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MANAGEMENT BRIEF

Use of the North American Standard Gill Net for Sampling the Invasive White Perch: Information from Three Kansas Reservoirs

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Abstract
The invasive White Perch *Morone americana* occurs intermittently throughout Kansas and is ubiquitous in three Kansas reservoirs. However, a paucity of information on the effectiveness of sampling gears for providing accurate and precise estimates of size structure and relative abundance for White Perch precludes reasonable assessments of the effectiveness of control measures. The North American standard gill net has been used to sample White Perch in Kansas since 2010. Previous studies have provided selectivity curves for several species that are sampled with this gear to mitigate overall size bias, which is inherently present in gill-net catches. However, White Perch populations have not been included in these initial studies. We fit selectivity models to catch data from three Kansas reservoirs to adjust the gill-net catch data for contact selectivity. We used the most parsimonious selectivity curve to adjust the values for White Perch capture at length for 10 years of catch data. Most of the adjusted samples resulted in meaningful changes to the length distributions. To test for the effectiveness of the North American standard gill net for sampling White Perch populations, we measured the precision of the relative abundance estimates for White Perch and the frequency of obtaining 100 stock-size fish with a standard sampling effort from 9 to 10 years of historical gill-net samples. Our results suggest the North American standard gill net provides precise and robust estimates for the relative abundance of stock-sized White Perch, but a correction factor that is derived from the selectivity curve might be needed to accurately estimate relative abundance for small individuals and to evaluate population size structure.

Fish sampling gears that are efficient and accurately and precisely describe population metrics should be used to monitor changes to fish populations (Brown and Austen 1996; Bonar et al. 2009; Koch et al. 2014). Gill nets are a popular gear with fisheries managers and one of the most widely used tools for passively sampling pelagic fish populations in lentic systems in North America (Gabelhouse et al. 1992; Miranda and Boxrucker 2009). The length of the fish that are collected with a gill net is related to the mesh size of the net; therefore, multiple

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mesh sizes can be used to sample a wider length distribution and reduce the size bias that is inherent in single-mesh nets (Hamley 1975). The American Fisheries Society recommends the use of the North American standard (NAS) gill net to sample pelagic species in warmwater reservoirs. The gill net consists of eight panels, 3.1 m in length, each with a different bar-mesh size: 19, 25, 32, 38, 44, 51, 57, and 64 mm (Miranda and Boxrucker 2009). There is still length bias in the NAS gill net, but it can be reduced by correcting for the contact selectivity of a fish species (Shoup and Ryswyk 2016; Smith et al. 2017). The ability of a gear to efficiently collect a robust and precise sample with a reasonable amount of effort is also important when evaluating fish populations. Therefore, it is critical to identify biases and determine the effectiveness of the NAS gill net for the routine monitoring of fish populations.

The White Perch *Morone americana* is nonnative in 23 states and considered an aquatic nuisance species (ANS) in Kansas (Fuller et al. 2020). White Perch were first collected in Kansas in Browning Oxbow, an oxbow of the Missouri River, in 1995 (Stein 2001). This population was not surprising because downstream movement into the Missouri River from Nebraska had been documented (Pflieger 1997). Collections in Cheney and Wilson reservoirs followed in 1996 although the transport mechanism remains unknown (Mosher 2014). White Perch populations have since expanded in Kansas, especially below Cheney Reservoir into the Ninnescah River, and ultimately the Arkansas River, further spreading southward into Oklahoma (Kuklinski 2007; Mosher 2014). Other isolated introductions have occurred, most notably into El Dorado Reservoir in 2009. That population has been attributed to angler stockings, although the actual means of introduction is unknown. The management of White Perch in Kansas has focused on biological control through piscivory. Specifically, pelagic predators (i.e., Walleye *Sander vitreus* and palmetto bass [male White Bass *Morone chrysops* × female Striped Bass *Morone saxatilis*]) have been increasingly stocked in waters with White Perch populations and have been protected with stringent length and creel limits. A recent survey of Kansas Department of Wildlife, Parks, and Tourism employees regarding their awareness and concern for ANS ranked the White Perch as the most concerning ANS by Fisheries Division personnel (Thomsen and Steffen 2017).

