Wildlife and Sport Fish Restoration Program

U.S. Fish and Wildlife Service

OK T-122-R-1 Kiamichi Crayfish Status Assessment in Eastern Oklahoma

Final Performance Report Generated 04/28/2024

Performance Report Approval Status:

Awaiting Federal Approval

Recipient:

OKLAHOMA DEPARTMENT OF WILDLIFE CONSERVATION

Recipient Grant ID:

Federal Award Number:

F21AF02707

Funding Program(s) Name:

SWG Implementation

Federal Award Start and End Date:

Jan 01, 2022 to Dec 31, 2023

Performance Reporting Period:

Jan 01, 2023 to Dec 31, 2023

Federal Award Recipient Contact(s):

Andrea Crews

Federal Award Specialist(s):

William Amy

Type of Performance Report:

Final Performance Report

Public Description:

Crayfish extinction rates are increasing across North America (Ricciardi and Rasmussen 1999). Kiamichi Crayfish (*Faxonius saxatilis)* is an Oklahoma endemic crayfish (Bouchard and Bouchard 1976; Taylor et al. 2004; Robison and McAllister 2012). Kiamichi Crayfish have an extremely narrow range and represents a species of concern in Oklahoma (Jones and Bergey 2007). Increased land-use (e.g., silviculture) and other anthropogenic stressors threaten Kiamichi Crayfish existence (Jones and Bergey 2007). We propose updating Kiamichi Crayfish range and distributions through traditional quantitative surveys (e.g., quadrat sampling; DiStefano et al. 2003). Surveys will encompass the present and historically known range (i.e., Pigeon Creek and upper Kiamichi River reaches). Macro- and micro-habitat features will be recorded at all survey sites. Our study will update current Kiamichi Crayfish range and distribution.

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-122-R-1 Kiamichi Crayfish Status Assessment in Eastern Oklahoma
Project Statement Approval Status: Final Approved

Objective Name: Objective 1 - Fish and Wildlife Species Data Collection and Analysis

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: Quinton Phelps
Geographic Location:

- General Location: Oklahoma
- Includes Marine Federal Waters: No
- Detailed Location:
    - Le Flore County
- Location Description:

  Crayfish surveys will be conducted in the Kiamichi River watershed. Specifically, Pigeon Creek, Little Pigeon Creek, and Corral Creek in Le Flore county, Oklahoma.

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, 2022 to Dec 31, 2022	
Jan 1, 2023 to Dec 31, 2023	1
Totals to Date*	1

Species Tags

Species Tags
Kiamichi crayfish *Faxonius saxatilis*

Activity Performed Attachments

Note: Some attachments listed here may not appear in the Appendix due to file incompatibility. All attachments can be accessed using the links below.

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?

The objectives have been completed for this project. See full report attached.

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

There were no changes to the objectives or approach of this project.

3. If applicable, please share if the project resulted in any unexpected benefits, promising practices, new understandings, cost efficiencies, management recommendations, or lessons learned.
Not Applicable

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

Note: Some attachments listed here may not appear in the Appendix due to file incompatibility. All attachments can be accessed using the links below.

Descriptive Name	Field tags	Attachment Type
Final Report T-122-R-1 Kiamichi Crayfish...	• Objective Completion Progress	Performance Report / Performance Hard Copy Report

Appendix

FINAL PERFORMANCE REPORT

Federal Aid Grant No. F21AF02707 (T-122-R-1)

Kiamichi Crayfish Status Assessment in Eastern Oklahoma

Oklahoma Department of Wildlife Conservation

January 1, 2022 – December 31, 2023

FINAL PERFOMANCE REPORT

State: Oklahoma **Grant Number:** F21AF02707 (T-122-R-1)

Grant Program: State Wildlife Grants

Grant Name: Kiamichi Crayfish Status Assessment in Eastern Oklahoma

Grant Period: January 1, 2022 to December 31, 2023

Principal Investigators: Dr. Quinton Phelps and Hae Kim
Applied Fisheries Management Lab, Department of Biology, College of Natural and Applied Sciences, Missouri State University, Springfield, MO

EXECUTIVE SUMMARY

A multi-site, habitat, gear and seasonal sampling approach was used to sample crayfish across the Upper Kiamichi River and its tributaries. Three gears were evaluated as a means to address the following objectives:

Objective 1: Develop a standardized quantitative crayfish survey and assess current distribution, relative abundance and status of Kiamichi Crayfish in the Kiamichi River watershed.

Objective 2: Update the current crayfish assemblage information on the Upper Kiamichi River.

A generalized additive modeling (GAMs) approach was used to estimate the relative influences of selected sampling variables.

Model Parameters Evaluated

Parametric Variables		Research Interest
	Gear - Kick-Seine - Quadrat Sampling - Traps	How to sample
	Habitat - Riffle - Pool	Where to sample
	Substrate - Boulder - Cobble - Gravel - Sand	Where to sample
Continuous Variables		
	Surface Velocity	Where/When to sample
	Average Daily Water Temp.	When to sample
	Average Daily River Gauge	Where/When to sample
	Depth Sampled	Where/When to sample

Across all factors evaluated, quadrat sampling performed the best across all crayfish and specifically for Kiamichi Crayfish. Our analyses suggest riffle habitats during warmer periods (i.e., average water temperatures 22 ºC – 25 ºC) produced the highest overall and Kiamichi Crayfish specific catch rates (Figure 17). Further, depth appeared to influence Kiamichi Crayfish and was optimized around approximately, 10 cm – 12 cm (Figure 18, 19).

	Gear	***Habitat***	***Temperatures***	***Depths***
Kiamichi Crayfish	Quadrat Sampling	Riffle	25ºC June-July	10-12 cm

Quadrat sampling captured the widest range of species and other gears often underestimated the observed total species richness (Figure 12). Species-accumulation curves suggested quadrat samples require less sampling effort to reach the observed total species richness (Figure 13). Overall, seven species were observed throughout all sites sampled. Three of these species represent Oklahoma Species of Greatest Conservation Need Tier-1 (Oklahoma Comprehensive Wildlife Conservation Strategy, Appendix E). Across the three Tier-1 species, the Kiamichi Crayfish were most frequently observed across sites and most abundant.

Overall, the influence of gear and water temperatures appears to influence crayfish catch rates in the Upper Kiamichi River and its tributaries. Future studies should continue monitoring these sites and habitats using the quadrat sampling method and trends and abundances can be tracked over time.

OBJECTIVES

Objective 1: Develop a standardized quantitative crayfish survey and assess current distribution, relative abundance and status of Kiamichi Crayfish in the Kiamichi River watershed.

Objective 2: Update the current crayfish assemblage information on the Upper Kiamichi River.

INTRODUCTION

Crayfish are among some of the most diverse taxa in North America (Ricciardi and Rasmussen 1999; Loughman and Fetzner 2015). Oklahoma crayfish diversity is high and likely a result of diverse habitats and ecoregions (Abell et al. 2000; Taylor et al. 2004; Abell et al. 2008). Geographic barriers have produced unique distributions and high endemism rates throughout Eastern Oklahoma (Taylor et al. 2004; Abell et al. 2008). The Kiamichi Crayfish *Faxonius saxatilis* is a regionally endemic species in Eastern Oklahoma and represents an Oklahoma species of greatest conservation need (Tier I species; Oklahoma Comprehensive Wildlife Plan, Appendix E p.401) (Bouchard and Bouchard 1976; Jones and Bergey 2007; Robison and McAllister 2012). Kiamichi Crayfish inhabit seasonally intermittent streams in Eastern Oklahoma (Bouchard and Bouchard 1976; Jones and Bergey 2007; Dyer and Brewer 2018). These streams represent a very high priority conservation landscape (OCWCS).

During dry periods, Kiamichi Crayfish have been observed utilizing the hyporheic zone (Jones and Bergey 2007; Dyer and Brewer 2018). Moreover, during this period Kiamichi Crayfish have been observed displaying preference for hyporheic zones over wetted pools (Dyer and Brewer 2018). Historically, Kiamichi Crayfish distribution was limited to Pigeon Creek, but subsequent surveys have expanded their known range (Bouchard and Bouchard 1976; Taylor et al. 2004; Jones and Bergey 2007; Robison and McAllister 2012).

Given recent discoveries within the watershed, actual Kiamichi Crayfish range and distribution is uncertain (Taylor et al. 2004; Jones and Bergey 2007; Dyer and Brewer 2018). Further, increased land use within the watershed may negatively impact Kiamichi Crayfish distributions in Eastern Oklahoma. Baseline biological information is imperative for Kiamichi Crayfish conservation and management (Loughman and Fetzner 2015). Standardized quantitative surveys are important to address current Kiamichi Crayfish presence and relative abundance within Pigeon Creek, its tributaries, and newly discovered reaches (i.e., Little Pigeon Creek and Corral Creek; Jones and Bergey 2007).

Through a State Wildlife Grant, the Oklahoma Department of Wildlife Conservation (ODWC) funded Missouri State University (MSU) to address the following objectives:

Objective 1: Develop a standardized quantitative crayfish survey and assess current distribution, relative abundance and status of Kiamichi Crayfish in the Kiamichi River watershed.

Objective 2: Update the current crayfish assemblage information on the Upper Kiamichi River.

APPROACH

Study Area

Crayfish were sampled along the Kiamichi River and its tributaries from Pigeon Creek near Oklahoma State Highway 63 downstream to Frazier Creek near Whitesboro, OK (Table 1; Appendix 1; Appendix 2). Ten reaches were delineated across this gradient and sampled monthly (Table 1; Appendix 1). Reaches were selected across the Kiamichi River and its associated tributaries. Each reach was delineated approximately 300-400m and various habitat measurements were collected. Within each reach, one randomly selected riffle and pool macrohabitat were sampled monthly.

Randomly selected kick-seine, quadrat (excavation), and trap gears were used to capture crayfish. Kick-seines were conducted by disturbing substrate immediately upstream of a seine. Quadrat (excavation) sampling was conducted in a 1m^2 area until approximately 20 cm of substrate was disturbed or excavated (DiStefano et al. 2003; Jones and Bergey 2007). A passive hexagonal-shaped nylon mesh netting trap consisting of six openings was baited and allowed to fish overnight. All collected crayfish were identified, enumerated, sexed and measured for total carapace length (TCL; Taylor et al. 2004).

Data Analysis

Overall and species-specific catch rates were calculated as averages across various factors evaluated (Heck et al. 1975; Ugland et al. 2003). Species accumulation curves were constructed across gears and habitats evaluated (Colwell et al. 2004; Colwell et al. 2012). Total expected observed species was modeled as a function of samples (e.g., sampling effort) conducted

(Colwell et al. 2004). Confidence intervals (CI; 95%) were estimated using standard errors (Colwell et al. 2004).

Generalized additive models (GAMs) were used to estimate overall and species-specific catch-rates (Wood 2017; Pedersen et al. 2019). All models were constructed under the MGCV package (Wood 2011) and modeled using the GAM function in R (R Development Core Team 2018). This approach models non-linear relationships using a smoothing function for continuous variables similar to a generalized linear model (GLM; Wood 2011; Wood 2017; Pedersen et al. 2019). Average daily water temperature and discharge was calculated from USGS station – 07335700 on the Kiamichi River near Big Cedar. Additionally, surface velocity and depth were included as smooth terms. Three parametric variables (i.e., categorical), habitat, gear, and dominant substrate were evaluated. Coefficient significance was determined at $\alpha < 0.05$ level. Non-significant factors were removed, and a more parsimonious and optimized model was used to predict overall and Kiamichi Crayfish catch rates.

RESULTS AND DISCUSSION

Seven species of crayfish were encountered in the Kiamichi River and its associated tributaries (Table 1; Figure 1, 2). Three Tier-1 Species of Greatest Conservation Need species were encountered across 10 sampled reaches (Table 1; Figure 1). Kiamichi Crayfish were detected across 90% of sampled reaches (Table 1). Mena Crayfish and Ouachita Mountain Crayfish were detected in 50% and 30% of all sampled reaches, respectively (Table 1). Across all other sampled species, the Western Painted Crayfish and Devil Crayfish were commonly sampled (i.e., >80%; Table 1). Painted Crayfish and Water Nymph Crayfish detection across all sampled sites was low (i.e., <20%; Table 1). Seasonal detections varied across species and reaches (Table 3-9). Kiamichi Crayfish were detected across all seasons at Big Cedar and Billy Creek reaches (Table 2, 3). Western Painted Crayfish were most commonly detected seasonally across all sampled reaches (Table 9).

Across all sampled reaches, 659 individual crayfish were sampled (Figure 3). Quadrat sampling accounted for 81% of all crayfish sampled (Figure 3). Across sampled reaches quadrat samples comprised 67% - 88% of the overall crayfish captured (Figure 3). Quadrat sampling generally produced higher catch per unit effort (CPUE) averages across all samples (Figure 4). Seasonally, quadrat CPUE averages were generally higher than other gears (Figure 5). Catch rates appeared to be higher during the summer both overall (i.e., all gears) and across gears (Figure 5, 6). Across evaluated reaches, CPUE was highest during summer overall across all gears (Figure 7).

Quadrat sampling generally sampled more overall crayfish across reaches and seasons (Figure 8, 11). Kick-Seine average CPUE was generally higher during summer months across all sampled reaches (Figure 9). Traps were largely ineffective during the winter, spring, and fall seasons and generally produced no catches (Figure 10). Quadrat sampling detected more species across sampled reaches (Figure 12). Observed species richness was lowest with traps (Figure 12). More sampling effort is needed to effectively capture species richness with kick-seine and trapping methods (Figure 13).

Overall CPUE across all gears appeared to be higher in riffle habitats (Figure 14). Quadrat sampling CPUE was higher within macrohabitat types (Figure 15). Less sampling effort was required to obtain expected species richness when riffle habitats were sampled (Figure 16). Within riffle habitats, quadrats required fewer samples to obtain species richness (Figure 16).

Overall crayfish catch-rates were significantly related to average daily water temperature (Table 10). Devil Crayfish, Ouachita Mountain Crayfish, and Painted Crayfish displayed no significant relationships between the smooth terms (Table 10). The Kiamichi Crayfish model suggested significant influences of average daily water temperature and depth (Table 10). Mena Crayfish catch rates were significantly influenced by surface velocity and average daily gauge height (Table 10). Average daily water temp and gauge height influenced Water Nymph Crayfish catch rates (Table 10). Western Painted Crayfish were significantly influenced by average daily water temperature (Table 10). Average daily water temperature influenced 43% of all species sampled overall across all crayfish (Table 10) while depth and surface velocity appeared to influence few species (Table 10).

