Evaluation of Antler-based Selective Harvest Criteria on Harvest and Antler Size of Male White-tailed Deer in Florida

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Abstract: Antler-based selective-harvest criteria (SHC) for white-tailed deer (*Odocoileus virginianus*) management is common on public lands throughout the Southeast despite little published literature examining their effects on harvest composition, antlered harvest per unit effort (HPE), and antler scores. Particularly, SHCs may select against larger-antlered males within each age cohort, resulting in smaller antler size of the residual population. We examined the effects of SHC on harvest composition, number of antlered deer harvested per 100 days hunter effort, and antler-scores within age cohorts on 23 Wildlife Management Areas (WMAs) in Florida. These WMAs, which had harvest regulations which required a legal antlered deer to have at least one antler ≥5 inches in length or at least one antler with two or more points, all implemented a more restrictive SHC requiring legal males to have at least one antler with three or more points between 2004 and 2008. We used generalized linear mixed models to assess effects of geographic region, age class, and pre-SHC type (5-inch or 2-point), and the interactions of these variables on age-class harvest composition, HPE, and gross Boone and Crockett (GBC) scores after implementation of the 3-point SHC. The 3-point SHC decreased the proportion of 1.5 year olds in harvest ($P < 0.001$) regardless of the pre-type SHC. Only on WMAs with a previous 5-inch SHC did antler size of the harvest increase ($P < 0.01$), but this effect was not different across age cohorts ($P > 0.10$). Also, only on WMAs with a 5-inch SHC did HPE decrease. Antler-based SHCs may increase average antler scores of males in harvest; however, they may cause longer than expected declines in antlered harvest.

Key words: antler point restrictions, Florida, *Odocoileus virginianus*, public land harvest, select harvest criteria, white-tailed deer

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As white-tailed deer (*Odocoileus virginianus*) hunters demand more opportunities to harvest older-age bucks (Adams and Hamilton 2011), state agencies have used antler-based selective-harvest criteria (SHC) to recruit males into subsequent age classes. These criteria require bucks eligible for harvest to have a minimum number of antler points (antler point restrictions; APRs), main beam length, spread width, or some combination thereof (Demarais and Strickland 2011). Antler-based SHC, particularly APRs, are appealing because they can protect younger cohorts, are easy to implement, and have high public acceptance (Carpenter and Gill 1987, Duda et al. 1998, Bender and Miller 1999, Demarais et al. 2005). These strategies typically result in a more balanced age- and sex-structured population, which in turn promotes natural behaviors and social interactions (Milner et al. 2007). As a result, they have become common across the white-tailed deer's range, particularly in the southeastern United States (Adams and Hamilton 2011). De-

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spite the benefits, some hunters are opposed to antler-based SHC because it may reduce harvest opportunities (Duda et al. 1998). Also, antler-based SHCs may negatively affect mean antler size within cohorts by disproportionately selecting larger-antlered and/or protecting smaller-antlered young males (Strickland et al. 2001, Demarais et al. 2005). In Mississippi for example, an antler-based SHC which decreased harvest representation of 1.5-year-old males from 72% to 37%, also was related to an 11%–17% decline in antler size of 2- and 3-year-old deer in subsequent years (Strickland et al. 2001). Although this decline in antler size occurred on the majority of areas where it was implemented, the magnitude varied across soil type and habitat quality (Demarais et al. 2005).

Antler characteristics fluctuate within and across cohorts, making protection of entire cohorts difficult. Antler development is influenced by age, genetics, environmental conditions, and individual nutrition (Lukefahr and Jacobson 1998, Kruuk et al. 2002). In the southeastern United States, the amount of poor and sub-optimal quality forage is more pronounced than elsewhere in its range and environmental conditions can be highly variable (Deifenbach and Shea 2011), making protection of age classes across broad landscapes a challenge. For example, in Florida the abundance of forages with low nutritional quality, coupled with mild winters and asynchronous fawning periods within and among regions of the state, exacerbates protection of age classes (Diefenbach and Shea 2011). A delayed birth date relative to the population norm may detrimentally effect body size and antler characteristics for the first three years of a deer's life (Shea et al. 1992, Jacobson 1995, Gray et al. 2002), further clouding statewide or even regional application of an antler-based SHC as a tool to protect young deer in the Southeast.

