Evaluation of Recruitment Variability Factors and Indexing Techniques for Channel Catfish in Oklahoma

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Abstract: Commonly, fisheries management decisions are based on one-time samples, which are generally adequate for assessing key rate functions, such as age and growth, but are of limited value for assessing recruitment. Recruitment variability has not been indexed for channel catfish (*Ictalurus punctatus*). Further evaluation of practical recruitment indexing methods from single sampling events and identification of potential drivers in recruitment variability could provide biologists with additional information needed for improved management of channel catfish populations. In this study, we assess the feasibility of indexing channel catfish recruitment variability with one-time samples using the recruitment variability index (RVI) and recruitment coefficient of determination (RCD). Then we examine spatial, abiotic, and biotic factors that influence recruitment variability across 15 study reservoirs in Oklahoma. Agreement among quartile range-based recruitment categories between RVI and RCD was 60%. The RVI was positively correlated to the CV in mean CPUE of channel catfish for all reservoirs combined. The strongest predictor of RVI from the candidate model set was longitude and no additional predictors fell within 2 ΔAICc of the longitude model. Based on our results, the RVI has utility as a tool for evaluating multiple channel catfish populations within a region, providing managers with an additional method to prioritize stocking needs or identify candidate reservoirs for habitat improvement efforts (e.g., spawning structure, nursery habitat). This method may also provide insight into the application of improvement efforts through the identification of systems that support self-sustaining populations.

Key words: abiotic drivers, biotic drivers, channel catfish, environmental drivers, recruitment variability

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To inform fisheries management decisions (i.e., stocking rates, harvest regulations), rate functions including growth, mortality, and recruitment should be considered (Ricker 1975). Although growth and mortality functions are frequently assessed, recruitment and its associated variability is difficult to quantify and subsequently assessed less frequently (Isermann et al. 2002). Variability in recruitment can also affect estimates of other population metrics (i.e., size structure, growth, and mortality; Ricker 1975, Isermann et al. 2002, Quist 2007). Growth and mortality are generally easier to assess from one-time samples while recruitment is often variable and difficult to determine quantitatively without tracking long-term trends in age structured catch (Ricker 1975, Isermann et al. 2002, Quist 2007). These data are often unavailable or unrealistically attainable due to time and funding constraints (Isermann et al. 2002). Therefore, the need exists for managers to assess population recruitment with one-time samples.

Over the past few decades, three different strategies have been employed to evaluate recruitment patterns derived from single sampling events. These include the recruitment variability index (RVI), recruitment coefficient of determination (RCD), and the use of studentized residuals from catch-curve regressions (Guy and Willis 1995, Maceina 1997, Isermann et al. 2002, Quist 2007). The RVI was introduced by Guy and Willis (1995) for assessment of black crappie (*Pomoxis nigromaculatus*) recruitment and evaluated by Isermann et al. (2002) and Quist (2007) using simulation models and long-term datasets to index crappie (*Pomoxis spp.*, 122 populations, one-time samples) and walleye (*Sander vitreus*, 8 populations, 2–7 annual samples dependent on population),

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respectively. The method has also recently been applied to buffalo fishes (*Ictiobus* spp.) and freshwater drum (*Aplodinotus grunniens*) recruitment (e.g., Montague et al. 2024). The RVI is influenced by the cumulative relative frequency of the sample's age-frequency distribution and the proportion of missing age classes in the sample (Guy 1993, Guy and Willis 1995). It is intended to work with species that commonly have missing age classes in samples, but RVI can have issues indexing recruitment for populations with high fluctuation in recruitment but no missing age classes (Guy and Willis 1995, Isermann et al. 2002). The RCD was introduced by Isermann et al. (2002) and utilizes the coefficient of determination (r^2) of the catch curve to index recruitment variability (Quist 2007). It simply describes variation in catch at age not accounted for by age (Isermann et al. 2002).

Ostensibly, channel catfish (*Ictalurus punctatus*) recruitment variability has not been indexed, however channel catfish commonly exhibit variability in recruitment (i.e., missing or underrepresented age classes) and population density in reservoirs (Hubert 1999, Holley 2006, Settineri 2015, Tyszko et al. 2021). Reasons for variable recruitment patterns likely include interruptions in spawning activity due to water temperature fluctuations from cold weather, predation on eggs and fry, and limited availability of spawning habitat (especially in smaller impoundments; Hubert 1999). Further evaluation of practical recruitment indexing methods (i.e., from single sampling events) as well as identification of potential drivers in recruitment variability may provide biologists with additional information needed for improved management of channel catfish populations. Therefore, the objectives of this study were to 1) assess the feasibility of indexing channel catfish recruitment variability with single samples using RVI and RCD and 2) Examine spatial, abiotic, and biotic factors that influence recruitment variability across study reservoirs.