Habitat level differences were observed in Kiamichi Crayfish, Mena Crayfish, and Western Painted Crayfish (Table 11, 12). Kiamichi Crayfish and Mena Crayfish catch rates were higher in riffle habitats while catch rates were higher in pools for Western Painted Crayfish (Table 11, 12). No substrate influences were observed overall and across species-specific models evaluated (Table 11). Quadrat sampling estimated higher catch-rates overall and across most species-specific models evaluated (Table 11). No gear influences were detected for Painted Crayfish (Table 11).

Average daily water temperatures ranged from 7.95 ºC – 28.34 ºC (mean = 17.28 ºC; SD = 6.26 ºC) across samples evaluated (Table 13). Predicted overall crayfish catch rates were similar between kick-seine and trapping across the range of temperatures sampled (Figure 17). Quadrat sampling predicted higher overall crayfish catch rates across all gears and was maximized around 22 ºC – 25 ºC (Figure 17). Overall crayfish catch rates increase from June (mean water temp = 24.3 ºC) through September (mean water temp = 24.1 ºC; Figure 17; Table 14).

Riffle habitats predicted higher Kiamichi Crayfish catch rates across all evaluated variables (Figure 19, 20; Table 11, 12). Significant overlaps were observed in predicted Kiamichi Crayfish catch rates between kick-seine and trapping efforts (Figure 18, 19). Similarly, catches were maximized above 22 ºC – 23 ºC during June through September (Figure 18, Figure 19; Table 14). Predicted Kiamichi Crayfish catch rates varied across depths sampled (mean = 5.32 cm; SD = 4.78 cm; Table 13; Figure 20, 21). Regardless of habitat (i.e., riffle vs pool) catch rates were highest using quadrat sampling (Figure 20, 21). Depths between 10 cm – 15 cm appear to maximize Kiamichi Crayfish

MANAGEMENT RECOMMENDATIONS

I. ***Tracking Kiamichi Crayfish Abundances*** – Quadrat Sampling should be used to assess abundances over time in historically collected streams. Quadrats produced significantly greater catch-rates across all habitats and seasons.

II. ***Tracking Kiamichi Crayfish Abundances*** – Riffle habitats produced the highest catch-rates. Targeted sampling in these macrohabitats will likely produce the highest catch rates and allow ODWC to monitor trends over time.

III. ***Tracking Kiamichi Crayfish Abundances*** – Sampling effort is likely maximized during summer months. Catch rates were maximized during warmer temperatures that coincided with the June – July period. Given the intermittent hydrology, depths where catch rates were maximized are likely most present during these months as well.

IV. ***Current Kiamichi Crayfish Abundances*** – Range expansions within the Kiamichi River system does not appear to have occurred. Similar to Jones and Bergey (2007), Kiamichi Crayfish were not observed below Whitesboro, OK.

V. ***Current Kiamichi Crayfish Abundances*** – Some exploratory sampling efforts encountered a potential Kiamichi Crayfish in the Mountain Fork near the Arkansas state line (34.64263, -94.49337). The specimen has been vouchered and keyed out to *saxatilis*, but further analysis of the specimen along with other crayfish species from the watershed is warranted. Additional sampling should be conducted where access is possible in adjacent tributaries. Perhaps, range is limited longitudinally but not across watershed.

VI. ***Quantifying Crayfish Assemblages*** – While Quadrat Sampling produced the highest catch-rates across all crayfish and SGCN spp. sampled, gear choice should consider various biotic and abiotic factors. Specific objectives should also be considered. Higher catch-rates likely lead to better abundance estimates and indices. Greater effort is required per unit of quadrat sampling relative to kick-seines and trap methods. When time and resources are limited, or if presence/absence data is being collected, these other two methods may provide adequate results. Additionally, if sampling or objectives are species specific, those species-specific factors must be considered (e.g., life-history).

VII. ***Kiamichi Crayfish Threats*** – Variables observed influencing Kiamichi Crayfish are likely influenced by various factors. Higher catch-rates in summer months could be influenced by decreased available habitat and a subsequent congregating effect. Kiamichi Crayfish appear to be good burrowers and are likely seeking aquatic refuge within the hyporheic zone. Landscape changes and reductions in water availability are likely to negatively influence Kiamichi Crayfish populations.

VIII. ***Kiamichi Crayfish Status*** – While narrowly distributed, overall range reductions were not observed compared to Jones and Bergey (2007). Our results further support riffle preference and similarly suggest Kiamichi Crayfish are likely under-sampled throughout the Kiamichi River. Access and limited riffle availability throughout the Upper Kiamichi River and its tributaries are likely limiting factors.

IX. ***Kiamichi Crayfish Status*** – At this time criteria for Endangered Species Listing does not appear to be met.

a. ***The present or threatened destruction, modification, or curtailment of its habitat or range*** – much of the observed range is within various state and federal lands. No immediate threats were observed or identified during the grant period. Much of the range is undeveloped and generally managed as wilderness areas.

b. Overutilization for commercial, recreational, scientific, or educational purposes – at this time no overutilization has been observed. No commercial value appears to exist currently. Recreational value appears to be minimal.

c. Disease or predation – We observed no disease or excessive predation during this study.

d. The inadequacy of existing regulatory mechanisms **–** While no specific regulations limit the potential harvest or take, it does not appear any substantial harvest is occurring.

e. ***Other natural or manmade factors affecting its survival*** – Broad-scale anthropogenic influences (e.g., climate change) could potentially influence Kiamichi Crayfish abundances and range, however, these same changes are likely to influence all biota. Disturbance and other habitat modifications do not appear to disproportionately affect Kiamichi Crayfish.

REFERENCES

Abell, R. A., D. M. Olsen, E. Dinersrein, P. T. Hurley, J. T. Diggs, W. Eichbaum, S. Walters, W. Wettengel, T. Allnutt, C. J. Loucks, and P. Hedao. 2000. Freshwater ecoregions of North America: a conservation assessment. Island Press, Washington, D.C.

Abell, R. A., M. L. Thieme, C. Revenga, M. Bryer, M. Kottelat, N. Bogutskaya, B. Coad, N. Mandrak, S. C. Balderas, W. Bussing, M. L. J. Stiassny, P. Skelton, G. R. Allen, P. Unmack, A. Naseka, R. Ng, N. Sindorf, J. Robertson, E. Armijo, J. V. Higgins, T. J. Heibel, E. Wikramanayake, D. Olson, H. L. Lopez, R. E. Reis, J. G. Lundberg, M. H. Sabaj Perez, and P. Petry. 2008. Freshwater ecoregions of the world: A new map of biogeographic units for freshwater biodiversity conservation. BioScience 58:403-414.

Bouchard, R. W. and J. W. Bouchard. 1976. Orconectes saxatilis, a new species of crayfish from eastern Oklahoma. Proceedings of the Biological Society of Washington 41:439-446.

Colwell, R.K., C.X. Mao & J. Chang. 2004. Interpolating, extrapolating, and comparing incidence-based species accumulation curves. Ecology 85:2717-2727.

Colwell, R.K., Chao, A., Gotelli, N.J., Lin, S.-Y., Mao, C.X., Chazdon, R.L., Longino, J.T. 2012. Models and estimators linking individual-based and sample-based rarefaction, extrapolation and comparison of assemblages. Journal of Plant Ecology 5:3–21.

Dyer, J. J., and S. K. Brewer. 2018. Habitat associations of three crayfish endemic to the Ouachita Mountain ecoregion. Southeastern Naturalist 17:257-269.

DiStefano, R. J., C. M. Gale, B. A. Wagner, and R. D. Zweifel. 2003. A sampling method to assess lotic crayfish communities. Journal of Crustacean Biology 23:678-690.

Heck, K. L., G. Belle, and D. Simberloff. 1975. Explicit calculation of the rarefaction diversity measurement and the determination of sufficient sample size. Ecology 56:1459-1461.

Jones, S. N., and E. A. Bergey. 2007. Habitat segregation in stream crayfishes: implications for conservation. Journal of the North American Benthological Society 26:134-144.

Loughman, Z. J., and J. W. J. Fetzner. 2015. Astacology and crayfish conservation in the southeastern United States: Past, present, and future. Freshwater Crayfish 21:1-5.

Pedersen, E. J., D. L. Miller, G. L. Simpson, and N. Ross. 2019. Hierarchial generalized additive models in ecology: an introduction with mgcv. Peer J 7:e6876.

Ricciardi, A., and J. B. Rasmussen. 1999. Extinction rates of North American freshwater fauna. Conservation Biology 13:1220-1222.

Robison, H. W., and C. T. McAllister. 2012. The endemic biota of Oklahoma. Proceedings of the Oklahoma Academy of Sciences 92:21-28.

Taylor, C. A., S. N. Jones, and E. A. Bergey. 2004. Crayfishes of Oklahoma revisited: new state records and checklist of species. Southwestern Naturalist 49:250-255.

Wood, S. N. 2001. Partially specified ecological models. Ecological Monographs 71(1):1-25.

Wood, S. N. 2017. Generalized additive models: An introduction with R. 2nd ed. Chapman and Hall, New York.

TABLES

Table 1 – Sampled species detection across all sampled reaches.

Species	Percent Reaches Detected
Devil Crayfish	80%
Kiamichi Crayfish*	90%
Mena Crayfish*	50%
Ouachita Mountain Crayfish*	30%
Painted Crayfish	10%
Water Nymph Crayfish	20%
Western Painted Crayfish	90%

*Oklahoma Species of Greatest Conservation Need Tier-1 (Oklahoma Comprehensive Wildlife Conservation Strategy, Appendix E)

Table 2 – General geographic coordinates of reach and macrohabitat specific sites sampled.

Reach-Macrohabitat	Latitude	Longitude
Upper Kiamichi		
Riffle	34.64723	-94.54296
Pool	34.64728	-94.54247
Pigeon Creek		
Riffle	34.64687	-94.54191
Pool	34.64656	-94.54197
Little Pigeon		
Riffle	34.64795	-94.53435
Pool	34.64779	-94.53463
Golden Branch		
Riffle	34.63692	-94.60653
Pool	34.63674	-94.60624
Big Cedar		
Riffle	34.66735	-94.65088
Pool	34.66779	-94.65112
Big Branch		
Riffle	34.65722	-94.61215
Pool	34.65698	-94.61212
Little Cedar		
Riffle	34.66571	-94.70188
Pool	34.66642	-94.70140
Sycamore Creek		
Riffle	34.68722	-94.83432
Pool	34.68723	-94.83426
Frazier Creek		
Riffle	34.72776	-94.93771
Pool	34.72786	-94.93777
Billy Creek		
Riffle	34.71917	-94.74006
Pool	34.71858	-94.73755

Table 3. – Seasonal Kiamichi Crayfish detections across all sampled reaches.

Kiamichi Crayfish* *Faxonius saxatilis*	Fall	Spring	Summer	Winter
Upper Kiamichi	X	X	X	X
Pigeon Creek		X	X	X
Little Pigeon		X	X	
Golden Branch		X	X	
Big Cedar	X	X	X	X
Big Branch		X	X	
Little Cedar	X	X	X	X
Sycamore Creek	X	X		
Frazier Creek				
Billy Creek	X	X	X	X

*Oklahoma Species of Greatest Conservation Need Tier-1 (Oklahoma Comprehensive Wildlife Conservation Strategy, Appendix E)

Table 4. – Seasonal Mena Crayfish detections across all sampled reaches.

Mena Crayfish* *Faxonius menae*	Fall	Spring	Summer	Winter
Upper Kiamichi				
Pigeon Creek		X	X	
Little Pigeon		X		
Golden Branch	X	X	X	X
Big Cedar		X		
Big Branch		X	X	X
Little Cedar				
Sycamore Creek				
Frazier Creek				
Billy Creek				

*Oklahoma Species of Greatest Conservation Need Tier-1 (Oklahoma Comprehensive Wildlife Conservation Strategy, Appendix E)

Table 5. – Seasonal Ouachita Mountain Crayfish detections across all sampled reaches.

Ouachita Mountain Crayfish* *Procambarus tenuis*	Fall	Spring	Summer	Winter
Upper Kiamichi	X			
Pigeon Creek		X		
Little Pigeon				
Golden Branch		X	X	
Big Cedar				
Big Branch				
Little Cedar				
Sycamore Creek				
Frazier Creek				
Billy Creek				

*Oklahoma Species of Greatest Conservation Need Tier-1 (Oklahoma Comprehensive Wildlife Conservation Strategy, Appendix E)

Table 6. – Seasonal Devil Crayfish detections across all sampled reaches.

Devil Crayfish *Cambarus diogenes*	Fall	Spring	Summer	Winter
Upper Kiamichi	X		X	
Pigeon Creek			X	X
Little Pigeon			X	
Golden Branch			X	
Big Cedar			X	
Big Branch				
Little Cedar	X		X	
Sycamore Creek		X	X	
Frazier Creek				
Billy Creek	X		X	

Table 7. – Seasonal Painted Crayfish detections across all sampled reaches.

Painted Crayfish *Faxonius difficilis*	Fall	Spring	Summer	Winter
Upper Kiamichi				
Pigeon Creek	X		X	
Little Pigeon				
Golden Branch				
Big Cedar				
Big Branch				
Little Cedar				
Sycamore Creek				
Frazier Creek				
Billy Creek				

Table 8. – Seasonal Water Nymph Crayfish detections across all sampled reaches.

Water Nymph Crayfish *Faxonius nais*	Fall	Spring	Summer	Winter
Upper Kiamichi				
Pigeon Creek				
Little Pigeon				
Golden Branch				
Big Cedar				
Big Branch				
Little Cedar				
Sycamore Creek			X	
Frazier Creek				
Billy Creek			X	

Table 9. – Seasonal Western Painted Crayfish detections across all sampled reaches.

