Final Performance Report

Wildlife and Sport Fish Restoration Program

U.S. Fish and Wildlife Service

OK T-120-R-1 Detection and Occupancy of Bluntface Shiner (Cyprinella camura) in wadeable streams of northeastern Oklahoma

Final Performance Report Generated 10/19/2023

Performance Report Approval Status:

Awaiting Non-federal Review and Approval

Recipient:

OKLAHOMA DEPARTMENT OF WILDLIFE CONSERVATION

Recipient Grant ID:

Federal Award Number:

F20AF11966

Funding Program(s) Name:

SWG Implementation

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Jan 01, 2021 to Jun 30, 2023

Performance Reporting Period:

Jan 01, 2023 to Jun 30, 2023

Federal Award Recipient Contact(s):

Andrea Crews

Federal Award Specialist(s):

William Amy

Type of Performance Report:

Final Performance Report

Public Description:

The Bluntface Shiner (*Cyprinella camura*) is a Tier II Species of Greatest Conservation Need in Oklahoma. Herein, we propose two objectives to update the known distribution and habitat associations of the species. First, we will conduct a thorough survey for existing occurrence records in Oklahoma, providing insight into historic and current distribution across the state. Second, we will conduct directed field surveys to identify the most important habitat correlates for this species via detection and occupancy modeling. The proposed work will

provide a foundation for future, proactive conservation efforts.

Federal Award Accomplishments				
Strategy	**Proposed Objective**	**Activity**	**Unit of Measure - Proposed**	**Unit of Measure - Reported**
Research, Survey, Data Collection and Analysis	Conduct investigations	Fish and wildlife species data acquisition and analysis	1 Investigations	1 Investigations

Table of Contents - Project Statements

Project Statement: OK T-120-R-1 Detection and Occupancy of Bluntface Shiner (Cyprinella camura) in wadeable streams of northeastern Oklahoma
Project Statement Approval Status: Final Approved

Objective Name: Objective 1: Conduct 1 investigation by Dec. 31, 2022

Strategy: Research, Survey, Data Collection and Analysis
Proposed Objective: Conduct investigations
Pertains to R3: No

Activity Performed: Fish and wildlife species data acquisition and analysis
# of Investigations: 1.0000
Principal Investigator: Andrew Taylor
Geographic Location:

- General Location: Oklahoma
- Includes Marine Federal Waters: No
- Detailed Location:
    - Adair County
    - Cherokee County
    - Craig County
    - Delaware County
    - Grant County
    - Kay County
    - Mayes County
    - Nowata County
    - Osage County
    - Ottawa County
    - Rogers County
    - Sequoyah County
    - Tulsa County
    - Wagoner County
    - Washington County
- Location Description:

  According to Miller and Robsion (2004), Cross (1967), and Eberle (2014) sampling sites for Bluntface Shiner may span wadeable streams within the following northeastern Oklahoma counties: Adair, Cherokee, Craig, Delaware, Grant, Kay, Mayes, Nowata, Osage, Ottawa, Rogers, Sequoyah, Tulsa, Wagoner, and Washington.

Activity Report Comments:

*Totals to date represent a cumulative total of all period of performance and may exceed the objective.

Objective Report	
Period of Performance	**# of Investigations**
Jan 1, 2021 to Dec 31, 2021	
Jan 1, 2022 to Dec 31, 2022	
Jan 1, 2023 to Jun 30, 2023	1
Totals to Date*	1

Species Tags

Species Tags
bluntface shiner *Cyprinella camura*

Activity Performed Attachments

Descriptive Name	Field tags	Attachment Type
No Files Attached		

Performance Reporting Questionnaire

1. What progress has been made towards completing the objective(s) of the project?

In Oklahoma, Bluntface Shiner (*Cyprinella camura*; BFS) populations are considered "decreasing" or "unknown," and the species is designated as a Tier II Species of Greatest Conservation Need. Current information on the distribution and habitat associations of BFS is lacking. To update knowledge and inform future conservation efforts for BFS, we performed a thorough survey of existing occurrence records in Oklahoma to glean insight into the historic species range across the state. Additionally, we conducted field surveys across large portions of the historic range in Oklahoma with the goals of identifying the most effective capture methods for BFS (seine versus backpack electrofisher) in wadable streams and quantifying habitat associations that influence species occupancy. Our historic BFS record survey revealed a historic range that included tributaries and mainstem river segments of watersheds along the north-central and eastern parts of Oklahoma. Several historic records were flooded by reservoirs and dams disjunct clusters of species records between watersheds. We performed surveys during the summers of 2021 and 2022 in search of BFS in wadable streams across the historic range. We surveyed 61 unique sites with 191 site visits, and we captured BFS at a total of 18 sites across the Chikaskia, Caney, Verdigris, Spring, Elk, and Lake O' the Cherokees watersheds. Capture of BFS differed between channel units (i.e., riffle, run, and pool), with riffle units producing the greatest raw catches followed by run and pool. Detection modeling supported interactions between gears and environmental conditions at sites, which can be used to inform optimal gear choice in specific conditions. Accounting for imperfect detection, our occupancy model estimated an occupancy rate of 29.5% which matched our naïve occupancy of 29.5% observed in the field. The low occupancy estimate of BFS suggests a decline from their historic range within Oklahoma. We recommend increased monitoring of BFS populations and further research on the life history, metapopulation dynamics, and population genetics of BFS to further our understanding of their ecology, status, and conservation needs.

See attached for full report.

2. Please describe and justify any changes in the implementation of your objective(s) or approach(es).

No changes.

3. If applicable, please share if the project resulted in any unexpected benefits, promising practices, new understandings, cost efficiencies, management recommendations, or lessons learned.

- The most recent BFS records (years 2000- 2018) exist along the northern border of Oklahoma, but there is a paucity of recent records in eastern portions of the historic range. The apparent lack of recent occurrence records in the Lower Neosho, Dirty-Greenleaf, and Illinois could indicate largescale declines from the historic range. Declines in eastern Oklahoma should be considered in the context of the entire BFS range in the Arkansas River Basin (e.g., Missouri and Arkansas) because the watersheds that once supported BFS are not confined within the state boundaries of Oklahoma. Range declines or extirpation from neighboring states brings into question the overall stability of BFS populations in the Arkansas River Basin and emphasizes the need for close monitoring of extant populations in Oklahoma.
- Large impoundments are prominent features across the contemporary riverscape in areas of the historic BFS range. Several occurrence records are presently flooded by reservoirs, while groups of records between watersheds are disjunct by dams. Similarly, some populations have persisted upstream of large impoundments, while others have apparently suffered extirpation. Studies to investigate spatial relationships between large impoundments and their effects on BFS range may help prioritize populations for conservation action.
- Field surveys in search of BFS within the historic range in Oklahoma yielded captures of the minnow from sites that coincided with the most recent historic records. Sites in the Caney and Verdigris watersheds produced the largest number of BFS (approximately 200 individuals total), while captures from Chikaskia, Spring, Lake O' the Cherokees, and Elk produced much fewer BFS. The Caney and Verdigris represent strongholds for BFS in Oklahoma and would be good opportunities for investigating reproduction, growth, macro- and microhabitat requirements, and movement patterns of healthy populations. Such information could be leveraged in investigations of, and conservation actions for, BFS populations elsewhere.
- One of the uniting factors among sites where BFS were captured in this study was the presence of riffle and run habitat that held sufficient flow throughout the summer months. Maintaining summer baseflows may be critical to BFS natural reproduction.
- Surveys in search of BFS presence could focus on riffle and run habitats, where we found catch rates to be highest. Such information can help minimize time spent in habitats where BFS are more difficult to detect, such as pools.
- From our detection models, we found that seine net was the most effective gear for detecting BFS in wadeable streams across a broad range of environmental conditions encountered at our sites. We recommend the use of seine when targeting BFS for its effectiveness in capturing BFS and versatility in highly variable environments, in addition to its ease of use and cost-effectiveness. However, our results also suggest that in specific conditions, BPEF may be suitable for BFS detection. Our results allow for future investigations to employ a more-informed sampling approach by selecting the appropriate gear based on conditions present at the site (e.g., turbidity, conductivity, depth, etc.).