Methods

Study Area

Channel catfish were sampled from 15 reservoirs located in the Cross Timbers and Central Great Plains ecoregions of central Oklahoma (Figure 1; Woods et al. 2005). Reservoir surface area was 8.9–1363.8 ha (Table 1). Primary uses for each reservoir include municipal water supply, flood control, and recreation (OWRB 2024). Siltation within the river reservoir interface and limited amounts of aquatic vegetation and standing timber/brush piles are present at all 15 reservoirs (A. D. Griffin, personal observation). Substrates are composed of a mixture of sandstone, coarse gravel, clay, and sand with riprap rock present along dams and fishing jetties (A. D. Griffin, personal observation). All study reservoirs contain populations of channel catfish, white crappie (*Pomoxis annularis*), largemouth bass (*Micropterus nigricans*), common carp (*Cyprinus carpio*), and flathead catfish (*Pylodictis olivaris*; OFAA 2022). However, many of the reservoirs vary in their composition of other species based on management practices. For instance, Carl Blackwell Reservoir has hatchery-sustained saugeye (*Sander vitreus x S. canadensis*) and hybrid striped bass (*Morone chrysops x M. saxatilis*) populations (OFAA 2022). McMurtry, Guthrie, and

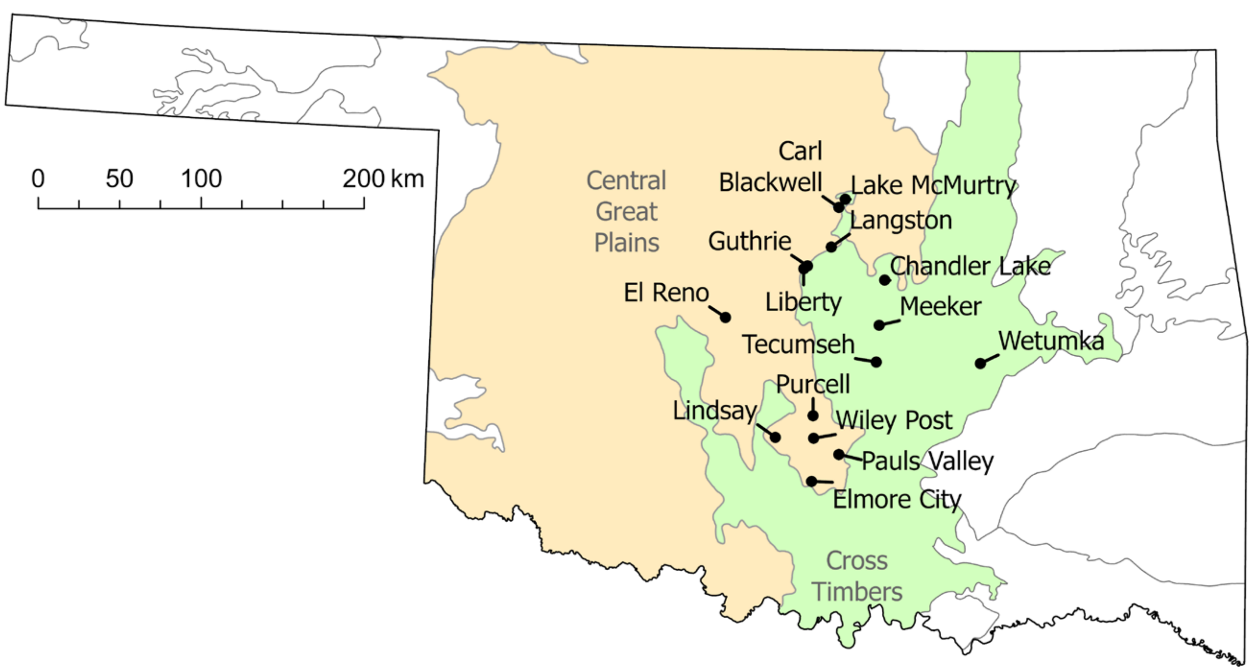

Figure 1. Study area map showing distribution of the 15 study reservoirs across the Central Great Plains and Cross Timbers ecoregions of central Oklahoma.