Western Painted Crayfish *Faxonius palmeri longimanus*	Fall	Spring	Summer	Winter
Upper Kiamichi	X		X	
Pigeon Creek		X	X	
Little Pigeon		X	X	
Golden Branch		X	X	
Big Cedar	X		X	X
Big Branch				
Little Cedar	X	X	X	
Sycamore Creek	X	X	X	
Frazier Creek		X	X	X
Billy Creek		X	X	

Table 10. – Overall and species-specific estimated significance values of evaluated continuous variables. Bolded p-values represent significant relationships at the α < 0.05* and α < 0.01** levels.

	Surface Velocity	Average Daily Water Temperature	Average Daily Gauge Height	Depth
Overall	0.977	**>0.00001****	0.374	0.136
Devil Crayfish	0.509	0.839	0.674	0.225
Kiamichi Crayfish[1]	0.916	**0.031***	0.235	**0.004****
Mena Crayfish[1]	**0.039***	0.198	**0.019****	0.220
Ouachita Mountain Crayfish[1]	0.910	0.918	0.649	0.438
Painted Crayfish	0.832	0.305	0.724	0.545
Water Nymph Crayfish	0714	**>0.00001****	**>0.0001****	0.258
Western Painted Crayfish	0.461	**>0.0002****	0.201	0.499
Percent of Species	14%	43%	29%	14%

[1]Oklahoma Species of Greatest Conservation Need Tier-1 (Oklahoma Comprehensive Wildlife Conservation Strategy, Appendix E)

Table 11. – Overall and species-specific parameter estimates and corresponding *p-values* derived from generalized additive models (GAMs). Estimated slopes indicate the relative increases and decreases in catch-rates. A positive value indicates higher predicted catch-rates of the latter categorical variable. For example, a positive parameter estimate within habitat suggests higher catch-rates in riffle (RF) habitats relative to pool (PL) habitats. Kick-Seine (KS), quadrat (QS), and traps (TP) were evaluated in gear. Boulder (BD), cobble (CB), gravel (GV), and sand (SD) substrates were evaluated as substrate. Statistically significant *(p < 0.05)* are bolded.

Difference Between	*Overall*	*Devil Crayfish*	*Kiamichi Crayfish**	*Mena Crayfish**	*Ouachita Mountain Crayfish**	*Painted Crayfish*	*Water Nymph Crayfish*	*Western Painted Crayfish*
Habitat								
PL – RF	*0.123 (p = 0.706)*	0.0237 *(p = 0.193)*	**0.390 *(p = 0.0124)***	**0.113 *(p = 0.0004)***	0.0162 *(p = 0.192)*	-0.0000059 *(p = 0.628)*	-0.132 *(p = 0.186)*	**-0.298 *(p = 0.05)***
Gear								
KS – QS	**2.019 *(p > 0.0001)***	0.031 *(p = 0.0936)*	**0.825 *(p > 0.0001)***	**0.0976 *(p = 0.0022)***	**0.0260 *(p = 0.041)***	0.00881 *(p = 0.231)*	**0.364 *(p = 0.0004)***	**0.672 *(p = 0.00003)***
KS – TP	-0.069 *(p = 0.837)*	-0.0189 *(p = 0.315)*	-0.0640 *(p = 0.690)*	-0.0325 *(p = 0.313)*	-0.00434 *(p = 0.735)*	-0.000006 *(p = 0.999)*	0.0229 *(p = 0.824)*	0.0276 *(p = 0.864)*
QS – TP	**-2.088 *(p > 0.0001)***	**-0.0500 *(p = 0.00703)***	**-0.889 *(p > 0.0001)***	**-0.130 *(p > 0.0001)***	**-0.0302 *(p = 0.0167)***	-0.00882 *(p = 0.230)*	**-0.342 *(p = 0.0008)***	**-0.644 *(p > 0.0001)***
Substrate								
BD – CB	0.324 *(p = 0.354)*	-0.0082 *(p = 0.673)*	-0.007 *(p = 0.966)*	0.027 *(p = 0.535)*	0.0177 *(p = 0.182)*	-0.0103 *(p = 0.182)*	0.177 *(p = 0.1)*	0.154 *(p = 0.359)*
BD – GV	0.3576 *(p = 0.412)*	-0.0285 *(p = 0.2392)*	0.0445 *(p = 0.8332)*	0.038 *(p = 0.367)*	-0.00236 *(p = 0.887)*	-0.0111 *(p = 0.249)*	0.0544 *(p = 0.69)*	0.200 *(p = 0.338)*
BD – SD	-0.307 *(p = 0.743)*	-0.0146 *(p = 0.779)*	-0.200 *(p = 0.657)*	-0.046 *(p = 0.609)*	0.007 *(p = 0.844)*	-0.0151 *(p = 0.468)*	0.0261 *(p = 0.928)*	-0.129 *(p = 0.774)*
CB – GV	0.0337 *(p = 0.929)*	-0.0203 *(p = 0.334)*	0.0515 *(p = 0.778)*	0.0168 *(p = 0.642)*	-0.020 *(p = 0.163)*	-0.0008 *(p = 0.926)*	-0.1223 *(p = 0.301)*	0.0464 *(p = 0.798)*
CB – SD	-0.631 *(p = 0.493)*	-0.00614 *(p = 0.901)*	-0.193 *(p = 0.664)*	-0.0668 *(p = 0.450)*	-0.0107 *(p = 0.761)*	-0.0047 *(p = 0.816)*	-0.151 *(p = 0.597)*	-0.282 *(p = 0.522)*
GV – SD	-0.665 *(p = 0.490)*	0.0139 *(p = 0.795)*	-0.244 *(p = 0.597)*	-0.0837 *(p = 0.366)*	0.00939 *(p = 0.798)*	-0.00397 *(p = 0852)*	-0.0282 *(p = 0.925)*	-0.329 *(p = 0.476)*

*Oklahoma Species of Greatest Conservation Need Tier-1 (Oklahoma Comprehensive Wildlife Conservation Strategy, Appendix E)

Table 12. – Simplified estimated statistically significant catch-rate differences between evaluated parameters. Percentage of species in the respective categories where parametric differences were detected are given.

Parametric Differences			
Riffle > Pool	**Pool > Riffle**	**Quadrat > Kick-Seine**	**Quadrat > Trap**
Percent of Overall Species Represented			
29%	**14%**	**71%**	**86%**
Kiamichi Crayfish*	Western Painted Crayfish	Overall (All Species)	Overall (All Species)
Mena Crayfish*		Kiamichi Crayfish*	Devil Crayfish
		Mena Crayfish*	Kiamichi Crayfish*
		Ouachita Mountain Crayfish*	Mena Crayfish*
		Water Nymph Crayfish	Ouachita Mountain Crayfish*
		Western Painted Crayfish	Water Nymph Crayfish
			Western Painted Crayfish

*Oklahoma Species of Greatest Conservation Need Tier-1 (Oklahoma Comprehensive Wildlife Conservation Strategy, Appendix E)

Table 13. – Mean, range, and standard deviation of evaluated smoothing term variables.

	Mean	Range	SD
Surface Velocity (m/s)	0.18	0 - 1.94	0.25
Average Daily Temperature (ºC)	17.28	7.95 - 28.34	6.26
Average Daily Gauge Height (ft)	3.60	2.38 - 5.90	0.78
Depth (cm)	5.32	0 - 25	4.78

Table 14. – Monthly average daily water temperature averages and ranges. All water temperature (ºC) data obtained from USGS gauging station 07335700 on the Kiamichi River near Big Cedar, OK.

	Mean Water Temperature (ºC)	Range
January	10.0	8.0 –12.2
February	10.9	10.5 – 12.3
March	13.2	13.2 – 13.3
April	15.9	14.9 – 16.1
May	18.2	18.2 – 18.2
June	24.3	23.6 – 25.4
July	27.0	26.6 – 28.3
August	27.6	27.4 – 27.8
September	24.1	24.0 – 24.2
October	15.0	14.1 – 15.2
November	14.4	14.2 – 14.8
December	10.1	9.0 – 11.0

FIGURES

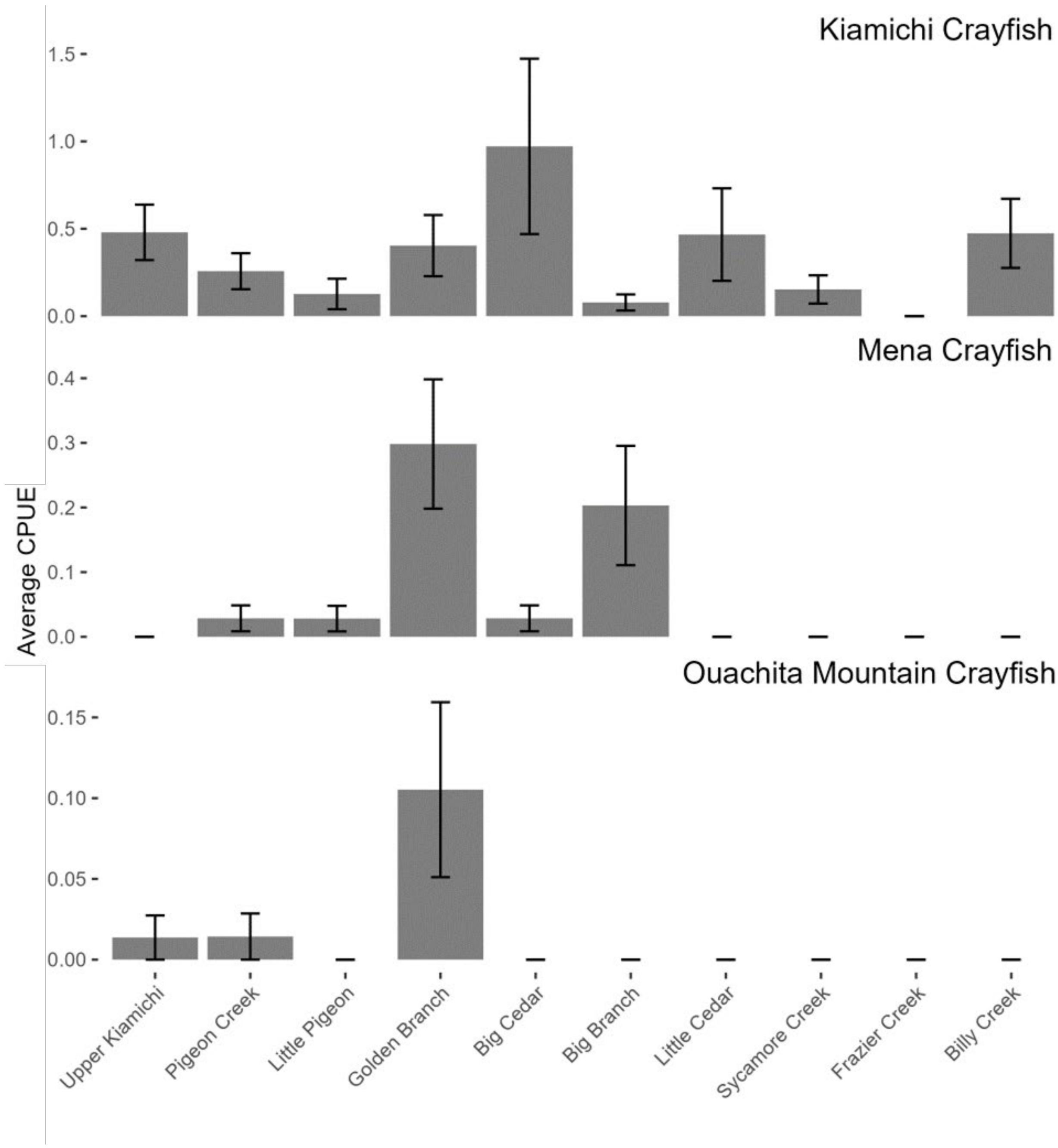


Figure 1. – Oklahoma Species of Greatest Conservation Need Tier-1 (Oklahoma Comprehensive Wildlife Conservation Strategy, Appendix E) crayfish species average captures across all sampled reaches. Average (±SE) catch per unit effort (CPUE) across all seasons, macrohabitats, and gears are displayed. Reaches are listed in downstream or lower elevation order.

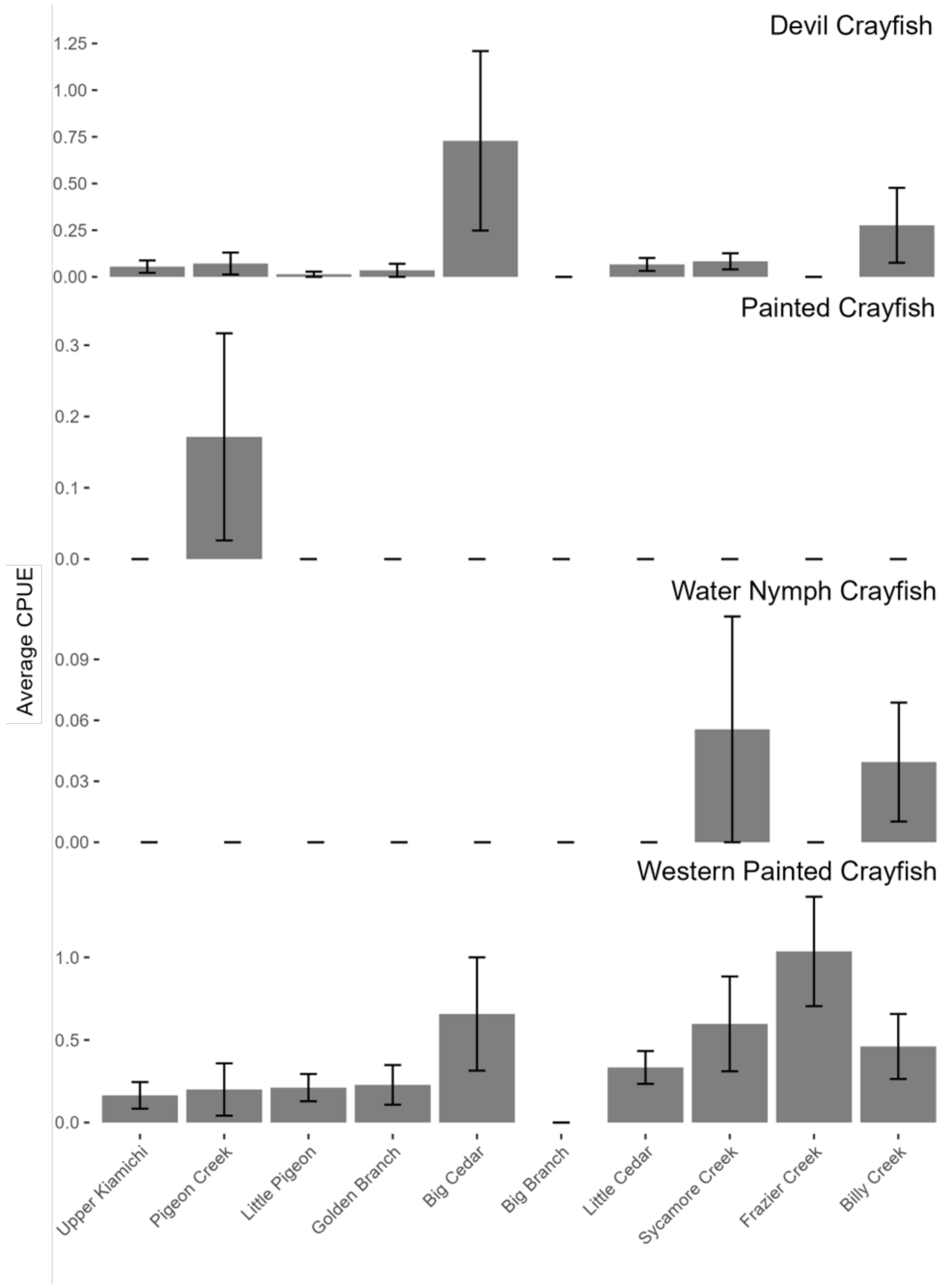


Figure 2. – Average (±SE) catch per unit effort (CPUE) across all seasons, macrohabitats, and gears for individual reaches. Reaches are listed in downstream or lower elevation order.