White Perch populations are monitored in Kansas by using NAS gill nets in autumn. In most years, few small individuals are sampled, suggesting the potential for weak year-classes. However, anecdotal observations typically suggest there are many small individuals present but not accurately indexed using the NAS gill net. No formal studies have been conducted on the effectiveness of the NAS gill net for monitoring White Perch, and previous studies on contact selectivity did not include this species, so the degree of size bias the NAS gill net has for the species is unclear. Therefore, estimation of contact-selectivity values for White Perch in NAS gill nets is necessary to improve the accuracy of stock assessments and determine the true extent of population change to better inform management decisions. Furthermore, determining the effort that is required to obtain robust and precise samples of White Perch populations by using the NAS gill net is warranted. Therefore, the objectives of this project were to (1) estimate contact-selectivity values for White Perch that are captured in NAS gill nets and (2) estimate the number of NAS gill-net deployments that is necessary for sampling 100 stock-length individuals for size-structure analyses and to obtain a relative standard error of mean CPUE <25% (RSE25; Dumont and Schlechte 2004; Koch et al. 2014; Miller et al. 2018).

METHODS

We sampled three Kansas impoundments with established White Perch populations in October and November 2019 to evaluate contact selectivity for the NAS gill net. Cheney Reservoir (3,865 ha) was sampled with 22 net nights, El Dorado Reservoir (3,235 ha) with 15 net nights, and Wilson Reservoir (3,658 ha) with 30 net nights. The net deployments followed the procedures that are recommended by Miranda and Boxrucker (2009) for warmwater fish in large standing waters. The nets were set during afternoons in October and November and fished overnight for 17–20 h. The gill nets were set at random locations, perpendicular to the shoreline in 1.8 to 6 m of water. We recorded catch by mesh size per net night and measured total length (mm) for all of the captured White Perch.

We developed selectivity curves from the 2019 samples as described by Millar and Holst (1997) and Shoup and Ryswyk (2016) with the program Pasgear II (version 2.13). The catch data were summarized as the number of White Perch within 10-mm length-groups per mesh size. Fish <110 mm were excluded from the analysis due to low sample size and the assumption that they were not fully recruited to the sampling gear. Five different log-linear models were used to develop a selectivity curve based on the abundance and length of the fish that were captured in each bar mesh (Shoup and Ryswyk 2016). The best-fit model, and its associated selectivity curve, was determined based on the lowest deviance and most randomly distributed residuals (Millar and Holst 1997). The selectivity curve was used to develop relative probability of retention values for each 10-mm length-group (Holst et al. 1996; Hansen et al. 1997; Shoup and Ryswyk 2016).

To test for effects of selectivity corrections, precision (relative standard error; RSE), and effort required to obtain 100 stock-length White Perch, we used the

TABLE 1. Model parameters (fitted constants), residual deviance, degrees of freedom (df), and R^2 for five gill-net selectivity models (Normal Scale [N. Scale], Normal Location [N. Location], Log-Normal, Gamma, and Bimodal) estimated using the SELECT (share each length-class's catch total) method. The model with the lowest deviance for White Perch is indicated in bold text. Input for the models came from the catch data for White Perch that were sampled by using the North American standard gill net from Cheney, El Dorado, and Wilson reservoirs in Kansas, (Miranda and Boxrucker 2009). The model parameters are defined in Shoup and Ryswyk (2016).

