TRANSITIONING TO THE NORTH AMERICAN STANDARD GILL NET: SIZE SELECTIVITY CORRECTIONS AND THE EFFECTS OF NET DESIGN ON CPUE, SIZE STRUCTURE, AND SITE SELECTION.

By

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TABLE OF CONTENTS

Page

Chapter 1: The effects of gill net design and random versus fixed sampling on CPUE, precision, and size structure of pelagic fishes.

Chapter 2: Size Bias and Correction Factors for the North American Standardized Gill Net

Page

LIST OF TABLES

Chapter 1 Table Page

Chapter 2 Table

LIST OF FIGURES

LIST OF FIGURES CONTINUED

INTRODUCTION CHAPTER

Introduction to Standardized Gillnet Sampling and Gill Net Size Biases

Fisheries managers must consider many types of information including ecological, economic, political, and sociocultural information, when making management decisions (e.g., regulations) to achieve specific goals for a fishery (Krueger and Decker 1999). Although ecological information is not the only type of information that is important in fisheries management, it often receives a large amount of attention from fisheries managers. Sampling fish populations and looking at the “numbers” is a considerable part of a manager’s job in a typical wildlife and fisheries state agency. Managers often make comparisons of fisheries data between different years and even systems; however, this can be difficult when sampling is done with different gears or when a similar gear is used with inconsistent procedures (Bonar et al 2009).

Standardized sampling procedures are important in fisheries management and needed for comparable evaluations of fish populations over time and among systems (Noble 2002). Standardized sampling can be generally described as sampling targeted species in a defined, consistent manner during every sample event (e.g., same gear, deployment of gear, effort, location, time of year, time of day, etc.). Although many state agencies standardize sampling methods within their agency (Bonar and Hubert 2002), no nationwide standards had been recommended for the United States before 2009. The Fisheries Techniques Standardization Committee of the Fisheries Management Section of the American Fisheries Society recognized the need for national (or at least regional) standardization and published the book, *Standardized Methods for Sampling North American Freshwater Fishes* in 2009 to address this need. The intent was to identify and establish standardized sampling methods for routine fish-population assessments that would allow managers to compare data among agencies and ultimately better manage fish populations (Bonar et al. 2009).

Ideally, any standardized sampling procedure would produce accurate information about the fish population sampled. Unfortunately, all sampling gears have biases (Bonar et al. 2009) and quantifying these biases of a is important for making management decisions (Mero and Willis 1992). If a gear produces a consistent bias, it can be accounted for if the catch of the gear can be related proportionally to the actual population (i.e., capture efficiency [Bonar et al. 2009]). Capture efficiency of a gear can only be determined using an unbiased or known density and size structure of fish (Hamely 1975; Vokoun and Rabeni 1999). However, capture efficiency for a gear can also vary temporally and spatially for a species (Buckmeier and Schlechte 2009), making corrections difficult.

Gill nets are one of the most widely-used fisheries gears (Gablehouse et al. 1992). With this gear, fish are caught when they penetrate the mesh of the net and become wedge-held by mesh around the body or gilled-held by mesh slipping behind opercula, although sometimes they are tangled by spines, teeth, or other protrusions without actually penetrating the mesh. Therefore, mesh size is an important factor influencing (and potentially biasing) the size of fish captured with gill nets (Reddin 1986; Hubert 2012; Holst et al. 1998, Miranda and Boxrucker 2009). To minimize the size bias, “gangs” of differing mesh sizes (i.e., experimental gillnets) are often fished simultaneously; however, this does not completely eliminate selectivity (Hamely 1975). If a fish’s length differs from the optimum fish length captured in a given mesh size it contacts, there is a high probability that the fish will not be captured and instead “bounce” off the mesh if the fish is too large or swim through the mesh if the fish is too small (Hamley 1975). As a result, length-frequency distributions and associated size-structure indices such as proportional size distribution (PSD; formerly proportional stock density, Guy et al. 2007), from gill net catches may not give a true representation of the fish that contact the net (Hamely 1975; Willis et al. 1985; Wilde 1991; Ney 1993).

In an effort to improve data comparisons with other agencies, the Oklahoma Department of Wildlife Conservation (ODWC) adopted the new North American standardized methods for gill netting proposed by Miranda and Boxrucker (2009). The ODWC was using standardized gill net sampling procedures developed within their own agency since 1977 (Erickson 1978), which used a different net design than the North American standard gill net. Because managers often look at trends in fish populations overtime, it was necessary to compare the catch rates and length frequencies of the North American standard net and the old net design used in Oklahoma. When comparing different gear types, both gears should be used at the same time and same location providing a method for converting historic data collected with one gear type to data collected with another (Peterson and Paukert 2009; Noble et al. 2007). Therefore, the first objective of this thesis was to understand the consequences of adopting the North American standard gill net by quantifying differences in mean catch rate, catch rate precision, and length frequencies of the ODWC’s previous gill net and the new North

American standard gill net and to compare catch data at fixed and random sites (as defined by the ODWC and North American standard gill net protocols, respectively).

To improve the quality of the data collected with the North American standard gill net, my second objective was to develop contact selectivity curves which correct for the size biases of the gill net (i.e., differential size-specific probability that a fish that encounters the net becomes entrapped) (Hamely 1975). Corrections for contact selectivity differ from capture efficiency as they only account for fish contacting the gill net and do not account for the proportion of fish captured in the net compared to the population as a whole (Hamely 1975). Although a true measure of capture efficiency would be preferable, it is logistically difficult given the few gears available to sample some species of interest and the high mortality rate inherent in gill net sampling which precludes the use of mark-recapture methods. Therefore, contact selectivity corrections are an important first step in correcting for size bias of this gear, even though they may not be a complete solution to all forms of size bias for this gear.

Fisheries managers are often limited in the decision making process to information provided by biased gears (Krueger and Decker 1999). Correlating the new net data to the old net data and accounting for the contact selectivity bias of the new net design with selectivity curves will improve the ecological data interpretation portion of the fisheries management process for managers using the North American standard net.

REFERENCES

Bonar, S.A., S. Contreras-Balderas, and A.C. Iles. 2009. An introduction to standardized sampling. Pages 1-12 *in* S.A. Bonar, W.A. Hubert, and D.W. Willis, editors. Standard methods for sampling North American freshwater fishes. American Fisheries Society, Bethesda, Maryland.

Bonar, S.A., and W.A. Hubert. 2002. Standard sampling of inland fish: benefits, challenges, and a call for action. Fisheries 27(3):10-16.

Buckmeier, D.L. and J. W. Schlechte. 2009. Capture efficiency and size selectivity of channel catfish and blue catfish sampling gears. North American Journal of Fisheries Management. 29: 404-416.

Erickson, K.E. 1978. Standardized sampling procedures for lake and reservoir management recommendations. Oklahoma Federal Aid Project F-38-R, Job 1. Performance Report. 27p.

Gabelhouse, D., and 20 coauthors. 1992. Fish sampling and data analysis techniques used by conservation agencies in the U.W. and Canada. American Fisheries Society, Fisheries Management Section, Bethesda, Maryland.

Guy, C. S., R. M., Neumann, D. W. Willis, and R. O. Anderson. 2007. Proportional size distribution: a further refinement of population size structure index terminology. *Fisheries*. 32(7):348.

Hamely, J.M. 1975. Review of gillnet selectivity. Journal of the Fisheries Research Board of Canada. 32:1943-1969.

Holst, R., Madsen, N., Moth-Poulsen, T, Fonseca, P., Campos, A. 1998. Manual for Gillnet Selectivity. European Commission.

Hubert, W. A., K. L. Pope, and J. M. Dettmers. 2012. Passive capture techniques. Pages 223-265 *in* A. V. Zale, D. L. Parrish, and T. M. Sutton, editors. Fisheries techniques, 3rd edition. American Fisheries Society, Bethesda, Maryland.

Krueger, C.C., and D.J. Decker. 1999. The process of fisheries management. Pages 31-59 *in* C.C. Kohler and W.A. Hubert, editors. Inland fisheries management in North America. American Fisheries Society, Bethesda, Maryland.

Mero, S.W. and D.W. Willis. 1992. Seasonal variation in sampling data for walleye and sauger collected with gill nets from Lake Sakakawea, North Dakota. Prairie Naturalist. 24(4):231-240.

Miranda, L.E., and J. Boxrucker. 2009. Warmwater fish in standing waters. Pages 29-42 *in* S.A. Bonar, W.A. Hubert, and D.W. Willis, editors. Standard methods for sampling North American freshwater fishes. American Fisheries Society, Bethesda, Maryland.

Ney, J.J. 1999. Practical use of biological statistics. Pages 167-191 *in* C.C. Kolker, and W.A. Hubert, editors. Inland fisheries management in North America. American Fisheries Society, Bethesda, Maryland.

Noble, R.L. 2002. Reflections on 25 years of progress in black bass management. Pages 139-146 *in* D.P. Philipp and M. S. Ridgway, editors. Black bass: ecology, conservation, and management. American Fisheries Society, Symposium 31, Bethesda, Maryland.

Noble, R.L., D.J. Austen, and M.A. Pegg. 2007. Fisheries management study design considerations. Pages 31-49 *in* C.S. Guy and M.L. Brown, editors. Analysis and interpretation of freshwater fisheries data. American Fisheries Society, Bethesda, Maryland.

Peterson, J.T., and C.P. Paukert. 2009. Converting nonstandard fish sampling data to standardized data. Pages195-215 *in* S.A. Bonar, W.A. Hubert, and D.W. Willis, editors. Standard methods for sampling North American freshwater fishes. American Fisheries Society, Bethesda, Maryland.

Reddin, D.G. 1986. Effects of different mesh sizes on gill-net catches of Atlantic Salmon in Newfoundland. North American Journal of Fisheries Management. 6:209-215.

Vokoun, J.C., and C.F. Rabeni. 1999. Catfish sampling in rivers and streams: a review of strategies, gears, and methods. Pages 271-286 in E.R. Irwin, W.A. Hubert, C.F. Rabeni, H.L. Schramm Jr., and T. Coon. Editors. Catfish 2000: proceedings of the international ictalurid symposium. American Fisheries Society, Symposium 24, Bethesda, Maryland.

Wilde, G.R. 1991. Gill net selectivity and size structure in white bass. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies. 45:470-476.

Willis, D.W., K.D. McCloskey, and D.W. Gabelhouse, Jr. 1985. Calculation of stock density indices based on adjustments for efficiency of gill-net mesh size. North American Journal of Fisheries Management. 5:126-137.

CHAPTER I

The effects of gill net design and random versus fixed sampling on CPUE, precision, and size structure, of pelagic fishes.

ABSTRACT

The Oklahoma Department of Wildlife Conservation (ODWC) has used Standardized Sampling Procedures (SSP) to monitor fish populations in Oklahoma waters since 1977. The gill net configuration suggested by Miranda and Boxrucker (2009) for the entire southern USA was recently adopted by ODWC to replace the current standard. This change in standard sampling gear warranted the comparison of CPUE, variability, and length-frequency distributions of the old and new net configurations. Fixed site sampling was the standard for ODWC gill netting although use of random sites is thought to be less biased. Therefore, comparisons were also made between fixed and random sites using the new net configuration. There were no significant differences in catch rates between the old and new net configuration for four of the six target species at fixed sites. The CPUE variability of the new nets at fixed sites was lower or similar to the old nets, except for hybrid striped bass, which had higher variability in the new nets. Length-frequency distributions differed between the two net types for most species at fixed sites; however, after accounting for the fish caught in the smallest meshes of the old net, only channel catfish and some hybrids striped bass length distributions differed. White bass was the only species to show a significant difference in CPUE between fixed and random sites. CPUE variability was slightly higher at random sites for only white bass. Length frequencies were mostly unaffected by fixed or random sampling. I recommend ODWC include random gill net sites in their SSP because the variability of CPUE from random and fixed sites is only slightly different, but random sites are expected to provide a better representation of the true population.

INTRODUCTION

Gill nets, underwater walls of netting usually set in a straight line (Hubert et al 2012; Miranda and Boxrucker 2009), are a passive capture gear that catches fish by entanglement. Fish are caught by being wedged-held by mesh around the body, gilled-held by mesh slipping behind the opercula, or tangled-caught by spines, teeth, or other protrusions without actually penetrating a mesh. Therefore, mesh size is an important factor influencing the size of fish captured (Hubert et al 2012; Reddin 1986; Miranda and Boxrucker 2009). Other factors that influence catch of gill nets include color (Jester 1977) , season (Jester 1977) , baiting (Jester 1977), net length (Minns and Hurley 1988), set time (Minns and Hurley 1988) net material (Anonymous 1952; Hogman 1973; Henderson and Nepszy 1992), size of filaments (Hansen 1974; Yokota et al. 2001), and hanging ratio (Machiels et al. 1994). Gill nets are one of the most widely used fisheries gears in the United States and Canada (Gablehouse et al. 1992). Many variations exist, which can make comparisons among nets difficult.

Standardized sampling procedures are important in fisheries management and are needed for comparable evaluations of fish populations over time and/or between reservoirs in a region or state (Noble 2002). Fish populations are often monitored to detect relative changes over time as opposed to determining true population estimates (Johnson and Nielsen 1983) because population estimates are time-consuming and expensive. Therefore, most standard sampling protocols in large systems use catch-per-unit effort (CPUE) as an index of abundance (Bonar et. al. 2009, Quist et al 2009). The

Oklahoma Department of Wildlife Conservation (ODWC) first developed “Standardized Sampling Procedures (SSP) for Reservoir and Reservoir Management Recommendations” for their state in 1977 (Erickson 1978). This protocol called for the use of gill nets 61-m long by 1.8-m deep with specified bar-mesh sizes. Since that time, ODWC’s SSP have been revised several times in an effort to obtain more accurate population parameters as well as maximize the efficiency of time spent afield by managers.

Recently, Miranda and Boxrucker (2009) introduced new standards for gill netting in North America that specify net design, deployment, effort, and timing of collection. Their net design consists of 24.8-m long by 1.8-m deep nets composed of 3.1-m long panels with bar mesh sizes of 19, 25, 32, 38, 44, 51, 57, and 64 mm respectively and with a 0.5 hanging ratio. It is deployed perpendicular to the bank normally in depths of 3-8 m. The end of the net closest to shore is randomized for each site. Nets are not set on slopes greater than 45^o or over drop-offs that would cause the meshes in the net to compress. Sampling is conducted in late summer through winter when water temperatures are less than 20^o C. The intention of their protocol was to reduce variability, which often prevents adequate comparisons among agencies, while maintaining effort levels that would be logistically feasible for most state management agencies. The ODWC has adopted the Miranda and Boxrucker (2009) standard for their routine sampling. Because biologists use gill nets to look at trends in fish populations over time, it is beneficial to compare the catch rates and length frequencies of these two net designs in order to understand the consequences of changing net configurations. When comparing different gear types, both gears should be used at the same time and same location, providing a method for converting historic data collected with one gear type to data collected with another (Peterson and Paukert 2009; Noble et al. 2007).

The new Miranda and Boxrucker gill net design (hereafter referred to as the “short” net) replaces a larger gill net design (hereafter referred to as the “long” net) the ODWC had used for nine years. The long net was 61-m long by 1.8-m deep with 7.6-m long panels with bar mesh sizes of 13, 16, 19, 25, 38, 51, 57, and 76 mm. The 13-and 16-mm mesh sizes were included in the net design for the sole purpose of targeting shad (*Dorosoma* spp.: L. Cofer, ODWC, personal communication). In 2009, the ODWC further refined their shad sampling and began using separate floating ‘shad’ gill nets with small bar mesh sizes specifically designed to target shad. The addition of separate shad nets to the ODWC’s SSP made the data gained from the 13- and 16-mm mesh sizes of the SSP gill net configuration no longer necessary. The SSP also specified the number of gill net samples required as a function of impoundment surface area: less than 40 ha, not more than 5 sites; 40-404 ha, 5 sites; 404-2023 ha, 10 sites; greater than 2023 ha, 15 sites (Kuklinski, ODWC, personal communication).

In addition to changing the net design, the North American standard gill net protocol (Miranda and Boxrucker 2009) uses randomly-selected sites rather than fixed sites selected by the biologist, as the previous ODWC gill net SSP specified. Fixed sites minimize variance that may be caused by spatial patterns and are thus useful for precisely monitoring relative changes in the abundance of fish over time, at least at the sites where sampling occurs (Wilde and Fisher 1996; Noble et al. 2007). However, fixed sites are potentially more biased than random sites with respect to abundance and length frequencies of fish they capture from a lake-wide population (Hubbard and Miranda

1986; Wilde and Fisher 1996). Random sampling may give a more accurate assessment of sportfish populations and allow biologists to make more reliable comparisons among reservoirs, but at the possible cost of requiring additional replication to achieve the same precision. Consistent precision of the data collected from the fishery is a key component in making management decisions (Ney 1999; Noble 2007). Therefore, a direct comparison of fixed versus random sampling needs to be made to determine if additional sampling effort would be needed in a random sampling design to achieve the same desired level of precision.