- From our occupancy models, it was estimated that BFS occupied 29.5% of our sites, which was no different than our naïve occupancy of 29.5%. This result could be explained by detection probability of BFS being high enough that we would detect the minnow if present at the site (given that we visited each site up to four times). In reality, we know that our ability to detect BFS may have been slightly lower. During our field seasons, other survey teams (including ODWC and OCC) captured BFS individuals at (or in immediate proximity to) sites that we sampled but did not capture any BFS. When BFS abundance is very low in a system, we posit that detection probability is largely random chance.
- The low naïve and estimated occupancy across sites that we pre-selected for a higher likelihood of containing BFS provides strong evidence that that modern BFS populations may occupy less than a third of their historic range. This is particularly concerning because our survey area was entirely within the historic BFS distribution, and we biased our site locations based on proximity to historic BFS records. Additional surveys would improve the accuracy of occupancy estimates and further refine our knowledge of the BFS whereabouts in Oklahoma.
- Total drainage area was the most supported variable in explaining occupancy across our study sites, wherein occupancy probability of BFS increased as total drainage area size increased. Drainage area size is correlated with many factors including water flow, depth, stream size and length, and various physicochemical properties that change with increasing size and are closely linked to fish assemblage structure and richness (Allan et al., 2021; Matthews, 2012). We hypothesize that larger total drainage area sizes are important in metapopulation dynamics involving source and sink populations of BFS. Source habitats would include areas suitable for spawning, rearing, and refugia, while sink habitats are those with unfavorable conditions where local extinction would occur without rescue from populations elsewhere (Falke and Fausch, 2010). Because the availability of these habitats varies unpredictably across space and time (Falke et al., 2012), greater access to and connectivity between critical habitats is crucial for population persistence, reproduction, and dispersal (Dodds et al., 2004; Sedell et al., 1990; Labbe and Fausch, 2000; Falke et al., 2010). For BFS populations, larger total drainage area sizes may provide greater environmental stability, access to important mesohabitats, and increased chances of successful colonization (Hoagstrom and Berry, 2006).
- The presence of impoundments across the BFS distribution is problematic for several reasons. Besides the flooding of stream area with suitable habitat (as shown from the historic records map), impoundments shift lotic habitats toward lentic conditions, degrade or remove suitable habitat, promote the invasion of tolerant or non-native species, and block fish movement, which together disrupts metapopulation dynamics and can result in local extirpation (Luttrell et al., 1999; Hubbs and Pigg, 1976; Wilde and Ostrand, 1999; Schrank et al., 2001; Winston et al., 1991).We know that BFS are sensitive to water and habitat quality and therefore are likely negatively affected by

large impoundments in the aforementioned ways. Remaining BFS likely exist as several disconnected and isolated populations that are increasingly vulnerable to local extirpation without opportunity for rescue or recolonization from other areas. Future investigations should more explicitly investigate the effects of impoundments on BFS because there are areas where the minnow historically existed but have apparently disappeared (e.g., Illinois River Basin, Greenleaf Creek), but there are also extant populations upstream of some reservoirs (e.g., Caney and Verdigris rivers). Exploring the drivers of BFS decline would be useful for ODWC in determining at-risk populations and developing conservation plans for BFS populations in Oklahoma.

- Investigating the population genetics of BFS in Oklahoma would be beneficial in prioritizing conservation actions. Such work could help elucidate historic and contemporary gene flow across populations (i.e., have dams fragmented populations?), identify populations experiencing hybridization with Red Shiner or Steelcolor Shiner, and estimate conservation-oriented metrics such as inbreeding coefficients and effective population sizes.
- Though we focused on wadeable streams during summer months, occupancy modelling frameworks can be readily adapted to test other gears and habitats. For example, there is substantial evidence of BFS inhabiting large mainstreams of rivers. Hill et al. (1981) captured BFS exclusively from their sites within the mainstem of the Grand River and not in tributary creeks nearby, whereas in the Chikaskia, we found juveniles in the mainstream river but adults in tributaries. Detection and occupancy modelling can quantify the effectiveness of gears like tote-barge shocker or trawl net in capturing BFS in these habitats with the additional benefit of capturing drastically different abiotic conditions that are potentially suitable for BFS. It would be worthwhile to incorporate detection probabilities in future BFS monitoring programs to determine threshold conditions for effective gear use, or to inform gear efficacy prior to implementation (Schloesser et al., 2012) and occupancy probabilities to further refining our understanding of where BFS persist and habitat conditions that are most suitable.

4. For Survey projects only: If applicable, does this project continue work from a previous grant? If so, how do the current results compare to prior results? (Recipients may elect to add attachments such as tables, figures, or graphs to provide further detail when answering this question.)

Not Applicable

5. If applicable, identify and attach selected publications, photographs, screenshots of websites, or other documentation (including articles in popular literature, scientific literature, or other public information products) that have resulted from this project that highlight the accomplishments of the project.

Not Applicable

6. Is this a project you wish to highlight for communication purposes?

No

Questionnaire Attachments

Descriptive Name	Field tags	Attachment Type
2023 Final Report T-120-R-1 Bluntface Sh...	• Objective Completion Progress	Performance Report / Performance Hard Copy Report

Appendix

FINAL PERFORMANCE REPORT

Federal Aid Grant No. F20AF11966 (T-120-R-1)

Detection and Occupancy of Bluntface Shiner (*Cyprinella Camura*) in Wadeable Streams of Northeastern Oklahoma

Oklahoma Department of Wildlife Conservation

January 1, 2021 through August 10, 2023

FINAL PERFORMANCE REPORT

State: Oklahoma **Grant Number:** F20AF11966 (T-120-R-1)

Grant Program: State Wildlife Grants

Grant Title: Detection and occupancy of Bluntface Shiner (*Cyprinella camura*) in wadeable streams of northeastern Oklahoma

Grant Period: January 1, 2021 – August 10, 2023

Principal Investigators names and affiliation:

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EXECUTIVE SUMMARY

In Oklahoma, Bluntface Shiner (*Cyprinella camura*; BFS*)* populations are considered "decreasing" or "unknown," and the species is designated as a Tier II Species of Greatest Conservation Need. Current information on the distribution and habitat associations of BFS is lacking. To update knowledge and inform future conservation efforts for BFS, we performed a thorough survey of existing occurrence records in Oklahoma to glean insight into the historic species range across the state. Additionally, we conducted field surveys across large portions of the historic range in Oklahoma with the goals of identifying the most effective capture methods for BFS (seine versus backpack electrofisher) in wadable streams and quantifying habitat associations that influence species occupancy. Our historic BFS record survey revealed a historic range that included tributaries and mainstem river segments of watersheds along the north-central

and eastern parts of Oklahoma. Several historic records were flooded by reservoirs and dams disjunct clusters of species records between watersheds. We performed surveys during the summers of 2021 and 2022 in search of BFS in wadable streams across the historic range. We surveyed 61 unique sites with 191 site visits, and we captured BFS at a total of 18 sites across the Chikaskia, Caney, Verdigris, Spring, Elk, and Lake O' the Cherokees watersheds. Capture of BFS differed between channel units (i.e., riffle, run, and pool), with riffle units producing the greatest raw catches followed by run and pool. Detection modeling supported interactions between gears and environmental conditions at sites, which can be used to inform optimal gear choice in specific conditions. Accounting for imperfect detection, our occupancy model estimated an occupancy rate of 29.5% which matched our naïve occupancy of 29.5% observed in the field. The low occupancy estimate of BFS suggests a decline from their historic range within Oklahoma. We recommend increased monitoring of BFS populations and further research on the life history, metapopulation dynamics, and population genetics of BFS to further our understanding of their ecology, status, and conservation needs.

I. OBJECTIVES

<u>Objective 1</u> (TRACS Strategy – Research, Survey, Data Collection and Analysis)

Conduct 1 investigation by June 30, 2023.

- **Activity Tag 1: Fish and wildlife species data acquisition and analysis**
    - **Target Species: Bluntface Shiner (Cyprinella camura)**

Objective 1: To conduct a literature/museum search for existing records of Bluntface Shiner in Oklahoma

Objective 2: To quantify the habitat associations of Bluntface Shiner using detection and occupancy modeling informed by contemporary field surveys and habitat measurements

II. BACKGROUND

BFS is native to the Arkansas, Mississippi, and Tennessee river basins and currently exists as two disjunct populations to the east and west of the Mississippi River valley. On either side of the Mississippi River, BFS is associated with medium-to-large sized streams with clear, flowing waters over riffle and run habitats (Wilkinson and Edds, 2001; Cross, 1954; Etnier and Starnes, 1993; Farr, 1996). In the west, BFS is less abundant in lowland streams that generally have lower average base flow, higher turbidities, and sand, silt, and mud substrates (Cross and Calvin, 1971; Metcalf et al., 2010; Wilkinson and Edds, 2001). Similarly, BFS occurring east of the Mississippi River are mostly associated with upland headwaters of tributaries with moderate-to-swift flow and sand or gravel substrates (Johnston, 1999; Mayden, 1989; Farr, 1996; Ross and Brenneman, 2001). Despite some variation between east and west populations, BFS has specific habitat requirements for survival and reproduction. BFS is a crevice spawner that requires access

to rocky substrates for egg deposition and sufficient flow for egg aeration (Mayden 1989; Johnston, 1999), and spawning generally occurs during the spring and summer months from late April to August in the western range (Distler, 2014; Robinson and Buchanan, 2020; Miller and Robinson, 2004), and from March to August in the eastern range (Ross and Brenneman, 2001; Etner and Starnes, 1993).

BFS are of Least Concern according to the International Union for Conservation of Nature's global population assessment, but the population trend is unknown. Populations are apparently stable and secure in Kansas and Mississippi; however, BFS are susceptible to local declines (e.g., Cross and Braasch, 1968) and there is evidence of declines in several states. For example, in Louisiana, the BFS has not been captured in recent years (Robby Maxwell, Inland Fisheries Biologist, Louisiana Dept. of Wildlife and Fisheries, Pers. Comm.). In Oklahoma, BFS are captured in less abundance and from a limited number of areas in the eastern part of the state (Anthony Rodger, Stream Program Biologist, Oklahoma Dept. of Wildlife Conservation, Pers. Comm.; Nathan Carter, Biologist, Oklahoma Conservation Commission, Pers. Comm.). A number of streams that historically held BFS in Missouri and Oklahoma flow into the state of Arkansas, yet no BFS have been documented since the late 1960s (Robinson and Buchanan, 2020). As such, BFS are considered at-risk of extirpation in Oklahoma, Missouri, and Louisiana (Oklahoma Department of Wildlife Conservation, 2016; Missouri Department of Conservation, 2021, Louisiana Wildlife and Fisheries, 2022) and extirpated from Arkansas (Arkansas Game and Fish Commission, 2017). BFS population declines are often attributed to the species being sensitive to anthropogenic degradation of water quality and in-stream habitat quality degradation (Jester et. Al., 1992). For example, Cross and Calvin (1971) found that the once abundant BFS had been mostly extirpated after increased cattle ranching activity in the upper Neosho River.