Antler-based SHCs can apply selective pressure on individuals with antler characteristics on the right-side of the normal distribution (Strickland et al. 2001, Demarais and Strickland 2011). Theoretically, intense harvest of larger-antlered yearling males could negatively affect average antler characteristics of surviving cohorts in subsequent seasons (Demarais and Strickland 2011), and if these pressures are consistent across time, physical and life history traits could be affected (Hutchings 2004, Olsen et al. 2004, Allendorf and Hard 2009). In addition, SHC can create management issues related to decreased harvest per unit effort or unintended increases on female harvest. Despite these potential impacts, research concerning the effects of antler-based SHCs on antler characteristics and hunter success in the Southeast seems to be limited to two related publications in Mississippi (Strickland et al. 2001, Demarais et al. 2005), but studies continue to speculate about its possible negative consequences on mean antler sizes (e.g., Hewitt et al. 2014).

In 1994, the Florida Fish and Wildlife Conservation Commission (FWC) implemented a statewide SHC requiring males to have one antler at least 5 inches in length (hereafter 5-inch), protecting on average 44% of yearling males, but up to 65% of yearlings on some WMAs. (J. D. Kelly, Florida Fish and Wildlife Conservation Commission, unpublished data). Shortly thereafter, in response to Shea and Vanderhoof (1999), which indicated cohort antler size degradation due to selective pressures on the yearling age class, some wildlife management areas (WMAs) adopted SHCs requiring antlered deer to have two or more 1-inch points on at least one side (hereafter 2-point) to be legally harvested. Based on historic hunter harvest data, this 2-point SHC would protect on average 64% of 1.5- and 18% of 2.5-year-old males across all WMAs. Beginning in 2004, FWC implemented a more restrictive SHC requiring legal antlered deer to have at least one antler with three or more 1-inch points (hereafter 3-point) across its WMAs. This 3-point SHC should have protected on average 83% of 1.5- and 44% of 2.5-year-old males respectively across all WMAs (J. D. Kelly, Florida Fish and Wildlife Conservation Commission, unpublished data). This provided a unique opportunity to examine if implementing more restrictive SHC (3-point) on areas where less restrictive SHCs (5-inch or 2-point) already existed reversed degradation of cohort antler sizes as suggested by Shea and Vanderhoof (1999). We examined how varying SHC affected mean antler quality of the surviving cohorts and if implementation of the more restrictive SHC affected age composition of the harvest, antlered harvest per unit effort (HPE), and mean gross Boone and Crockett scores of the harvest across public lands in Florida.

Methods

We compiled deer harvest data from 23 WMAs across Florida (Figure 1). Each WMA operated multiple short-term hunts each year and allowed hunting for hunt-specific quota permit holders and their guests only. All harvest data were collected at WMA check-stations by trained technicians and/or biologists. For all male deer harvested, we recorded an estimate of age (Severinghaus 1949) and several antler measurements. Whenever permissible by hunters, jawbones were extracted so age could be more carefully estimated. When jawbone extraction was not permissible, check-station operators estimated age on-site via oral examination of tooth replacement and wear and/or other morphological characteristics. Whether or not the jawbone was extracted was a required data field for each deer examined. We recorded the length of the inside spread, number of points ≥1 inch, beam lengths, and basal circumferences for each antler (see Strickland et al. 2013 for more details). HPE for each WMA was calculated by dividing the number of antlered deer harvested by the total number of quota permits divided by 100. We examined harvest data for each WMA five years before and all years after the new SHC was implemented through the end of the 2012–13 hunting season.