Model	Fitted constants					Deviance	df	R^2
	1	2	3	4	5			
N. Scale	$k_1 = 0.77$	$k_2 = 0.09$				191.67	62	0.97
N. Location	$k = 0.73$	$\sigma = 2.61$				293.81	62	0.89
Log-normal	$\mu = 2.68$	$\sigma = 0.13$				176.06	62	0.96
Gamma	$\alpha = 67.82$	$k = 0.01$				178.54	62	0.97
Bimodal	$\mathbf{k_1 = 0.76}$	$\mathbf{k_2 = 0.08}$	$\mathbf{k_3 = 1.16}$	$\mathbf{k_4 = 0.02}$	$\mathbf{c = 0.21}$	**152.42**	**59**	**0.97**

available catch data for White Perch from the past 10 years (2010–2019) for fish that were collected by using the NAS gill net at Cheney and Wilson reservoirs. Only 9 years (2011–2019) were available for El Dorado Reservoir due to low catch in 2010, 1 year after the introduction of White Perch. The data from all of the NAS gill-net deployments at a given reservoir each year were pooled, providing 29 sampling occasions for the analysis. The observed length distributions were adjusted for contact selectivity by dividing the catch in each length-bin by the relative probability of retention for that length-bin as derived above (Holst et al. 1996; Hansen et al. 1997; Shoup and Ryswyk 2016). The observed sample length frequencies and the length frequencies adjusted for contact selectivity were compared for each reservoir and each year using a Kolmogorov–Smirnov (KS) test ($P \leq 0.05$). The proportional size distribution (PSD) and 95% confidence intervals (Gustafson 1988) between the adjusted and observed length frequencies for each reservoir and each year were compared using the FSA package in R version 4.0.2 (Ogle 2016; Ogle et al. 2020; R Core Team 2020). Finally, nonoverlapping 95% binomial confidence intervals were used to identify significant differences in PSDs from the adjusted and observed catch data for White Perch (Gustafson 1988; Miranda 1993).

Sampling efficiency was evaluated by assessing the precision and number of stock-length White Perch in each of the 29 sampling occasions. Sample precision was quantified with RSE [(100 × SE of estimate)/estimate] of stock-sized White Perch CPUE (number per net night). The number of individuals was simply a count of all of the captured stock-length White Perch. We used a target RSE of 25% (RSE25) and a minimum of 100 stock-length individuals as thresholds to describe precise and robust samples, respectively (Anderson and Neumann 1996; Dumont and Schlechte 2004; Koch et al. 2014; Flammang et al. 2016; Porta et al. 2021). A resampling approach was used to estimate the number of samples that is required to achieve RSE25 and a minimum of 100 stock-size fish in 80% of cases by using 1,000 Monte Carlo simulations, drawing samples from the 583 net sets

TABLE 2. The relative probability of retention (Rel S_l) derived with a bimodal model for White Perch that were collected by using the North American standard gill net (Miranda and Boxrucker 2009). To use these values to correct the length frequencies for White Perch for contact-selection bias, divide the number of fish that was captured in each length-class by the Rel S_l value for that length-class.

Length-class (mm)	Rel S_l
110–119	0.08
120–129	0.23
130–139	0.43
140–149	0.55
150–159	0.53
160–169	0.47
170–179	0.48
180–189	0.55
190–199	0.60
200–209	0.59
210–219	0.62
220–229	0.62
230–239	0.65
240–249	0.73
250–259	0.80
260–269	0.83
270–279	0.86
280–289	0.95
290–299	0.95
300–309	0.93
310–319	0.95
320–329	0.97
330–339	0.98
340–349	0.99
350–359	1.00