Table 1. Study reservoir parameters for 15 Oklahoma reservoirs and channel catfish populations including area (ha), sample year, stocking ratio (number of years stocked vs number of age classes in the sample; reservoirs with no value were not stocked), sample size (*n*), age at recruitment (minimum age fully recruited to the gear as determined by catch curve), total number of age classes included in the analysis, recruitment variability index values (RVI), recruitment coefficient of determination values (RCD), mean catch per unit effort [Mean CPUE; number of fish (72-hr set)$^{-1}$] of age classes used in the analysis, and coefficient of variation (CV) in mean CPUE.

Reservoir	Area (ha)	Sample Year	Stocking Ratio (%)	*n*	Age at Recruitment	# Age Classes	RVI	RCD	Mean CPUE	CV (%)
Elmore City	23.1	2021	56	248	2	9	0.68	0.21	3.24	750
Langston	169.9	2020	90	346	1	10	0.79	0.46	3.42	1114
Liberty	79.7	2021	17	380	7	6	0.53	0.06	5.85	720
Lindsay	8.9	2022	25	167	2	8	0.47	0.02	2.32	512
Meeker	85.4	2019	45	815	2	11	0.74	0.84	10.11	1228
Pauls Valley	303.5	2023	18	369	3	11	0.58	0.10	3.02	1058
Tecumseh	51.4	2020	75	498	6	12	0.44	0.39	12.08	238
Wetumka	68.4	2020	100	129	6	10	0.88	0.56	1.70	323
Wiley Post	122.2	2020	56	241	2	9	0.57	0.23	1.82	801
Blackwell	1363.8	2020	–	291	3	14	0.50	0.26	4.06	696
Chandler	72	2021	–	624	4	9	0.82	0.21	15.37	337
El Reno	68.8	2021	–	117	2	7	0.35	0.002	1.96	760
Guthrie	82.9	2021	–	282	3	9	0.56	0.02	4.30	952
McMurtry	467	2022	–	757	3	9	0.71	0.53	6.15	1004
Purcell	63.5	2021	–	97	5	8	0.27	0.08	1.42	423

Pauls Valley reservoirs contain saugeye, and Wiley Post Reservoir contains a stunted blue catfish (*Ictalurus furcatus*) population (OFAA 2022). Primary forage species across all reservoirs include gizzard shad (*Dorosoma cepedianum*), *Lepomis* spp., and inland silversides (*Menidia beryllina*; OFAA 2022). Trophic class ranges from mesotrophic to hypereutrophic and turbidity varies greatly across systems (OWRB 2024). Channel catfish were stocked in nine reservoirs with varying regularity during the age range of fish sampled while the remaining six were not stocked (Table 1).

Sampling

Channel catfish collection dates ranged from 2019–2023 during the months of July, August, and September (one sample per reservoir). Tandem sets of three baited hoop nets were used in all study reservoirs. These sets consisted of two 25-mm and one 12.5-mm bar mesh, 3.4-m long nets tied 0.9 m apart. The smaller mesh nets were used in conjunction with the standard nets to capture smaller fish in potentially stunted populations (Michaletz and Sullivan 2002, Montague et al. 2022, Griffin et al. 2023). Nets were set according to standardized Oklahoma Department of Wildlife Conservation (ODWC) protocols and the methods of Montague et al. (2022) and Griffin et al. (2023). Sites were selected randomly and included five to ten sets per sample (dependent on reservoir size). Nets were baited with fish food pellets (Sportsman's Choice Trophy Fish Feed-Multispecies Formula, Cargill Animal Nutrition, Minneapolis, Minnesota) and fished for 72 hr. Temperature (C) and dissolved oxygen (DO) were recorded 0.5 m above the substrate during each sample to ensure adequate DO levels (≥4 mg/L) to avoid unnecessary mortality (YSI, model Pro 2030, Yellow Springs Instruments, Yellow Springs, Ohio).

Total length (TL; mm) and weight (g) were recorded for all channel catfish (except for the Langston Reservoir and Wiley Post Reservoir samples where only TL was recorded). Up to 20 fish per 25-mm TL group were euthanized for age estimation using a 1:1 ice water slurry (Blessing et al. 2010). Fish were then brought back to the Oklahoma Fisheries Research Laboratory (OFRL), Norman, or another regional office where sex and maturity were determined through visual examination of the gonads and lapilli otoliths were removed for age estimation (Davis and Posey 1958, Perry and Carver 1972, Buckmeier et al. 2002).