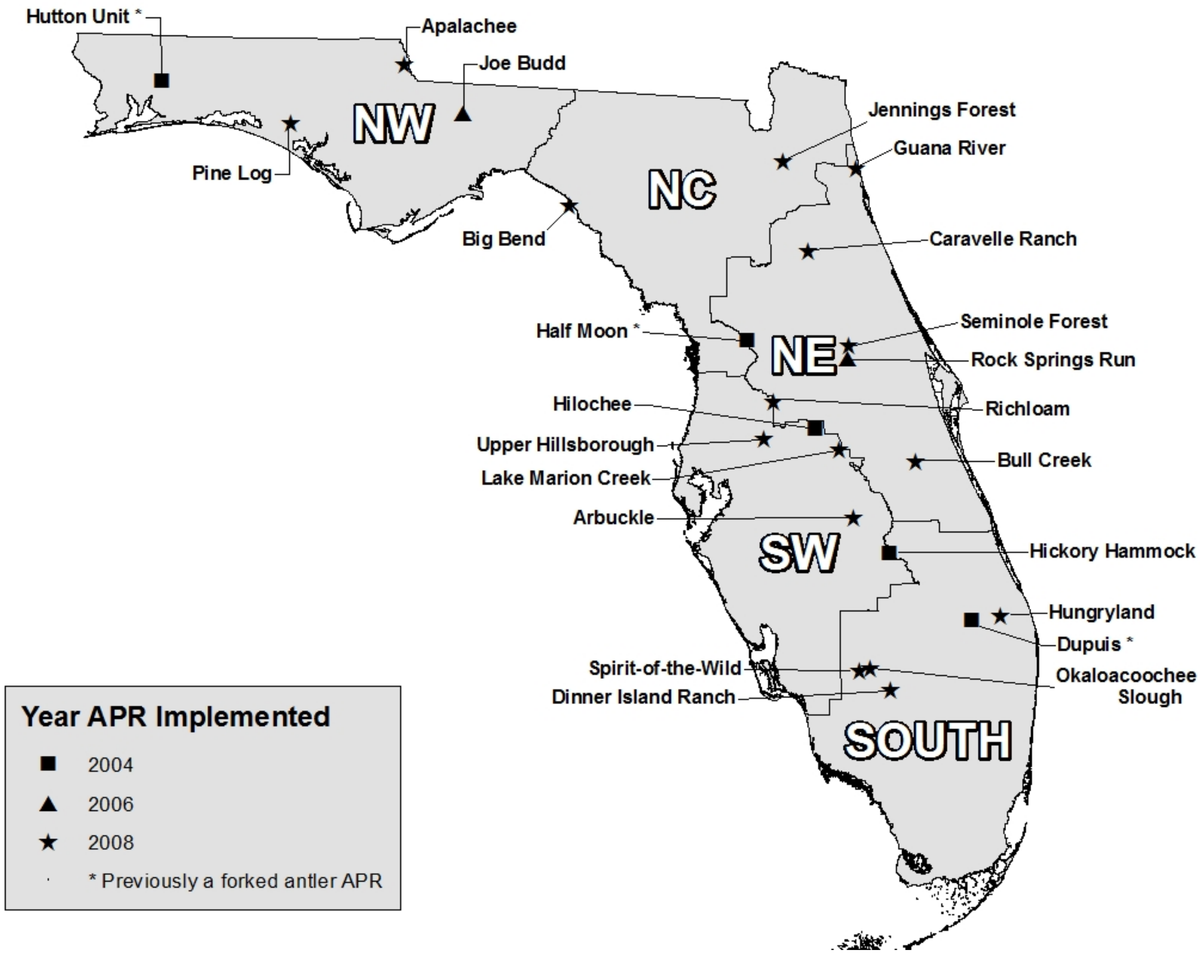

Figure 1. Locations of Wildlife Management Areas (WMAs) where harvest data was collected to determine the effects of antler-based selective-harvest restrictions on age-specific harvest composition of antlered individuals, antlered harvest per unit effort, and average gross Boone and Crockett antler scores. WMAs were initially under restrictions protecting either males with a 5-inch antler spike (5-inch) or two 1-inch points (2-point). Beginning in 2004, antler-based selective-harvest criteria requiring legal to harvest male deer have three 1-inch points on at least one antler side was implemented and allowed for examination of the effects of more-restrictive harvest criteria on characteristics of antlered harvest.

We categorized all harvest data based on the treatment period (i.e., pre- or post-3-point SHC), pre-type SHC (i.e., 5-inch or 2-point), and region (Figure 1). Regions were based on broad differences in soil and habitat and were the administrative units for management of WMAs. Although breeding and birthing dates of deer vary widely across Florida, they are relatively uniform within regions. Thus, examining our data within regions helped us control for effects of birthing dates on antler expression. To examine the impact of changing antler restrictions on the composition of cohorts in the harvest, we looked at harvest in each year on each WMA. We built a generalized linear mixed model to examine the fixed effects of treatment period, pre-treatment type, region (northwest, northcentral, northeast, southwest, and south), and age class (1.5-, 2.5-, 3.5-, and ≥4.5-year-old) on harvest proportion, assuming a binomial distribution. To account for variation between sampling location and multiple seasons of data within each selective-harvest regime on each WMA, we included WMA as a random variable and a repeated measures covariance structure for year.