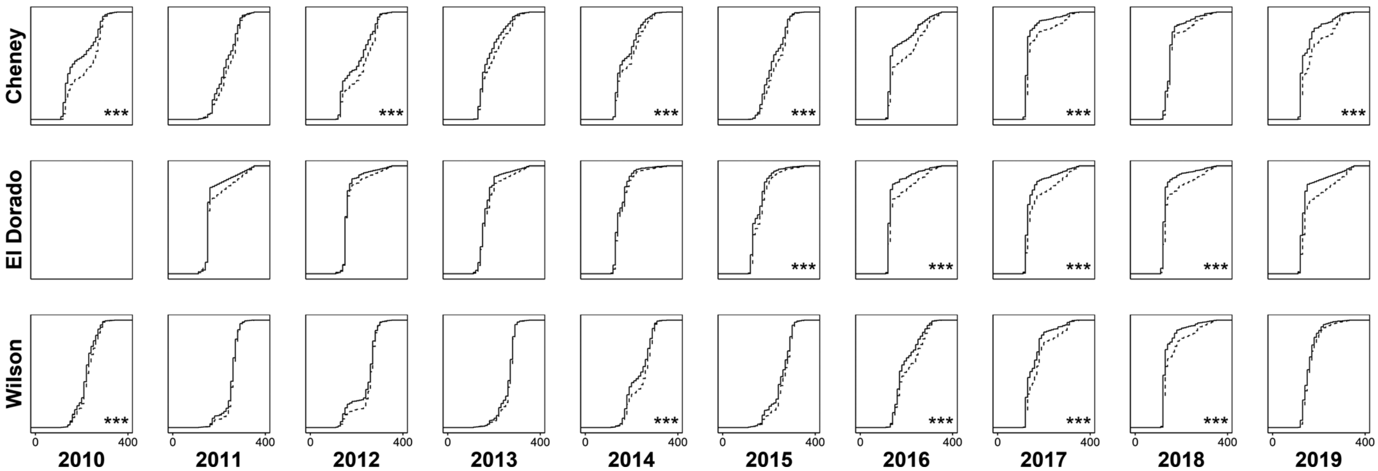

FIGURE 1. Cumulative length distributions for White Perch that were collected with the North American standard gill net for observed (solid black line) catch and catch adjusted for contact selectivity (dashed line), derived from three Kansas reservoirs from 2010 to 2019. The asterisks (***) denote significant differences between the observed and adjusted length distributions, which were derived from Kolmogorov–Smirnov tests (α ≤ 0.05).

that were available from the three reservoirs from the 2010–2019 sampling events (Dumont and Schlechte 2004).

RESULTS

A total of 792 White Perch from 110 to 354 mm in length were collected from the three reservoirs in 2019. The bimodal model had the best-fitting selectivity curve and accounted for 97% of the variability in lengths caught among the six mesh sizes (Table 1; no White Perch were captured in the 57- and 64-mm mesh sizes). Selectivity was low for individuals less than 130 mm TL and moderate for fish 130–270 mm, and it approached a value of 1 for fish >280 mm (Table 2).

The corrections for relative selectivity in the NAS gill net resulted in significant changes to most of the length frequency distributions, but changes to the PSD values were often not as pronounced. The adjusted and observed length frequencies and PSD values were compared for 29 annual sampling events from 2010–2019: 10 annual samples from Cheney, 10 annual samples from Wilson, and nine annual samples from El Dorado. Fifteen, or 52%, of the length-frequency comparisons were significantly different: 6 out of 10 for Cheney, 4 out of 9 for El Dorado, and 5 out of 10 for Wilson (Figure 1). The adjusted length frequencies had a greater proportion of smaller fish and a lower proportion of larger fish than did the observed length distributions. Five of 29 PSD comparisons had nonoverlapping PSD 95% confidence intervals (Figure 2). Where differences occurred, the adjusted values were always lower than the observed values. The value for estimated CPUE was always greater within length-bins when using the adjusted data, although these estimates paralleled the observed CPUE estimates by length-bin in most