Otolith preparation followed the methods of Waters et al. (2020), disregarding the browning process. Specifically, otoliths were mounted in a silicon mold using epoxy, cut in the transverse plane, polished until all annuli were visible, and viewed under a dissecting microscope capable of 130× magnification with the aid of a fiber optic filament attached to a light source. Initial age estimation was carried out by two independent readers and disagreements in initial age estimates were settled with a final consensus read (Hoff et al. 1997). Ages were then assigned to the entire sample using an age-length key.

Analysis

The RVI was calculated per the methods described by Guy and Willis (1995) and is described as:

$$RVI = [S_N/(N_m + N_p)] - N_m/N_p,$$

where S_N equals the sum of cumulative relative frequency for ages present in the sample, N_m is the number of missing age classes (between minimum age recruited to the gear and last age represented), N_p is the number of age classes present, and N_p must exceed N_m. The scale for RVI values is -1 to 1 with 1 indicating no variability in recruitment (Guy and Willis 1995). The RCD was calculated from weighted catch curves per the methods of Isermann et al. (2002) and Quist (2007). Age at recruitment ranged from 1–7 dependent on the individual population and was set accordingly using the youngest age class fully recruited to the gear based on the catch-curve (Table 1). Year classes with less than two fish were only included if successive year classes included more than two fish or were not present in the sample (Isermann et al. 2002).

Quartile-based range categories for RVI and RCD were used to subjectively describe patterns in recruitment variation and agreement rates were compared between the two indices (Isermann et al. 2002; Table 2). Spearman's rank correlation (r_s) was used to gauge strength of the correlation of RVI and RCD across all samples (Spearman 1904, Guy and Willis 1995, Isermann et al. 2002). To investigate the assumption that stocked lakes would artificially exhibit higher recruitment stability, we used two-sample *t*-tests (Welch 1947) to determine if RVI and RCD differed significantly between stocked and unstocked reservoirs. Separate tests were conducted for each index. We also used Shapiro-Wilk normality and Bartlett tests to confirm assumptions of normality and homogeneous variances, respectively (Bartlett 1937, Shapiro and Wilk 1965).

Recognizing that previous work developed these indices using long-term data sets, we sought to determine the utility of using the RVI and RCD as tools to index variable recruitment based on empirical data from single sampling events to see if the indices still tracked uneven recruitment (Isermann et al. 2002, Quist 2007). To do so, we used coefficients of variation (CV) in the mean CPUE over the range of ages described above for each sample as a measure of recruitment (Quist 2007). We then used linear regression analyses to determine if the RVI and RCD were related to CV in mean CPUE across all, stocked, and unstocked samples. Specifically, a Breusch-Pagan test was used to test for heteroscedasticity in the simple linear regression model and a subsequent weighted linear regression was used to account for the presence of heteroscedasticity (Breusch and Pagan 1979). Analyses listed above were performed using the Oklahoma Fisheries Analysis Application (OFAA 2022) and Program R (R Core Team 2022). We assigned significance for all comparisons at $\alpha = 0.10$ to increase power as some comparisons had low sample sizes (e.g., unstocked reservoirs $n = 6$).

To better determine spatial, abiotic, and biotic drivers of recruitment variability based on RVI estimates, we hypothesized potential factors for all three categories that were readily available for the study reservoirs. Spatial drivers available were latitude and longitude, common variables known to influence population dynamics (Power and McKinley 1997, Belk and Houston 2002). Available abiotic variables included elevation, maximum reservoir depth at standard pool, shoreline length at standard pool, reservoir storage, and reservoir surface area at standard pool. Biotic variables were obtained from catch data and included PSD-Q (proportional size distribution of fish ≥ quality size) mean CPUE [catch per unit effort; number of fish (72-hr set)$^{-1}$], stocking ratio of the reservoir (ratio of number of years stocked to number of age classes in sample), mean length at age three (average age fully recruited to the gear), maximum total length observed, and annual mortality (*A*). An intercept-only model (i.e., null model) was also included to determine the viability of the candidate set rankings (i.e., if variables had better predictive potential than a null hypothesis; Montague et al. 2023, Zentner et al. 2023).