We also examined the impact of antler restrictions on HPE. Because of the nature of the data (positive and skewed ratio values) we used a generalized linear mixed model with a gamma distribution to test for the fixed effects of region, treatment period, pre-type SHC, and their interaction. Again, WMA was included in the analysis as a random variable and year as a repeated measure. Because the gamma distribution does not include zero values we excluded the six zero observations from the analysis from the total of 689 observations.

To assess the impact of our SHCs on mean gross Boone & Crockett scores within cohorts and within the total harvest, we first removed all deer from which the jawbone was not extracted. From our pre-treatment sample, individuals not meeting the new harvest criteria (the 3-point SHC) were removed. To ensure standardization, all deer born prior to treatment implementation were removed from the post-treatment sample. We then calculated an estimated gross Boone and Crocket score for each deer (Strickland et al. 2013). We built a linear mixed model to test the fixed effects of age class, pre-type, treatment, region, and all potential interactions as fixed factors on gross Boone and Crocket scores. As with our previous models we included WMA as a random effect and year as a repeated measure. All analyses were performed using SAS (2011). For each model we started with a global model including all possible pair-wise interactions. Insignificant interactions were removed from the analysis in a backwards step-wise process to ensure these interactions did not obscure interpretation of remaining relevant effects. We then used the final model to calculate predicted population means and standard error of the mean (SEM; Table 1), and examined statistical significance within fixed effects using least-squares means comparisons. We chose a relatively liberal alpha level ($\alpha < 0.10$) given the highly variable and observational nature of the data, and the fact that we were more concerned about Type II errors than Type I.

Table 1. Mean ± standard error (SE) Gross Boone and Crockett (GBC) scores of harvested male white-tailed deer across five different regions in Florida. Deer were aged using tooth wear and replacement (Severinghaus 1949) and GBC scores were estimated using the equation from Strickland et al. (2013). Deer were harvested on wildlife management areas across Florida pre- and post-implementation of selective harvest criteria (SHC) requiring males to have at least one antler side with three one-inch points to be eligible for harvest. Prior to the 3-point SHC, all WMAs were under SHC requiring males to have one antler at least 5 inches in length or two one-inch points on at least one side to be legally harvested. For these statistics, deer harvested from WMAs were pooled into regions which shared similar soil and habitat characteristics as well as breeding dates.

		Gross Boone and Crockett score (inches)			
		Pre- 3-point SHC		Post- 3-point SHC	
Region	**Age class**	***n***	**Mean ± SE**	***n***	**Mean ± SE**
Northcentral	1.5	3	36 ± 7.2	9	59 ± 6.4
	2.5	48	65 ± 2.5	55	69 ± 2.3
	3.5	60	85 ± 2.0	44	76 ± 2.7
	4.5+	36	94 ± 3.9	28	89 ± 3.4
Northeast	1.5	111	53 ± 1.4	113	55 ± 1.2
	2.5	428	71 ± 0.8	510	76 ± 0.8
	3.5	273	85 ± 1.2	269	88 ± 1.1
	4.5+	149	99 ± 1.4	73	102 ± 1.9
Northwest	1.5	42	57 ± 2.9	53	55 ± 1.7
	2.5	136	72 ± 1.5	302	74 ± 1.0
	3.5	63	87 ± 2.5	102	89 ± 1.6
	4.5+	22	85 ± 4.4	19	94 ± 4.4
South	1.5	39	57 ± 3.1	89	57 ± 1.4
	2.5	57	72 ± 2.3	181	72 ± 1.3
	3.5	28	85 ± 3.1	78	91 ± 1.7
	4.5+	25	96 ± 3.2	38	96 ± 2.4
Southwest	1.5	7	43 ± 6.6	16	52 ± 2.8
	2.5	33	68 ± 3.0	40	75 ± 2.9
	3.5	13	83 ± 8.0	35	91 ± 3.5
	4.5+	5	87 ± 11.6	5	112 ± 8.2