They attributed this decline to low oxygen-stress tolerance and limited optimal habitat during summer months which, in conjunction with increased pollution, prevented BFS from reestablishing after fish-kills. Where BFS cannot recover from disturbance, it is also possible that they are replaced by more tolerant species such as Red Shiner (*Cyprinella lutrensis*) which is tolerant to a range of water conditions including low dissolved oxygen, high turbidities, and thermal shock (Cross and Calvin, 1971; Jester et al., 1992; Matthews and Hill, 1997). This may explain past observations of Red Shiner having higher abundances in stream segments where BFS abundance was low and vice versa (Cross, 1954). Unfortunately, there is a general lack of recent, in-depth investigations on BFS habitat needs and distribution to inform conservation and more work is needed to understand basic habitat associations of BFS and to identify drivers of range loss.

II. SUMMARY OF PROGRESS:

A. METHODS

Objective 1

Historic records survey – We collected Bluntface Shiner (BFS) occurrence records by querying online species databases, state resource agencies, and natural history museums. Online databases included GBIF, FishNet2, iDigBio, iNaturalist, and BISON. We also contacted the following state agencies: Oklahoma Department of Wildlife Conservation (ODWC) and Oklahoma Conservation Commission (OCC). To discover records held at museums or by researchers affiliated with them, we contacted the University of Oklahoma Sam Noble Museum (including Dr. Matthews and Dr. Marsh-Matthews), and the Oklahoma State University Collection of Vertebrates (including Dr. Echelle). The database of collected occurrence records

contained the following information: personal database collection number, occurrence record locality information, state, latitude, longitude, collection date, collection year, data source, reference or collector information, gear used, and collector notes.

We performed measures to ensure occurrence data quality. First, extraneous data points existing outside of the native range (Arkansas River Basin) or outside of Oklahoma were removed. Next, data lacking both latitude/longitude and locality information were removed. For data points with locality information but no coordinates, we georeferenced localities with GEOLocate Web client v3.22 (Rios and Bart, 2010) to obtain coordinates. Records with vague locality information that could not be georeferenced were removed. These steps ensured that all occurrence records contained coordinate information. Lastly, duplicate records were removed so that only unique collection events (i.e., unique date and location combinations) remained.

As an additional quality filter for the spatial dataset, we ensured that all coordinates could be geospatially linked to a valid stream location. Using ESRI ArcMap v10.6.1, the Arkansas River stream network was mapped with the National Hydrography Dataset (NHD) flowline within the NHDPlusV2 dataset (Environmental Protection Agency, 2021). Occurrence records were mapped and spatially joined to the nearest stream segment. Join distance (km) and locality information of the occurrence record were referenced to determine if occurrence records were joined to the appropriate stream segment. For example, records with an unusually large join distance could indicate a join to an incorrect stream segment. Furthermore, occurrence records near a confluence of two streams may erroneously join to a different segment nearby, so sampling locality descriptions were manually compared to the joined stream segment names as an additional quality filter. In these cases, we made slight manual adjustments to coordinates using imagery in Google Earth Pro v7.3.4, then re-imported and re-joined records so that all occurrence records aligned

geospatially with the correct stream segment. Following these measures, the resulting spatial dataset can be imported along with latitude and longitude for use in GIS mapping applications.

Objective 2

Field surveys – Field surveys in search of BFS were divided into two field seasons during the summers of 2021 and 2022. The first field season searched the western watersheds of the historic BFS range from the Chikaskia to the Middle Verdigris watershed, while the second field season searched eastern watersheds from the Spring, southward to the Dry- Greenleaf watersheds.

We conducted an aerial-visual survey using satellite imagery in Google Earth Pro to identify up to 40 potential sites per field season that appeared to have safe access to the stream channel and were ostensibly wadable (< 1.5 meters deep). Sites were selected at exact and proximal locations in relation to existing BFS occurrence records (see Objective 1), as well as exploratory sites within streams where the minnow had not been previously recorded but where we hypothesized habitats to be conducive to BFS occurrence. Thus, we focused our field sites in areas we considered to have a higher likelihood of being occupied by BFS compared to a randomized selection of sites across the landscape. Landowner information was obtained using a statewide parcel layer (OKMaps, 2021) and using the OnX Hunt app. Landowner permission to enter the stream and perform field surveys influenced final site selection.

Field sampling protocol involved four planned visits to each site, with sampling gears alternated with each visit between backpack electrofishing and seining. Upon the first visit to a site, location descriptions and GPS coordinates were recorded. Within the site, a sampling reach consisted of available channel unit types (i.e., riffle, run, and pool), with each channel unit treated independently for fish and habitat data collection. Sampling began at the most downstream channel

unit and progressed in the upstream direction. Seine hauls were conducted using a 5 x 1.2 m seine with 3/16" mesh, whereas electrofishing was performed with a backpack electrofisher and two dip nets. We standardized electrofishing settings by targeting an average-out amps of 2.5 for each channel unit, and we stayed within duty cycles of 10 - 15 and rates between 45 - 60. Voltage, duty cycle, and rate were adjusted as needed during sampling for best fish-shocking results. In high conductivity (< 800 μS/cm), we adjusted settings outside of these parameters with a focus on lower voltage but increased current. Initial shock settings were tested outside the study reach before sampling began.

The channel unit type that was sampled and the effort (number of seine hauls or shock time) necessary to survey each unit were recorded. The fishes that were collected within a unit were kept in containers until sampling of the entire channel unit was completed. Captured fish were identified, enumerated, and released back into the channel unit. Captured BFS were given a small fin-clip to allow for identification of recaptures during revisits.

Water quality measurements of pH, conductivity, salinity, and turbidity were recorded once per visit, prior to sampling. For each channel unit, water temperature and dissolved oxygen were recorded at the mid-point of the unit. For collection of habitat data, the length of the channel unit was recorded and divided equally into three transects which were perpendicular to stream flow direction. Along each transect length, the wetted channel width was measured, and the substrate type (similar to Bain et al., 1992), water depth, and water velocity were measured at five equally spaced points along the transects for each unit. Also at each unit, we recorded a visual assessment of aquatic vegetation (percentage of unit area covered), large woody debris (count within the unit), and substrate embeddedness scaled between 1 (least embedded) to 5 (most embedded).

Detection and occupancy modeling – Detection and occupancy models were constructed with R coding language using the package 'unmarked' (Fiske and Chandler, 2011; R Core Team, 2020) following a single-season framework that accounts for imperfect detection (i.e., detection rates <1; MacKenzie et al., 2002; 2006). Models were created based on *a priori* hypotheses of environmental factors that influence the detectability and occurrence of BFS (Table 1; Table 2). Pearson's correlation tests were run to remove variables with correlation coefficients of $r < 0.7$ (Dormann et al., 2013). All continuous variables were standardized by first a natural long transformation followed by calculation of a z-score while percentage variables were arcsine square root transformed.

Model selection was based on Akaike Information Criterion (AIC) and Akaike weights (W_t). Models were ranked using AIC values (Burnham and Anderson, 2002). The model with the lowest AIC value was considered the best model, but we also considered models with delta AIC (ΔAIC) scores less than 2.00 to have support. Detection probabilities were estimated with logistic regression (Mackenzie et al., 2006). We used logit link function to back-transform estimates into interpretable results. A candidate set of models in which occupancy was held constant ($\Psi(.)\rho(\text{Cov})$) was used to examine detection models. The best detection model was then used in a combined model set that accounted for occupancy ($\psi(\text{Cov})p(\text{Cov})$). The top model of the combined model set was used to estimate occupancy probability. We assessed model fit on the global model (all covariates) with Pearson's chi-squared statistic and a measure of overdispersion ($\hat{c}$) estimated with parametric bootstrapping (n = 10,000), wherein $\hat{c} > 1.2$ would be indicative of lack of fit (MacKenzie and Bailey, 2004). Occupancy probability estimates were calculated using empirical Bayes methods (Fiske and Chandler 2011; Fiske and Chandler 2015).

B. RESULTS

Objective 1

Historic records survey – In the Spring of 2021, a total of 195 historic BFS records were obtained within Oklahoma. Data without locality information *and* latitude/longitude data were removed (2 records) so that all remaining occurrence records held locality information or coordinates. Several records had coordinates that were not placed to a stream (e.g., county-level records), and because there was no supporting locality information to identify a possible site location at a stream, these records were removed (18 records). No records required georeferencing. Occurrence records that did not represent a unique survey event were removed (4 records). At this stage, 173 records remained.