To avoid using variables that would be redundant in our analysis, we first examined simple correlations between drivers to determine which variables tracked similar relationships within the dataset. Variables were assumed to track similar relationships when $r \geq 0.7$ (Booth 1994, Dormann et al. 2013, Akoglu 2018). Elevation was removed due to its strong negative correlation with longitude ($r = -0.84$). Also, since reservoir storage and shoreline length were highly correlated with surface area at standard pool (all $r > 0.99$), we strictly used surface area for the model as it has been shown to be a driver in the recruitment and abundance of fishes (e.g., increased reservoir size results in higher recruitment stability and subsequent abundance), presuming that increased surface area means greater habitat diversity and availability (Jackson and Francis 1999, Nate et al. 2000). As with increased surface area, we hypothesized that increased reservoir depth could relate to more stable recruitment due to greater accessibility to various habitat types including spawning and nursery cover. We also hypothesized that biotic parameters would represent rate functions that may lead to bias due to size or environmental based influences on capture (Isermann et al. 2002, Michaletz and Sullivan 2002, Columbo et al. 2008, Buckmeier and Schlechte 2009, Bodine et al. 2013). Higher values for PSD-Q and CPUE were predicted to reflect more stable

Table 2. Channel catfish recruitment variability categories based on the recruitment variability index (RVI) and recruitment coefficient of determination (RCD) calculated for 15 Oklahoma channel catfish populations.

Recruitment Category	Quartile Range	RVI Range	RCD Range
Variable	0–25	0.27–0.52	0.002–0.079
Mod variable	26–50	0.53–0.69	0.080–0.226
Mod consistent	51–75	0.70–0.75	0.227–0.527
Consistent	76–100	0.76–1.00	0.528–1.000

recruitment and inflated stocking ratio values should indicate artificially stabilized recruitment through the introduction of stocked fish. We propose that low recruitment variability could decrease size (mean length, maximum TL) due to increased fish abundance and intraspecific competition and that *A* would increase as well.

To determine if any hypothesized spatial, abiotic, or biotic variables were related to recruitment variability (based on RVI), we used an information-theoretic approach to compare the predictive potential of variables (Burnham and Anderson 2002). Given the sample size of reservoirs (n = 15), only single variable models were used (Harrell 2001). Candidate models were ranked using Akaike information criterion corrected for small sample size (AICc; Hurvich and Tsai 1989). We considered models within 2 ΔAICc of the top candidate model to have equal support relative to the top ranked model (Burnham and Anderson 2002). We also estimated coefficients of determination (r^2), AICc weights (w_i), and evidence ratios (estimated via w_i) for each candidate model (Royall 1997, Burnham and Anderson 2002). All models were run using a Gaussian distributed generalized linear model (McCullagh and Nelder 1989) in Program R (R Core Team 2022). Each model was assessed for normality using a Shapiro-Wilks normality test on the residuals. Homoscedasticity and points with leverage, or influential points, were assessed using residual diagnostic plots (McCullagh and Nelder 1989). Reciprocal or $\log_{10}$ transformations (Zar 1999) were used to transform predictor variables that exhibited heteroscedasticity or had points exhibiting leverage or influence without transformation.

Results

Values for RVI and RCD had comparable upper limits and differing lower limits, with ranges of 0.35–0.88 and <0.01–0.84, respectively. However, ranges among quartiles differed considerably (Table 2). Agreement among recruitment categories between RVI and RCD was 60% (9 of 15) and agreement within one or two categories was 80% (12 of 15) and 93% (14 of 15) respectively (Table 2). Small or missing age classes negatively impacted RCD values disproportionately compared to RVI values. Values of RVI and RCD were positively correlated (r_s = 0.51, P = 0.05) across all systems suggesting both indices track each other to some degree (Figure 2). Data were distributed normally for both RVI and RCD among stocked and unstocked reservoirs, respectively (W = 0.93, P = 0.49; W = 0.89, P = 0.31). Between stocked and unstocked reservoirs, both the RVI ($t_{7.18}$ = 0.63, P = 0.55) and RCD ($t_{12.80}$ = 1.13, P = 0.28) did not differ significantly. Variance was homogenous for RVI (K^2 = 0.35, df = 1, P = 0.56) and RCD (K^2 = 0.72, df = 1, P = 0.40) between stocked and unstocked reservoirs.