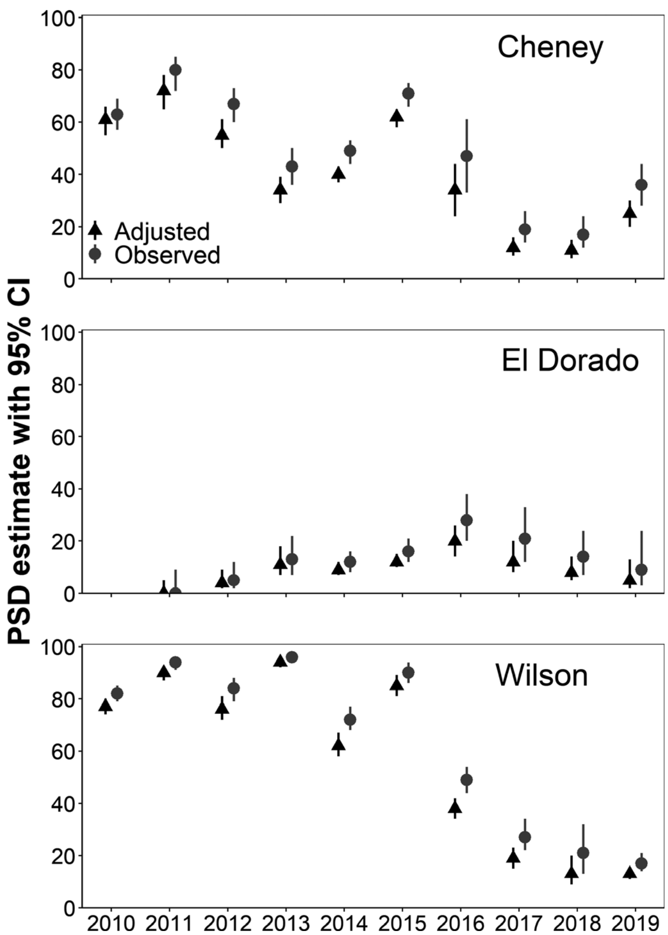

FIGURE 2. White Perch proportional size distribution (PSD) and 95% binomial confidence intervals estimated for North American standard gillnet annual samples (Miranda and Boxrucker 2009) for Cheney, El Dorado, and Wilson reservoirs in Kansas from 2010 through 2019. The gray circles are the observed PSD values, and the black triangles represent the PSD values after the catch was adjusted for contact selectivity.

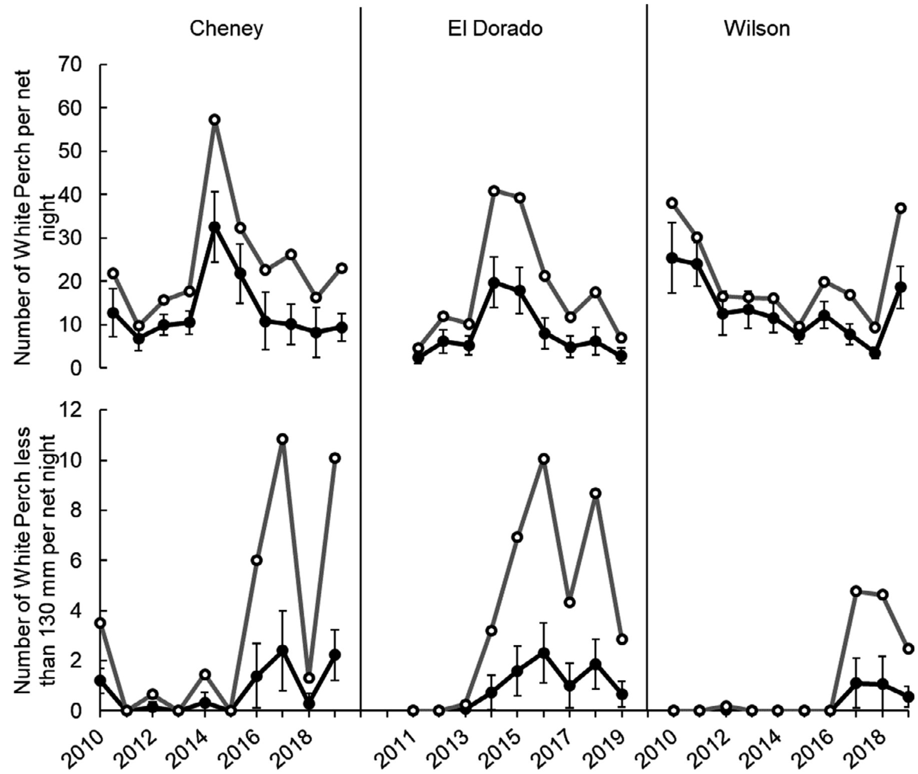

FIGURE 3. The top series represents 10, 9, and 10 years of total CPUE data for White Perch that were sampled with the North American standard gill net (Miranda and Boxrucker 2009) at Cheney, El Dorado, and Wilson reservoirs in Kansas, respectively, during 2010–2019. The bottom series represents substock-size (<130 mm) White Perch CPUE from the same period. The solid, black circles represent the observed CPUE with a 95% confidence interval, and the open circles represent the CPUE adjusted for contact selectivity.

cases (Figure 3). However, in a few cases the adjusted CPUE was more than twice as large as the observed value for substock-sized (<130 mm) White Perch. The largest divergence of adjusted and observed CPUE within length-bins typically occurred when relatively high numbers of substock-sized individuals were sampled.