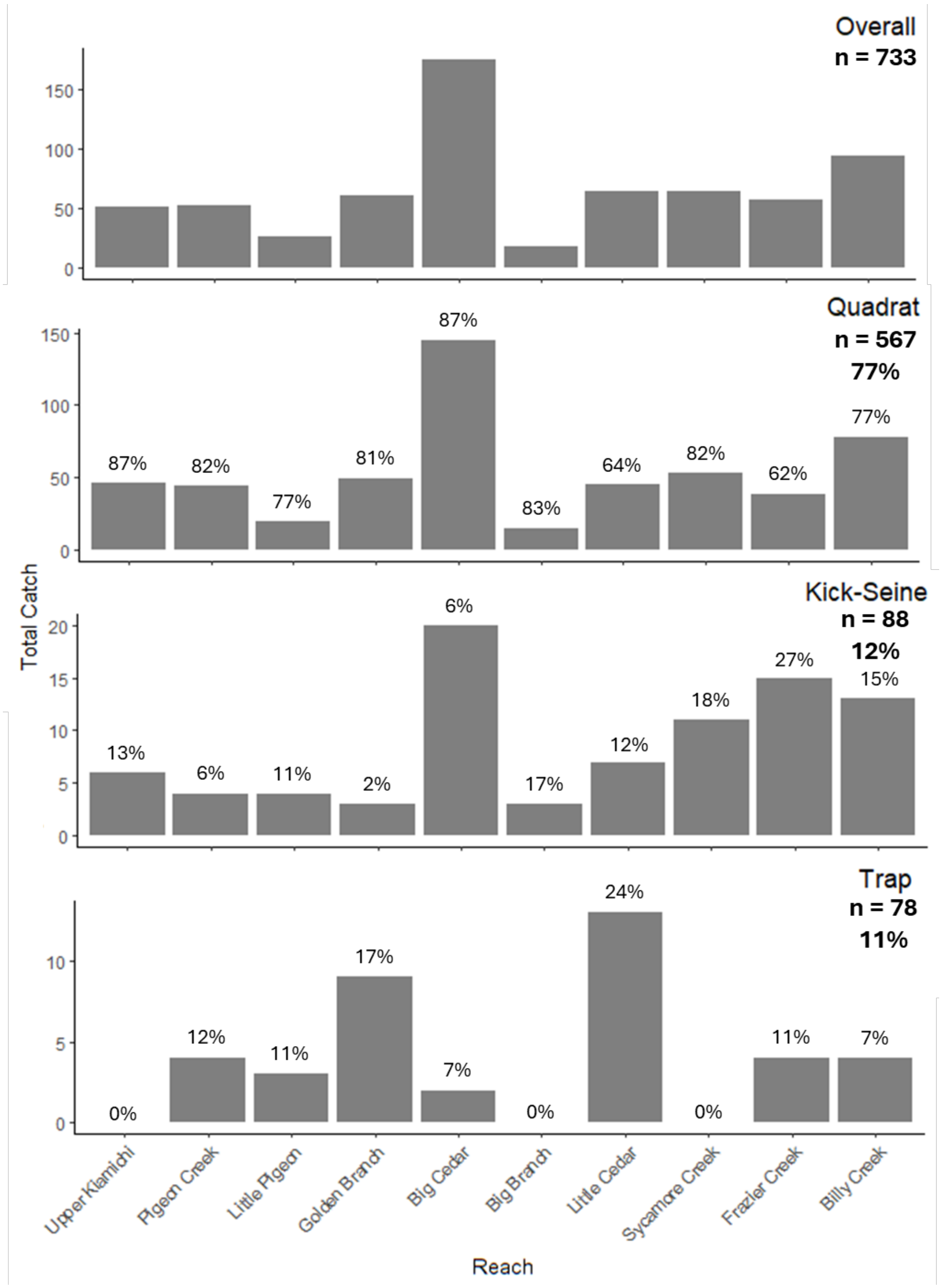


Figure 3. – Total captured individuals across all sampled reaches. Percentages represent the gear specific contribution to the overall total.

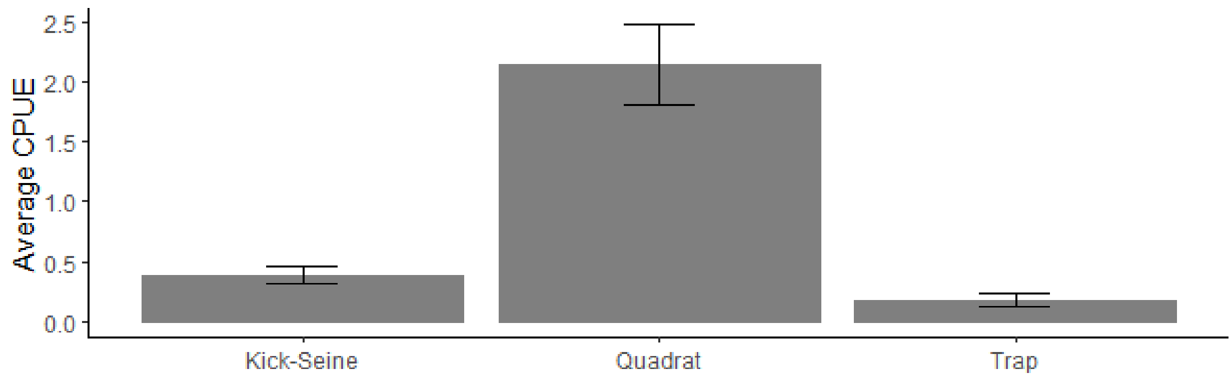


Figure 4. – Average (±SE) catch per unit effort (CPUE) by gear across all samples.

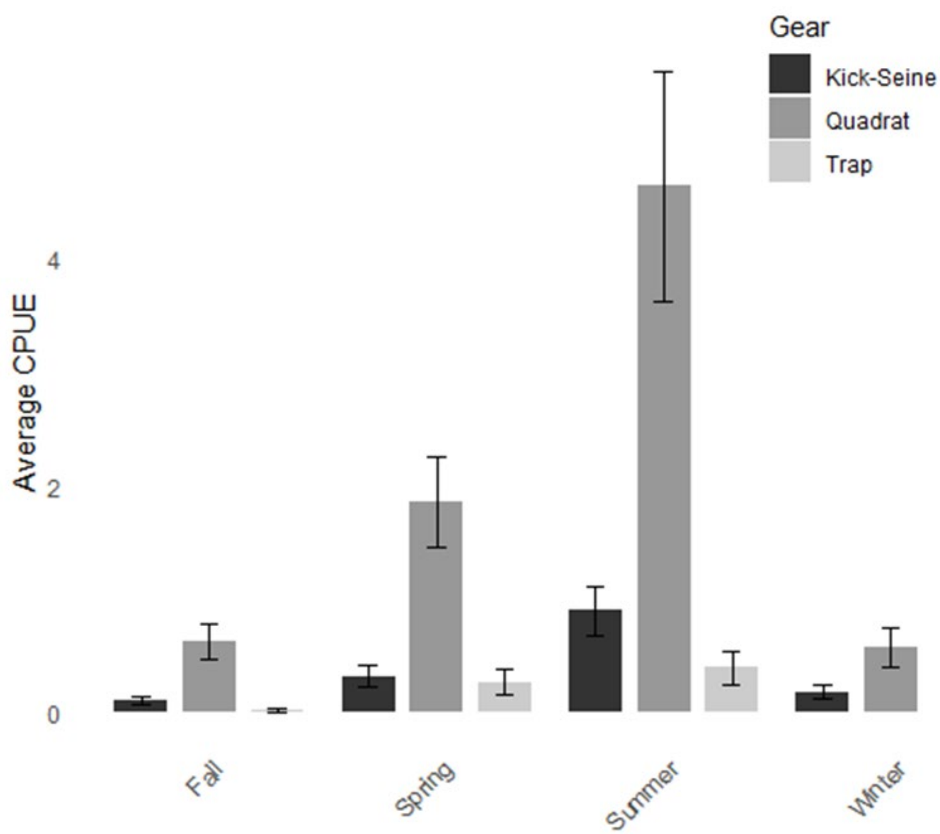


Figure 5. – Seasonal average (±SE) catch per unit effort (CPUE) across gears.

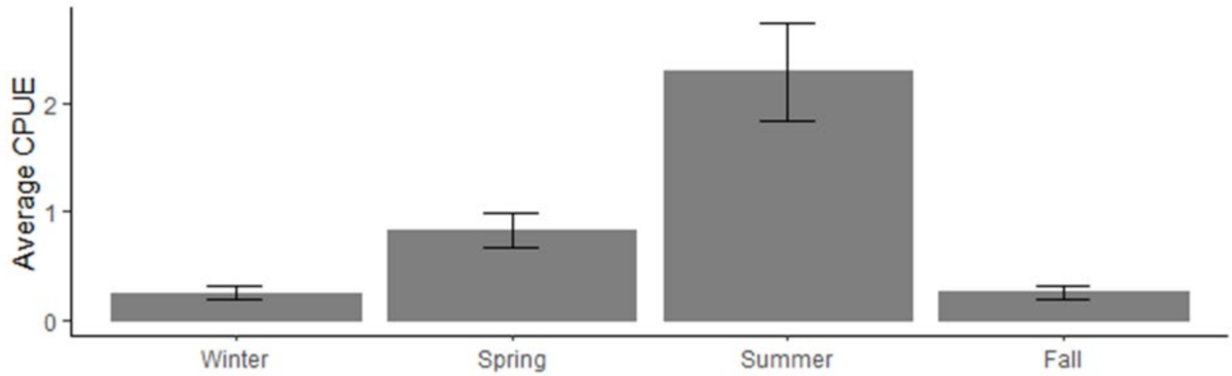


Figure 6. – Pooled average (±SE) catch per unit effort (CPUE) across sampled seasons.

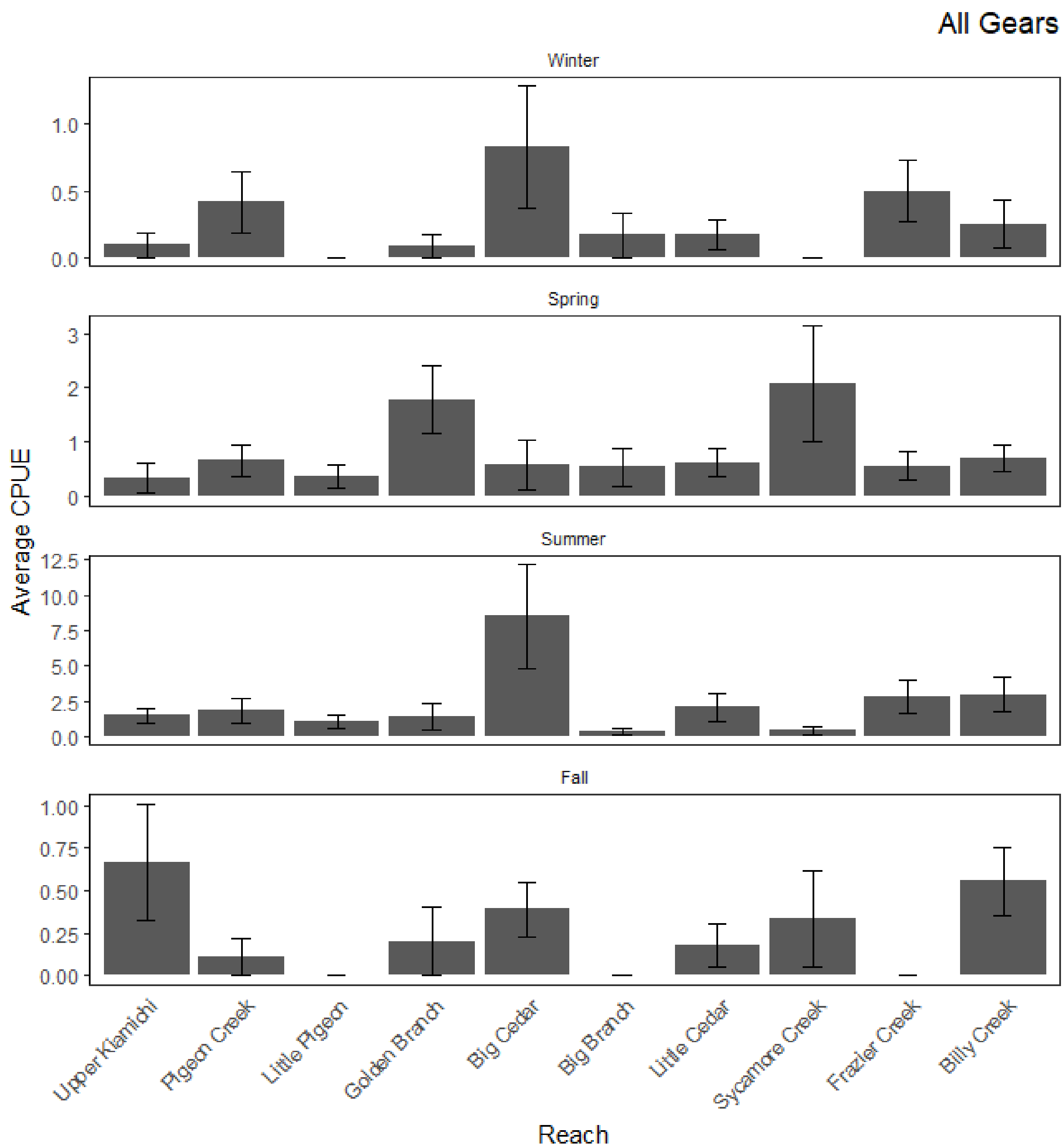


Figure 7. – Overall average (±SE) catch per unit effort (CPUE) between sites across seasons.