Records were imported into ArcMap and linked to the NHDplusV2 flowlines to identify erroneous coordinate information. Occurrence record coordinates that did not coincide with locality information were removed (2 records). Three records required manual adjustment of coordinates to link them with the correct stream segment. Somewhat unexpectedly, a number of records were located along reservoirs (Tenkiller; 3 records), while others preceded the creation of the reservoir and are now located within the reservoirs after their completion (Tenkiller, Fort Gibson, Hudson, Grand; 13 records). Although BFS are typically associated with fluvial habitats, we cannot rule out that the species may occasionally use lentic habitats, so we chose to retain all records associated with reservoirs. Worth noting, one occurrence record of Bluntface Shiner was located in the Mountain Fork River within the Ouachita Mountains ecoregion. Given the known range of Bluntface Shiner, we questioned the validity of this record and removed it from the dataset.

The cleaned occurrence record database had a total of 171 records of BFS linked to 105 unique NHD stream segments across Oklahoma. The occurrence records of BFS were distributed across several watersheds along the north-central and eastern parts of Oklahoma (Figure 1). To the west of the occurrence distribution was the Salt Fork (1 record), Chikaskia (18 records) and the Black Bear – Red Rock (1 record) watersheds. Central areas of the distribution were the Bird (1 record), Caney (17 records), and Middle Verdigris watersheds (3 records). To the farthest east of the distribution were the Spring (8 records), Elk (6 records), Lake O' the Cherokees (11 records), Lower Neosho (64 records), Illinois (53 records), and the Dirty - Greenleaf (12 records) watersheds.

Examining the dates of these existing records was also informative. The earliest record of Bluntface Shiner in Oklahoma was in 1927 and located at the mouth of the Elk River at Grand Lake, while the most recent record attained in our search was in 2018 and located in Greenleaf Creek. Interestingly, older records generally exist along the Grand/Neosho, Illinois, and lower-Arkansas rivers watersheds, while the most recent records exist along the Oklahoma-Kansas border.

Objective 2

Field surveys – Field surveys were performed between late May and early August of 2021 and 2022 in wadeable streams of watersheds that comprised the historic distribution of BFS. A total of 61 sites were surveyed with 191 total visits. We performed surveys at 31 sites/104 visits in 2021 and 30 sites/87 visits in 2022. For site visits in 2021, the average BPEF/SE effort was 731s/22 hauls, whereas in 2022 the average BPEF/SE effort for the visits was 365s/17 hauls. The goal of up to 40 survey sites per summer with 4 revisits each was not achieved due to high stream

flows early in the field season or sites beginning to dry later in the field season. Of the 61 sites, 10 were exact locations of a historic BFS record, 33 were proximal to a historic record, and 18 were exploratory locations (Figure 2).

Physical habitat values varied markedly between the western sites surveyed in 2021 and the eastern sites surveyed in 2022. For the purposes of this report, mean values were calculated to illustrate central tendencies. Beginning with the western sites, the mean value of pH, conductivity, salinity, and turbidity were 8.1, 800 µS/cm, 0.39 ppt, and 19.9 NTU respectively. The mean dissolved oxygen was 6.60 mg/L, while mean water temperature was 26.0˚C. Mean water depth was 0.34 m; however, some sites had areas with water exceeding the 1.5 m depth threshold we sampled. Mean surface water velocity was 0.24 m/s.

In the eastern sites, the mean value of pH, conductivity, salinity, and turbidity were 7.99, 448 µS/cm, 0.23 ppt, and 3.09 NTU respectively. The mean dissolved oxygen was 8.23 mg/L, while the mean water temperature was 25.5 ˚C. Mean water depth was 0.27 m, though once again, several sites had areas with depths greater than 1.5 m. Mean surface water velocity was 0.47 m/s.

Regarding fish capture data, species communities differed between the west and east sites. In the western sites, 50 species were documented over the duration of the field season with an average of 17 species per site. A maximum number of unique species documented across all visits to a site was 28 species (Buck Creek, Hula WMA) while a minimum number of 9 was documented in a first order tributary of the middle Arkansas River (Clear Creek). In the eastern sites, 55 species were documented over the duration of the field season with an average of 14 species per site. A maximum number of unique species documented across all visits to a site was 29 species (Lost Creek), while a minimum number of 3 was documented in Flint Creek, a tributary of the Illinois River. The small number of species captured at Flint Creek was likely due to difficult sampling

conditions including high water velocity and deep pools restricting the wadeable area within the reach. We documented 20 species in the western sites that were not found in the eastern sites. Conversely, 23 species from the eastern sites were not found in the western sites. We encountered seven Oklahoma SGCN fish species across both survey seasons: Bluntface Shiner (*Cyprinella camura*), Cardinal Shiner (*Luxilus cardinalis*), Ozark Minnow (*Notropis nubilus*), Redspot Chub (*Nocomis asper*), Sunburst Darter (*Etheostoma mihileze*), Wedgespot Shiner (*Notropis greenei*), and Spotfin Shiner (*Cyprinella spiloptera*).

BFS were captured during both field survey years at 18 of the 61 sites for a naïve occupancy of 29.5% (Figure 3). In the west, BFS were captured at 14 of the 31 total sites (45%). Of the sites at which BFS were captured, two were exact locations, 11 were proximal locations, and one was an exploratory location. In the east, BFS were captured at 4 of the 30 sites (1.3%), 3 of which were proximal to historic records and 1 site representing an exact location.

In total, 369 BFS were captured and raw catch was noticeably different across channel unit types (Figure 4). The most captures were from the riffles (211 individuals), followed by runs (143 individuals), and then pools (15 individuals). In the west, the highest number of BFS captured at a single site was 176 individuals from Buck Creek (Hulah WMA), wherein only two individuals were recaptured (as indicated by clipped fins). Raw captures were lower in the east, where a total of 25 BFS were captured, with the most captured from runs (17 individuals), followed by pools (7 individuals) then riffles (1 individual). The highest number of BFS captured at a single eastern site was 14 individuals from Buffalo Creek (Grand River Dam Authority property), wherein no individuals were recaptured.

Raw capture data suggested that seine net was the most effective capture method for BFS (Figure 5). There were 10 sites where we detected BFS only during visits using the seine (“SE”),

1 site where we detected BFS only during visits using the backpack electrofisher ("BPEF"), and 7 sites where we detected BFS during visits using SE and visits using BPEF. We further explored gear effectiveness and factors influencing them in the detection models.

Detection models – The candidate model set of 19 models results in six well-supported models ($\Delta AIC \leq 2.00$; Table 3). The highest ranked detection model contained turbidity with a gear interaction (Turb*Gear; $W_t = 0.20$). Other supported models also included gear interactions: wetted channel width with a gear interaction (WCW*Gear; $W_t = 0.16$); an additive relation between conductivity and turbidity with a gear interaction (Cond + Turb*Gear; $W_t = 0.15$); depth with a gear interaction (Dep*Gear; $W_t = 0.09$); velocity with a gear interaction (Vel*Gear; $W_t = 0.07$); and conductivity with a gear interaction (Cond*Gear; $W_t = 0.07$). The highest ranked model ρ(Turb*Gear) estimated a detection probability of 51.2% based on the mean turbidity measured at our study sites.

Further analysis parsed detection probability estimates between sampling gears (Figure 6). The models revealed differences in detection probability of BFS with BPEF and SE as a function of survey-level covariates. Model ρ(Turb*Gear), estimated an inverse relationship between turbidity and BPEF and turbidity and SE, and as turbidity increased, detection probability using SE increased, while detection probability using BPEF decreased (Fig. 6A). Model ρ(Cond + Turb*Gear) demonstrated the same trend, though overall detection probabilities were higher for both gears than when estimated with turbidity alone (Fig. 6C). Estimated detection probabilities for ρ(Cond*Gear) were similar to the aforementioned models, however, detection probability remained constant throughout (Fig. 6F). In contrast to the other models with gradual trends, detection probability under the ρ(Vel*Gear) model decreased sharply for either gear as water velocity increased (Fig. 6E). The remaining models estimated inverse relationships with overlap.

Model ρ(WCW*Gear) estimated a detection probability for SE that increased as WCW increased, while detection probability for BPEF decreased as WCW increased (Fig. 6B). Lastly, model ρ(Dep*Gear) estimated inverse detection probabilities for gears against depth, in which detection probability using BPEF decreased as depth increased in the same fashion that detection probability using SE increased as depth increased (Fig. 6D).

Occupancy models – The detection covariate Turb*Gear was the most supported detection model in the candidate set, so we adopted this detection component for the occupancy modeling. The goodness of fit test showed the global occupancy model fit the data ($\hat{c}$ = 0.92). Only one of the 8 candidate occupancy models was well supported (ΔAIC ≤ 2.00; Table 3). The highest ranked model included total drainage area as the occupancy covariate ((ψ(zmeanTotDA)ρ(Turb*Gear); W_t = 0.88) and estimated an occupancy probability of 32.6% for the study area based on the mean total drainage area of the study sites. The model estimated a positive relationship in which occupancy probability increased as total drainage area size increased (Figure 7). Empirical Bayes methods estimated the proportion of our study sites occupied to be 29.5%, no different than our naïve occupancy of 29.5%.