Study Objectives

The purpose of this study was to understand consequences of adopting the North American standard net configuration. Specifically, I quantified: 1) differences in mean catch rate, catch rate precision, and length frequencies of previous long-net (61-m) and current short-net (24.8-m) SSP configurations at historic fixed sites; 2) differences in mean catch rate, catch rate precision, and length frequencies of fixed and random sites using current short (24.8-m) SSP nets.

METHODS

Hybrid striped bass *Morone chrysops x Morone saxatilis*, white bass *Morone chrysops*, walleye *Sander vitreus*, and saugeye *Sander canadense x Sander vitreus* are the primary target species for the ODWC's gill net SSP. Information gathered from gill nets about white crappie *Pomoxis annularis*, and channel catfish *Ictalurus punctatus* is useful to the ODWC, but these are considered secondary target species. As such my study will focus on catch data from these six target species or hybrids. All other species will be referred to as non-target species.

In 2009 and 2010, eight Oklahoma reservoirs (Canton, Thunderbird, Kaw, Waurika, and Tom Steed Reservoirs in 2009; Foss, Ft. Cobb, Skiatook, and Tom Steed Reservoirs in 2010) were selected for sampling based on stockings of hybrid striped bass and either saugeye or walleye within the previous five years. Most sample reservoirs had natural populations of white bass (except Foss Reservoir) and channel catfish. Although Thunderbird Reservoir was not stocked with hybrid striped bass, it was sampled because it was considered Oklahoma's best saugeye fishery. Waurika Reservoir was only stocked periodically with saugeye but was sampled because it was considered Oklahoma's best hybrid striped bass fishery. Canton Reservoir was considered Oklahoma's best and most productive walleye fishery.

Each reservoir received a total of 45 net-nights of effort in a given sample year (15 net-nights of long nets at fixed sites, 15 net-nights of short nets at same fixed sites as long nets, and 15 net-nights of short nets at random sites) except Ft. Cobb Reservoir, which only received 30 net-nights of effort (10 net-nights of effort for each net type and site type) due to its smaller size (1,659 ha). In 2009, gillnet sampling began October 5th and continued through November 6th. In 2010, sampling began October 11th and continued through November 10th in accordance with the ODWC's SSP recommended time frame. Five sites for each net and site type combination were sampled on each day such that most reservoirs were sampled on three consecutive days to obtain the 15 replicates of each net and site type combination (two days were used to obtain the 10 replicates from Ft. Cobb Reservoir).

At each of 15 historic gill net sites (fixed sites) in each reservoir, one long net and one short net were set parallel to each other and approximately 90 meters apart such that both nets were perpendicular to the shore. Nets were set this way in order to give the same schools of fish the opportunity to pass through each of the nets and become entangled. Fifteen random sites were selected by using a map of each reservoir with numbered grids representing 274 by 274 meter sections and shoreline grid numbers were randomly selected. The Miranda and Boxrucker (2009) standardized protocols were followed for net deployment. All nets were fished for a period of 17 to 24 hours. The number of fish of each species in each net was divided by the number of hours that net was fished and multiplied by 24 to give catch per unit effort (CPUE) as catch per 24 hours.

Gillnets were pulled and fish were processed at a work station. Total length (mm) was recorded for all fish caught. Coefficient of variation (c.v.) of mean CPUE was calculated for each species in each net and site combination. The number of samples needed to detect a target c.v. of 0.25 and 0.125 was calculated using the random resampling method of Dumont and Schlechte (2004). Catch per unit effort data were log transformed ($\ln[X+0.0004]$) to correct for deviations from normality. For each species captured, a mixed-model analysis of variance (ANOVA) (net length treated as a fixed factor and reservoir treated as a blocking variable) was used to test for differences in mean CPUE between short and long nets at fixed sites. A mixed-model ANOVA (site type treated as a fixed factor and lake treated as a blocking variable) was also used to test for differences in mean CPUE of each species from short nets at fixed versus random sites. Four regression models (linear, power, exponential, and second order polynomial) were fit between mean catch rates of the long and short nets at fixed sites for each of the five target species (channel catfish, hybrid striped bass, white bass, white crappie, and saugeye/walleye combined). Mean square error (MSE) and R^2 were used to assess the best-fitting model for each species. In cases where more than one model had similarly low MSE and R2, the simpler model (fewer parameters) was selected. All ANOVA tests were evaluated as significant if $P < 0.05$.

For each species at each lake, a Kolomogorov-Smirnov test (KS test) was used to test for differences in length-frequency distributions between short and long nets at fixed sites. A KS test was also used to test for differences in length-frequency distributions between short nets at fixed and random sites for each species at each lake. The 13- and 16-mm panels (shad meshes) in the long nets were only intended to sample shad species, but may have influenced the frequency of small sportfish captured. Therefore, a KS test was also used to look for differences in the short and long net with the catch of these shad meshes removed (these long nets with no shad meshes are hereafter referred to as "long-nsm"). Length-frequency histograms for a given lake and species combination were eliminated from length-frequency comparisons if the number of individuals caught was low (i.e., number caught was less than the lower end of that species' 95% confidence interval of the mean sample size from the past 15 years of statewide gill net data (ODWC, unpublished data)). All statistical tests were evaluated as significant if $P < 0.05$ except for KS tests, which used a Bonferroni adjusted *P* values.

RESULTS

Short vs. Long nets at Fixed Sites

Catch rates

The short and long nets had similar mean CPUE for most of the target species (Table 1). However, channel catfish and white crappie had significantly lower mean CPUE in the short nets. The short nets had significantly lower mean CPUE for half of the non-target species. Catch rates of other non-target species did not differ between net designs.

Precision (c.v. of the mean) of the short nets was similar to or greater than the long nets for the target species with the exception of hybrid striped bass, which was only slightly lower (Table 1). Using the 15 samples currently required by the new ODWC SSP, the long nets were only able to achieve the lower of the target precision levels (c.v. = 0.25) for channel catfish and walleye (Table 2). The short nets were able to achieve this level of precision for all target species except hybrid striped bass and white crappie using 15 samples. White crappie would only require two additional samples, but hybrid striped bass would require several additional samples to achieve this level of precision (Table 2). Neither net type was able to achieve the second target for precision (c.v. = 0.125) for any species with 15 samples.

A linear equation provided the best (lowest mean square error and highest R^2) model relating the CPUE of the long and short net types for all of the target species except white bass. All slopes were significantly different form zero except for white bass (Figure 1). Linear regression of mean CPUE explained from 66% (white crappie) to 86%

(saugeye/walleye) of the variation in catch rates between short and long net types (Figure 1).

Length Frequency

At least one lake's length-frequency histogram differed for every species except walleye when comparing long and short net designs (Table 3; Figures 2-6). All channel catfish and white crappie length frequencies tested were significantly different. Some species had subtly different length-frequencies for some length classes in the middle of the distribution, but these were not dramatic enough to be of statistical significance nor of significance in most management situations. At times the long nets caught fish in the shad meshes from small length groups that were not caught in the short nets. The influence of the shad mesh is especially apparent for white crappie (Figure 3), but can also be seen to a lesser degree for hybrid striped bass (Figure 5) and white bass (Figure 4). Length frequencies from the long-nsm nets were significantly different from the short nets for channel catfish at all lakes and for hybrid striped bass from one third of the lakes. All other species and lakes had similar length frequencies from long-nsm and short nets.

Fixed vs. Random Sampling Sites

Mean catch rates were similar between fixed and random sites for most target species. Only white bass differed significantly, with fixed sites having a higher catch rate (Table 1). Precision at random sites was slightly lower (higher c.v.) than that at fixed sites for all target species except hybrid striped bass (which had the same c.v. at both sites) and saugeye (which had higher precision at random sites). Hybrid striped bass had the lowest precision of all target species (Table 1). Using either sample site strategy, it was not possible to achieve c.v. = 0.125 for any of the target species with only 15 net nights (Table 2). Using fixed sites, it was possible to achieve c.v. = 0.25 with < 15 net nights of effort for all species except hybrid striped bass and white crappie. An additional two samples would make this target achievable for white crappie. Using the random site sampling strategy, it was only possible to achieve c.v. = 0.25 with < 15 net nights for saugeye and walleye. An additional sample would make this target achievable for channel catfish and 3 additional samples would make it achievable for white crappie. The length frequencies from short nets at fixed and random sites were similar for all species except channel catfish at Canton Lake (Figures 2-6).

DISCUSSION

Short vs. Long nets at Fixed Sites

Catch rate

The short gill net configuration offered by Miranda and Boxrucker (2009) should be advantageous for state agencies and researchers for several reasons. This net design provided similar information about hybrid striped bass, saugeye, walleye, and white bass as the long nets but was much easier and faster to deploy and retrieve. By-catch was also lower in short nets, so total processing time of these nets was lower than for long nets in situations where sportfish data are being collected. Lower overall processing time of the short nets would allow managers to increase the number of nets set when greater numbers of fish are needed or precision is below a target level.

Mean CPUE for white crappie was significantly lower in the short nets suggesting the long nets may be better for collecting this species. However, most biologists use trap nets as the main sampling gear for crappie (Kuklinski, ODWC, personal communication). Boxrucker and Ploskey (1988) found trap nets to have higher catch rates and less variability in catch rates and length-frequency distributions of white crappie than electrofishing and gill net samples. Guy et al. (1996) recommends trap nets over gill nets for sampling crappie because trap net catch rates gave a better index of abundance than gill net catch rates, although size-structure data were similar for both gears. Changing to the short net design may change the quality of the crappie data, but this is offset by the similar catch rates with shorter processing time for other target species and the availability of other gear types to sample crappie.

Channel catfish mean CPUE was also significantly lower for the short nets. Gill nets are commonly used by managers to survey channel catfish because biological data for channel catfish are easily obtained with little additional cost during routine gill net sampling of other sportfish (Bodine et al. In Press). Bodine et al. (In Press) reviewed channel catfish sampling literature and found that tandem hoopnets had the highest capture efficiency and required least total effort to use compared with other common channel catfish sampling gears (i.e., hoop nets, gill nets, and high frequency electrofishing). However, most of the tandem hoop net research has been directed toward small impoundments (<200 ha) and rivers. Research has only recently been conducted on channel catfish sampling with tandem hoopnets in large standing waters (>200 ha; Richters and Pope 2011; Stewart and Long 2012), such as the reservoirs sampled with gill nets in this study. Although less effective than tandem hoopnets, gillnets may still be beneficial because they provide a larger range of fish sizes than most other channel catfish sampling gear (Bodine et al. In Press). Until tandem hoopnet sampling is better evaluated in large reservoirs, or in cases when adding additional sampling methods is cost/time prohibitive, mangers will undoubtedly continue to collect biological data on channel catfish using gillnets during routine sampling. Therefore, new benchmarks based on the lower catch rate of the short nets to catch this species should be established for channel catfish management in large standing waters.

Understanding the mean CPUE relationship between the two net types will be critical for biologist when making management decisions that involve patterns from both old and new net designs (Peterson and Paukert 2009). Catch rates of short and long nets were significantly correlated for every target species except white bass. One way these equations could be useful is for making adjustments to stocking criteria. According to the ODWC's stocking criteria, a reservoir is considered an established hybrid striped bass fishery if it has a mean gill net CPUE of 2.4 fish using the long nets (ODWC, Unpublished data). Using the equation produced from the hybrid striped bass regression analysis, a mean CPUE of 2.4 fish from long nets is equivalent to a mean CPUE of 1.9 fish using the new short nets. These types of conversions will need to be made to all stocking criteria or other standards that were developed using the old long nets. Although these regressions are based on a relatively small sample sizes, they provide a better approach for establishing new benchmarks for management than arbitrarily picking new standards or by basing them on historic standards developed using a different gear. Data conversions should only be applied to a similar context to where they were developed (Peterson and Paukert 2009). These regressions were developed from lakes with moderate to high catch rates of hybrid striped bass, saugeye, and walleye so I urge managers to use caution when applying these regressions to low-catch systems.

Using either net configuration, it would be impractical for most managers or researchers to set enough nets to obtain c.v. = 0.125 (requiring 39-122 samples) for any of the target species. Other studies (Wilde1993) also found that achieving a target c.v. = 0.125 (requiring 45-150 samples) is not practical when sampling with gill nets, except in cases of well-funded research projects. The long nets were able to obtain c.v. = 0.25 for only channel catfish and walleye with ≤ 15 samples. The short nets were able to meet the c.v. = 0.25 target for all target species with 15 samples except in the case of hybrid striped bass and white crappie, although only 2 more samples would also make this level of precision possible for white crappie (Table 2). Hybrid striped bass sampled with gillnets have highly variable catch rates requiring more sample efforts to achieve a desired level of precision than most other sportfish species (Wilde 1993; this study). The better precision of the short nets suggests it would not be necessary to increase sample-size requirements in all systems for this new net design; however, I do not recommend reducing effort to less than 15 samples per reservoir as precision is still just acceptable at this level for tracking changes in relative abundance. I recommend that managers increase sample sizes on reservoirs where hybrid striped bass are a management concern. Due to the ease of use of the short nets, the addition of as many as 15 net nights (5 additional nets each of the 3 sample nights) should not drastically impact the amount of time spent in the field when sampling hybrid striped bass and would allow the c.v. to approach the target of 0.25.

Length Frequency

The length-frequency distributions of the two net types were significantly different for most species before considering the catch of the shortest length classes in the shad meshes. To better understand the mechanism underlying these differences it is necessary to examine the construction of the two nets and the purpose of each mesh panel. The long nets have 13- and 16-mm mesh panels, which are not found in the short nets. These panels were included in the long net to specifically target small shad that are vulnerable to predation, thus making up the forage base for predators (Cofer, ODWC, personal communication). These meshes not only catch small shad but also other small fishes (particularly white crappie, and to a lesser extent white bass and hybrid striped bass). Once fish caught in the shad meshes were eliminated from the data set, the length-frequency distributions of the two net types provided similar information for all species except channel catfish (which differed in all lakes) and hybrid striped bass (which differed in one third of the lakes). Managers should recognize that the length frequencies for channel catfish and provided by the short nets will be different than the long nets, and they should keep this difference in mind when transitioning to the short nets for routine sampling. Managers should also consider the potential for differences in hybrid striped bass length data after transitioning to the short net. Eliminating the shad meshes improved the similarity between the two net type's length data; however, it did not completely eliminate the differences at all lakes. Therefore, managers should carefully consider whether or not changes observed in length data for hybrid striped bass are caused by changes in the population sampled or net design used. However, even where significant differences were detected, the differences were not extreme and using one net type’s length frequency instead of the other would not lead to a different management strategy for any of the other target species.

The information gained about small, non-shad species could be useful when looking at things such as post-stocking survival or young-of-year abundance (Anonymous 1958; Willis 1987; Fielder 1992). However, as a standardized gear to collect information about age and growth, length frequency, and relative abundance of predatory fish, these mesh sizes would be less useful (Miranda and Boxrucker 2009). It is important to consider sampling objectives when comparing gear types (Peterson and Paukert 2009). When assessing predatory fish-stock size and size structure (e.g., for setting creel regulations, length limits, and other management decisions), generally only fish that have recruited to a size that is catchable by anglers are used (Noble and Jones 1999). Therefore, I suggest the short nets are better for predatory fish assessment and that separate gill nets (i.e., supplemental nets; Miranda and Boxrucker 2009) should be used when data on smaller fish are desired.

Short Fixed Sites vs. Short Random Sites

There are advantages and disadvantages to both fixed and random sampling strategies for fisheries managers. It is generally accepted that fixed sites chosen by biologist should produce higher catch rates than random sites (Wilde and Fisher 1996) because these sites are usually selected based on the presence of desired habitat for the targeted species (Hubbard and Miranda 1986; Noble et al. 2007). Monitoring fisheries with fixed sites maximizes precision (Wilde and Fisher 1996) and the ability to detect changes in populations over time within a system (Hubbard and Miranda 1986; Bonar et al. 2009). However, fixed-site samples may not be reflective of the entire population (Wilde and Fisher 1996; Quinn and Keough 2002; Noble et al. 2007), and are potentially more biased than random sites with respect to abundance and length structure (Hubbard and Miranda 1986; Wilde and Fisher 1996; Larnsen et al. 2001). Therefore, fixed samples should not be used to compare across systems and may only be useful for detecting relative changes over time rather than truly representing the current state of a fishery. Monitoring fisheries with random sampling ensures that the conclusions from statistical tests are reliable (Hubbard and Miranda, 1986; Quinn and Keough 2002) and facilitate comparisons among lakes. However, spatial heterogeneity of random sites can make detecting temporal trends more difficult (Quinn and Keough 2002), requiring more effort to achieve acceptable levels of precision than when using fixed sites. Variations in habitat (e.g., water depth and vegetation coverage; Cohen and Radomski 1993; Havens et al. 2005) can also occur from year to year, potentially causing fixed sites to no longer function as desired habitats for a target species. Therefore, random sampling should be the first choice for managers when all sampling objectives can be met with the desired level of precision and with an acceptable amount of effort.