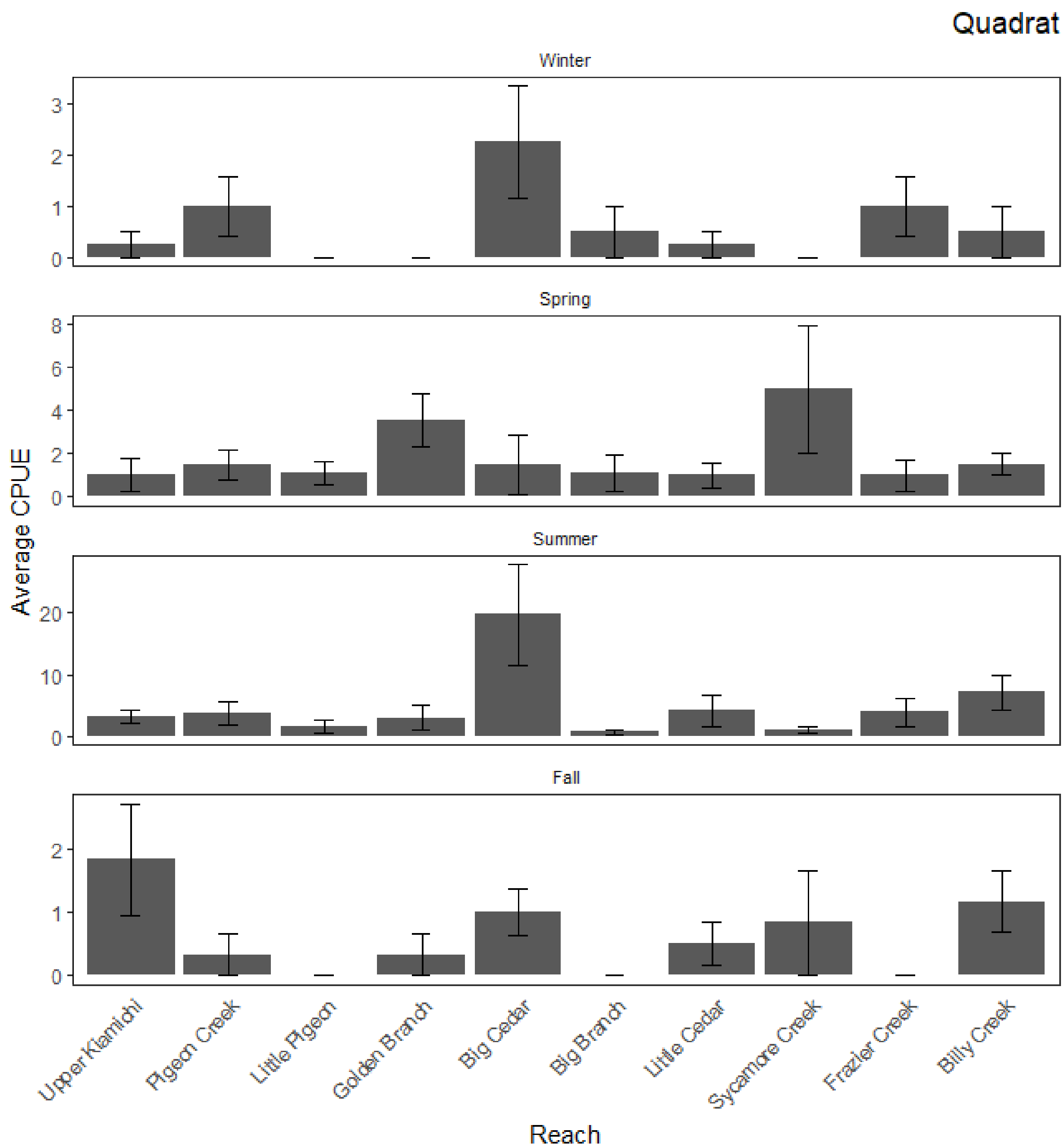


Figure 8. – Quadrat sampling average (±SE) catch per unit effort (CPUE) between sites across seasons.

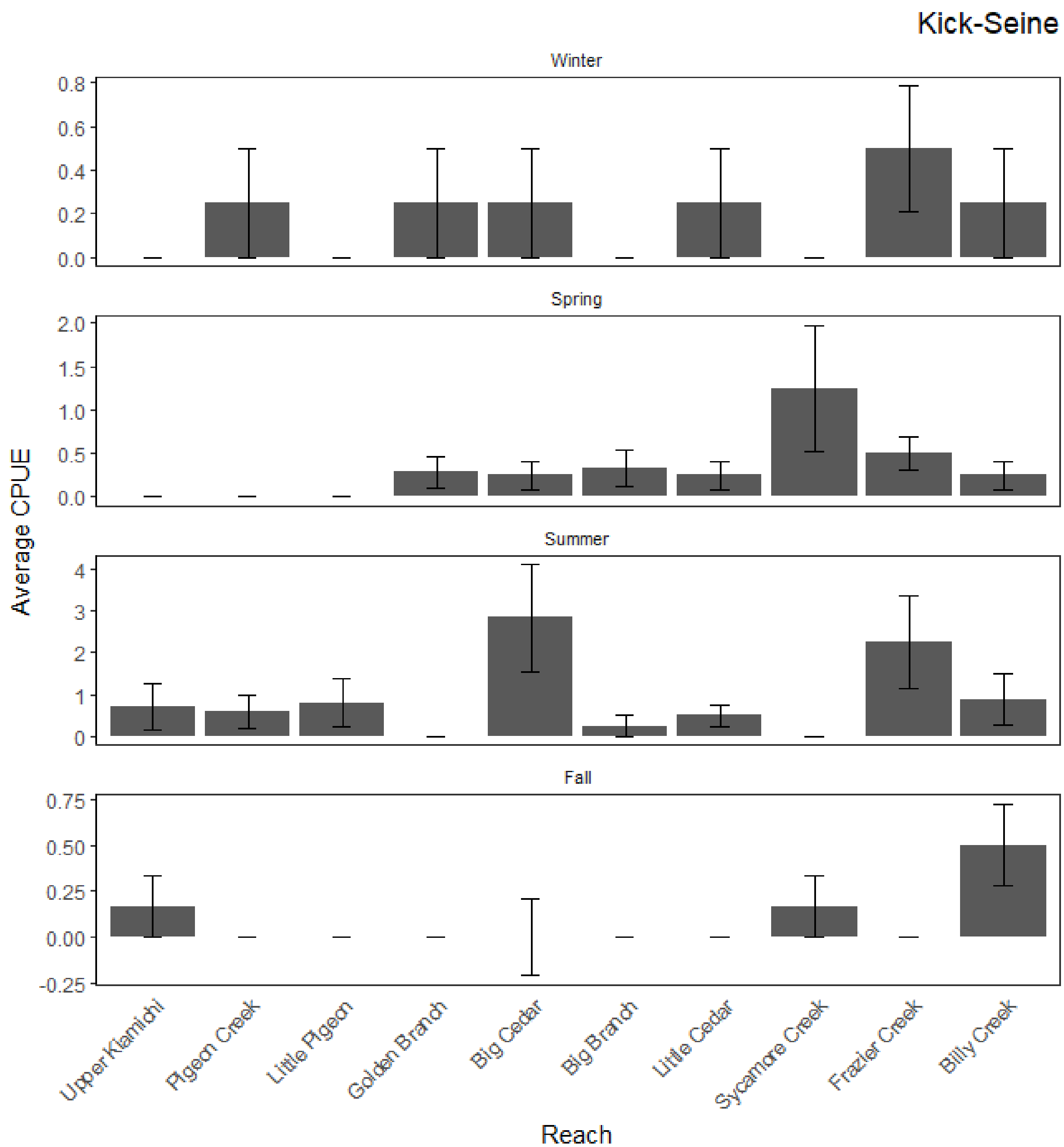


Figure 9. – Kick-Seine sampling average (±SE) catch per unit effort (CPUE) between sites across seasons.

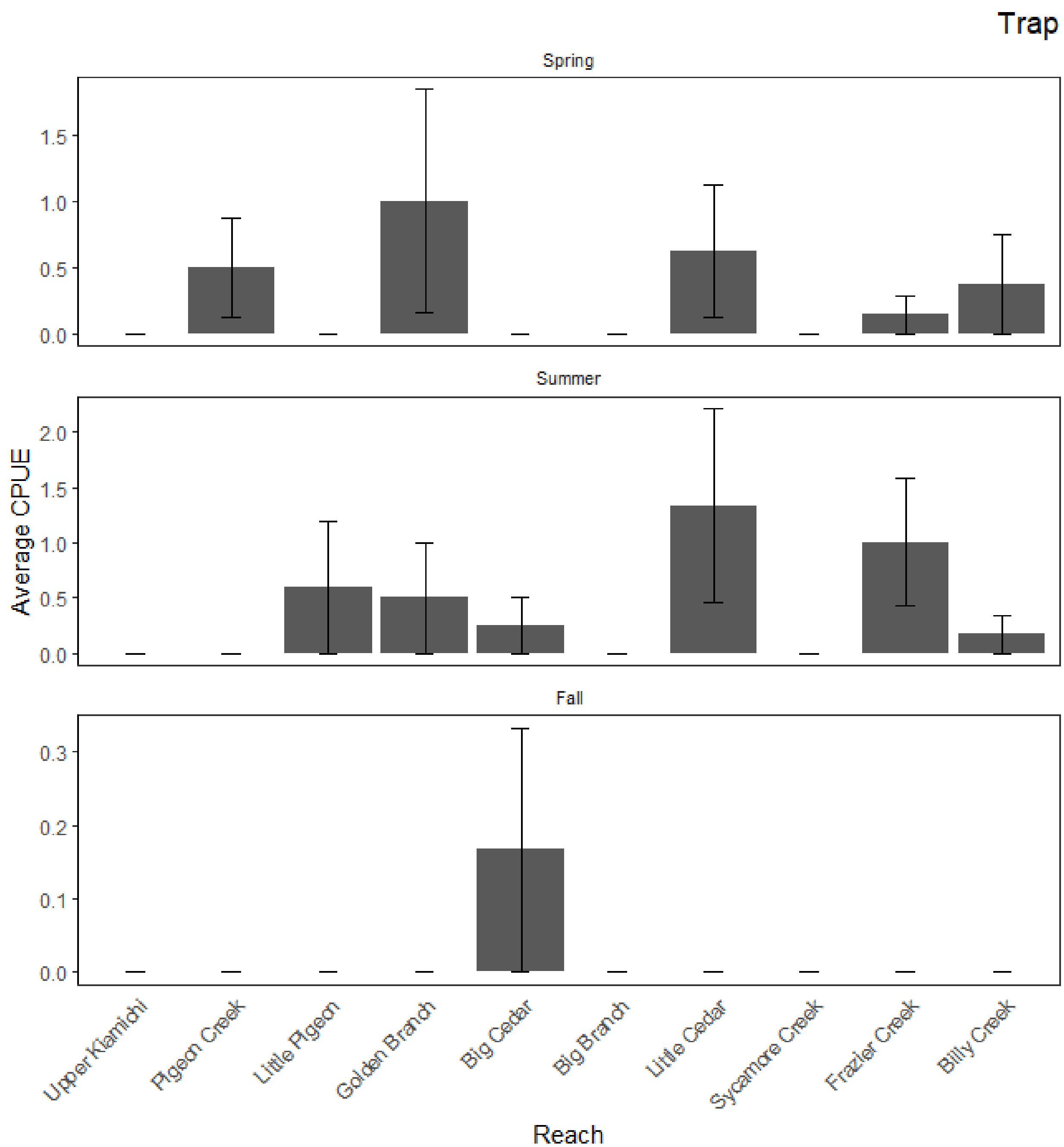


Figure 10. – Trap sampling average (±SE) catch per unit effort (CPUE) between sites across seasons.