IV. RECOMMENDATIONS

- Our survey of historic BFS records revealed an ecologically diverse (crossing six ecoregions) distribution across the northern and eastern watersheds of Oklahoma. However, it is very likely that existing records do not fully characterize all watersheds and tributaries that BFS occurred within, both historically and contemporarily. Distribution modeling and expanded occupancy surveys, similar to those performed herein, could be useful in further characterizing the historical and contemporary range

extents of BFS in Oklahoma. A more precise and accurate understanding of the contemporary range can be used by ODWC to inform conservation measures for BFS populations.

- The most recent BFS records (years 2000- 2018) exist along the northern border of Oklahoma, but there is a paucity of recent records in eastern portions of the historic range. The apparent lack of recent occurrence records in the Lower Neosho, Dirty-Greenleaf, and Illinois could indicate largescale declines from the historic range. Declines in eastern Oklahoma should be considered in the context of the entire BFS range in the Arkansas River Basin (e.g., Missouri and Arkansas) because the watersheds that once supported BFS are not confined within the state boundaries of Oklahoma. Range declines or extirpation from neighboring states brings into question the overall stability of BFS populations in the Arkansas River Basin and emphasizes the need for close monitoring of extant populations in Oklahoma.
- Large impoundments are prominent features across the contemporary riverscape in areas of the historic BFS range. Several occurrence records are presently flooded by reservoirs, while groups of records between watersheds are disjunct by dams. Similarly, some populations have persisted upstream of large impoundments, while others have apparently suffered extirpation. Studies to investigate spatial relationships between large impoundments and their effects on BFS range may help prioritize populations for conservation action.
- Field surveys in search of BFS within the historic range in Oklahoma yielded captures of the minnow from sites that coincided with the most recent historic records. Sites in the Caney and Verdigris watersheds produced the largest number of BFS (approximately 200

individuals total), while captures from Chikaskia, Spring, Lake O' the Cherokees, and Elk produced much fewer BFS. The Caney and Verdigris represent strongholds for BFS in Oklahoma and would be good opportunities for investigating reproduction, growth, macro- and microhabitat requirements, and movement patterns of healthy populations. Such information could be leveraged in investigations of, and conservation actions for, BFS populations elsewhere.

- One of the uniting factors among sites where BFS were captured in this study was the presence of riffle and run habitat that held sufficient flow throughout the summer months. Maintaining summer baseflows may be critical to BFS natural reproduction.
- Surveys in search of BFS presence could focus on riffle and run habitats, where we found catch rates to be highest. Such information can help minimize time spent in habitats where BFS are more difficult to detect, such as pools.
- From our detection models, we found that seine net was the most effective gear for detecting BFS in wadeable streams across a broad range of environmental conditions encountered at our sites. We recommend the use of seine when targeting BFS for its effectiveness in capturing BFS and versatility in highly variable environments, in addition to its ease of use and cost-effectiveness. However, our results also suggest that in specific conditions, BPEF may be suitable for BFS detection. Our results allow for future investigations to employ a more-informed sampling approach by selecting the appropriate gear based on conditions present at the site (e.g., turbidity, conductivity, depth, etc.).
- From our occupancy models, it was estimated that BFS occupied 29.5% of our sites, which was no different than our naïve occupancy of 29.5%. This result could be explained by detection probability of BFS being high enough that we would detect the

minnow if present at the site (given that we visited each site up to four times). In reality, we know that our ability to detect BFS may have been slightly lower. During our field seasons, other survey teams (including ODWC and OCC) captured BFS individuals at (or in immediate proximity to) sites that we sampled but did not capture any BFS. When BFS abundance is very low in a system, we posit that detection probability is largely random chance.

- The low naïve and estimated occupancy across sites that we pre-selected for a higher likelihood of containing BFS provides strong evidence that that modern BFS populations may occupy less than a third of their historic range. This is particularly concerning because our survey area was entirely within the historic BFS distribution, and we biased our site locations based on proximity to historic BFS records. Additional surveys would improve the accuracy of occupancy estimates and further refine our knowledge of the BFS whereabouts in Oklahoma.
- Total drainage area was the most supported variable in explaining occupancy across our study sites, wherein occupancy probability of BFS increased as total drainage area size increased. Drainage area size is correlated with many factors including water flow, depth, stream size and length, and various physicochemical properties that change with increasing size and are closely linked to fish assemblage structure and richness (Allan et al., 2021; Matthews, 2012). We hypothesize that larger total drainage area sizes are important in metapopulation dynamics involving source and sink populations of BFS. Source habitats would include areas suitable for spawning, rearing, and refugia, while sink habitats are those with unfavorable conditions where local extinction would occur without rescue from populations elsewhere (Falke and Fausch, 2010). Because the

availability of these habitats varies unpredictably across space and time (Falke et al., 2012), greater access to and connectivity between critical habitats is crucial for population persistence, reproduction, and dispersal (Dodds et al., 2004; Sedell et al., 1990; Labbe and Fausch, 2000; Falke et al., 2010). For BFS populations, larger total drainage area sizes may provide greater environmental stability, access to important mesohabitats, and increased chances of successful colonization (Hoagstrom and Berry, 2006).

- The presence of impoundments across the BFS distribution is problematic for several reasons. Besides the flooding of stream area with suitable habitat (as shown from the historic records map), impoundments shift lotic habitats toward lentic conditions, degrade or remove suitable habitat, promote the invasion of tolerant or non-native species, and block fish movement, which together disrupts metapopulation dynamics and can result in local extirpation (Luttrell et al., 1999; Hubbs and Pigg, 1976; Wilde and Ostrand, 1999; Schrank et al., 2001; Winston et al., 1991).We know that BFS are sensitive to water and habitat quality and therefore are likely negatively affected by large impoundments in the aforementioned ways. Remaining BFS likely exist as several disconnected and isolated populations that are increasingly vulnerable to local extirpation without opportunity for rescue or recolonization from other areas. Future investigations should more explicitly investigate the effects of impoundments on BFS because there are areas where the minnow historically existed but have apparently disappeared (e.g., Illinois River Basin, Greenleaf Creek), but there are also extant populations upstream of some reservoirs (e.g., Caney and Verdigris rivers). Exploring the drivers of BFS decline would be useful for

ODWC in determining at-risk populations and developing conservation plans for BFS populations in Oklahoma.

- Investigating the population genetics of BFS in Oklahoma would be beneficial in prioritizing conservation actions. Such work could help elucidate historic and contemporary gene flow across populations (i.e., have dams fragmented populations?), identify populations experiencing hybridization with Red Shiner or Steelcolor Shiner, and estimate conservation-oriented metrics such as inbreeding coefficients and effective population sizes.
- Though we focused on wadeable streams during summer months, occupancy modelling frameworks can be readily adapted to test other gears and habitats. For example, there is substantial evidence of BFS inhabiting large mainstreams of rivers. Hill et al. (1981) captured BFS exclusively from their sites within the mainstem of the Grand River and not in tributary creeks nearby, whereas in the Chikaskia, we found juveniles in the mainstream river but adults in tributaries. Detection and occupancy modelling can quantify the effectiveness of gears like tote-barge shocker or trawl net in capturing BFS in these habitats with the additional benefit of capturing drastically different abiotic conditions that are potentially suitable for BFS. It would be worthwhile to incorporate detection probabilities in future BFS monitoring programs to determine threshold conditions for effective gear use, or to inform gear efficacy prior to implementation (Schloesser et al., 2012) and occupancy probabilities to further refining our understanding of where BFS persist and habitat conditions that are most suitable.

V. SIGNIFICANT DEVIATIONS

We were granted an extension on the delivery of the Final Report for this project, which is due August 10, 2023. Otherwise, there were no significant deviations.

VI. EQUIPMENT

In year one of the grant, we purchased a complete ETS Electrofishing Systems ABP-4-MR backpack electrofishing system, with lithium battery, charger, and travel case for a total purchase order cost of $7,460.00 ($7,385.00 + $75.00 shipping). In an email dated June 8, 2020, ODWC Stream Biologists provided an estimate of 10 years for useful life of the backpack electrofishing unit. Following the completion of the field work for this project in August 2022, this equipment was returned to ODWC stream survey biologists.

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VIII. TABLES AND FIGURES

Table 1. Survey- and site-level covariates used for detection and occupancy modeling

Environmental covariates	Abbreviation	Scale	Description
Sampling gear (BPEF or Seine)	Gear	Survey-level	Gear type used during the survey
Conductivity (µS/cm)	Cond	Survey-level	Ease at which electricity passes through water
Average depth of the reach (m)	Dep	Survey-level	Average water depth at transects
Maximum depth (m) of the reach	MaxD	Survey-level	Deepest water depth within the reach (maximum capped at 1.5 m)
Proportion of coarse substrates	PropCoarse	Survey-level	Proportion of boulder and bedrock substrates in transects
Turbidity (NTU)	Turb	Survey-level	Point estimate of water clarity
Average surface velocity of the reach (m/s)	Vel	Survey-level	Average surface velocity at transects
Average wetted channel width (m)	WCW	Survey-level	Average width of the wetted channel at transects
Average substate type	AvgSub	Site-level	Average score (from 1 [most fine] to 5 [most coarse]) for substrate type at transects
Standard deviation of substrate type	SubSD	Site-level	Describes which site had the most variable substrate composition
Base flow index	BFI	Site-level	Base flow index of the catchment
Dissolved Oxygen (ppt)	DO	Site-level	Point estimate of dissolved oxygen
Elevation (m)	Elev	Site-level	Elevation at the site
Percent hay or crop land use (%)	AgLand	Site-level	Percentage of hay or crop land use in the catchment
Total drainage area (km^2)	TotDA	Site-level	Total drainage area upstream of the reach

Table 2. Descriptions and hypotheses of Bluntface Shiner detection and occupancy models for wadable streams in Oklahoma during the summer months of 2021-2022.