Recruited channel catfish CV in mean CPUE ranged 238–1228% (Table 1). The RVI was significantly positively correlated to the CV in mean CPUE for all reservoirs combined and stocked

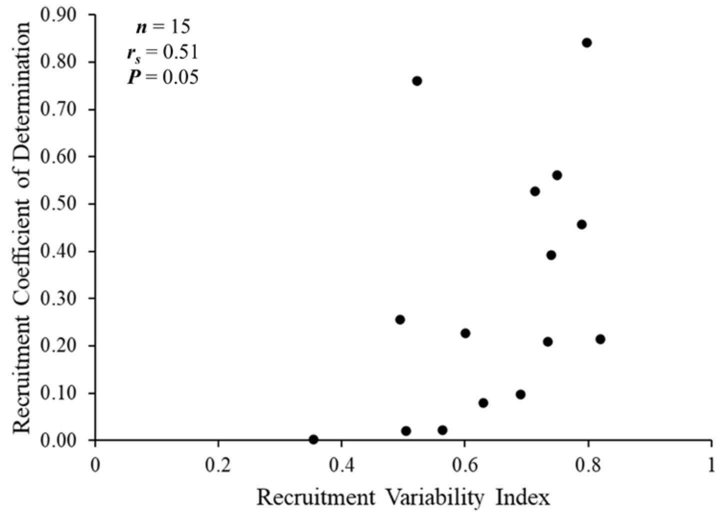

Figure 2. Scatter plot showing the relationship between the recruitment variability index (RVI) and the recruitment coefficient of determination (RCD) for channel catfish populations from 15 central Oklahoma reservoirs. Spearman's Rank Correlation results are shown.

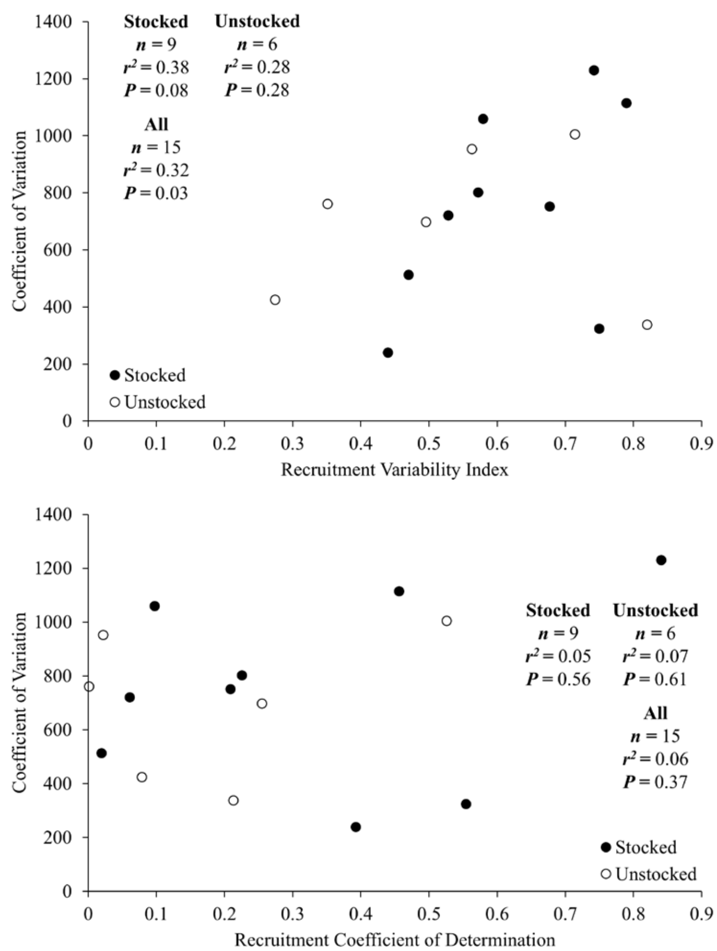

Figure 3. Scatter plot showing the relationship between the recruitment variability index (RVI), recruitment coefficient of determination (RCD) and coefficient of variation (CV) in mean catch per unit effort of age classes used in the analysis for stocked, unstocked, and all reservoirs combined for channel catfish populations from 15 central Oklahoma reservoirs. Weighted regression results are shown.

reservoirs, respectively when compared using weighted linear regression (all reservoirs $r^2 = 0.32$, $P = 0.03$; stocked reservoirs $r^2 = 0.38$, $P = 0.08$; Figure 3). The correlations between RVI and CV in mean CPUE for unstocked reservoirs, as well as RCD for all categories (all, stocked, and unstocked) were not significant (Figure 3).

The strongest predictor of RVI from the candidate model set was longitude (Table 3). No other variables were within 2 ΔAICc of the top ranked model although Stocking Ratio, PSD-Q, and CPUE had more predictive potential than the intercept only model (i.e., the null model). All other predictors were suggested to have less predictive potential (based on AICc) than the intercept only model. Longitude appeared to have a positive linear relationship with RVI (Figure 4).