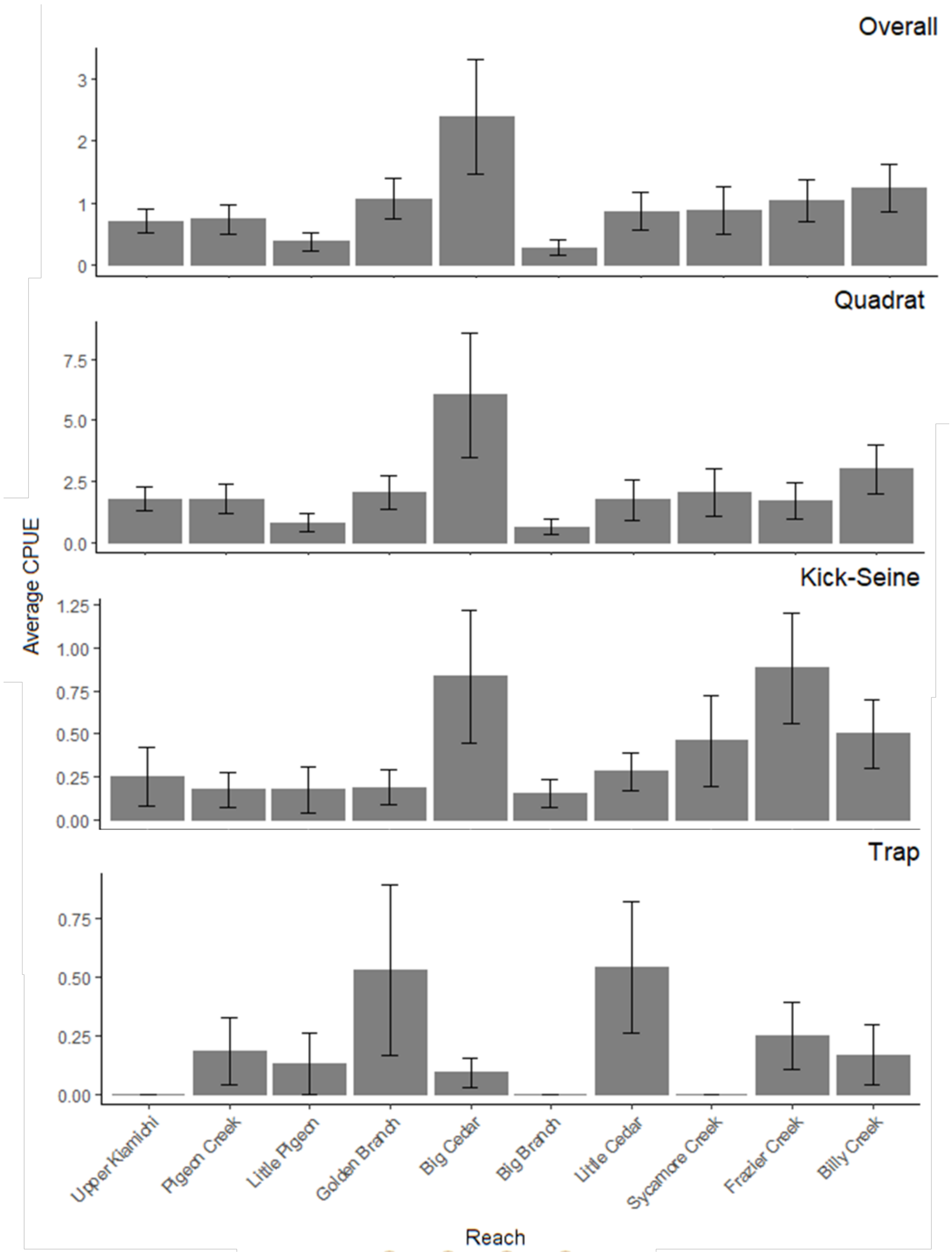


Figure 11. – Average (±SE) overall catch per unit effort (CPUE) across sampled reaches and gears.

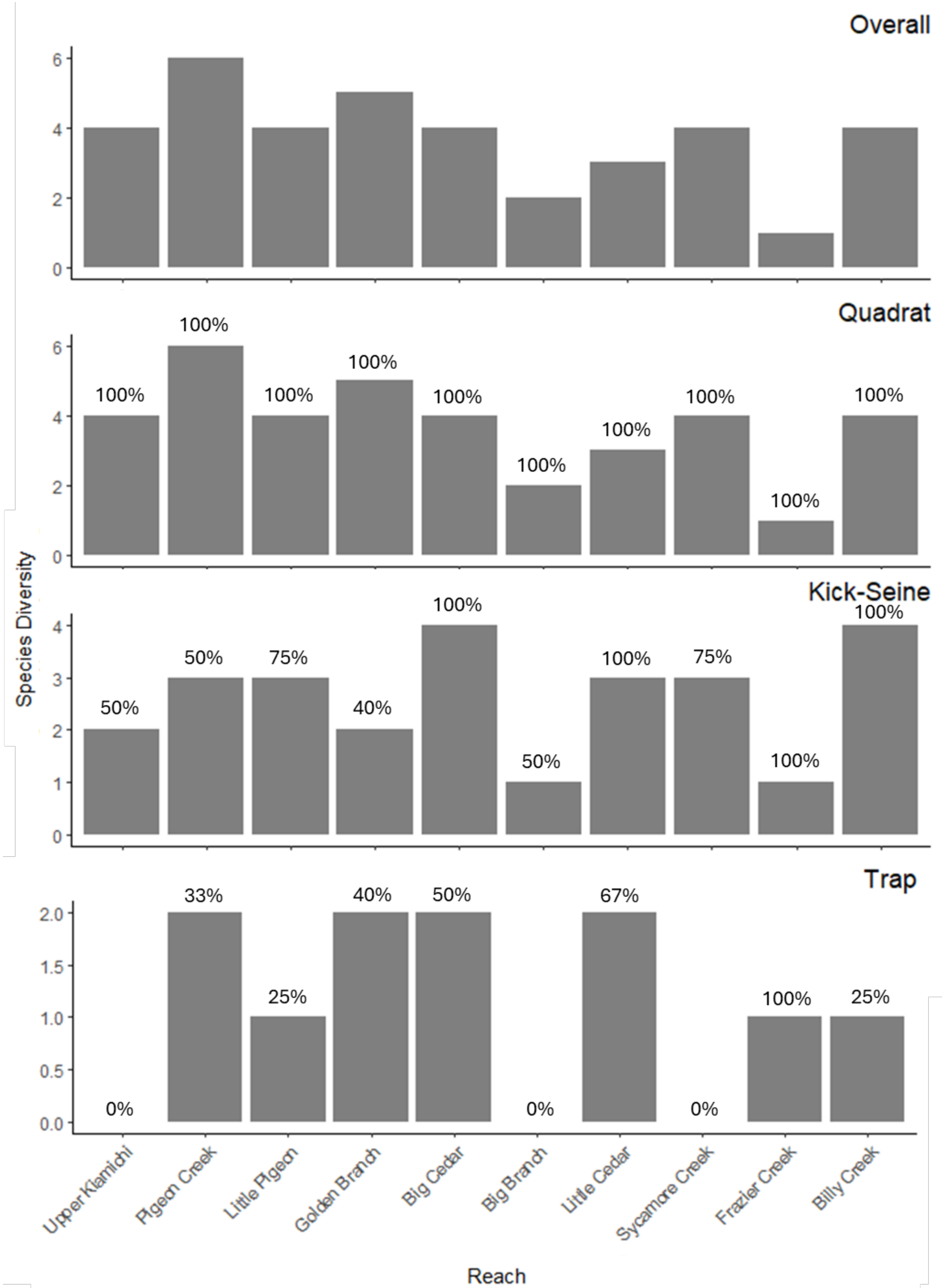


Figure 12. – Observed species diversity across sampled reaches. Overall reflects pooled total observed species across all gears. Percent of species detected by each gear are given across sampled reaches.

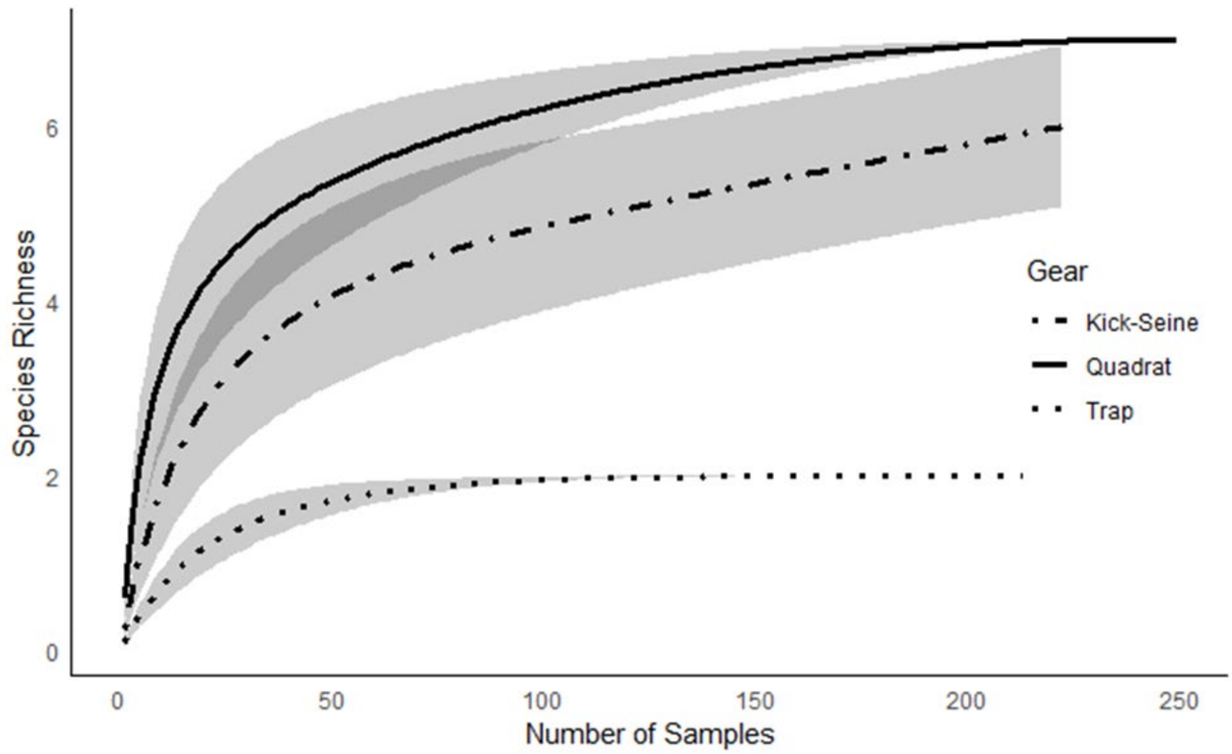


Figure 13. – Gear specific species accumulation curves across all sampled reaches.

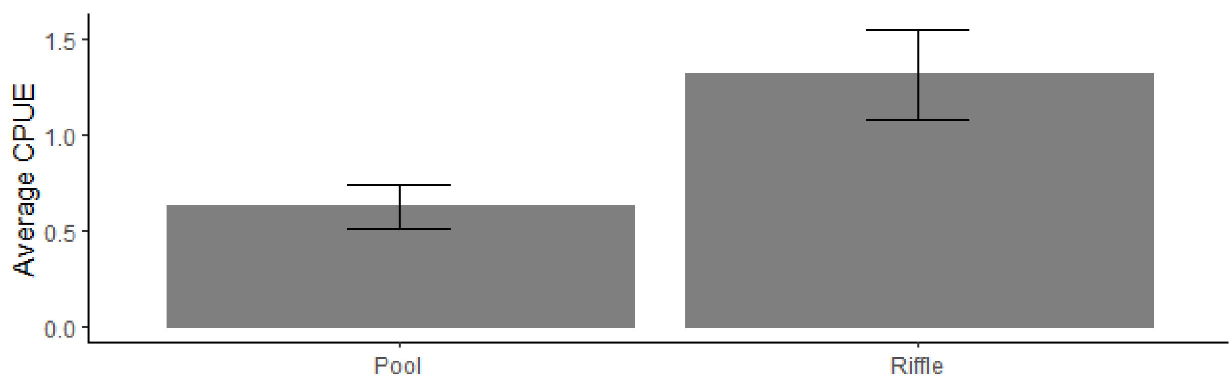


Figure 14. – Overall average (±SE) overall catch per unit effort (CPUE) across macrohabitats sampled.

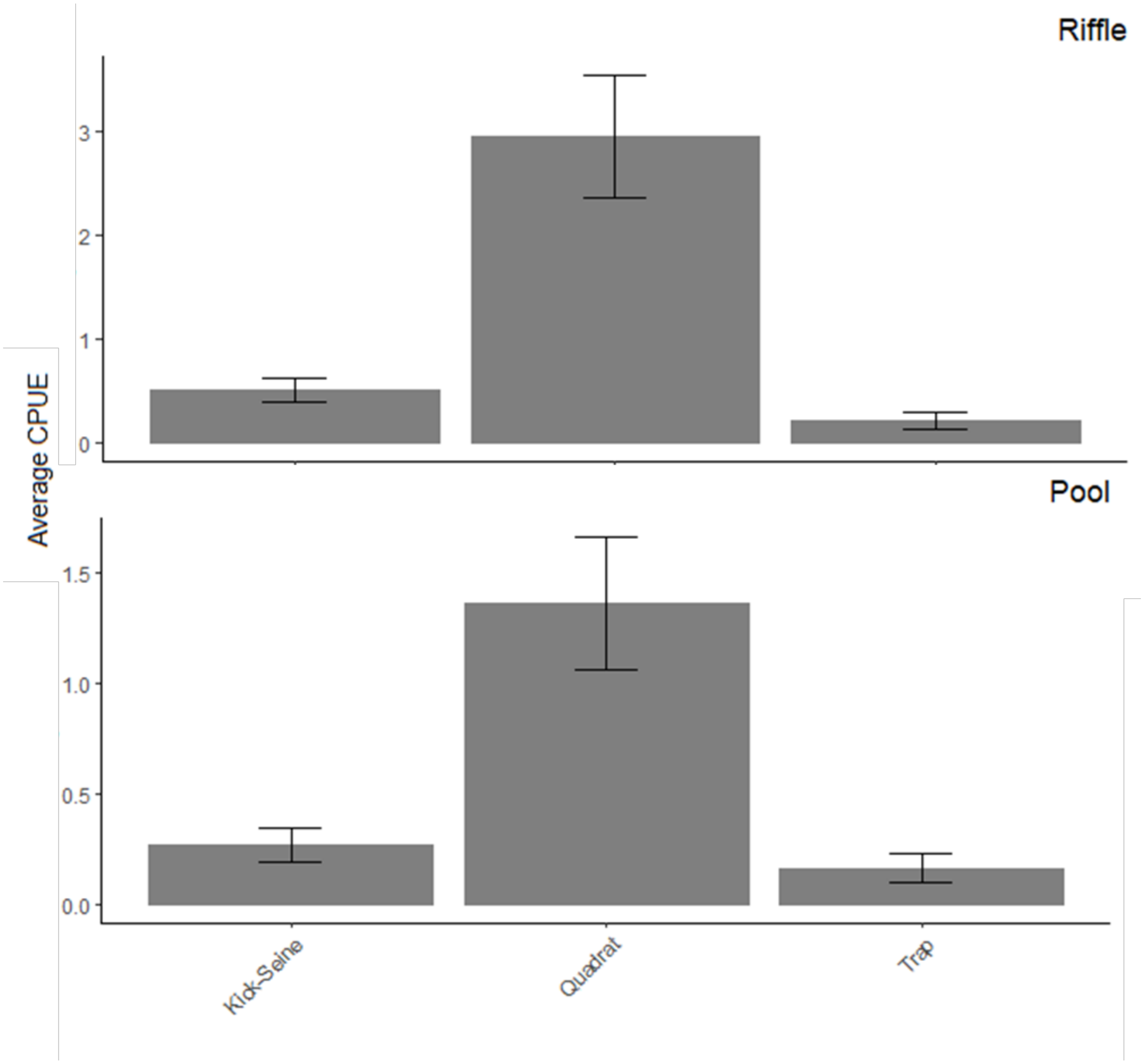


Figure 15. – Gear specific average (±SE) overall catch per unit effort (CPUE) across macrohabitats sampled.