My results suggest OWDC should transition to random sites for gill net SSP because length frequency and CPUE were similar to fixed sites and precision would be similar with only a few additional replicates for most species. The mean CPUE was similar at fixed and random for all species except white bass. As expected, the precision at random sites was slightly lower than that at fixed sites for most species (Wilde and Fisher 1996), but in most cases, the difference was minor because it could be overcome with little additional replication. There were no consistently significant differences in length-frequency distributions observed between the fixed and random sites using the short nets for any of the target species. Therefore, I recommend ODWC use random sites for gill net SSP as it would provide a large advantage by facilitating among-lake CPUE comparisons (Wilde and Fisher 1996; Nobel et al. 2007) and provide a more accurate assessment of the fishery (Wilde and Fisher 1996; Quinn and Keough 2002; Noble et al. 2007) with only a minor decrease in precision (or a slight increase in replication to achieve the same precision).

Additional replicates may be needed with the new random sampling design. It would be impractical to set enough nets to achieve the c.v. = 0.125 target for any of the target species with either fixed or random sampling. Gill net catch rates are inherently variable and inordinately large samples are required for precise samples (Wilde 1993). However, with 10 additional net nights of sampling (additional 3-4 nets during each of 3 sample nights) it would be possible to meet or exceed the c.v. = 0.25 target for all target species except hybrid striped bass. Gill net CPUE of hybrid striped bass is often more variable than other species (Wilde 1993). I recommend ODWC increase the required SSP sample to 25 net nights to achieve the target c.v. of 0.25 for most target species. I further recommend increasing sample size to 34 net nights to achieve the target c.v. of 0.25 when there is a need for intensive management of systems with hybrid striped bass.

CONCLUSIONS

The short and long nets provide similar catch rate and length-frequency information for saugeye, walleye, white bass and most hybrid striped bass. The reduced catch rate for channel catfish and white crappie should be an acceptable trade off, because the short nets caught fewer non-target species, allowed their samples to be processed in less time, and other gears are available to sample these two species. The new short-net configuration should benefit managers and researchers by providing similar data quality while decreasing the time spent afield deploying, retrieving, and processing fish caught in the nets. The regression equations developed should help revise benchmarks for evaluating and monitoring trends in sportfish populations over time. The variability of the new short nets at fixed sites was essentially equal to or less than the long nets with the exception of hybrid striped bass. The reduced precision for hybrid striped bass could be offset by adding more sample sites to reservoirs with hybrid striped bass fisheries. This would not greatly increase time spent afield when compared to sampling with the previous long nets. This would also be true for the transition from fixed-site sampling to a random sampling strategy. I recommend ODWC include random gill net sites in theirs SSP because the precision of CPUE at random and fixed sites is only slightly different but random sites are expected to provide a better representation of the true population (Wilde and Fisher 1996; Quinn and Keough 2002; Noble et al. 2007). Randomization of sample sites would also follow the standardized sampling methods for North America (Bonar et al. 2009) and would allow for comparisons to be made among water bodies across North America.

REFERENCES

Anonymous. 1952. From a report on study of nylon and linen gill nets. The Progressive Fish Culturist. 14:18-18.

Anonymous. 1958. Small-mesh gill nets used in Wyoming studies. The Progressive Fish Culturist. 20:32-32.

Bodine, K.A., D.E. Shoup, J. Olive, Z.L Ford, R. Krogman, and T.J. Stubbs. In Press. Catfish Sampling Techniques: Where are we now and where we should go? Fisheries.

Bonar, S.A., Contrearas-Balderas, S., and A.C. Iles. 2009. An introduction to standardized sampling. Pages 1-12 *in* S.A. Bonar, W.A. Hubert, and D.W. Willis, editors. Standard methods for sampling North American freshwater fishes. American Fisheries Society, Bethesda, Maryland.

Boxrucker, J., and G. Ploskey. 1988. Gear and seasonal biases associated with sampling crappie in Oklahoma. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies. 42:89-97.

Boxrucker, J., P.J. Michaletz, M.J. Van Den Avyle, and B. Vondracek. 1995. Overview of gear evaluation study for sampling gizzard shad and threadfin shad populations in reservoirs. North American Journal of Fisheries Management. 15: 885-890.

Buckmeier, D.L., and J.W. Schlechte. 2009. Capture efficiency and size selectivity of channel catfish and blue catfish sampling gears. North American Journal of Fisheries Management 29:404–416.

Cohen, Y., and P. Radomski. 1993. Water level regulations and fisheries in Rainy Lake and Namakan Reservoir. Canadian Journal of Fisheries and Aquatic Sciences. 50: 1934-1945.

Dumont, S.C., and W. Schlechte. 2004. Use of resampling to evaluate a simple random sampling design for general monitoring of fishes in Texas reservoirs. North American Journal of Fisheries Management 24:408–416.

Erickson, K.E. 1978. Standardized sampling procedures for lake and reservoir management recommendations. Oklahoma Federal Aid Project F-38-R, Job 1. Performance Report. 27p.

Fielder, D.G. 1992. Relationships between walleye fingerling stocking density and recruitment in Lower Lake Oahe, South Dakota. North American Journal of Fisheries Management. 12: 346-352.

Gablehouse, D., and 20 coauthors. 1992. Fish sampling and data analysis techniques used by conservation agencies in the U.W. and Canada. American Fisheries Society, Fisheries Management Section, Bethesda, Maryland.

Guy, C.S., D.W. Willis, and R.D. Shultz. 1996. Comparison of catch per unit effort and size structure of white crappies collected with trap nets and gill nets. North American Journal of Fisheries Management 16:947-951.

Hamely. J.M. 1975 Review of gillnet selectivity. Journal of the Fisheries Research Board of Canada. 32:1943-1969.

Hansen, R.G. 1974. Effects of different filament diameters on the selective action of monofilament gill nets. Transactions of the American Fisheries Society. 2:386-387.

Havens, K.E., D. Fox, S. Gornak, and C. Hanlon. 2005. Aquatic vegetation and largemouth bass population responses to water-level variations in Lake Okeechobee, Florida (USA). Hydrobiologia. 539: 225-237.

Henderson, B.A., and S.J. Nepszy. 1992. Comparison in catches of mono- and multifilament gill nets in Lake Erie. North American Journal of Fisheries Management. 12:618-624.

Hogman, W.J. 1973. The relative efficiency of nylon gill nets after transition from cotton nets in a multispecies fishery. Transactions of the American Fisheries Society. 102:778-785.

Hubbard, W.D., and L.E. Miranda. 1996. Competence of non-random electrofishing sampling in assessment of structural indices. Proceedings of the Annual conference of the Southeastern Association of Fish and Wildlife Agencies. 40:79-84.

Hubert, Hubert, W. A., K. L. Pope, and J. M. Dettmers. 2012. Passive capture techniques. Pages 223-265 *in* A. V. Zale, D. L. Parrish, and T. M. Sutton, editors. Fisheries techniques, 3rd edition. American Fisheries Society, Bethesda, Maryland.

Jester, D.B. 1977. Effects of color, mesh size, fishing in seasonal concentrations, and baiting on catch rates of fishes in gill nets. Transactions of the American Fisheries Society 106:43-56.

Johnson, D.L., and L.A. Nielsen. 1983. Sampling Considerations. Pages 1-21 *in* L.A. Nielsen, and D.L. Johnson, editors. Fisheries Techniques. American Fisheries Society, Bethesda, Maryland.

Machiels, M.A.H., M. Klinge, R. Lanters, and W.L.T. van Densen. 1994. Effect of snood length and hanging ratio on efficiency and selectivity of bottom-set gillnets for pikeperch, *Stizostedion lucioperca*, and bream, *Abramis brama*. Fisheries Research 19:231-239.

Minns, C.K. and D.A. Hurley. 1988. Effects of net length and set time on fish catches in gill nets. North American Journal of Fisheries Management. 8:216-223.

Miranda, L.E., W.D. Hubbard, S. Sangare, and T. Holman. 1996. Optimizing electrofishing sample duration for estimating relative abundance of largemouth bass in reservoirs. North American Journal of Fisheries Management. 16:324-331.

Miranda, L.E. and J. Boxrucker. 2009. Warmwater fish in standing waters. Pages 29-42 *in* S.A. Bonar, W.A. Hubert, and D.W. Willis, editors. Standard methods for sampling North American freshwater fishes. American Fisheries Society, Bethesda, Maryland.

Ney, J.J., 1999. Practical use of biological statistics. Pages 167-191. *in* C.C. Kohler and W.A. Hubert, editors. Inland fisheries management in North America. Bethesda, Maryland.

Noble, R.L. and T.W. Jones. 1999. Managing fisheries with regulations. Pages 455-477 *in* C.C. Kohler and W.A. Hubert, editors. Inland fisheries management in North America. Bethesda, Maryland.

Noble, R.L. 2002. Reflections on 25 years of progress in black bass management. Pages 139-146 *in* D.P. Philipp and M. S. Ridgway, editors. Black bass: ecology, conservation, and management. American Fisheries Society, Symposium 31, Bethesda, Maryland.

Noble, R.L., D.J. Austen, and M.A. Pegg. 2007. Fisheries management study design considerations. Pages 31-49 *in* C.S. Guy and M.L. Brown, editors. Analysis and interpretation of freshwater fisheries data. American Fisheries Society, Bethesda, Maryland.

Peterson, J.T. and C.P. Paukert. 2009. Converting nonstandard fish sampling data to standardized data. Pages195-215 *in* S.A. Bonar, W.A. Hubert, and D.W. Willis, editors. Standard methods for sampling North American freshwater fishes. American Fisheries Society, Bethesda, Maryland.

Quinn, G.P. and M.J. Keough. 2002. Experimental design and data analysis for biologists. Cambridge University Press, New York.

Quist, M.C., K.I. Bonvechio, and M.S. Allen. 2009. Statistical analysis and data management. Pages 171-194 *in* S.A. Bonar, W.A. Hubert, and D.W. Willis, editors. Standard methods for sampling North American freshwater fishes. American Fisheries Society, Bethesda, Maryland.

Reddin, D.G. 1986. Effects of different mesh sizes on gill-net catches of Atlantic Salmon in Newfoundland. North American Journal of Fisheries Management 6:209-215.

Richters, L. K. and K. L. Pope. 2011. Catch of channel catfish with tandem-set hoop nets and gill nets in lentic systems of Nebraska. Pages 573-580 *in* P. H. Michaletz, and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Robinson, M.S. 1999. Evaluation of three gear types for sampling channel catfish in small impoundments. Pages 265-269 *in* E.R Irwin, W.A. Hubert, C.F. Rabeni, H.L. Schramm Jr., T. Coon, editors. Catfish 2000: proceedings of the international Ictalurid symposium. American Fisheries Society Symposium 24, Bethesda, Maryland.

Santucci, V.J. Jr., D.H. Wahl, and D.F. Clapp. 1999. Efficiency and selectivity of sampling methods used to collect channel catfish in impoundments. Pages 317-328 *in* E.R Irwin, W.A. Hubert, C.F. Rabeni, H.L. Schramm Jr., T. Coon, editors. Catfish 2000: proceedings of the international Ictalurid symposium. American Fisheries Society Symposium 24, Bethesda, Maryland.

Sullivan, K.P. and C.M. Gale. 1999. A comparison of channel catfish catch rates, size distributions, and mortalities using three different gears in a Missouri impoundment. Pages 293-300 *in* E.R Irwin, W.A. Hubert, C.F. Rabeni, H.L. Schramm Jr., T. Coon, editors. Catfish 2000: proceedings of the international Ictalurid symposium. American Fisheries Society Symposium 24, Bethesda, Maryland.

Stewart, D. R. and J. M. Long. 2012. Precision of channel catfish *Ictalurus punctatus* catch estimates using hoop nets in Oklahoma reservoirs (>200 ha). North American Journal of Fisheries Management 32:1108-1112.

Wilde, G.R. 1993. Gill net sample size requirements for temperate basses, shads, and catfishes. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies. 47: 588-595.

Wilde, G.R., and W.L. Fisher. 1996. Reservoir fisheries sampling and experimental design. Pages 397-409 *in* L.E. Miranda and D.R. DeVries, editors. Multidimensional approaches to reservoir fisheries management. American Fisheries Society Symposium 16, Bethesda, Maryland.

Willis. D.W. 1987. Use of gill net data to provide a recruitment index for walleyes. North American Journal of Fisheries Management. 7:591-592.

Yokota, K., Y. Fujimori, D. Shiode, and T. Tokai. 2001. Effect of thin twine on gill net size-selectivity analyzed with the direct estimation method. Fisheries Science. 67: 851-856.

Table 1. Mean CPUE, coefficient of variation of the mean (c.v. mean), F-statistic and *P* values for two gill net configurations: long (eight 7.6-m panels with 13, 16, 19, 25, 38, 51, 57, and 76-mm mesh sizes) and short (eight 3.1-m panels with 38, 57, 25, 44, 19, 64, 32, and 51-mm mesh sizes) nets fished at fixed and or random sites. Data were from 10-15 net-nights effort at 8 Oklahoma reservoirs. Significant results ($P < 0.05$) are bolded.

	Long Fixed		Long Fixed vs. Short Fixed		Short Fixed		Short Fixed vs. Short Random		Short Random	
Target Species	Mean CPUE	C.V. mean	F statistic	*P* value	Mean CPUE	C.V. mean	F statistic	*P* value	Mean CPUE	C.V. mean
channel cat	6.7	0.19	$F_{1,251} = 12.85$	**< 0.01**	3.8	0.20	$F_{1,252} = 0.47$	0.49	4.5	0.21
hybrid striped bass	10.4	0.28	$F_{1,222} = 1.12$	0.29	7.5	0.31	$F_{1,223} = 3.77$	0.05	5.4	0.31
saugeye	5.7	0.24	$F_{1,135} = 0.02$	0.89	4.4	0.19	$F_{1,135} = 0.10$	0.75	4.5	0.16
walleye	7.9	0.22	$F_{1,76} = 0.78$	0.38	5.1	0.19	$F_{1,77} = 0.51$	0.48	5.4	0.21
white bass	13.3	0.27	$F_{1,222} = 1.55$	0.22	8.7	0.21	$F_{1,222} = 8.68$	**< 0.01**	6.7	0.29
white crappie	14.1	0.24	$F_{1,251}= 10.32$	**< 0.01**	6.5	0.22	$F_{1,252} = 8.68$	0.49	5.2	0.24
Non-Target Species										
blue catfish	3.23	0.40	$F_{1,164} = 1.34$	0.25	1.66	0.41	$F_{1,164} = 2.64$	0.11	1.73	0.35
common carp	2.58	0.37	$F_{1,251} = 21.23$	**< 0.01**	1.05	0.39	$F_{1,252} = 1.88$	0.17	1.22	0.37
drum	8.32	0.35	$F_{1,251} = 44.05$	**< 0.01**	1.96	0.41	$F_{1,252} = 1.63$	0.20	2.61	0.31
flathead catfish	0.22	0.36	$F_{1,251} = 3.84$	0.05	0.09	0.39	$F_{1,252} = 0.04$	0.84	0.09	0.29
gizzard shad	50.58	0.29	$F_{1,251} = 9.81$	**< 0.01**	17.49	0.23	$F_{1,252} = 1.71$	0.19	15.15	0.22
longnose gar	0.26	0.58	$F_{1,222} = 0.10$	0.75	0.20	0.53	$F_{1,223} = 1.06$	0.30	0.40	0.45
river carpsucker	1.55	0.19	$F_{1,251} = 21.75$	**< 0.01**	0.42	0.37	$F_{1,252} = 0.51$	0.48	0.54	0.27
shortnose gar	0.23	0.77	$F_{1,145} = 1.08$	0.30	0.12	0.73	$F_{1,145} =2.43$	0.12	0.22	0.61
smallmouth buffalo	1.04	0.27	$F_{1,222} = 8.90$	**< 0.01**	0.52	0.41	$F_{1,222} = 0.01$	0.93	0.62	0.37
spotted gar	0.37	0.62	$F_{1,145} = 1.03$	0.31	0.24	0.78	$F_{1,145} = 2.18$	0.14	0.31	0.45

Table 2. Mean number of samples required to achieve two levels of sampling precision (c.v. = 0.125 or c.v. = 0.25) for target species using long (eight 7.6-m panels with 13, 16, 19, 25, 38, 51, 57, and 76-mm mesh sizes) and short (eight 3.1-m panels with 38, 57, 25, 44, 19, 64, 32, and 51-mm mesh sizes) gill nets at fixed and random sites in 8 Oklahoma reservoirs.