Discussion

Similar to Isermann et al. (2002), our results demonstrate that RVI and RCD are positively correlated and comparably index channel catfish recruitment variability in most of the samples. However, when comparing RVI and RCD values empirically to the CV of mean CPUE of one-time samples, only RVI showed a significant (although weak) positive correlation, indicating that RVI has utility for indexing recruitment variability in channel catfish from single sampling events. We were able to model stocking's impact on recruitment stability by indexing stocked populations (i.e., significant positive correlation of RVI to CV in mean CPUE). Ostensibly, this has not yet been explored for channel catfish and we believe that this contributes to the fit and utility of using RVI to quantify recruitment from single samples of channel catfish. Channel catfish recruitment dynamics would be better informed from long-term sampling datasets and RVI and RCD would likely benefit from validation against said data prior to implementation as assessment methods. For example, prior work on crappie spp. (Isermann et al. 2002) and walleye (Quist 2007) suggested that long-term datasets offer more reliable methods for validation assessment of recruitment variability. Still, as in our study, Quist (2007) showed a weak significant relation between RVI and CV in mean CPUE from a single sampling event. For managers dealing with time and budget constraints, infrequent sampling of the same population is common and one-time assessment of recruitment using RVI may be the only option available. While this study utilized a small sample size of reservoirs compared to others of its kind ($n = 15$), we were still able to associate RVI to channel catfish recruitment variability and identify one potential predictor variable (e.g., longitude). Building on our results, future work is needed to expand the geographic scope (e.g., number of reservoirs) and number of annual samples per reservoir.

Table 3. Model selection table used to assess predictive potential of factors hypothesized to influence channel catfish recruitment variability for 15 Oklahoma populations. Predictors include longitude, number of years stocked vs number of age classes in the sample (Stocking ratio), proportional size distribution of fish ≥ quality size (PSD-Q), mean catch per unit effort (CPUE), no predictor (intercept only), mean total length at age-3 (Mean length), maximum total length observed (Max TL), maximum reservoir depth (Max depth), latitude, reservoir surface area (Surface area), and annual mortality (*A*). Also included is whether each predictor is a spatial, abiotic, or biotic factor. Coefficients of determination (r^2), Akaike information criterion corrected for small sample size (AICc), change in AICc relative to the top ranked model (ΔAICc), AICc weights (w_i), and evidence rations (ER) are included for each model.

Variable	Factor	r^2	AICc	ΔAICc	w_i	ER
Longitude	Spatial	0.59	−15.31	0.00	0.88	1.00
Stocking ratio	Biotic	0.41	−10.02	5.29	0.06	14.11
PSD-Q	Biotic	0.32	−7.83	7.48	0.02	42.13
CPUE[1]	Biotic	0.31	−7.60	7.71	0.02	47.34
Intercept	–	–	−5.19	10.12	0.01	157.50
Mean length	Biotic	0.17	−4.73	10.58	<0.01	198.83
Max TL	Biotic	0.08	−3.20	12.11	<0.01	426.94
Max depth	Abiotic	0.06	−2.86	12.45	<0.01	504.51
Latitude	Spatial	0.02	−2.38	12.94	<0.01	644.14
Surface area[1]	Abiotic	<0.01	−2.04	13.27	<0.01	762.88
A[1]	Biotic	<0.01	−2.04	13.27	<0.01	763.06

[1]CPUE and surface area were $\log_{10}$ transformed for analysis; annual mortality *A* was reciprocal transformed.

