida Gar	Bigmouth Buffalo	Smallmouth Buffalo	Black Buffalo	Freshwater Drum	Bowfin	River Carpsucker	Quillback	Highfin Carpsucker	Shorthead Redhorse	Robust Redhorse	Silver Redhorse	Jumprock	Golden Redhorse	River Redhorse	White Sucker	Spotted Sucker	Gars	Buffalofishes	Carpsuckers
Alewife Floater																				1		0	0	0
Altamaha Arcmussel															1		1				1	0	0	0
Altamaha Lance															1							0	0	0
Altamaha Spinymussel																					1	0	0	0
Arkansas Brokenray																				1		0	0	0
Arkansas Fatmucket									1													0	0	0
Atlantic Pigtoe																	1					0	0	0
Black Sandshell									1													0	0	0
Bleufer									1													0	0	0
Butterfly									1													0	0	0
California Floater																				1		0	0	0
Clubshell																		1				0	0	0
Creek Heelsplitter		1				1				1										1		1	1	0
Cylindrical Papershell																				1		0	0	0
Deertoe									1													0	0	0
Eastern Floater																				1		0	0	0
Ebonyshell									1													0	0	0
Elktoe							1				1	1		1		1		1		1		0	1	2
Fat Pocketbook									1													0	0	0
Fatmucket					1													1		1		1	0	0
Fawnsfoot									1													0	0	0
Florida Sandshell					1																	1	0	0
Florida Spike					1																	1	0	0
Flutedshell	1					1			1	1		1		1		1			1	1		1	1	1
Fragile Papershell									1													0	0	0
Giant Floater	1								1		1									1		1	0	1
Higgins Eye									1													0	0	0
Inflated Heelsplitter									1													0	0	0
Neosho Mucket									1													0	0	0
Northern Riffleshell										1		1										0	0	1
Ohio Pigtoe																				1		0	0	0
Pink Heelsplitter									1													0	0	0
Pink Mucket									1													0	0	0
Pink Papershell									1													0	0	0
Plain Pocketbook									1													0	0	0
Pondmussel						1				1												0	1	0
Purple Bankclimber															1						1	0	0	0
Rabbitsfoot																		1				0	0	0
Rock Pocketbook							1		1			1		1						1		0	1	1
Round Pearlshell			1																			1	0	0
Round Pigtoe									1													0	0	0
Rough Fatmucket																						0	0	0
Scaleshell									1													0	0	0
Slippershell																						0	0	0
Southern Creekmussel																						0	0	0
Southern Kidneyshell																					1	0	0	0
Southern Pocketbook																						0	0	0
Southern Rainbow																						0	0	0
Spectaclecase														1								0	0	0
Threehorn Wartyback									1													0	0	0
Threeridge		1							1									1				1	0	0
Wabash Pigtoe																1						0	0	0
Washboard	1								1	1			1									1	0	1
Western Pearlshell																				1		0	0	0
White Heelsplitter	1																		1	1		1	0	0
Yellow Sandshell	1	1		1																		3	0	0
Totals	5	3	1	1	3	3	2	0	24	5	2	4	1	4	3	3	2	5	2	14	4	13	5	7