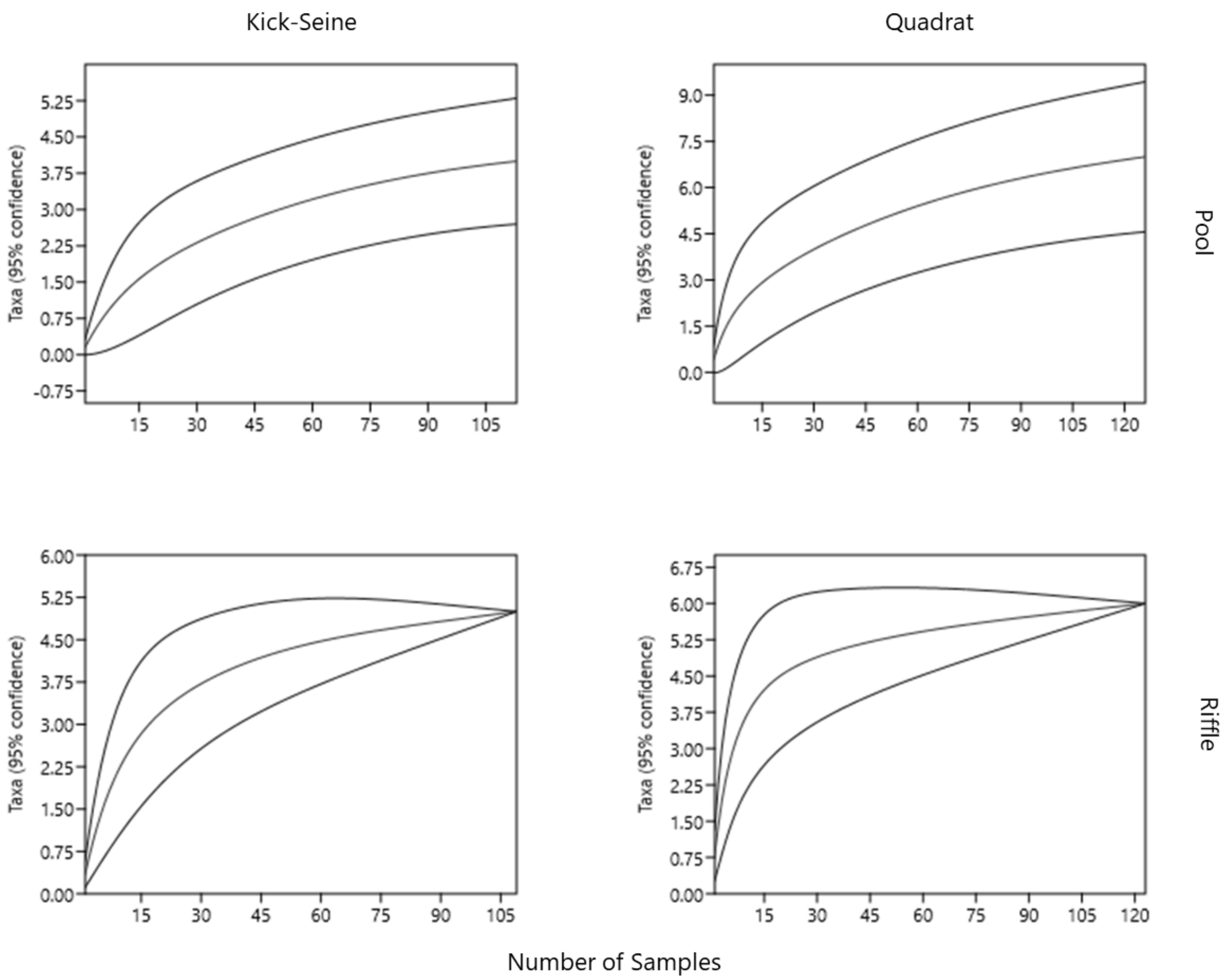


Figure 16. – Species accumulation curves by gear and macrohabitat. Traps were excluded due to low captures.

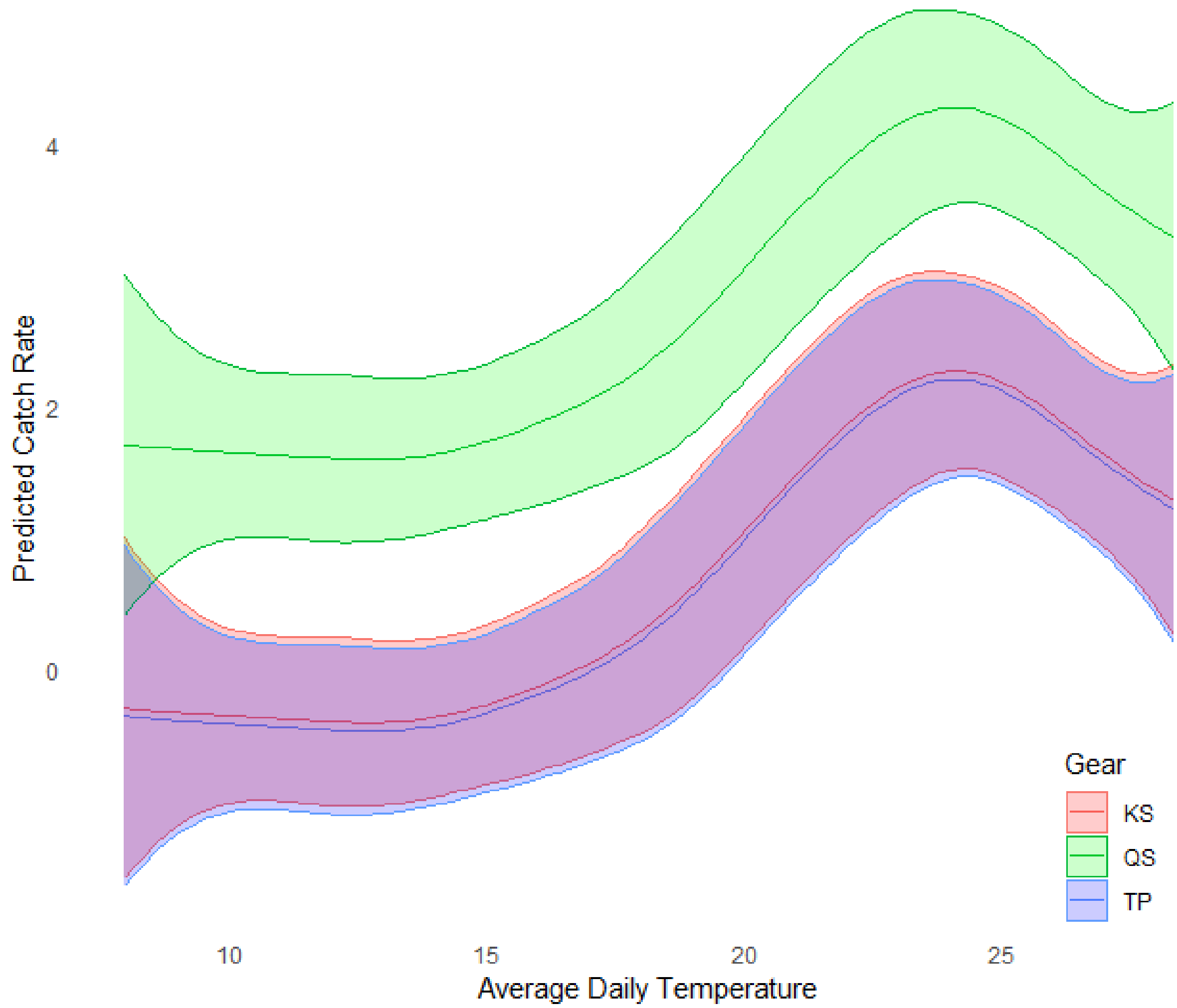


Figure 17. – Overall crayfish catch rates across sampled average daily temperatures. Significant overlap occurs between Kick-Seine (KS) and traps (TP). Quadrat sampling (QS) produced higher catch rates across most temperatures sampled. Catch rates appear to be optimized between 22 – 25 (ºC).

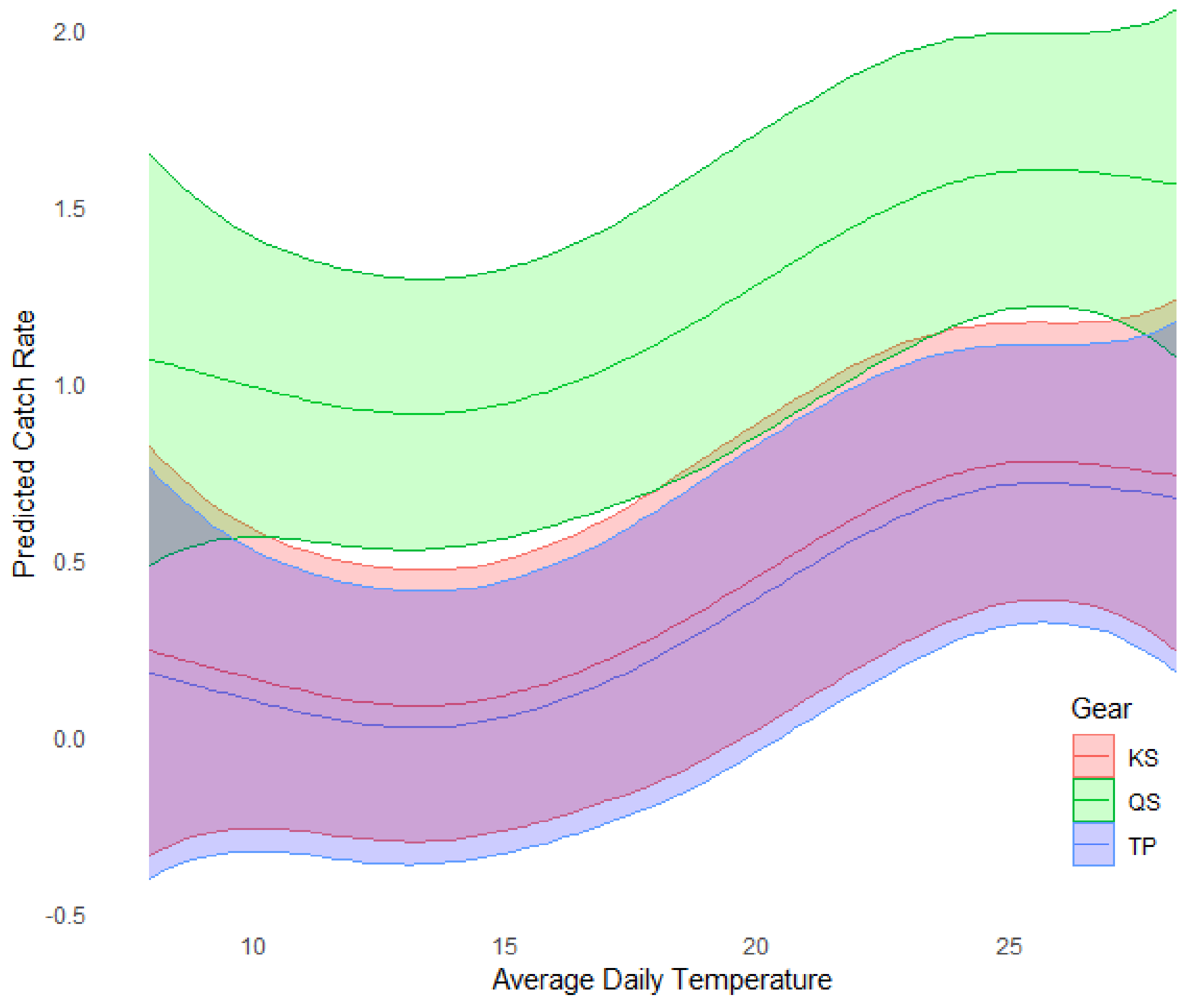


Figure 18. – Predicted Kiamichi Crayfish catch rates across average depth sampled (i.e., 5.3 cm) and average daily water temperature (ºC) in riffle habitats. Overlaps occur between Kick-Seine (KS) and trap (TP) gears. Quadrat sampling (QS) generally predicted higher catch rates across the average depth sampled.