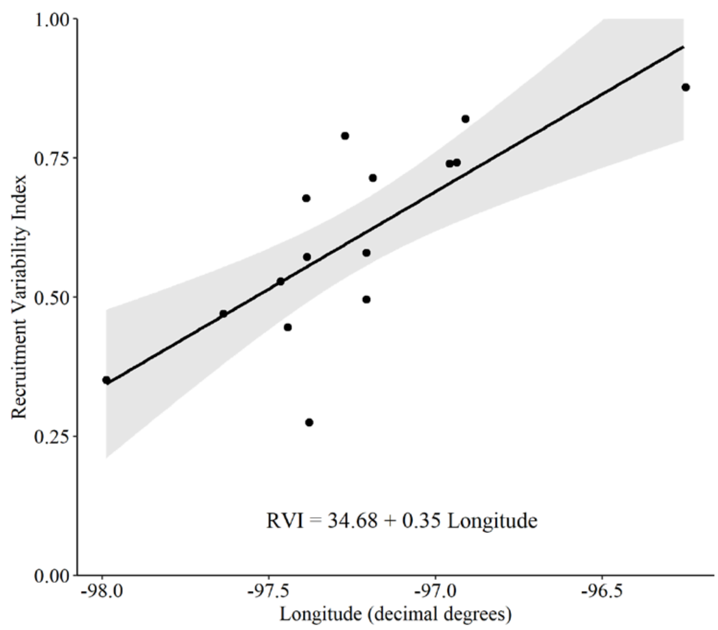

Figure 4. The best predictive model (Longitude) from the candidate set for estimating channel catfish Recruitment Variability Index (RVI) values across 15 central Oklahoma reservoirs. The solid line indicates the mean prediction for relationship with the equation for deriving the mean included. Grey shading indicates 95% CIs for the relationship. Points represent observed values from study reservoirs.

A variety of factors could negatively contribute to the detection of variable recruitment including various spatial (e.g., longitude; this study), abiotic, and biotic factors. For example, any gear used with channel catfish has inherent sampling biases (e.g., tandem hoop nets do not accurately represent size structure for fish <250 mm TL and mesh size directly impacts size structure estimates; Michaletz and Sullivan 2002, Columbo et al. 2008, Buckmeier and Schlechte 2009, Bodine et al. 2013). This can skew the representation of certain age groups of fish and resulting age structure data, directly impacting detection of recruitment variability (Ricker 1975, Maceina 1997, Quist 2007). Associated sampling bias as well as varying environmental conditions (e.g., temperature, day length, turbidity) during the sampling period can negatively impact recruitment-variability detection as well (Isermann et al. 2002). Though RVI appears to be a useful tool to assess variation in channel catfish recruitment, managers should take these factors into account when applying it.

Differential mortality among age classes (e.g., Quist 2007) may also negatively impact recruitment-variability detection as these indexing techniques assume that mortality does not differ between ages. When simulating consistent mortality across ages along with variable recruitment of crappie, Isermann et al. (2002) showed RVI and RCD sufficiently explained recruitment variability. It is possible that differential mortality among age classes of channel catfish in this study contributed to the weak relation of RVI and lack of RCD correlation with CV in mean CPUE, respectively. Care should be taken when obtaining ages of channel catfish for RVI, considering that values can change drastically with the addition or subtraction of age classes (Isermann et al. 2002). Through simulation modelling, Isermann et al. (2002) found RCD to have higher potential for indexing recruitment variability in populations with no missing age classes and high variability in catch at age, suggesting RVI be applied to populations with failed age classes. Missing (i.e., failed) age classes were common in this study's samples (53% had at least one missing age class), particularly in unstocked reservoirs, and likely contributed to the better application of RVI than RCD (Isermann et al. 2002).

We hypothesize longitude had an impact on channel catfish recruitment, although not necessarily a direct one. In Oklahoma, precipitation increases with decreasing longitude, i.e., from west to east (Oklahoma Mesonet 2024). Although it is unknown at this point which variable is the driving factor in the relationship we observed given that spatial factors often have background contribution of diverse abiotic drivers (e.g., geology, land use, annual precipitation; Brosset et al. 2020, Griffin et al. 2020), we hypothesize that increased precipitation could contribute to stability in recruitment by providing more stable water levels through time. Though not as important, factors that had more predictive potential than the null model (i.e., stocking ratio, PSD-Q, and CPUE) should be examined in future work as the relationship of these factors to recruitment variability could directly inform managers about whether naturally reproducing populations have potential for increased growth (variable recruitment) or increased harvest potential (stable recruitment) and help determine whether stocking is warranted. We also recognize that certain variables (i.e., interspecific competition, variable harvest rates) may influence the ability to estimate RVI and future studies are required to determine the strength of these associations.

Specifically related to management implications, we see utility in using RVI as a ranking tool for single-sample data from multiple channel catfish populations within a region. The ranking process, along with other population rate functions (e.g., growth and mortality), could provide managers with a quick method of identifying candidate reservoirs for habitat improvement efforts (e.g., spawning structure, nursery habitat). This method may also provide insight into the application of improvement efforts through the identification of systems that support self-sustaining populations to enable mimicking conditions from these self-sustaining systems in systems with insufficient recruitment. We also believe this has the potential to streamline the interaction between regional managers and hatchery personnel and further inform decisions on the need to stock channel catfish, particularly in small impoundments. Still, we encourage managers to exercise caution when applying RVI due to the previously stated limitations and utilize long-term datasets to assess variability in recruitment when possible.

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