Results

There was a significant interaction between age class and treatment period ($F_{3,686} = 37.85$, $P < 0.0001$; Figure 2) suggesting the 3-point SHC changed the age composition of the harvest. The proportion of harvest across age classes differed by region ($F_{12,686} = 2.99$, $P = 0.0004$) regardless of treatment period and pre-type SHC. Harvest composition was not different between pre-type SHCs ($F_{1,686} = 1.60$, $P = 0.20$), nor was its effect size dependent on age class ($F_{3,676} = 1.52$, $P = 0.20$), region ($F_{2,676} = 1.46$, $P = 0.23$), or treatment period ($F_{1,676} = 0.07$, $P = 0.79$). Thus, harvest proportions across age classes changed between treatment periods, but the change was independent of pre-type SHC.

Antlered HPE did not differ between pre-type SHCs ($F_{1,17.94} = 0.64$, $P = 0.43$) or among regions ($F_{4,18.11} = 0.24$, $P = 0.91$). Nor did the effect size of region on HPE depend on the treatment period ($F_{4,38.87} = 1.37$, $P = 0.26$) or the pre-type SHC ($F_{3,14.98} = 0.29$, $P = 0.83$). However, the effect size of treatment period on HPE depended on the pre-type SHC ($F_{1,38.59} = 3.66$, $P = 0.06$), suggesting the difference in HPE post-3-point SHC implementation was dependent on whether the WMA had a 5-inch SHC or 2-point SHC prior to the 3-point SHC. Specifically, HPE did not differ pre- and post-treatment period on WMAs with a 2-point pre-type

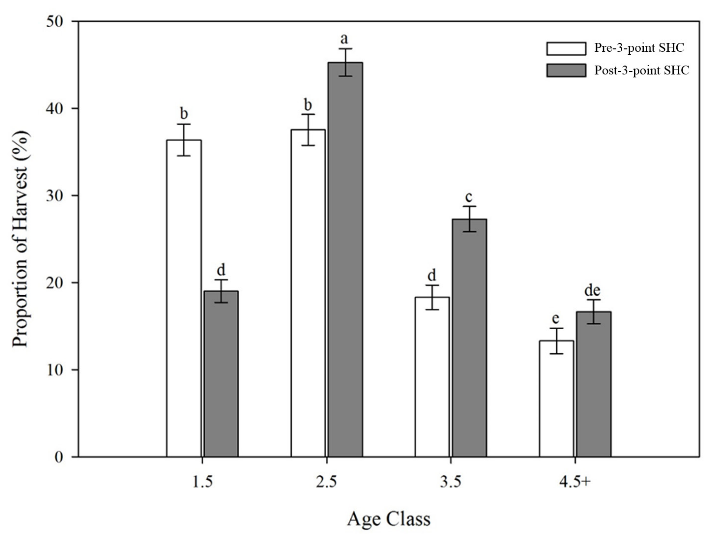

Figure 2. Predicted proportion (± SEM) of harvest of male white-tailed deer of different age cohorts during antler-based selective-harvest criteria of 5 inches, and after change of selective harvest criteria to three antler points on one side (3-point SHC). Immature males (1.5 years old) were better protected with the second selective harvest criteria. Different letters over each bar represent statistical differences in estimated population means ($P < 0.10$).