Candidate model set		
Hypotheses (Detection)	Model	Model structure
There is no covariate effect on detection probability	ρ(.)	β_0
Gear type affects detection	ρ(Gear)	$\beta_0 + \beta_1$(Gear)
Depth affects detection	ρ(Dep)	$\beta_0 + \beta_1$(Dep)
Max depth affects detection	ρ(MaxD)	$\beta_0 + \beta_1$(MaxD)
Proportion of coarse substrate affects detection	ρ(PropCoarse)	$\beta_0 + \beta_1$(PropCoarse)
Turbidity affects detection	ρ(Turb)	$\beta_0 + \beta_1$(Turb)
Water velocity affects detection	ρ(Vel)	$\beta_0 + \beta_1$(Vel)
Wetted channel width affects detection	ρ(WCW)	$\beta_0 + \beta_1$(WCW)
Depth with a gear interaction affects detection	ρ(Dep*Gear)	$\beta_0 + \beta_1$(Dep) x β_2(Gear)
Max depth with a gear interaction affects detection	ρ(MaxD*Gear)	$\beta_0 + \beta_1$(MaxD) x β_2(Gear)
Turbidity with a gear interaction affects detection	ρ(Turb*Gear)	$\beta_0 + \beta_1$(Turb) x β_2(Gear)
Proportion of coarse substrate with a gear interaction affects detection	ρ(PropCoarse*Gear)	$\beta_0 + \beta_1$(PropCoarse) x β_2(Gear)
Water velocity with a gear interaction affects detection	ρ(Vel*Gear)	$\beta_0 + \beta_1$(Vel) x β_2(Gear)
Wetted channel width with a gear interaction affects detection	ρ(WCW*Gear)	$\beta_0 + \beta_1$(WCW) x β_2(Gear)
Conductivity and turbidity with a gear interaction affects detection	ρ(Cond + Turb*Gear)	$\beta_0 + \beta_1$(Cond) + β_2(Turb) x β_3(Gear)
Depth and velocity with a gear interaction affects detection	ρ(Dep + Vel*Gear)	$\beta_0 + \beta_1$(Dep) + β_2(Vel) x β_3(Gear)
Depth, velocity, and wetted channel width with a gear interaction affects detection	ρ(Dep + Vel + WCW*Gear)	$\beta_0 + \beta_1$(Dep) + β_2(Vel) + β_3 (WCW) x β_4(Gear)
Depth, velocity, and proportion of coarse substrate with a gear interaction affects detection	ρ(Dep + Vel + PropCoarse*Gear)	$\beta_0 + \beta_1$(Dep) + β_2(Vel) + β_3(PropCoarse) x β_4(Gear)
Depth, velocity, wetted channel width, and proportion of coarse substrate with a gear interaction affects detection	ρ(Dep + Vel + WCW + PropCoarse*Gear)	$\beta_0 + \beta_1$(Dep) + β_2(Vel) + β_3(WCW) + β_4(PropCoarse) x β_5(Gear)
Combined model set		
Hypothesis (Occupancy)	Model	Model structure
No covariate affects occurrence	Ψ(.)	β_0
Average substrate type affects occupancy	Ψ(zmeanAvgSub)	$\beta_0 + \beta_1$(zmeanAvgSub)
Substrate variability affects occupancy	Ψ(zmeanSubSD)	$\beta_0 + \beta_1$(zmeanSubSD)
percent hay or crop land use affects occupancy	Ψ(arcsqAgLand)	$\beta_0 + \beta_1$(arcsqAgLand)
Base flow index affects occupancy	Ψ(zmeanBFI)	$\beta_0 + \beta_1$(zmeanBFI)
Dissolved oxygen affects occupancy	Ψ(zmeanDO)	$\beta_0 + \beta_1$(zmeanDO)
Elevation affects occupancy	Ψ(zmeanElev)	$\beta_0 + \beta_1$(zmeanElev)
Total drainage area affects occupancy	Ψ(zmeanTotDA)	$\beta_0 + \beta_1$(zmeanTotDA)

Table 3. Model ranking based on AIC scores.

Candidate model set						
Model	K	AIC	ΔAIC	AICWt	Cum.Wt	LL
Ψ(.)ρ(Turb*Gear)	7	149.9	0	0.2	0.2	-67.95
Ψ(.)ρ(WCW)	7	150.35	0.45	0.16	0.35	-68.17
Ψ(.)ρ(Cond + Turb*Gear)	8	151.42	0.52	0.15	0.5	-67.21
Ψ(.)ρ(Dep*Gear)	7	151.4	1.5	0.09	0.59	-68.7
Ψ(.)ρ(Vel*Gear)	7	151.64	1.74	0.08	0.68	-69.82
Ψ(.)ρ(Cond*Gear)	7	151.85	1.95	0.07	0.75	-68.92
Ψ(.)ρ(PropCoarse*Gear)	7	152.1	2.19	0.07	0.82	-69.05
Ψ(.)ρ(Dep + Vel*Gear)	8	153.63	3.73	0.03	0.85	-68.82
Ψ(.)ρ(Dep + Vel + WCW*Gear)	9	153.91	4.01	0.03	0.87	-67.96
Ψ(.)ρ(.)	2	153.99	4.09	0.03	0.9	-75
Combined model set						
Model	K	AIC	ΔAIC	AICWt	Cum.Wt	LL
(ψ(zmeanTotDA)ρ(Turb*Gear))	8	141.97	0	0.88	0.88	-62.99
(ψ(zmeanDO + zmeanAvgSub + zmeanSubSD + zmeanTotDA + zmeanBFI + zmeanElev + arcsqAgLand)ρ(Turb*Gear)	14	148.31	6.33	0.04	0.92	-60.15
(ψ(zmeanBFI)ρ(Turb*Gear))	8	149.56	7.59	0.02	0.94	-66.78
(ψ(.)ρ(.))	8	149.73	7.76	0.02	0.96	-66.87

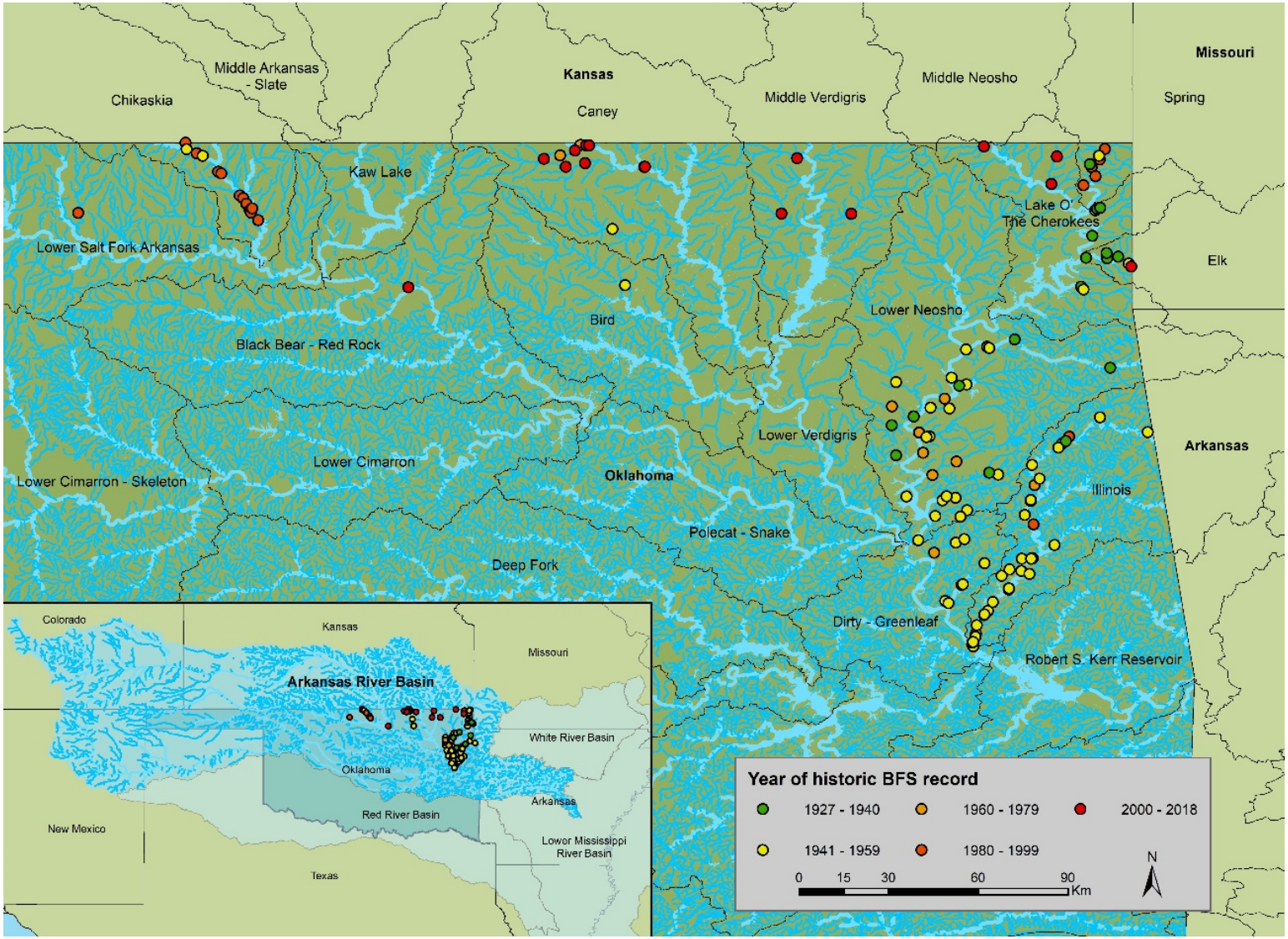

Figure 1. Map of historic Bluntface Shiner occurrence records within Oklahoma colored by year of collection.