	Number of Samples to Achieve Targeted c.v. of Mean					
	Long Fixed		Short Fixed		Short Random	
Species	c.v. = 0.25	c.v. = 0.125	c.v. = 0.25	c.v. = 0.125	c.v. = 0.25	c.v. = 0.125
channel catfish	12	42	15	50	16	55
hybrid striped bass	24	85	35	122	34	119
saugeye	19	70	12	43	11	37
walleye	15	54	12	39	15	53
white bass	24	82	14	50	25	88
white crappie	18	63	17	57	18	64

Table 3. Kolmogorov-Smirnov test results (KSa an P value) for length frequency comparisons of long vs. short nets, long-nsm vs. short nets, and fixed-short nets vs. random-short nets. Significant results (P < Bonferrioni adjusted significance level) are bolded.

Comparisons			long vs short		long-nsm vs short		fixed short vs random short	
species	Bonferrioni adjusted significance level	lake	KS_a	P value	KS_a	P value	KS_a	P value
channel catfish	0.025	Canton	1.64	**0.009**	1.59	**0.013**	1.52	**0.020**
		Thunderbird	1.85	**0.002**	1.59	**0.013**	0.63	0.829
hybrid striped bass	0.008	Canton	2.47	< **0.001**	1.03	0.243	1.29	0.073
		Foss	3.23	< **0.001**	3.28	< **0.001**	1.23	0.097
		Ft. Cobb	1.32	0.061	1.32	0.062	1.28	0.077
		Skiatook	1.31	0.064	0.85	0.467	1.20	0.113
		Tom Steed	1.70	**0.006**	1.75	**0.004**	0.92	0.367
		Waurika	0.84	0.487	0.83	0.494	0.61	0.854
saugeye	0.017	Ftcobb	1.23	0.096	1.19	0.116	0.59	0.875
		Steed	1.51	0.021	1.55	0.017	1.23	0.097
		Thunderbird	1.00	0.265	1.00	0.265	0.84	0.473
walleye	0.05	Canton	1.06	0.215	1.04	0.225	0.69	0.730
white bass	0.025	Tom Steed	1.29	0.071	1.02	0.250	1.01	0.261
		Waurika	1.87	**0.002**	1.05	0.220	1.26	0.085
white crappie	0.017	Kaw	5.69	< **0.001**	1.17	0.131	0.87	0.438
		Tom Steed	3.95	< **0.001**	1.42	0.036	0.78	0.573
		Thunderbird	3.24	< **0.001**	1.24	0.093	0.77	0.599

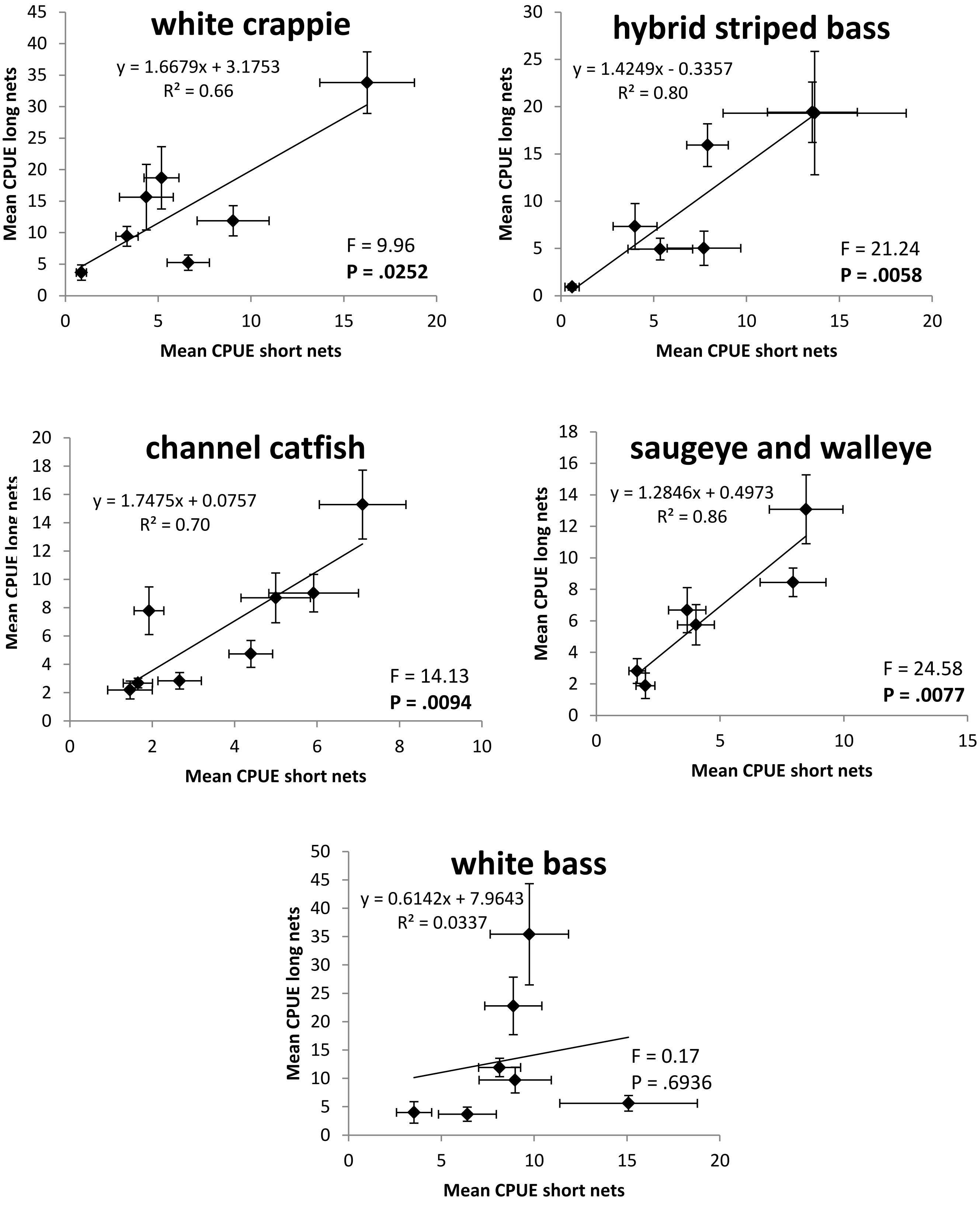

Figure 1. Linear regression relationships between the mean CPUE of short (eight 3.1-m panels with 38, 57, 25, 44, 19, 64, 32, and 51 mm mesh sizes) and long (eight 7.6-m panels with 13, 16, 19, 25, 38, 51, 57, and 76-mm mesh sizes) gill nets for white crappie, hybrid striped bass, channel catfish, saugeye/walleye, and white bass from eight Oklahoma reservoirs. Significant results (*P* < 0.05) are bolded.

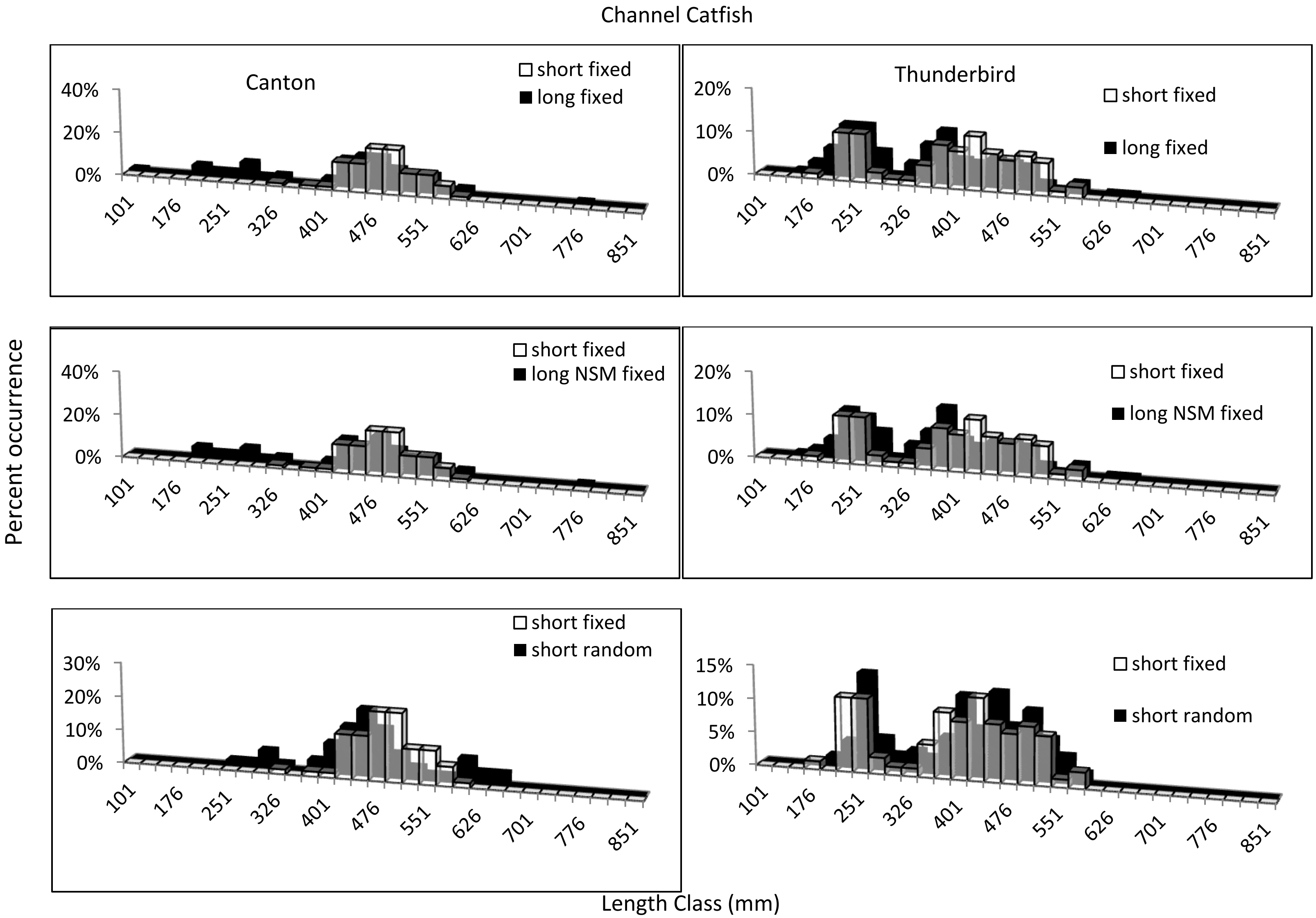

Figure 2. Length-frequency distributions of channel catfish in short vs. long gill nets at fixed sites (top row), short vs. long nets with no shad mesh on the long nets (long NSM) at fixed sites, and short nets at fixed sites vs. short nets at random sites. Significantly different length-frequency distributions according to the Kolmogorov-Smirnov test are indicated with a box around the graph.

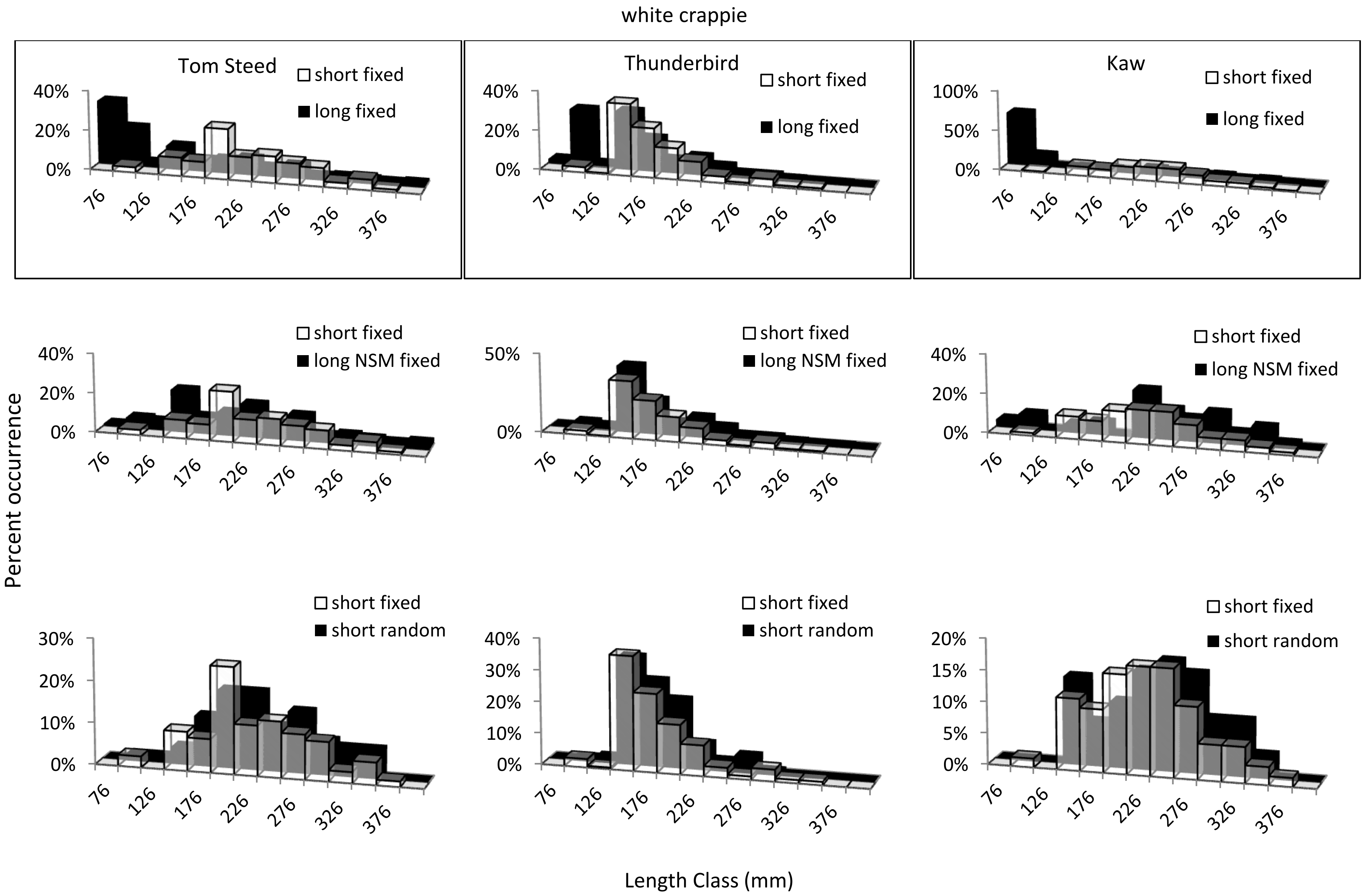

Figure 3. Length-frequency distributions of white crappie in short vs. long gill nets at fixed sites (top row), short vs. long nets with no shad mesh on the long nets (long NSM) at fixed sites, and short nets at fixed sites vs. short nets at random sites. Significantly different length-frequency distributions according to the Kolmogorov-Smirnov test are indicated with a box around the graph.

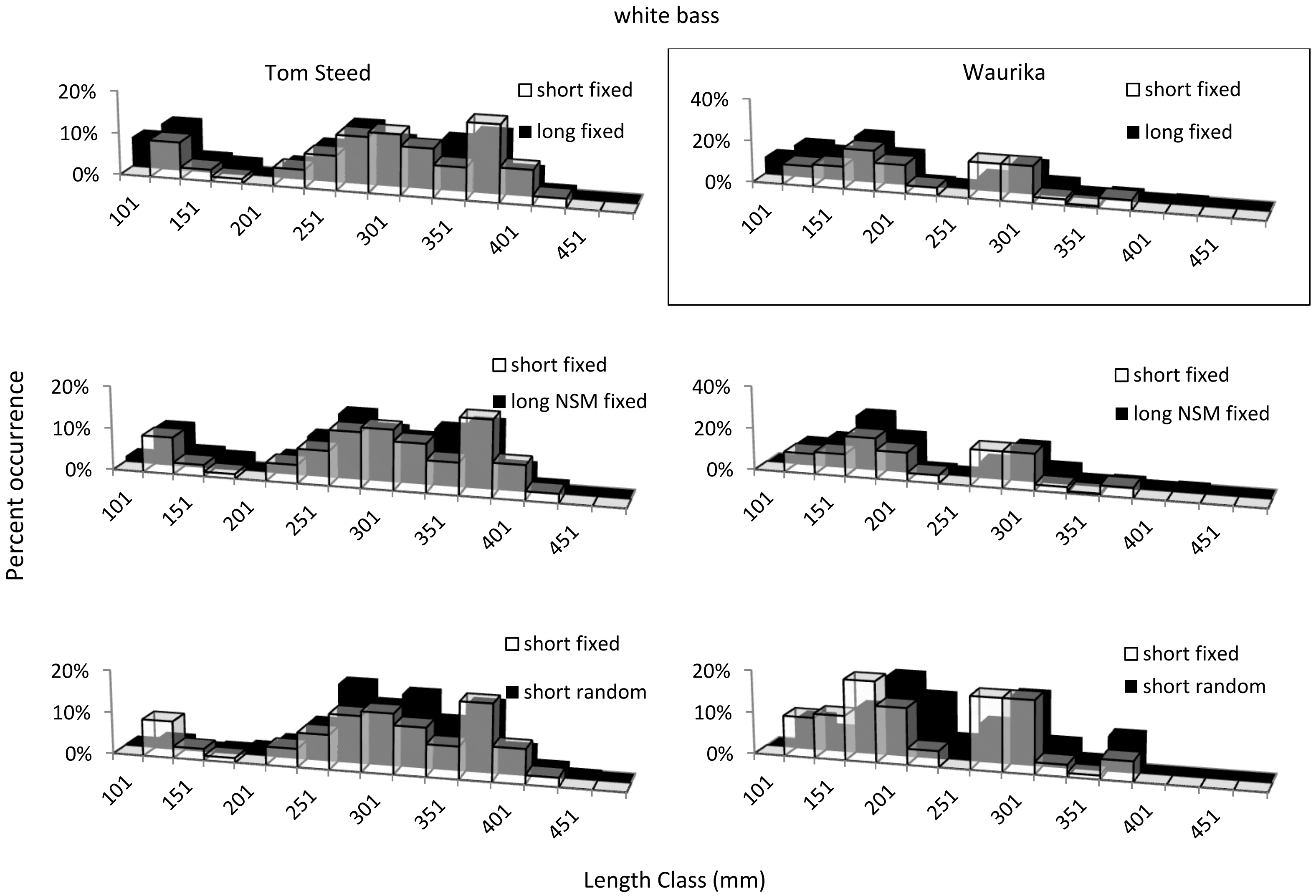

Figure 4. Length-frequency distributions of white bass in short vs. long gill nets at fixed sites (top row), short vs. long nets with no shad mesh on the long nets (long NSM) at fixed sites, and short nets at fixed sites vs. short nets at random sites. Significantly different length-frequency distributions according to the Kolmogorov-Smirnov test are indicated with a box around the graph.