The number of fish sampled was positively related to the number of gear deployments. White Perch count from the 29 annual samples ranged from 38 fish in the 2011 sample at El Dorado to 558 fish in the 2019 sample at Wilson. The number of gear deployments in the 29 samples varied from 5 to 30, with a median value of 20. At least 100 stock-length individuals were collected in 20 of the 29 sampling events (69%; Figure 4). However, 17 of the 18 (94%) samples with at least 100 stock-length individuals were samples with 20 or more gear deployments. The precision estimates were similar and related to sample size. An RSE25 was achieved in 24 of the 29 sampling events (83%). All but one of the samples not obtaining RSE25 came from events with <20 gear deployments. Monte Carlo resampling of the available data estimated that it took 12 net nights to collect 100 stock-size individuals in 80% of the trials and 19 net nights to achieve RSE25 in 80% of trials.

DISCUSSION

Selectivity curves are a valuable tool for reducing length bias of fish that contact a gill net (Holst et al. 1996; Hansen et al. 1997; Shoup and Ryswyk 2016; Smith et al. 2017). The NAS gill net reduces size bias by using eight different mesh sizes that fish can contact. However, size bias still occurs for many species (Shoup and Ryswyk 2016; Smith et al. 2017). For example, we observed unadjusted abundance estimates that were at times half the estimated number of fish that encountered the net due to contact selectivity. Managers can use selectivity curves for species that are collected with this gear to further reduce size bias, thus improving the accuracy of size-biased data. Our selectivity curve was consistently higher but closely paralleled the curve that was formulated by Shoup and Ryswyk (2016) for White Bass. Others have noted the similarity in contact selectivity between species with similar body shapes (Shoup and Ryswyk 2016; Smith et al. 2017). However, differences between White Perch and White Bass were likely large enough to warrant estimating contact selectivity for each species regardless of body shape similarities.

The value of selectivity curves for all species in widely used gill nets is apparent for accurate stock assessment.

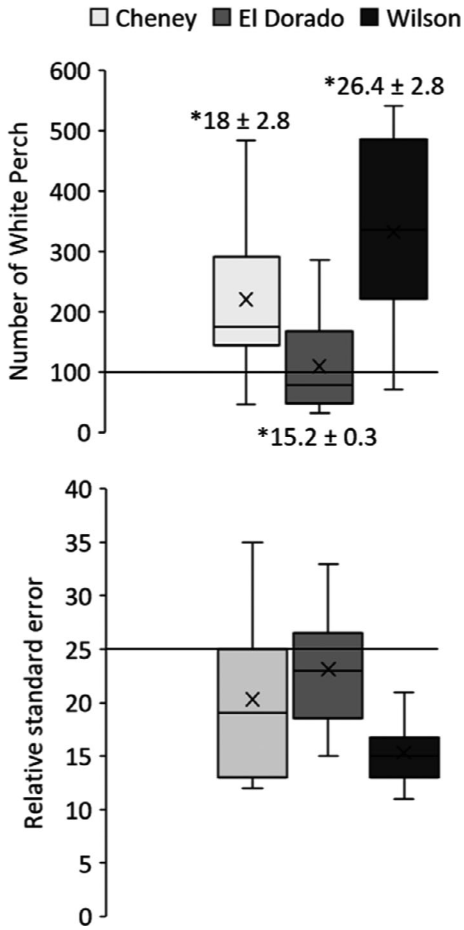

FIGURE 4. Box plots of number of stock-length White Perch (top panel) collected and relative standard errors of total CPUE among 10, 9, and 20 North American standard gill-net samples at Cheney, El Dorado, and Wilson reservoirs in Kansas, respectively, during 2010–2019. The lower and upper fences are the 25th and 75th percentiles, and the median is indicated with a cross symbol. The bars represent the 10th and 90th percentiles. The horizontal reference lines indicate 100 stock-length fish (top panel) and an RSE25 (bottom panel). The asterisks indicate the mean number of gill-net deployments and the 95% confidence interval for each reservoir during the 10-year period.