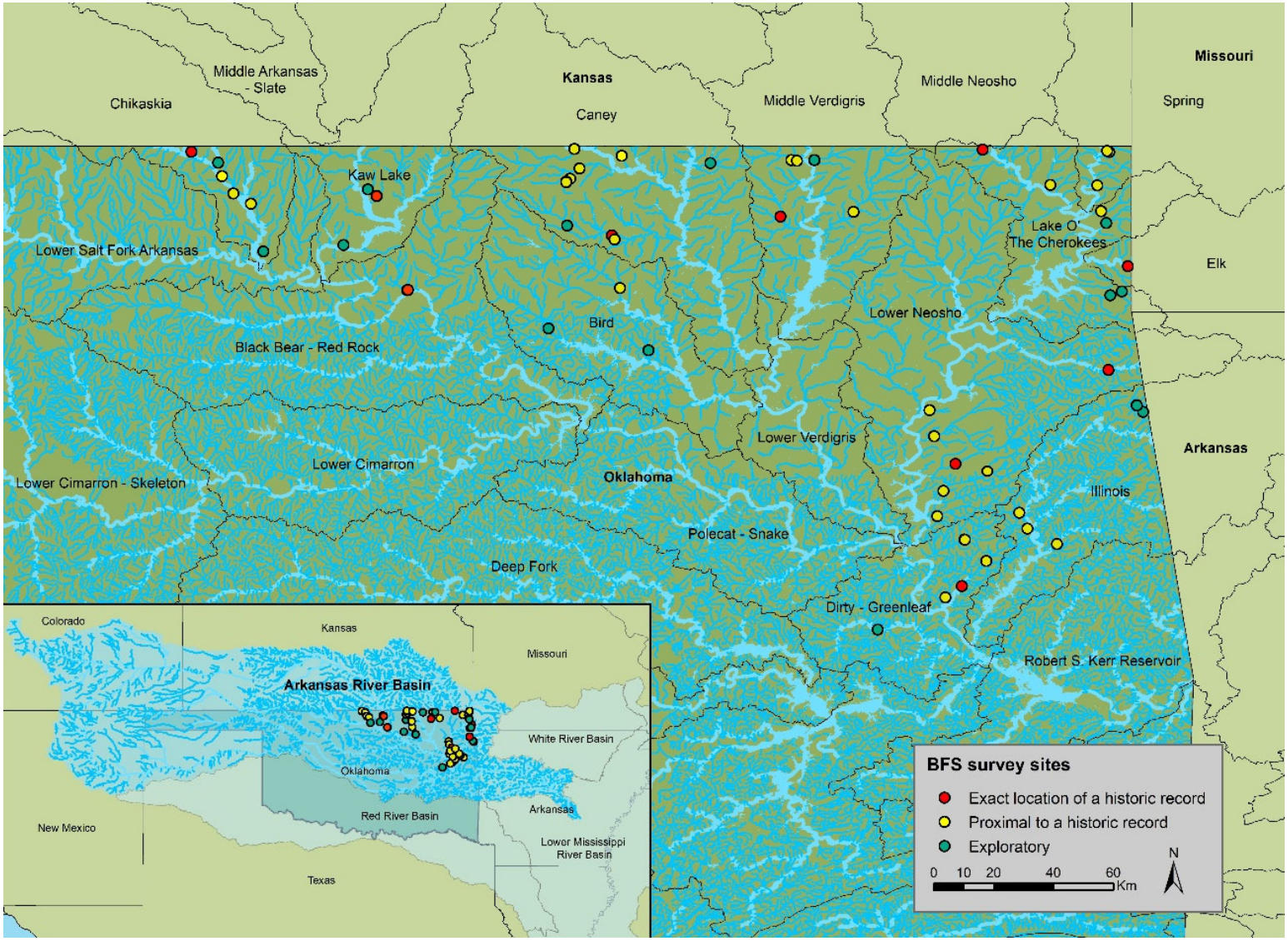

Figure 2. Map of Bluntface Shiner survey locations categorized by proximity to historical records.

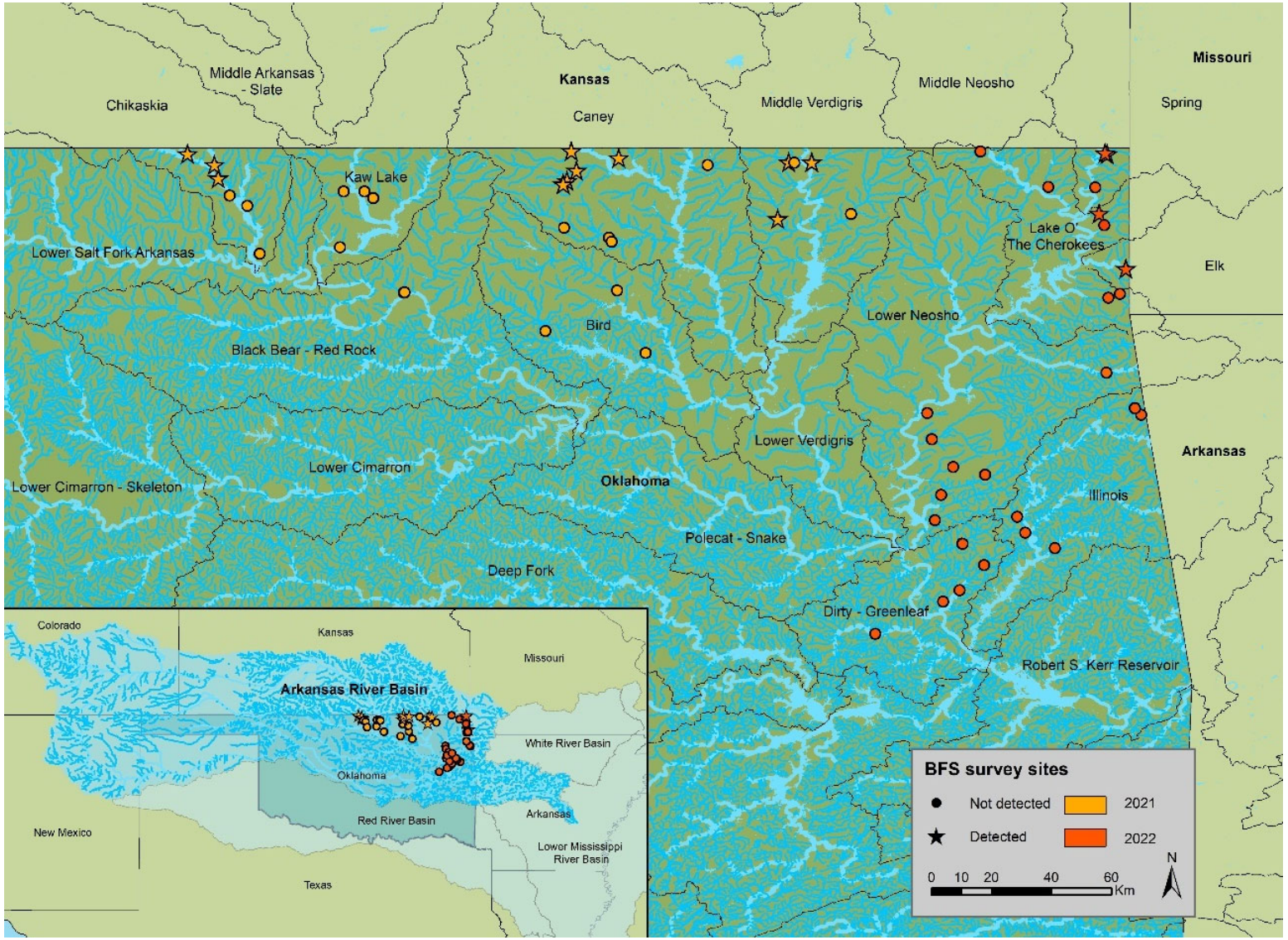

Figure 3. Map of Bluntface Shiner detections during field surveys in 2021 and 2022.