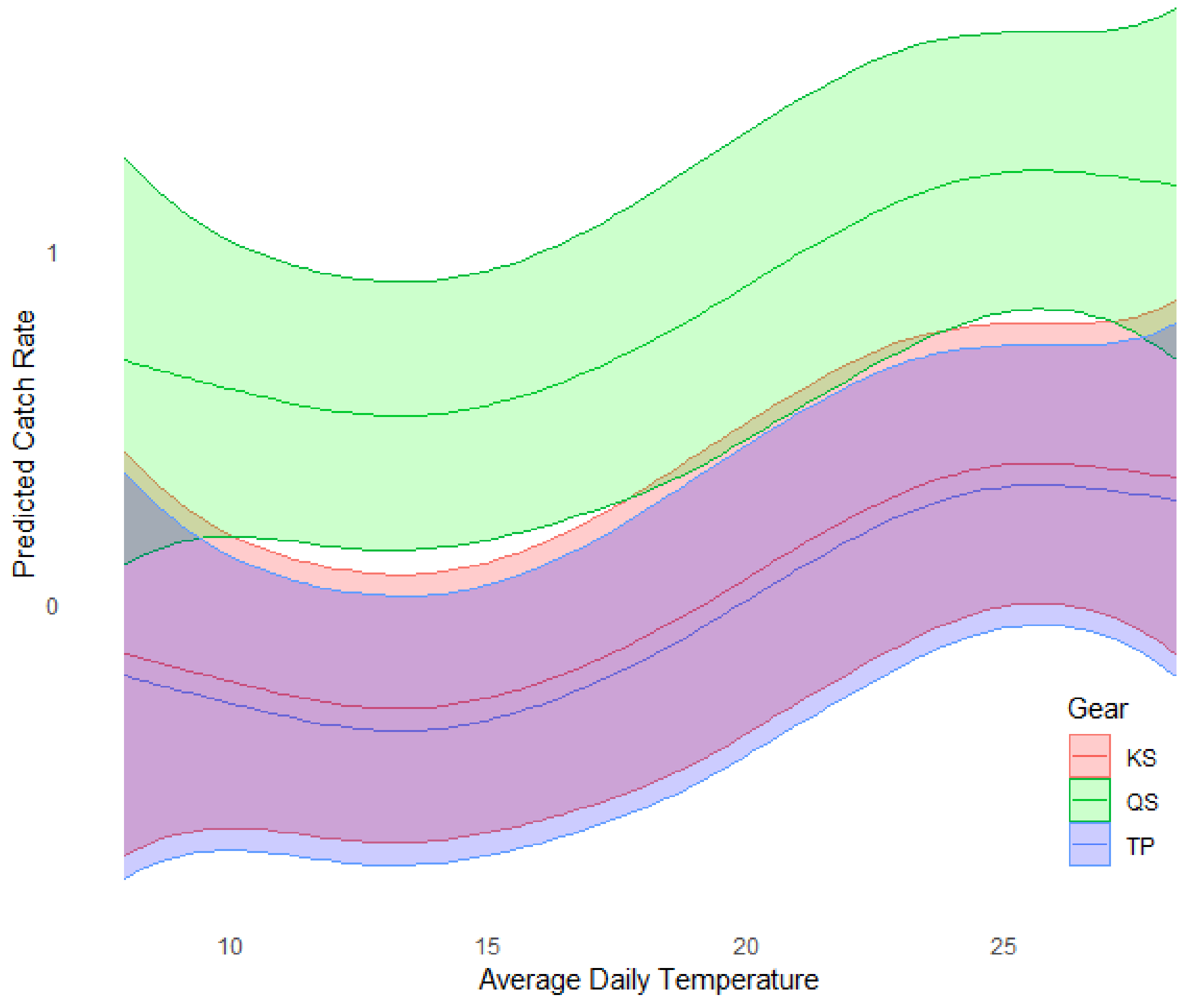


Figure 19. – Predicted Kiamichi Crayfish catch rates from the generalized additive model (GAMs) for pool habitats. Model estimates across average depth sampled (i.e., 5.3 cm) and range of average daily temperatures (ºC) sampled. Overlaps occur between Kick-Seine (KS) and trap (TP) gears. Quadrat sampling (QS) generally predicted higher catch rates across the average depth sampled.

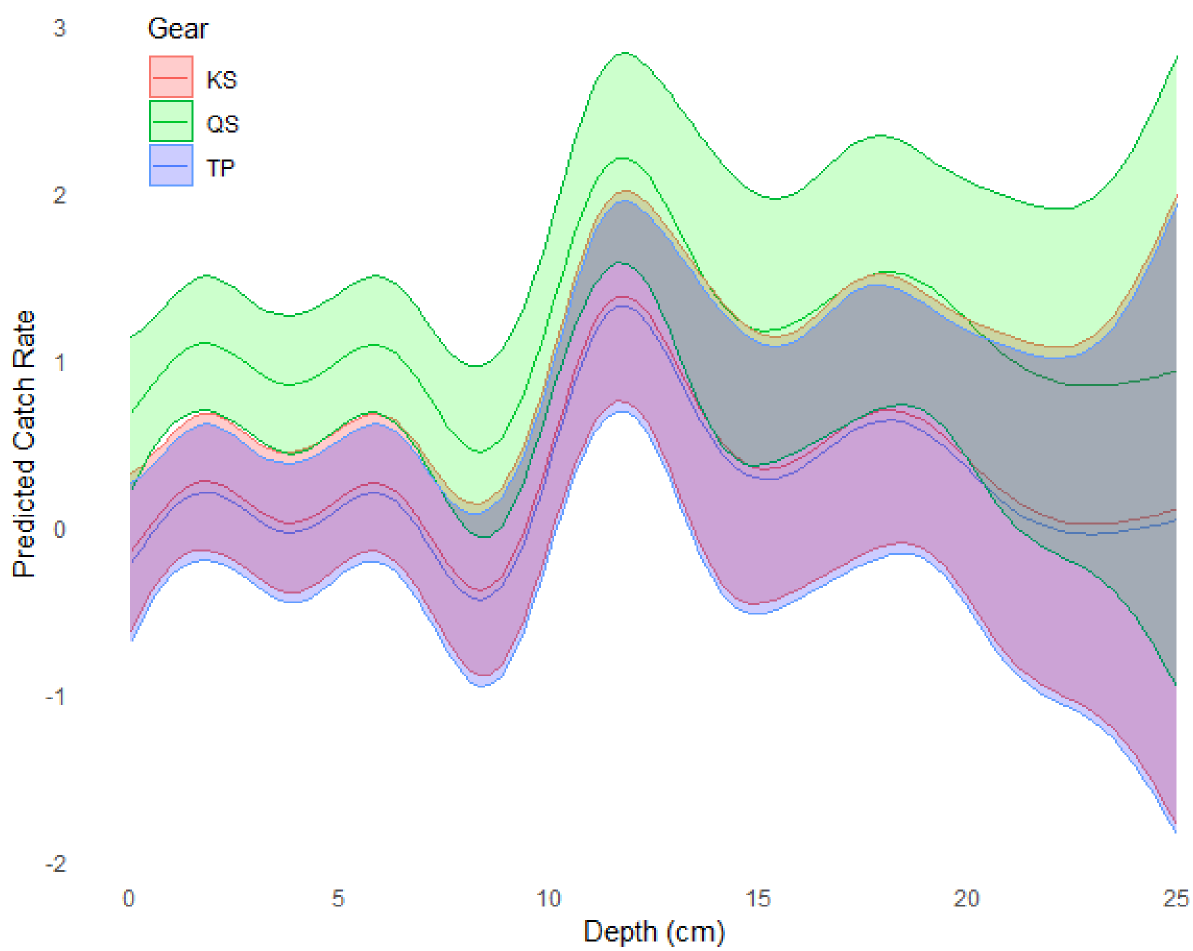


Figure 20. – Predicted Kiamichi Crayfish catch rates across average temperature sampled (i.e., 17.3º C) across depths and gears. Overlaps occur between Kick-Seine (KS) and trap (TP) gears across all depths sampled. Quadrat sampling (QS) generally, predicted higher catch rates up to 10 cm depth in riffle habitats.

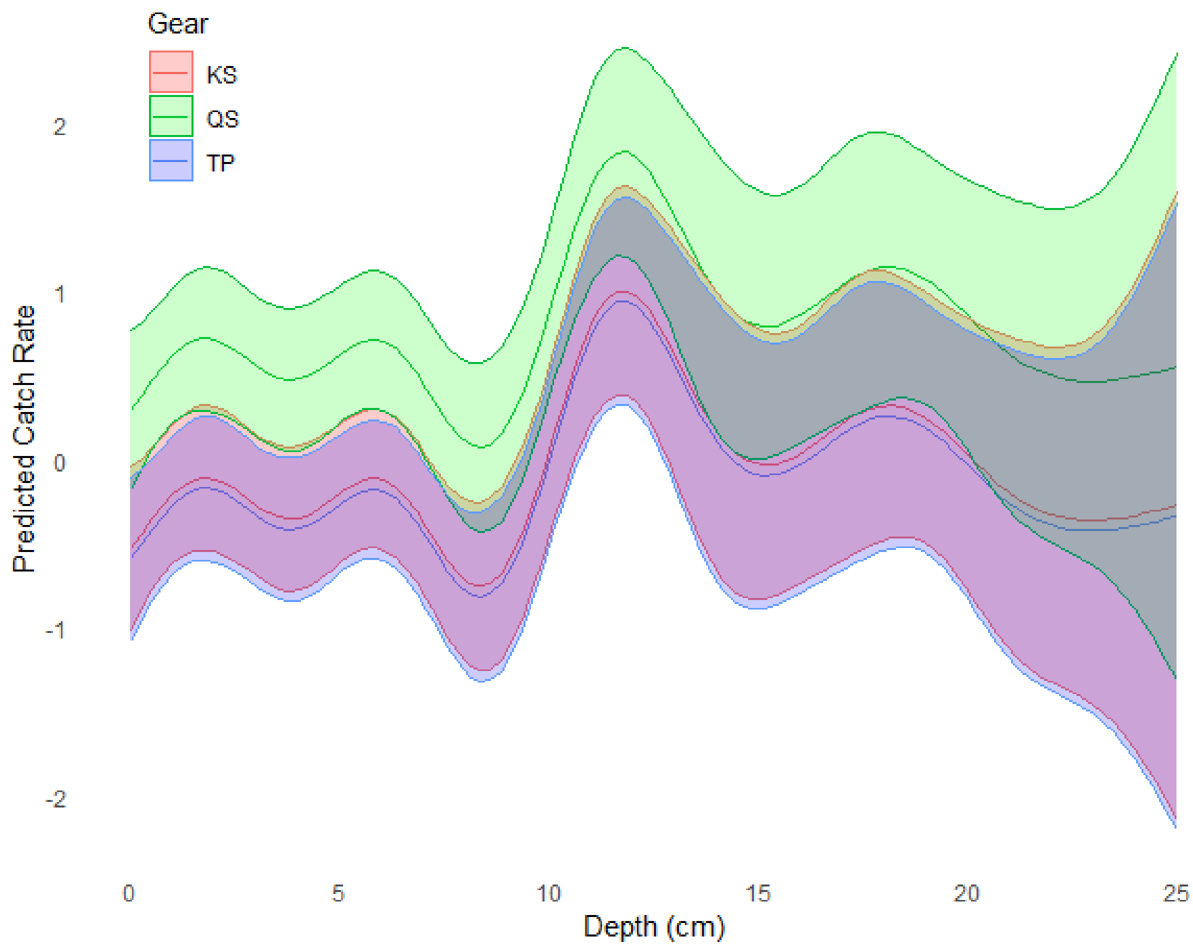
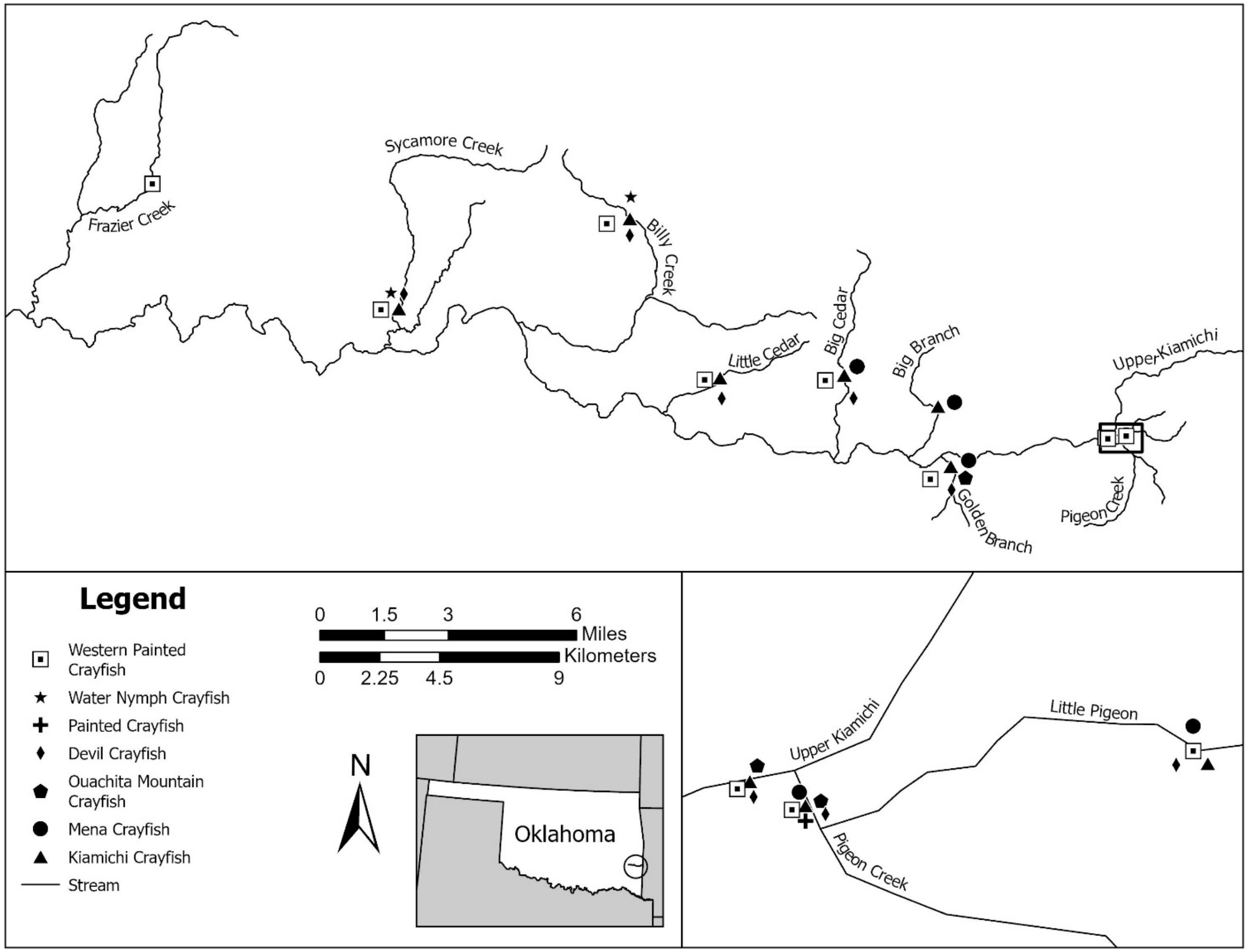


Figure 21. – Pool specific predicted Kiamichi Crayfish catch rates across sampled depths. Quadrat sampling (QS), kick-seine (KS), and traps (TP) were evaluated across average temperature sampled (i.e., 17.3º C).

APPENDIX

Appendix A – Crayfish species captured throughout the sampling reaches.



Appendix B – Kiamichi Crayfish captures across sampled reaches and respective riffle and pool habitats. Total captures are given overall (i.e., all gears) and for the most effective method, Quadrat Sampling (QS).