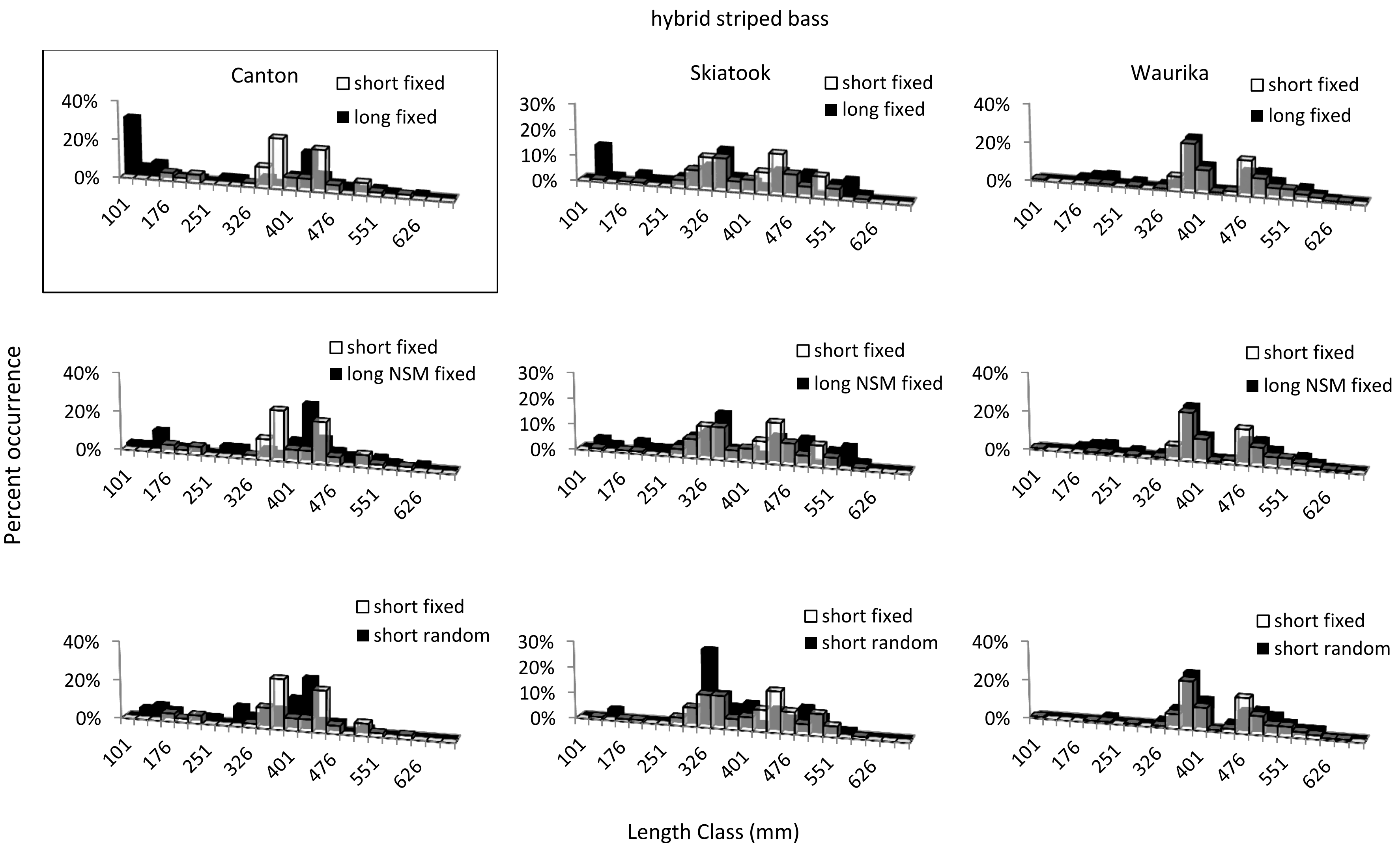

Figure 5. Length-frequency distributions of hybrid striped bass in short vs. long gill nets at fixed sites (top row), short vs. long nets with no shad mesh on the long nets (long NSM) at fixed sites, and short nets at fixed sites vs. short nets at random sites. Significantly different length-frequency distributions according to the Kolmogorov-Smirnov test are indicated with a box around the graph.

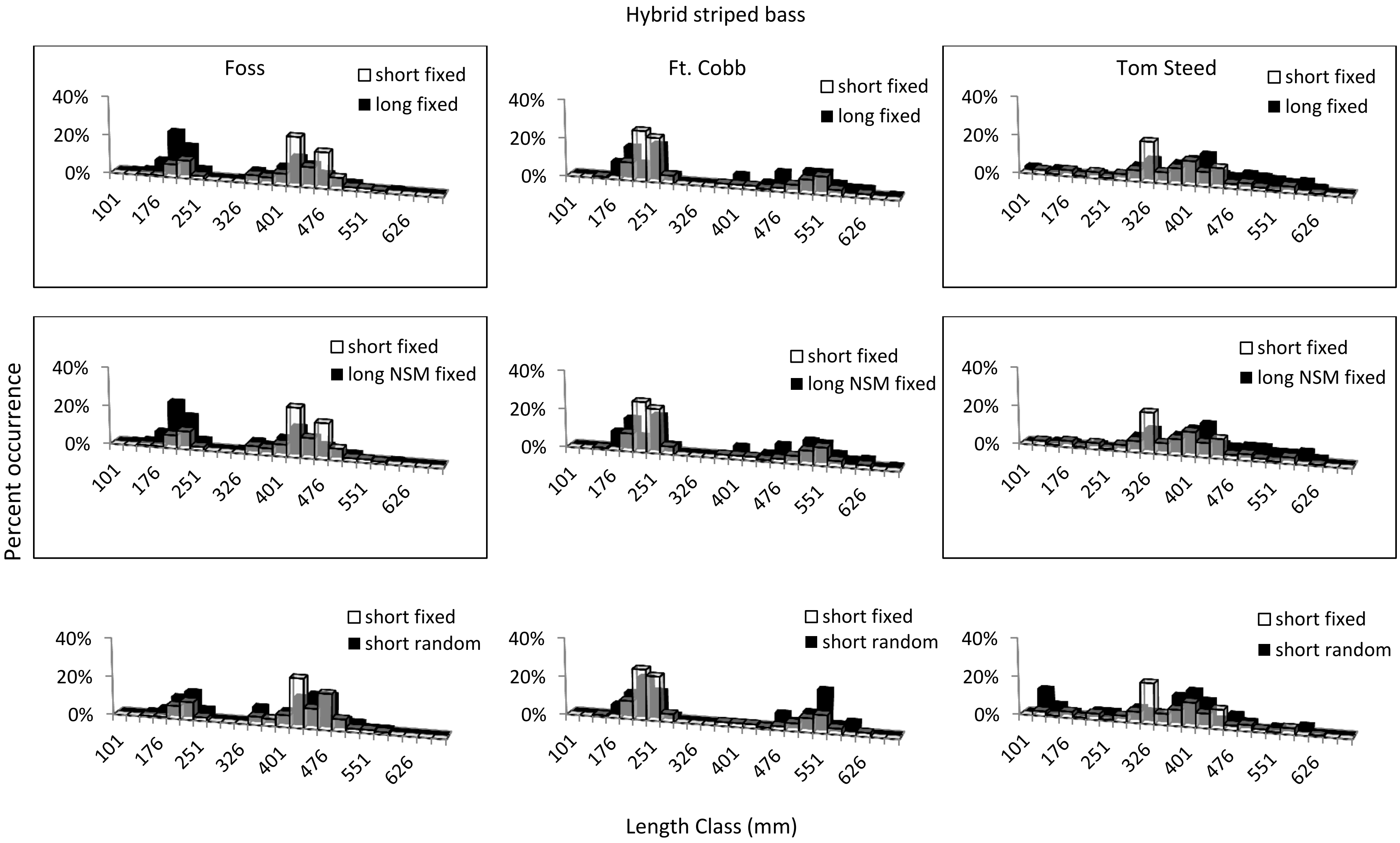

Figure 5b. Length-frequency distributions of hybrid striped bass in short vs. long gill nets at fixed sites (top row), short vs. long nets with no shad mesh on the long nets (long NSM) at fixed sites, and short nets at fixed sites vs. short nets at random sites. Significantly different length-frequency distributions according to the Kolmogorov-Smirnov test are indicated with a box around the graph.

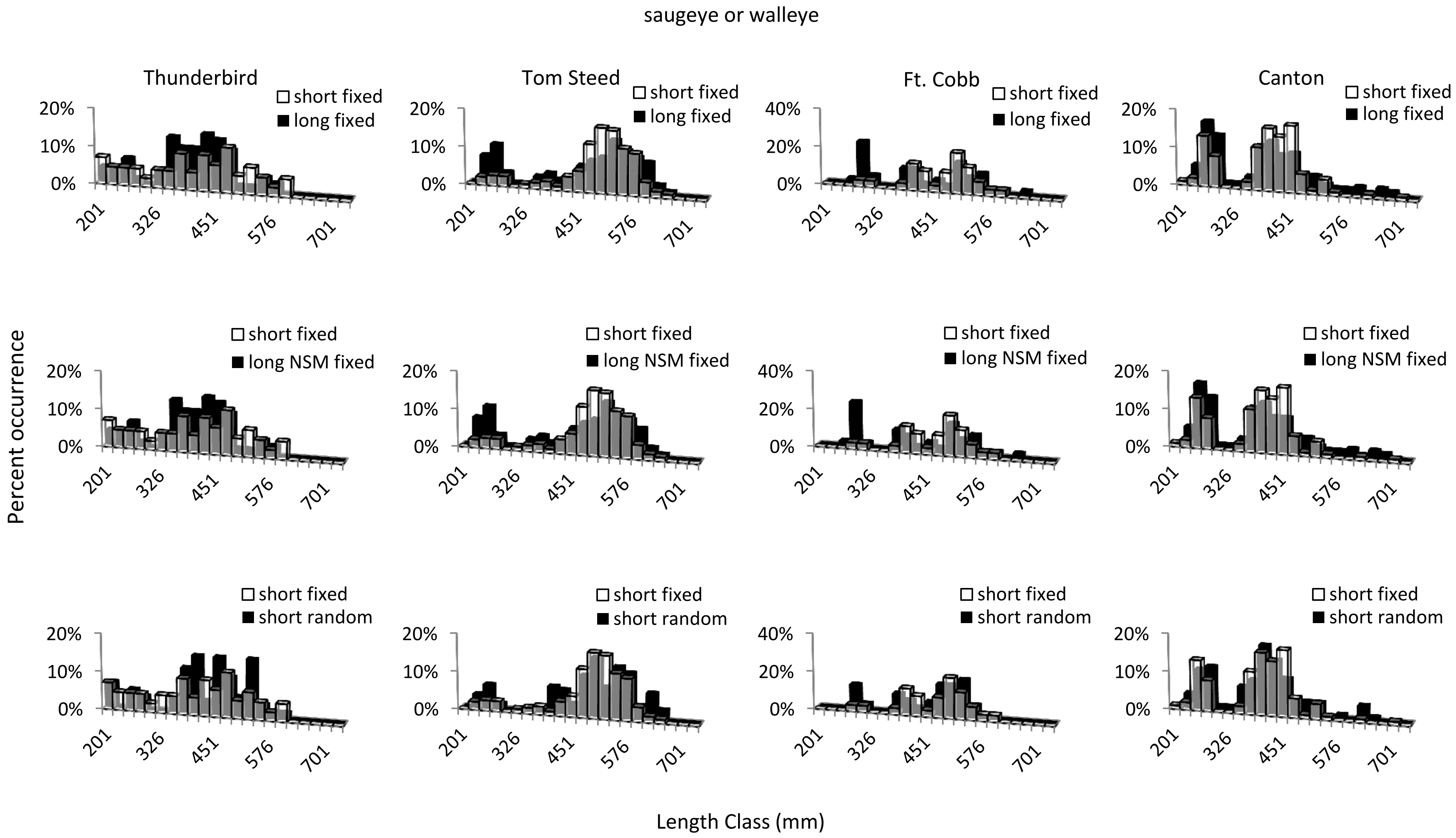

Figure 6. Length-frequency distributions of saugeye (Thunderbird, Tom Steed, and Ft. Cobb Reservoirs) and walleye (Canton Reservoir) in short vs. long gill nets at fixed sites (top row), short vs. long nets with no shad mesh on the long nets (long NSM) at fixed sites, and short nets at fixed sites vs. short nets at random sites. Significantly different length-frequency distributions according to the Kolmogorov-Smirnov test are indicated with a box around the graph.

CHAPTER II

Size Bias and Correction Factors for the North American Standard Gill Net

ABSTRACT

Gill nets are known to be size selective, but this bias can be corrected with the use of selectivity curves. I sampled eight reservoirs with the North American standard gill net to develop a large length-specific data set. I then used the SELECT method to find the best-fit selectivity model to adjust the gill net catch for contact selectivity. To determine the magnitude of these selectivity corrections, I compared adjusted and unadjusted length frequencies and size indices for channel catfish, white crappie, white bass, hybrid striped bass, saugeye, and walleye at each reservoir. The bimodal model was the best fit selectivity model for all species. When selectivity-adjusted length-frequency data were compared with the original data, one third of hybrid striped bass length-frequencies and two thirds of white bass length-frequencies were significantly different. Roughly one third of PSDs showed meaningful changes after selectivity adjustments were made. By correcting for contact selectivity the data are always improved (even if only subtly), and at times the adjustments can be large enough to alter management decisions. Therefore, I suggest that selectivity adjustments should become a part of routine data analysis for the North American standardized gill net design as they improve data for fisheries management.

INTRODUCTION

Gill nets are one of the most widely-used fisheries gears (Gablehouse et al. 1992). With this gear, fish are caught when they penetrate the mesh of the net and become wedge-held by mesh around the body or gilled-held by mesh slipping behind opercula, although sometimes fish are tangled by spines, teeth, or other protrusions without actually penetrating the mesh. Therefore, mesh size is an important factor influencing the size of fish captured in gill nets (Reddin 1986; Holst et al. 1998; Hubert et al 2012; Miranda and Boxrucker 2009). It is commonly accepted that fish caught in a given size of mesh typically differ in length by no more than 20% of the optimum length (Hamely 1975; Hamely 1980) causing gill nets to be strongly size selective. To minimize the length bias, “gangs” of differing mesh sizes (i.e., experimental gillnets) are often fished simultaneously; however, this does not completely eliminate selectivity (Hamely 1975). As a result, length-frequency distributions and associated size-structure indices such as proportional size distribution (PSD; formerly proportional stock density, Guy et al. 2007), from gill net catches may not give a true representation of the fish that contact the net (Hamely 1975; Willis et al. 1985; Wilde 1991; Ney 1993). Therefore, it is important to quantify gill net selectivity so corrections can be made to length frequency data collected with this gear.