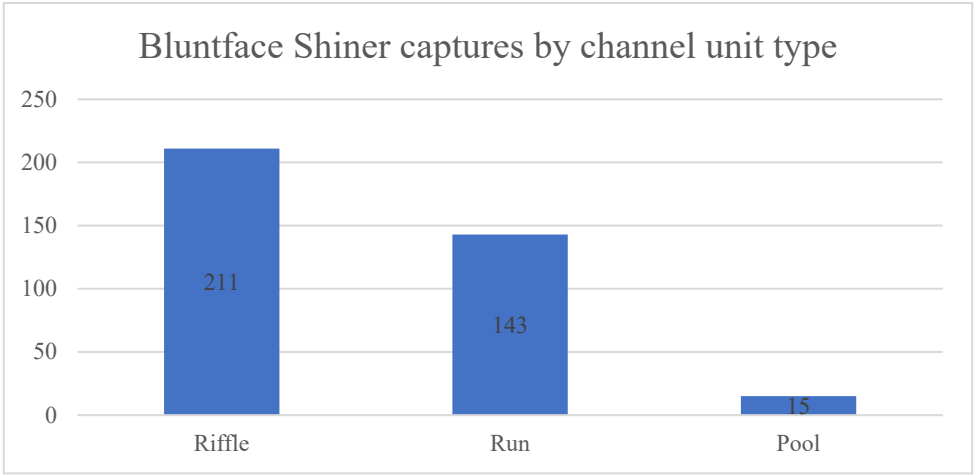

Figure 4. Bluntface Shiner raw captures as recorded by channel unit type.

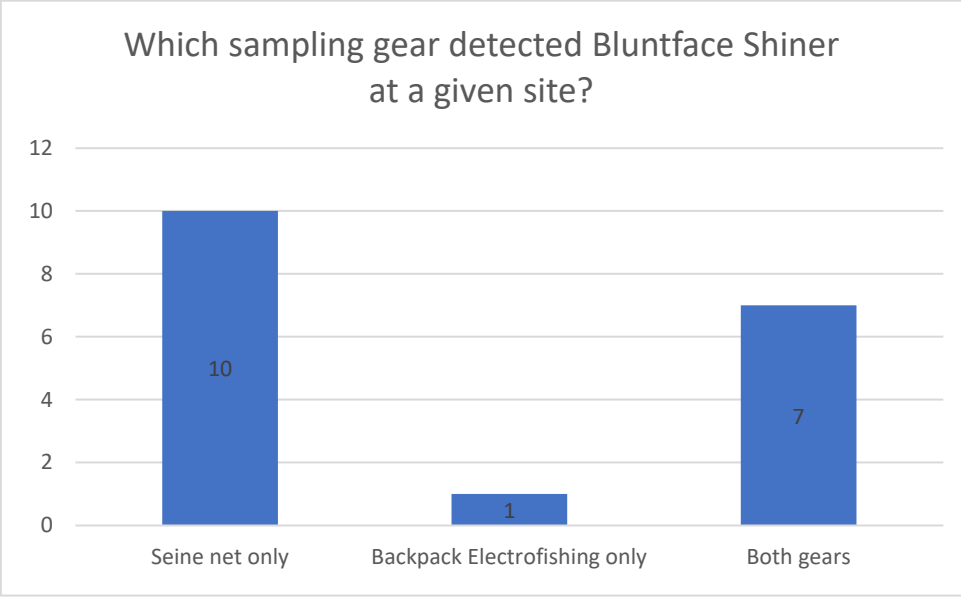

Figure 5. Among the unique sites where Bluntface Shiner were detected on at least one visit, sampling gear(s) contributed differently to those detections. Gears were alternated between each visit to a site.

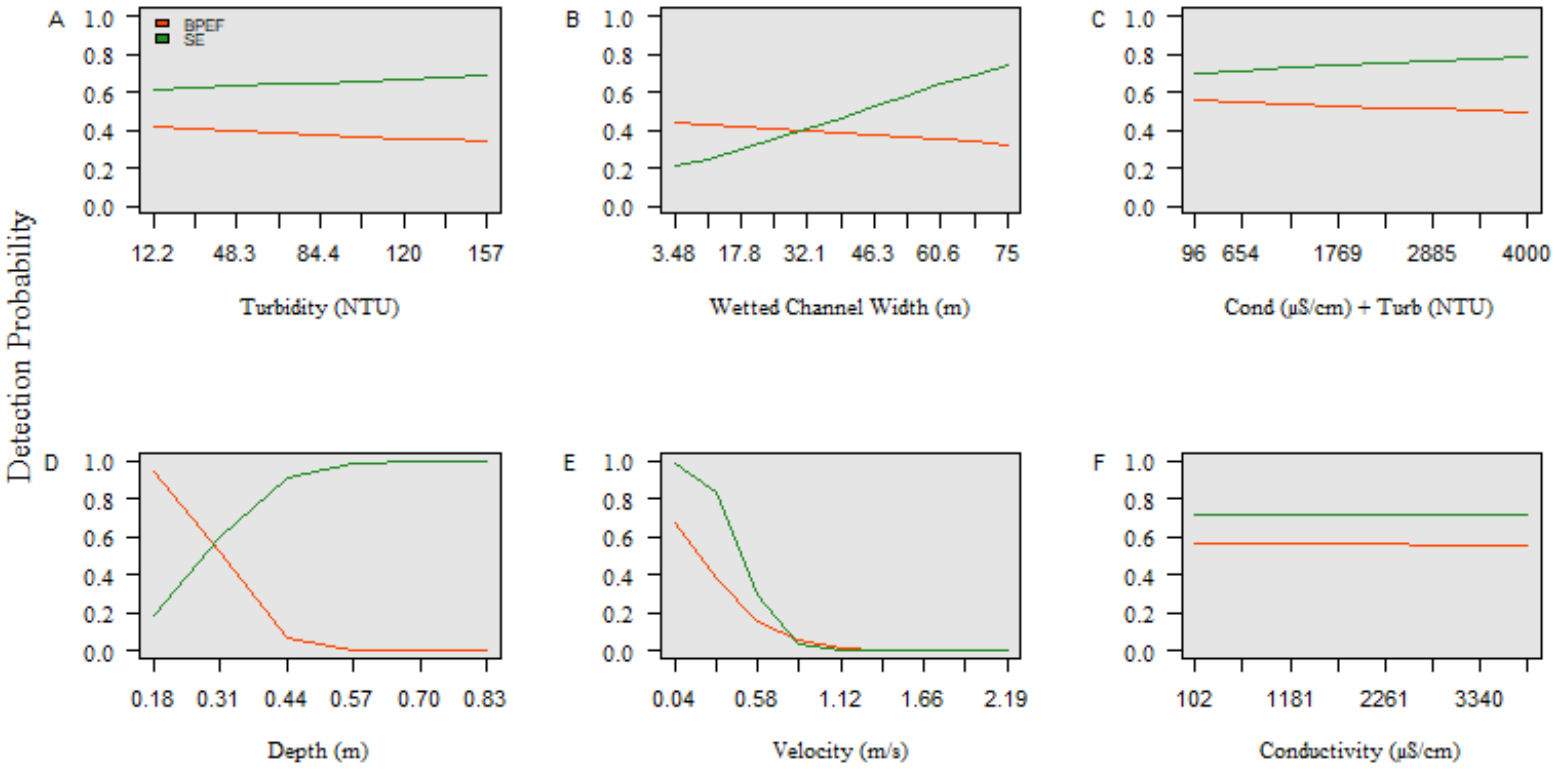

Figure 6. Comparison of relationships between detection probability of Bluntface Shiner and survey-level covariates across gear types (SE = seine net; BPEF = backpack electrofisher).

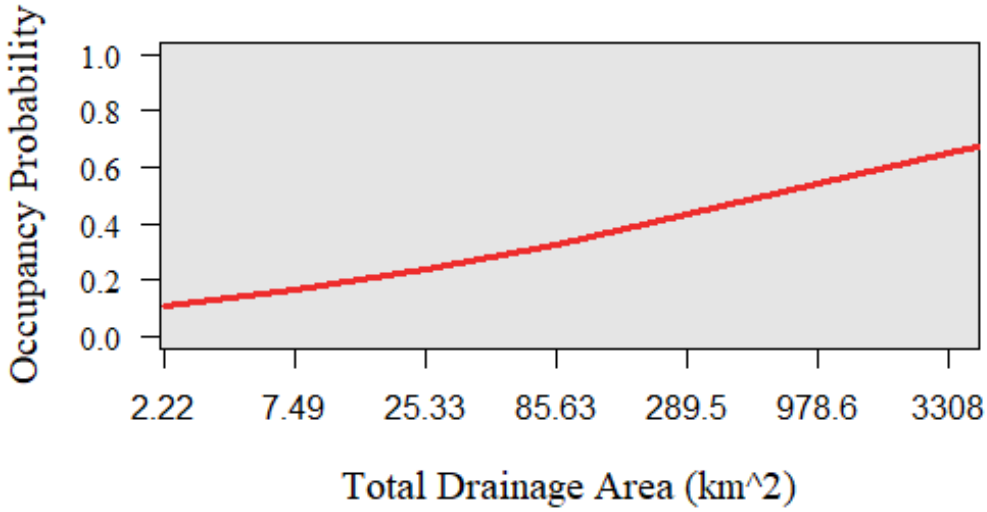

Figure 7. Estimated relationship between occupancy probability of Bluntface Shiner and total drainage area.