Managers need unbiased stock assessments to properly manage invasive species. For example, predatory control is currently used by the Kansas Department of Wildlife, Parks, and Tourism in several reservoirs, but this strategy will be most effective in populations with a large proportion of the White Perch population at the small end of the size distribution (e.g., <150 mm TL for Striped Bass, palmetto bass, Walleye, or saugeye [male Sauger *Sander canadensis* × female Walleye]; Hartman and Margraf 1992; Dennerline and Van Den Avyle 2000; Denlinger et al. 2006). This study provides evidence that unadjusted catch data for White Perch in the NAS gill net greatly underestimates the relative abundance of these smaller size-classes and could therefore underestimate the true portion of the population that is vulnerable to predation. Managing invasive populations also requires assessing cohort abundance at early size-classes to anticipate increases in the adult population size. Unadjusted NAS gill-net data might mask the presence of large year-classes until later life stages and delay management actions for biological control or other management strategies. Therefore, having contact selectivity adjustments available for White Perch is critical to their management.

Significant changes to the length distributions occurred most often when catches of substock-sized (<130 mm) White Perch were observed, especially in high numbers. While PSD is a useful metric for assessing the size structure of stock-sized fish, catch rates for younger fish might be more useful for fisheries managers, as they often indicate the magnitude of recent recruitment and the ability of predation pressure to control this invasive species. Episodic recruitment is common among fish populations and results in intermittent formation of strong year-classes that dominate populations (Hennemuth et al. 1980; Dippold et al. 2020). Therefore, a tool for identifying year-class strength at young ages could benefit managers by enabling them to recognize potential large year-classes and react with appropriate management actions (e.g., stocking predator species or placing restrictive harvest regulations on pelagic piscivores). The contact-selectivity adjustments presented herein provide a method for more accurately identifying year-class strength for White Perch, thus promoting more effective, and timely, management.

The precision and RSE of the White Perch samples that were collected with the NAS gill net were generally within acceptable levels (RSE ≤ 25, $n > 100$ stock-size fish), especially when using at least 19 gear deployments. Adjusting the gill net for selectivity improves the gill-net catch data, but if insufficient numbers are caught and relative abundance estimates are imprecise, then adjustments would be moot. Fortunately, the sample size and precision of the relative abundance estimates for White Perch that are captured with the NAS gill net are typically adequate; therefore, adjusting these samples for selectivity will improve the overall quality of these data for stock assessments.

We recommend using NAS gill nets with similar effort at other warmwater reservoirs to conduct stock assessments of invasive White Perch but recommend adjusting for contact selectivity to improve the accuracy of size-biased information. However, further research is warranted to evaluate supplementing the NAS gill net with smaller mesh sizes (10, 13, and 16 mm) to target young, small fish (Miranda and Boxrucker 2009). Additional understanding of the relative abundance of small fish would allow managers to react earlier to changes in the population structure that are caused by variation in recruitment. Furthermore, additional gears should be assessed for their effectiveness of collecting robust and precise relative abundance estimates for early year-classes of White Perch. Nighttime electrofishing has been suggested as an alternative sampling technique, but there is a paucity of rigorous evaluation (Wong 2002; Feiner et al. 2012; Porta and Snow 2017). The information that is presented herein provides evidence that NAS gill nets can be used to collect robust samples of White Perch from established populations. However, the relative abundance of juveniles is greatly underestimated unless contact-selectivity curves are used to adjust the values for catch. Recognizing this bias and implementing proper contact-selectivity curves to adjust catch values are paramount for obtaining proper stock assessments of invasive White Perch stocks and informing reactive management.

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