There are two generally accepted methods for estimating gill net selectivity: direct and indirect (Millar and Fryer 1999). Direct estimates are made when a known (marked) population is sampled and the catch of a gear is directly compared to the known (marked) population. While direct studies may be common with other gear types and systems, few true direct studies using gill net in reservoirs can be found in the literature due to their infeasibility (Millar and Fryer 1999; Millar and Holst 1997). Only a few direct studies have been conducted using gill nets in inland reservoirs (Hamely and Reiger 1973; Bortstrom 1989, Pierce et al 1994; Jensen 1995; Anderson 1998). More often, indirect estimates are obtained by fishing different mesh sizes simultaneously and comparing the catch of each fish length class among mesh sizes (McCombie and Fry 1960, Holt 1963, Regier and Robson 1966, Willis et al. 1985, Boy and Crivelli 1988, Henderson and Wong 1991, Wilde 1991, Spangler and Collins 1992, Hansen et al. 1997, Millar and Holst 1997, Anderson 1998, Carol and Garcia-Berthou 2007, Vandergoot et al 2011). It is important to understand that indirect estimates only evaluate gill net selectivity for fish that make contact with the net (i.e., contact selectivity) and not the fish population as a whole (Hamely 1975).

Indirect gill net selectivity can be quantified with selectivity curves. Selectivity curves were first modeled as unimodal, bell-shaped curves (Hamely 1975), where the mode represents the optimum length of fish caught in a given mesh size and the width represents the selection range. The height of the curve corresponds to how efficiently that mesh catches fish of the optimum length. Data from multiple mesh sizes that were fished simultaneously are used to determine the probability of capture in each mesh size. The mesh size with the highest catch rate is used to scale the relative probability of capture in all other mesh sizes. As understanding of gill net selectivity progressed, other unimodal models were developed with longer skewed right limbs to account for fish that are caught in ways other than wedging (Millar and Fryer 1999). A bimodal model was also developed to account for fish caught by multiple methods (e.g., tangling and gilling; Hamely 1975). Currently, the five most commonly applied selectivity models are: normal, normal location, log normal, gamma, and bimodal (Millar and Fryer 1999; Table 1). Developing selectivity curves for individual lakes is impractical on a large scale (Wilde 1991). However, because selectivity is a function of fish morphology and the physics involved in the entanglement process, selectivity curves developed from a large data set for a species should be applicable to other similar systems where that species occurs.

Miranda and Boxrucker (2009) developed a gill net sampling protocol for the entire southern USA with the intention of standardizing gill net selectivity, deployment, effort, and timing of collection to reduce the variability that prevents among-system comparisons, and to do so at effort levels logistically feasible by most state agencies. They recommend the use of the North American standard gill net (Bonar et al. 2009), which is 24.8-m long by 1.8-m deep of eight 3.1-m panels with bar mesh sizes of 19, 25, 32, 38, 44, 51, 57, and 64 mm respectively with a 0.5 hanging ratio. These standard nets could prove useful for managers who want to compare gill net catches among lakes or even agencies; however, no one has examined the selectivity of these nets. Once the selectivity biases of a gear are identified, the catch can be adjusted to better represent the number of fish that contact the gear (Henderson and Wong 1991, Millar and Fryer 1999). To quantify selectivity bias for this new net design, I developed selectivity curves from pooled data for six species commonly monitored for sportfish management. The selectivity curves were developed from pooled data in order to be tool for managers that would be applicable to other reservoirs in the Southern USA. I then applied correction factors derived from the developed selectivity curves to data sets from each lake to determine how strongly the corrections affected length-based metrics.

METHODS

In 2009 and 2010, eight Oklahoma reservoirs (Canton, Thunderbird, Kaw, Waurika, and Tom Steed Reservoirs in 2009; Foss, Ft. Cobb, Skiatook, and Tom Steed Reservoirs in 2010) were sampled. Reservoirs sampled in each year received a total of 30 net-nights of effort in a given sample year (except Ft Cobb Reservoir which is smaller and only received 20 net-nights) using the net design and deployment methods recommended by Miranda and Boxrucker (2009). Gill nets were set perpendicular to the shoreline at depths typically ranging from 1.8 to 4.6 meters. Gill net sites were equally divided between fixed (sites sampled by the Oklahoma Department of Wildlife Conservation (ODWC) as part of routine sampling) and random locations (sampled specifically for this project) at each reservoir. Gill net catch was recorded by mesh size and total length (mm) and weight (g) were recorded for six target species: hybrid striped bass (*Morone chrysops x Morone saxatilis),* saugeye (*Sander canadense x Sander vitreus*), walleye (*Sander vitreus*), white bass (*Morone chrysops*), white crappie (*Pomoxis annularis*), and channel catfish (*Ictalurus punctatus*).

The catch data for each species was pooled across lakes and sites and selectivity curves for each target species were calculated using the SELECT (Share Each LEngthclass's Catch Total) method with PASSGEAR II v 2.4 software (Institute of Marine Research, 2010) following the approach of Millar and Holst (1997). Catch rates were calculated within 10-mm length classes. Because abundances of fish decrease with age, it is expected that there would be more small (young) fish than larger (older) fish in the population. However; many gears are biased against young-of-year fish resulting in length distributions with low abundances of small fish (Van Den Avyle and Hayward 1999). Therefore, I excluded smaller length classes that had extremely low catch rates from analysis (Table 2). Five different log-linear models (normal scale, normal location, log normal, gamma, and bimodal) were fit for each species by maximum likelihood (Table 1). The best-fit model for each species was then determined based on lowest model deviance most randomly distributed residuals (Millar and Holst 1997).

The selectivity curves were then used to adjust length-frequency distributions of each species at each lake (Holst et al. 1996; Hansen et al. 1997) to illustrate the magnitude of selectivity bias. Overall selectivity values (S_l, the probability of retention of fish from size class *l*) for the catch of all mesh sizes were calculated as:

$$S_l = \sum_j \left(\frac{s_j(l)}{max_l} \right)$$

where $S_j(l)$ = selectivity of size *l* in mesh *j*, and max_l = the largest selectivity { $s_j(l)$} observed among all length classes. Adjustments to the abundance of each length class (i.e., adjusted length frequency) were made by dividing the total number of fish captured in a given length class (catch from all mesh sizes pooled) by the overall net selectivity value (S_l) for that length class.

Using unadjusted and S_l-adjusted length frequency data, several typical fisheries size-distribution metrics were evaluated to illustrate the magnitude of the gill net’s selectivity bias. A Kolmogorov Smirnov (KS) test was used to test for differences in adjusted and unadjusted length distributions for each species at each lake. KS tests were evaluated as significant if $P < 0.05$. Length-frequency distributions for individual species and lake combinations were eliminated from analysis when they had unusually small sample sizes (i.e., when the number caught was below the lower end of that species' 95 % confidence interval of the state-wide mean sample size for the species based on the past 15 years of statewide gill net data (ODWC, unpublished data). PSD-Qs, PSD-Ps, and PSD-Ms from unadjusted and adjusted data were compared for each species at each sample lake. A change of less than 5 units in PSD was considered unimportant (Miranda 1993).

RESULTS

Up to 1,399 fish with a wide range of total lengths (TL) and relative weights (W_r) were used to develop selectivity curves for each species (Table 2-3). For all species, the bimodal model had the best fit, accounting for 71-88% of the variability in fish lengths caught among different mesh sizes (Table 3). For all species, some degree of size bias existed. Length classes with the lowest selectivity were retained 10-40% as frequently as the length classes with the highest selectivity, indicating these experimental gillnets were 2.5 – 10 times more likely to retain some length classes than others (Figure 1). Selectivity was typically lowest for smaller size classes. For white crappie, white bass, and saugeye, peak selectivity occurred near the upper end of the length distribution. For hybrid striped bass, walleye and channel catfish, peak selectivity occurred at slightly smaller lengths and selectivity strongly declined for the largest fish lengths.

Adjusted and unadjusted length distributions were similar at all lakes for channel catfish, saugeye, walleye, and white crappie, however significant differences occurred after adjustments for one third of the hybrid striped bass length-frequencies (Figure 2) and two thirds of the white bass length-frequencies (Figure 3) with a noticeable increase in the smaller length classes of the adjusted length distributions. The number of fish in the length frequency distributions ranged from 59 individuals (Ft. Cobb saugeye) to 456 individuals (Tom Steed white bass) with an average of 162 fish per lake and species combination.

PSD changes of ≥5-units occurred for 35 % of lake and species combinations (Table 4). For most species, changes ≥5 units typically occurred for PSD-Q and PSD-P categories. Only Ft. Cobb hybrid striped bass, Tom Steed white crappie, and Skiatook white crappie had PSD-Ms with selectivity adjustments that caused changes ≥ 5 units. The largest change between adjusted and unadjusted size indexes occurred for Skiatook white crappie PSD-Q, which was 15 units lower after adjustment using the selectivity curve. None of the channel catfish PSDs changed ≥ 5 units with selectivity adjustments.

DISCUSSION

To reduce size bias, the selectivity curves I derived for these six sportfish can be used by other researchers and managers to adjust catch data when using the North American standard (Miranda and Boxrucker 2009) gill net sampling protocol. Data can be adjusted by dividing the number of fish caught within a given 10-mm length class (from all mesh sizes combined) by the derived S_l value (the overall probability of retention; Appendix 1) for that given length class (Holst et al. 1996; Hansen et al. 1997).

Where S_l values are <1.0, this will increase the number of fish captured to account for the number of fish that were expected to have contacted the net without being retained. I derived these species-specific selectivity values using pooled data from multiple reservoirs to produce a generalized selectivity curve that is applicable to a variety of lakes within the southern USA. This should prove beneficial to researchers and managers because determining selectivity curves for individual lakes would be impractical on a large scale (Wilde 1991). However, these curves should not be applied outside of the scope for which they were developed (Hamely 1975; Willis et al. 1985). These selectivity curves should only be applied in similar contexts to where they were derived (i.e., applied to the species for which they were developed using fall sampling data from the North American standardized gillnet [Bonar et al. 2009]).

The act of capturing fish in a gill net is a mechanical process that depends on the relative geometry of the mesh and the fish (Hamely 1975). As such, fish with dramatically different W_rs may have different selectivity's in the same mesh size. As long as there are no major differences in body condition of a species in a prospective body of water, these selectivity curves could be used for adjusting the catch of that population (Kurkilahti et al. 2002). To allow W_rs to be evaluated, I provide the total length and W_r ranges for my study populations (Table 2). Managers and researchers should not apply these curves to length classes that fall outside my range of TLs or for populations with W_rs that strongly differ from the fish observed in this study.

Because the gill net selectivity was lower for large hybrid striped bass and channel catfish, the addition of the optional large mesh sizes (i.e., 76-, 89-, and 102-mm bar mesh) specified by Miranda and Boxrucker (2009) might be useful for sampling these species. Additional research would be needed to refine these selectivity curves for a gill net design with these optional mesh sizes. The walleye selectivity curve was derived using data from two populations, and was therefore based on a smaller number of fish (N=242). This produced a data set with less variability in Wr and potentially a less uniform length distribution. Further research is needed to validate this selectivity curve.

The magnitude of a selectivity curve's adjustment on a length-frequency distribution will depend in part on the proportion of fish in length classes that had very high (S_l near 1.0) or low (S_l closer to 0 than to 1.0) selectivity. When fish are abundant in length classes with low selectivity, the effect of the selectivity curve's adjustment will be more pronounced (i.e., the number of fish in the length class is divided by a number that is close to zero, resulting in a large adjusted value). When fish are abundant in length classes with high selectivity, adjustments will be minor (i.e., the number of fish in that length class is divided by a number very close to 1, resulting in an adjusted value very similar to the original value). Therefore, these selectivity curves could produce strong adjustments in some populations but only minor differences in others.

The selectivity curves indicate that, of the fish that contacted the net, the gill nets were most effective at retaining mid-sized fish. Despite strong (2.5-10 fold) size-specific differences in the probability of retention for all species, the adjusted and unadjusted length-frequency distributions differed for only hybrid striped bass and white bass at some of the sample lakes. This suggests that the use of these selectivity curves may not be necessary in all cases; however, the magnitude of adjustment will be a function of the number of fish captured in length classes that had poor retention (i.e., larger adjustment effects will occur when larger numbers of fish are captured in these length classes). It is particularly important to use these corrections when very small or large length classes are of interest, such as when looking at recruitment or sampling trophy fisheries respectively, because of the inherent bias of the North American standard gill net against these size classes.

The effects of the selectivity curve corrections on PSD data were more pronounced and affected mores species than the effects of selectivity on length-frequency distributions. Roughly one third of the lake and species combinations had changes in PSDs that were are potentially meaningful to managers. Miranda (1993) suggests that a change in PSD of less than 5 units has little practical importance in fishery management situations, presumably because smaller changes would not be perceivable by anglers. Therefore, I used this as a conservative estimate for identifying when differences between adjusted and unadjusted PSD values might be relevant for management decisions. Even with this conservative cutoff for determining important changes to PSDs, I found about one third of the lake and species combinations had contact selectivity adjustments that were this large. The magnitude of change in PSD was pronounced in some cases. The largest magnitude of change occurred for white crappie at Skiatook Reservoir, in which the unadjusted gillnet overestimated PSD-Q by 15-units. However, for the majority of other comparisons, selectivity curve adjustments made little difference in the PSD values. This was particularly true for channel catfish.

It is possible that small sample sizes played a role in the ability to detect changes between unadjusted and adjusted length frequency or PSD values. Anderson and Neumann (1996) recommend at least 100 fish for estimating PSD. Vokoun et al. (2001) suggest 300-400 fish are needed for accurate length frequency analysis whereas Miranda

(2007) suggests a sample size of 375-1,200 fish may be needed (when using 10-mm length groupings). Miranda (1993) suggests approximately 1,000-1,500 fish are needed to detect a change in PSD of 5 units and 200-400 fish to detect a change of 10 units at an alpha level of 0.05. My length-frequency sample sizes averaged 162 per species, ranging from 59-456 fish. Therefore, it is possible the inherently low catch rates of gill nets produced too few fish to detect changes of some adjusted and unadjusted length frequencies. However, these sample sizes are typical or even larger than average compared with the sample sizes of most researchers or state agencies that collect data with this gear. I used a larger number of replicate net nights (N = 30 for most reservoirs) than is typically used by other state agencies (Bonar 2012). Further, mean catch rates of my study lakes were between the 62nd and 99th percentiles for the Oklahoma statewide average catch rate for the target species (ODWC, unpublished data). This underscores the importance of adequate replication pointed out by Vokoun et al. (2001) and Miranda (2007). However, the number of replicate net sets required to achieve adequate sample sizes for length analyses may be impractical in many cases. In these situations, researchers and managers need to recognize that length-based data will lack precision and contact-selectivity corrections may be very small relative to the large variability inherent in these smaller data sets.

Gill net selectivity curves have been much less used in inland fisheries than in marine fisheries (e.g., Stewart 2002 compiled a review of 116 publications dealing with gear selectivity in the Mediterranean Sea alone), but the few that have demonstrated that significant changes in some of the length-frequency or PSD values can occur when corrections are made. Willis et al (1985) found a significant increase in gizzard shad

PSD and decrease in white bass PSD using selectivity-corrected values, but walleye PDS values were not significantly altered by selectivity adjustments when “smoothing” length frequency histograms to calculate correction factors . Beamesderfer and Rieman (1988) found 11-46% differences in adjusted and unadjusted PSDs for smallmouth bass, walleye, and northern squawfish using mark-recapture methods to determine selectivity corrections (their study accounted for encounter selectivity as well as contact selectivity). Wilde (1991) used a normal skew curve for white bass and found small differences in adjusted and unadjusted PSDs with no consistent patterns (i.e., selectivity adjustments cause increased PSDs in some systems and decreased PSDs in others). Hansen et al. (1997) found the abundance of lake trout in some age classes were underestimated by as much as 20% before selectivity adjustments were made. The net configurations and methods for calibrating selectivity curves differed among these studies, making comparisons of these curves difficult. However, these results and those of the current study illustrate the importance of using selectivity adjustments, at least for some populations. Using selectivity corrections would minimize bias of age- and length-based population models, estimations of population length frequencies, and estimations of mortality derived from standardized gill net data (Millar and Fryer 1999).

Given the recently recommended standardization in data collection for the freshwater fisheries community (Bonar et al. 2009), selectivity correction values provided by this study could be easily implemented by anyone using the new standard gill net design to improve the quality of the data collected by this gear. Fisheries managers are often limited in the decision making process to information provided by biased gears (Krueger and Decker 1999). Although gill nets are inherently size biased, they are still widely used by managers (Gablehouse et al. 1992). By correcting for contact selectivity, fish length data collected with gill nets will always be improved (even if only subtly in some cases), and at times the adjustments can be large enough to affect management decisions. Therefore, I suggest selectivity adjustments should become a part of routine data analysis for the North American standardized gill net design.

REFERENCES

Anderson, C.S. 1998. Partitioning total size selectivity of gill nets for walleye (*Stizostedion vitreum*) into encounter, contact, and retention components. Canadian Journal of Fisheries and Aquatic Sciences. 55:1854-1863.

Anderson, R.O. and R.M. Neumann. 1996 Length, weight, and associated structural indices. Pages 447-482 *in* B.R. Murphy and D.W. Willis editors. Fisheries techniques, 2nd edition. American fisheries Society, Bethesda, Maryland.

Beamesderfer, R.C. and B.E. Rieman. 1988. Size selectivity and bias of population statistics of smallmouth bass, walleye, and northern squawfish in a Columbia River reservoir. North American Journal of Fisheries Management. 8:505-510.

Bonar, S.A. 2012. Existing State Provincial Standard Sampling Protocols. Available: http://www.cals.arizona.edu/research/azfwru/scott/scott_overviewProtocols.htm. (December 2012.)

Borgstram, R. 1989. Direct estimation of gill-net selectivity for roach (*Rutilus rutilus (L.*)) in a small lake. Fisheries Research, 7: 289-298.

Boy, V. and A.J. Crivelli. 1988. Simultaneous determination of gillnet selectivity and population age-class distribution for two cyprinids. Fisheries Research. 6:337-345.

Carol, J. and E. Garcia-Berthou. 2007. Gillnet selectivity and its relationship with body shape for eight freshwater fish species. Journal of Applied Ichthyology. 23:654-660.

Gabelhouse, D., and 20 coauthors. 1992. Fish sampling and data analysis techniques used by conservation agencies in the U.W. and Canada. American Fisheries Society, Fisheries Management Section, Bethesda, Maryland.

Guy, C. S., R. M., Neumann, D. W. Willis, and R. O. Anderson. 2007. Proportional size distribution: a further refinement of population size structure index terminology. *Fisheries*. 32(7):348.

Hamely, J.M. and H.A. Regier. 1973. Direct estimates of gillnet selectivity of walleye (*Stizostedion vitreum vitreum*). Journal of the Fisheries Research Board of Canada. 30:817-830.

Hamely, J.M. 1975. Review of gillnet selectivity. Journal of the Fisheries Research Board of Canada. 32:1943-1969.

Hamely, J.M. 1980. Sampling with gill nets. Pages 37-53 *in* T.Bachiel and R.L. Welcomme, editors. Guidelines for sampling fish in inland waters. Food and Agriculture Organization of the Unites Nations, European Inland Fisheries Advisory Commission Technical Paper 33, Rome Italy.

Hansen. M.J., C.P. Madenjian. J.H., Selgeby, and T.E. Helser. 1997. Gillnet selectivity for lake trout (*Salvelinus namaycush*) in Lake Superior. Canadian Journal of Fisheries and Aquatic Sciences. 54:2483-2490.

Henderson, B. A. and J.L. Wong. 1991. A method for estimating gillnet selectivity of walleye (*Stizostedion vitreum vitreum*) in multimesh multifilament gill nets in Lake Erie, and its applications. Canadian Journal of Fisheries and Aquatic Sciences. 48:2420-2428.

Holt, S.J. 1963. A method for determining gear selectivity and its application ICNAF Special Publication. 5:106-115.

Holst, R., Madsen, N., Moth-Poulsen, T, Fonseca, P., Campos, A. 1996. Manual for Gillnet Selectivity. European Commission.

Hubert, Hubert, W. A., K. L. Pope, and J. M. Dettmers. 2012. Passive capture techniques. Pages 223-265 *in* A. V. Zale, D. L. Parrish, and T. M. Sutton, editors. Fisheries techniques, 3rd edition. American Fisheries Society, Bethesda, Maryland.

Institute of Marine Research. 2010. Passgear II v 2.4. Havforskningsinstituttet. http://www.imr.no/forskning/bistandsarbeid/data/pasgear_2/en. July 2010.

Jensen, J.W. 1995. A direct estimate of gillnet selectivity for brown trout. Journal of Fish Biology. 46:857-861.

Krueger, C.C. and D.J. Decker. 1999. The process of fisheries management. Pages 31-59 *in* C.C. Kohler and W.A. Hubert, editors. Inland fisheries management in North America. American Fisheries Society, Bethesda, Maryland.

Kurkilahit, M., M. Appelberg, T. Hesthagen, and M. Rask. 2002. Effect of fish shape on gillnet selectivity: a study with Fultons's condition factor. Fisheries Research. 54:153-170.

McCombie, A.M. and F.E.J. Fry. 1960. Selectivity of gill nets for Lake Whitefish, *Coregonus clupeaformis*. Transactions of the American Fisheries Society. 89(2):176-184.

Millar, R.B. and R. Holst. 1997. Estimation of gillnet and hook selectivity using log-linear models. Journal of Marine Science. 54:471-477.

Millar, R.B. and R.J. Fryer. 1999. Estimating the size-selection curves of towed gears, traps, nets, and hooks. Reviews in Fish Biology and Fisheries. 9:89-116.

Miranda, L.E. 1993. Sample sizes for estimating and comparing proportion-based indices. North American Journal of Fisheries Management. 13:383-386.

Miranda, L.E. 2007. Approximate sample sizes required to estimate length distributions. Transactions of the American Fisheries Society. 136:409-415.

Miranda, L.E. and J. Boxrucker. 2009. Warmwater fish in standing waters. Pages 29-42 *in* S.A. Bonar, W.A. Hubert, and D.W. Willis, editors. Standard methods for sampling North American freshwater fishes. American Fisheries Society, Bethesda, Maryland.

Ney, J.J. 1999. Practical use of biological statistics. Pages 167-191 *in* C.C. Kolker, and W.A. Hubert, editors. Inland fisheries management in North America. American Fisheries Society, Bethesda, Maryland.

Pierce, R.B., C.M. Tomcko, and T.D. Kolander. 1994. Indirect and direct estimates of gill-net size selectivity for northern pike. North American Journal of Fisheries Management 14:170-177.

Reddin, D.G. 1986. Effects of different mesh sizes on gill-net catches of Atlantic salmon in Newfoundland. North American Journal of Fisheries Management 6:209-215.

Regier, H.A. and D.S. Robson, 1996. Selectivity of gillnets, especially to lake whitefish. Journal of Fisheries Research Board of Canada. 23:423-454.

Spangler, G.R. and J.J. Collins. 1992. Lake Huron fish community structure based on gill-net catches corrected for selectivity and encounter probability. North American Journal of Fisheries Management. 12:585-597.

Stewart, P.A. 2002. A review of studies of fishing gear selectivity in the Mediterranean. COPEMED Report No. 9, 57pp.

Van Den Avyle, M.J. and R.S. Hayward. 1999. Dynamics of exploited fish populations. Pages 127-166 *in* C.C Kohler, and W.A. Hubert, editors. Inland fisheries management in North America. American Fisheries Society, Bethesda Maryland.

Vandergoot, C.S., P.M. Kocovsky, T.O. Brenden, and W. Liu. 2011 Selectivity evaluation for two experimental gill-net configurations used to sample Lake Erie walleyes. North American Journal of Fisheries Management. 31:832-842.

Vokoun, J.C., C.F. Rabeni, and J.S. Stanovick. 2001. Sample-size requirements for evaluating population size structure. North American Journal of Fisheries Management. 21:660-665.

Wilde, G.R. 1991. Gill net selectivity and size structure in white bass. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies. 45:470-476.

Willis, D.W., K.D. McCloskey, and D.W. Gabelhouse, Jr. 1985. Calculation of stock density indices based on adjustments for efficiency of gill-net mesh size. North American Journal of Fisheries Management. 5:126-137.

Table 1. Equations and model parameters for five selectivity models used in Passgear II v 2.4. Equations relate the mesh size *j* (m_j) with the number of fish of length *l* captured in that mesh size. Other symbols used in equations are constants.

Model (*constants*)	Selection Curve Equation $\{S_j(l)\}$
Normal scale (k_1, k_2)	$\exp\left(-\frac{(l - k_j * m_j)^2}{2k_2^2 * m_j^2}\right)$
Normal location (k, σ)	$\exp\left(-\frac{(l - k * m_j)^2}{2\sigma^2}\right)$
Log Normal (μ, σ)	$\frac{m_j}{l * m_1}\, exp\left(\mu - \frac{\sigma^2}{2} - \frac{\left(\log(l) - \mu - \log\left(\frac{m_j}{m_1}\right)\right)^2}{2\sigma^2}\right)$
Gamma (α, k)	$\left(\frac{l}{(\alpha - 1) * k * m_j}\right)^{\alpha - 1} exp\left(\alpha - 1 - \frac{l}{k * m_j}\right)$
Bimodal $(k_1, k_2, k_3, k_{4,\,c})$	$exp\left(-\frac{\left(l - k_1 * m_j\right)^2}{2k_2^2 * m_j^2}\right) + c\ exp\left(-\frac{\left(l - k_3 * m_j\right)^2}{2k_4^2 * m_j^2}\right)$

Table 2. Range of total lengths (TL, mm) and relative weights (Wr) of fish used to fit selectivity models for the North American standard gill net (Bonar et al. 2009) using the SELECT method. Fish were sampled from eight Oklahoma reservoirs. Average Wr and Wr standard error (SE) are also shown.

Species	TL	Wr	Avg Wr	Wr SE
white crappie	111-380	68-134	98	0.41
white bass	121-510	40-133	91	0.30
hybrid striped bass	121-660	56-119	83	0.27
saugeye	191-670	66-119	92	0.38
walleye	191-720	62-106	85	0.59
channel catfish	121-860	62-113	85	0.37

Table 3. Model parameters, residual deviance, degrees of freedom (d.f.), 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 method. The model with the lowest deviance for each of six species is bolded. Input for models came from gill net catches from eight Oklahoma reservoirs using the North American standard gill net (Bonar et al. 2009).

Species	model	constants												Deviance	d.f.	R^2
white crappie n = 954	N. Scale	k_1	=	7.43	k_2	=	1.82							655.90	146	0.60
	N. Location	k	=	6.43	σ	=	66.32							666.96	146	0.59
	Log-normal	μ	=	4.94	σ	=	0.27							600.22	146	0.65
	Gamma	α	=	0.05	k	=	15.92							594.32	146	0.65
	Bimodal	**k_1**	**=**	**6.48**	**k_2**	**=**	**0.61**	**k_3 =**	**9.16**	**k_4 =**	**3.27**	**c =**	**0.18**	**285.63**	**143**	**0.87**
white bass n = 1399	N. Scale	k_1	=	8.94	k_2	=	1.89							610.56	173	0.78
	N. Location	k	=	8.08	σ	=	73.48							711.45	173	0.76
	Log-normal	μ	=	5.13	σ	=	0.24							646.97	173	0.80
	Gamma	α	=	0.46	k	=	19.75							603.42	173	0.80
	Bimodal	**k_1**	**=**	**7.97**	**k_2**	**=**	**0.73**	**k_3 =**	**10.02**	**k_4 =**	**2.75**	**c =**	**0.30**	**335.72**	**170**	**0.88**
hybrid striped bass n = 1041	N. Scale	k_1	=	10.71	k_2	=	4.00							646.45	244	0.65
	N. Location	k	=	9.09	σ	=	108.51							460.49	244	0.76
	Log-normal	μ	=	5.30	σ	=	0.31							480.67	244	0.75
	Gamma	α	=	1.05	k	=	10.45							520.24	244	0.72
	Bimodal	**k_1**	**=**	**8.99**	**k_2**	**=**	**1.18**	**k_3 =**	**15.73**	**k_4 =**	**6.05**	**c =**	**0.20**	**303.55**	**241**	**0.84**
saugeye n = 528	N. Scale	k_1	=	13.06	k_2	=	4.64							288.48	182	0.66
	N. Location	k	=	11.20	σ	=	116.53							207.31	182	0.77
	Log-normal	μ	=	5.50	σ	=	0.29							227.39	182	0.75
	Gamma	α	=	1.15	k	=	11.61							245.13	182	0.72
	Bimodal	**k_1**	**=**	**11.40**	**k_2**	**=**	**1.72**	**k_3 =**	**19.84**	**k_4 =**	**7.65**	**c =**	**0.15**	**173.45**	**179**	**0.79**
walleye n = 242	N. Scale	k_1	=	12.49	k_2	=	2.57							143.50	105	0.65
	N. Location	k	=	11.14	σ	=	105.66							169.57	105	0.62
	Log-normal	μ	=	5.47	σ	=	0.25							154.28	105	0.67
	Gamma	α	=	0.66	k	=	19.35							147.75	105	0.67
	Bimodal	**k_1**	**=**	**10.97**	**k_2**	**=**	**1.00**	**k_3 =**	**13.62**	**k_4 =**	**3.32**	**c =**	**0.55**	**130.43**	**102**	**0.71**
channel catfish n = 769	N. Scale	k_1	=	11.87	k_2	=	4.11							366.48	260	0.67
	N. Location	k	=	10.00	σ	=	129.09							315.59	260	0.73
	Log-normal	μ	=	5.41	σ	=	0.34							323.27	260	0.73
	Gamma	α	=	1.26	k	=	9.67							323.89	260	0.72
	Bimodal	**k_1**	**=**	**10.04**	**k_2**	**=**	**1.28**	**k_3 =**	**14.75**	**k_4 =**	**6.05**	**c =**	**0.28**	**225.09**	**257**	**0.81**

Table 4. Proportional size distributions (PSD) of six species for unadjusted and adjusted (via bimodal selectivity curves) gill net catches from eight Oklahoma reservoirs. Changes of ≥ 5 units, which may be of importance to fisheries managers, are bolded.

	PSD-Quality		PSD-Preferred		PSD-Memorable	
Reservoir	Original	Adjusted	Original	Adjusted	Original	Adjusted
white crappie						
Tom Steed	**82**	**75**	**45**	**36**	**20**	**15**
Waurika	98	97	88	85	12	11
Thunderbird	**37**	**29**	10	6	4	2
Skiatook	**64**	**49**	**47**	**34**	**15**	**10**
Kaw	**79**	**70**	**49**	**40**	18	14
Ft. Cobb	98	97	90	88	12	11
hybrid striped bass						
Tom Steed	91	87	**60**	**55**	9	10
Waurika	97	96	85	83	25	27
Skiatook	97	96	53	50	17	17
Ft. Cobb	**41**	**32**	**41**	**32**	**31**	**25**
Foss	**78**	**66**	**72**	**61**	10	9
Canton	94	90	71	67	7	8
white bass						
Tom Steed	97	94	**67**	**61**	24	20
Waurika	**55**	**44**	**31**	**23**	7	4
Thunderbird	**88**	**81**	**31**	**25**	1	1
Skiatook	94	91	**82**	**77**	4	4
Ft. Cobb	**78**	**73**	15	11	6	4
Canton	**72**	**61**	**65**	**54**	11	9
saugeye						
Tom Steed	**90**	**84**	**76**	**68**	28	25
Waurika	98	95	98	95	57	56
Thunderbird	**85**	**78**	**47**	**40**	7	6
Ft. Cobb	**88**	**82**	**64**	**57**	10	9
walleye						
Canton	**71**	**63**	10	8	3	2
Foss	**81**	**76**	**33**	**28**	0	0
channel catfish						
Tom Steed	53	51	14	18	4	7
Waurika	35	31	0	0	0	0
Thunderbird	72	68	0	0	0	0
Skiatook	47	44	2	3	2	3
Ft. Cobb	61	57	11	12	1	2
Foss	87	85	10	11	0	0
Canton	91	89	4	5	0	0

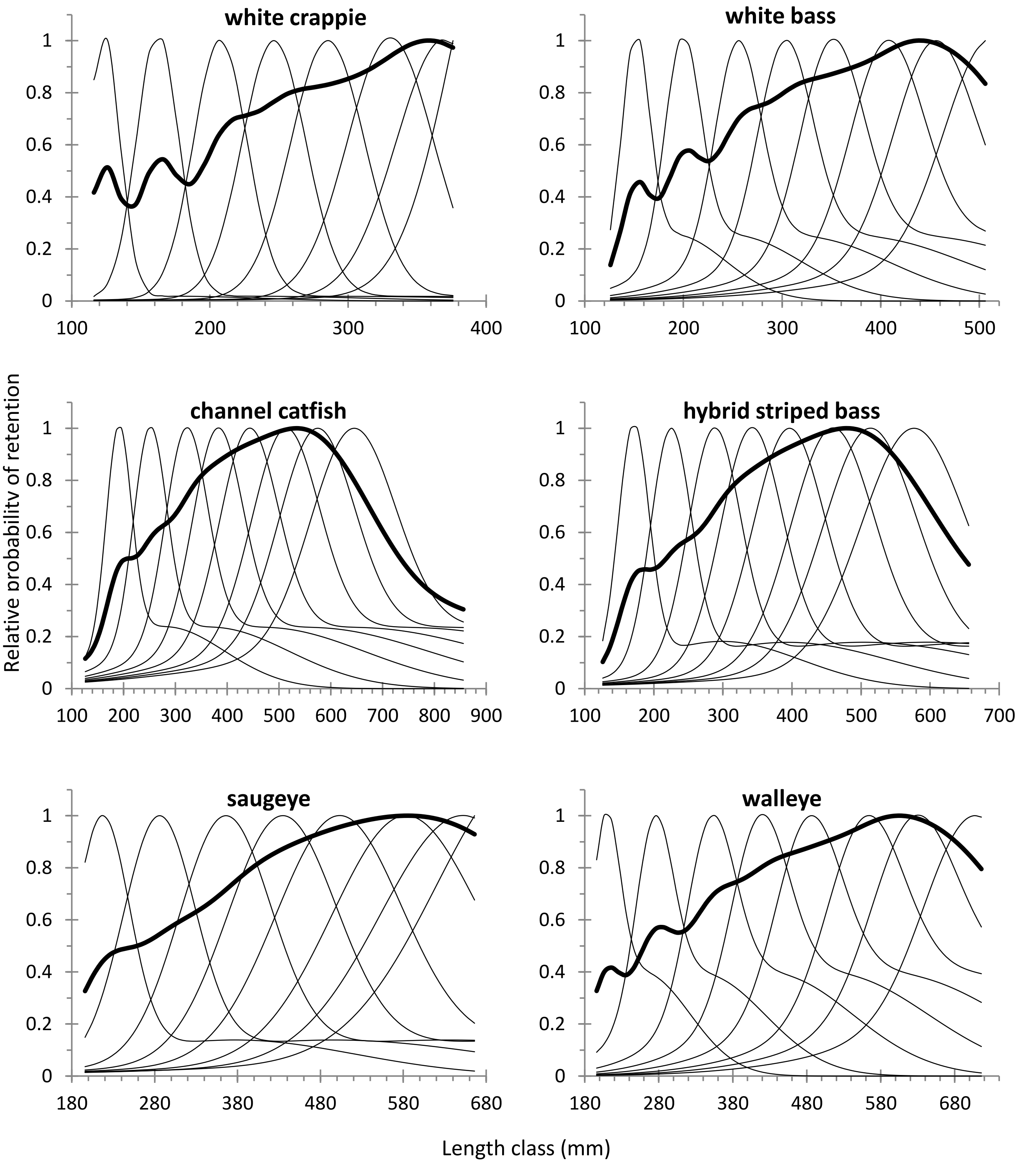

Figure 1. Overall selectivity curves (thick dark line) for the North American standard gill net (Bonar et al. 2009) using a bimodal model for six sportfish species based on data from eight southern reservoirs. The eight individual curves (thin lines) represent selectivity of individual meshes (19, 25, 32, 38, 44, 51, 57, and 64-mm bar mesh from left to right).

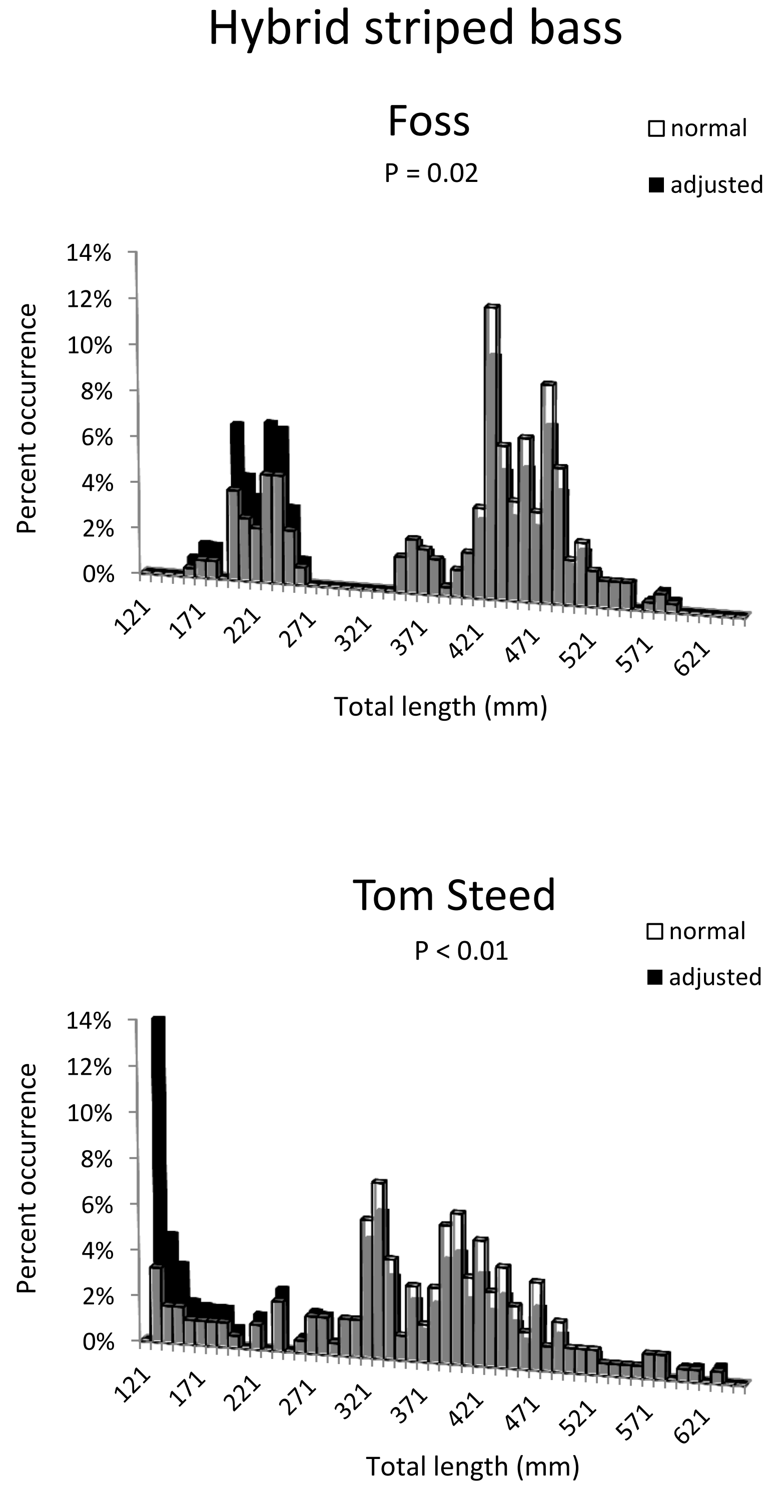

Figure 2. Significantly different Length distributions using Kolmogorov-Smirnov test for hybrids striped bass after adjusted using the developed selectivity correction curve.

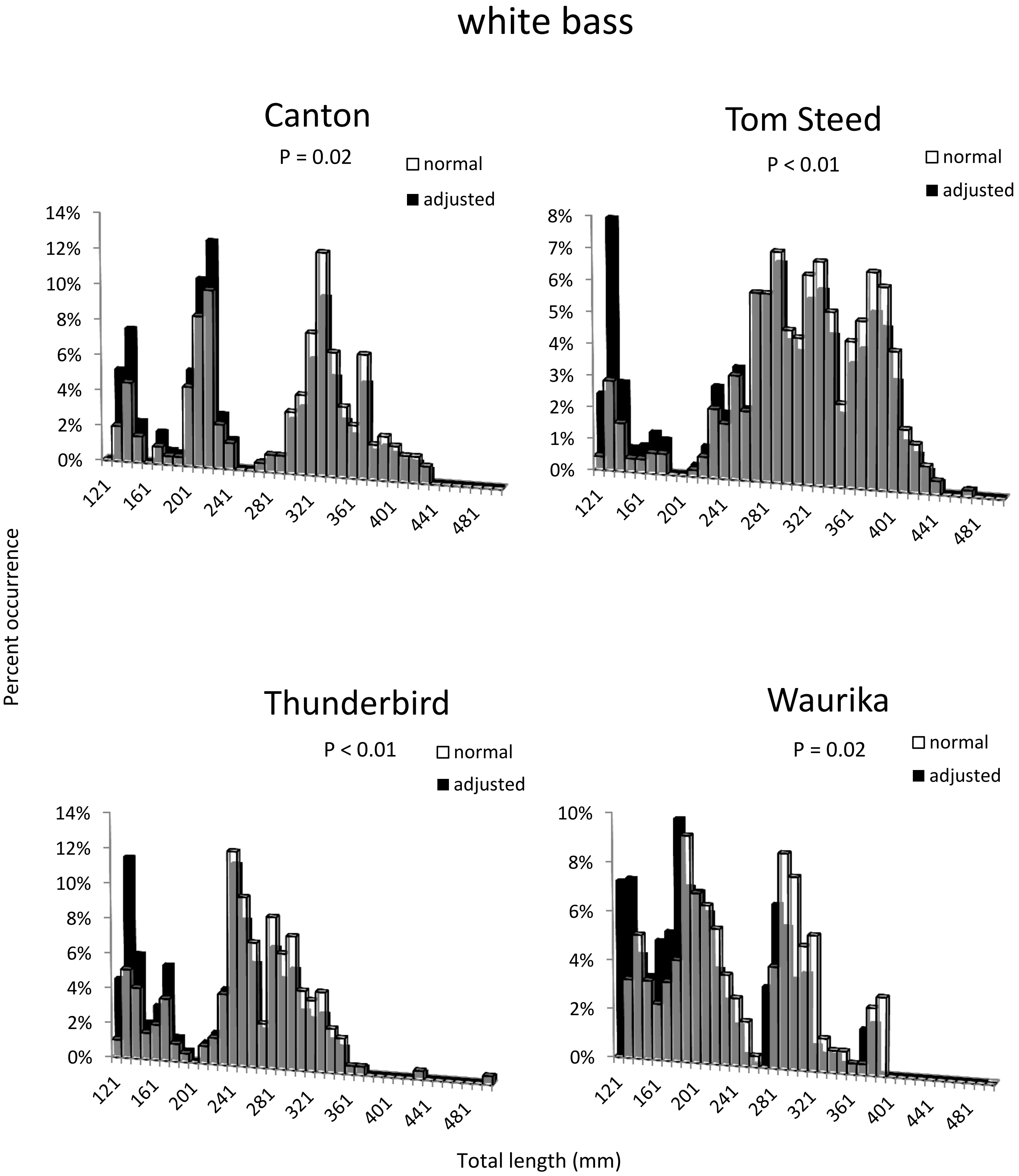

Figure 3. Significantly different length distributions using Kolmogorov –Smirnov test for white bass after adjusted using the developed selectivity correction curve.

Appendix 1. Relative probability of retention (Rel S_l) derived from the bimodal model for six fish species captured in the North American standard gill net (Bonar et al. 2009). These values can be used to correct for gill net size bias resulting from contact selectivity by dividing the number of fish captured in each length class by the Rel S_l value for that length class.

	Rel S_l					
length class	white crappie	white bass	saugeye	walleye	hybrid striped bass	channel catfish
111-120	0.42					
121-130	0.51	0.14			0.10	0.12
131-140	0.39	0.27			0.16	0.14
141-150	0.37	0.41			0.24	0.18
151-160	0.49	0.46			0.33	0.23
161-170	0.54	0.41			0.41	0.31
171-180	0.48	0.40			0.45	0.38
181-190	0.45	0.47			0.46	0.45
191-200	0.52	0.56	0.33	0.33	0.46	0.49
201-210	0.63	0.58	0.39	0.40	0.47	0.50
211-220	0.69	0.55	0.44	0.42	0.49	0.50
221-230	0.71	0.54	0.47	0.40	0.52	0.51
231-240	0.73	0.57	0.48	0.39	0.55	0.53
241-250	0.76	0.64	0.49	0.41	0.57	0.56
251-260	0.80	0.70	0.50	0.47	0.58	0.59
261-270	0.81	0.73	0.51	0.53	0.61	0.61
271-280	0.82	0.75	0.52	0.57	0.64	0.63
281-290	0.83	0.76	0.54	0.57	0.68	0.64
291-300	0.85	0.78	0.57	0.56	0.72	0.66
301-310	0.87	0.81	0.59	0.55	0.75	0.69
311-320	0.89	0.83	0.60	0.56	0.78	0.72
321-330	0.92	0.85	0.62	0.59	0.81	0.75
331-340	0.96	0.86	0.64	0.63	0.83	0.78
341-350	0.99	0.87	0.66	0.67	0.85	0.81
351-360	1.00	0.88	0.69	0.70	0.87	0.83
361-370	1.00	0.89	0.72	0.72	0.88	0.85
371-380	0.97	0.90	0.74	0.74	0.90	0.86
381-390		0.92	0.77	0.75	0.91	0.88
391-400		0.94	0.80	0.76	0.93	0.89
401-410		0.96	0.82	0.78	0.94	0.90
411-420		0.98	0.84	0.80	0.95	0.92
421-430		0.99	0.86	0.81	0.96	0.93
431-440		1.00	0.87	0.83	0.97	0.94
441-450		1.00	0.89	0.84	0.98	0.94
451-460		0.99	0.90	0.85	0.99	0.95

461-470	0.97	0.92	0.86	1.00	0.96
471-480	0.95	0.93	0.87	1.00	0.97
481-490	0.92	0.94	0.88	1.00	0.98
491-500	0.88	0.95	0.89	0.99	0.98
501-510	0.83	0.96	0.90	0.99	0.99
511-520		0.97	0.91	0.97	1.00
521-530		0.98	0.92	0.95	1.00
531-540		0.98	0.93	0.93	1.00
541-550		0.99	0.95	0.90	1.00
551-560		0.99	0.96	0.87	0.99
561-570		1.00	0.97	0.83	0.98
571-580		1.00	0.98	0.79	0.97
581-590		1.00	0.99	0.75	0.96
591-600		1.00	1.00	0.71	0.94
601-610		1.00	1.00	0.67	0.91
611-620		0.99	1.00	0.63	0.89
621-630		0.98	0.99	0.59	0.86
631-640		0.97	0.98	0.55	0.83
641-650		0.96	0.97	0.51	0.80
651-660		0.95	0.95	0.48	0.76
661-670		0.93	0.94		0.73
671-680			0.91		0.69
681-690			0.89		0.66
691-700			0.86		0.62
701-710			0.83		0.59
711-720			0.80		0.56
721-730					0.52
731-740					0.50
741-750					0.47
751-760					0.44
761-770					0.42
771-780					0.40
781-790					0.38
791-800					0.37
801-810					0.35
811-820					0.34
821-830					0.33
831-840					0.32
841-850					0.31
851-860					0.30

VITA

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Candidate for the Degree of

Master of Science

Thesis: TRANSITIONING TO THE NORTH AMERICAN STANDARD GILL NET: SIZE SELECTIVITY CORRECTIONS AND THE EFFECTS OF NET DESIGN ON CPUE, SIZE STRUCTURE, AND SITE SELECTION

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Title of Study: TRANSITIONING TO THE NORTH AMERICAN STANDARD GILL NET: SIZE SELECTIVITY CORRECTIONS AND THE EFFECTS OF NET DESIGN ON CPUE, SIZE STRUCTURE, AND SITE SELECTION

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Scope and Method of Study: The Oklahoma Department of Wildlife Conservation (ODWC) has used Standardized Sampling Procedures (SSP) to monitor fish populations in Oklahoma waters since 1977. The gill net configuration suggested by Miranda and Boxrucker (2009) for the entire southern USA was recently adopted by ODWC. This change in standard sampling gear warranted the comparison of catch rates, variability, and length frequency distributions of the old and new net configurations. Fixed site sampling has been the standard for ODWC gill netting although random sites are thought to be less biased (Wilde and Fisher 1996). Therefore, comparisons were also made between fixed and random sites using the new net configuration. Gill nets are known to be size selective, but this bias can be corrected with the use of selectivity curves. I used the SELECT method to find the best-fit selectivity models to adjust the gill net catch for channel catfish, white crappie, white bass, hybrid striped bass, saugeye, and walleye. I then examined corrected length frequencies and size indices to assess the magnitude of these corrections.

Findings and Conclusions: There were no significant differences in catch rates between the old and new net configuration for four of the six target species. The catch rate variability of the new nets at fixed sites was lower or similar to the old nets, except for hybrid striped bass, which had higher variability in the new nets. Length-frequency distributions differed between the two net types for all lakes where channel catfish were sampled and one third of the lakes where hybrid striped bass were sampled. Only white bass had a significant difference in catch rate between fixed and random sites. Length frequencies were typically unaffected by fixed or random sampling. The bimodal model was the best fit selectivity model for all species. One third of the hybrid striped bass length distributions and two thirds of the white bass length distributions differed after adjustments were made using selectivity correction curves. Roughly one third of PSDs showed meaningful changes after selectivity adjustments were made. By correcting for contact selectivity the data are always improved (even if only subtly), and at times the adjustments can be large enough to alter management decisions. Therefore, I suggest that selectivity adjustments should become a part of routine data analysis for the North American standardized gill net design as they improve data for fisheries management.

ADVISER’S APPROVAL: Dr. Dan Shoup