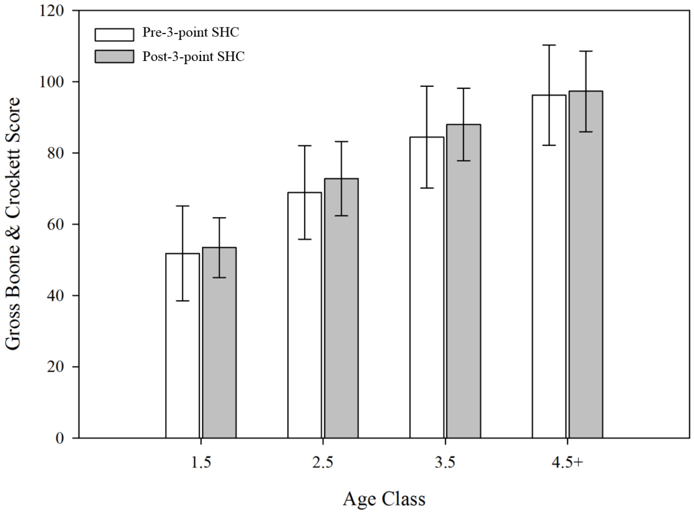

Figure 3. Observed gross Boone and Crockett scores in inches (± SD) of different age classes of male white-tailed deer before and after the implementation of an antler-based selective-harvest criteria (SHC) requiring legal to harvest male deer have three 1-inch points on at least one antler side (3-point SHC). The SHC was more restrictive than the SHCs which had already been in place, and was successful in protecting more 1.5-year-old deer. Average antler-size within standing cohorts at least 2.5 years old and older did not increase after providing increased protection for larger-antlered 1.5 year olds.

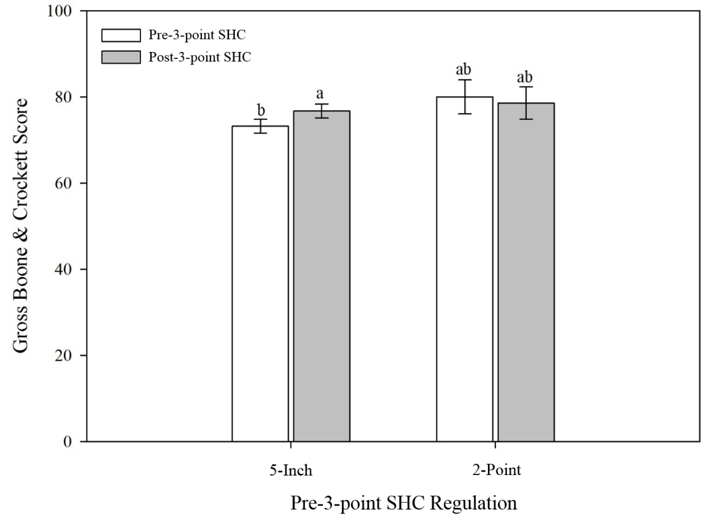

Figure 4. Predicted population mean (± SEM) Gross Boone and Crockett scores in inches before (pre) and following (post) the implementation of selective-harvest criteria (SHC) to three 1-inch points on one side of a male white-tailed deer's antler (3-point SHC) in Wildlife Management Areas (WMAs) previously protecting either males with a 5-inch antler spike (5-inch) or a antler side with two 1-inch points (2-point). When antler restrictions were changed for all WMAs, average gross Boone and Crockett scores only statistically increased in areas previously with a 5-inch SHC. Different letters over each bar represent statistical differences in estimated population means ($P < 0.10$).

SHC (pre-treatment = 3.07 ± 1.13; post-treatment = 3.19 ±1.13 antlered deer harvested per 100 hunter permits), but decreased from 2.66 ± 0.45 to 2.00 ± 0.34 antlered deer harvested per 100 hunter permits on WMAs with a 5-inch pre-type SHC.

After filtering our sample, we included records from 3,637 male white-tailed deer in our GBC analysis (Table 1). We found no differences in GBC scores across regions ($F_{4,16.1} = 0.28$, $P = 0.88$), nor did region's effect size depend on treatment period ($F_{4,530} = 0.96$, $P = 0.43$), age class ($F_{12,529} = 1.43$, $P = 0.15$;), or pre-type SHC ($F_{1,14.2} = 1.86$, $P = 0.19$; Table 1). As expected GBC score differed among age classes ($F_{3,550} = 378.29$, $P < 0.001$; Figure 3). The effect size of age class on GBC scores did not depend on the treatment period ($F_{3,527} = 4.51$, $P = 0.65$), nor pre-type SHC ($F_{2,12.6} = 0.06$, $P = 0.93$). However, the effect size of the treatment period on GBC scores depended on the pre-type SHC from which the deer was harvested ($F_{1,549} = 4.51$, $P = 0.03$). Implementation of the 3-point SHC had different effects on GBC scores between WMAs with a 5-inch pre-type SHC and a 2-point pre-type SHC (Figure 4). Thus, only on WMAs with the 5-inch pre-type SHC was there an increase in GBC scores in the harvest, regardless of region (Figure 5). Specifically, implementation of the 3-point SHC had no significant effect on average GBC scores for WMAs with a 2-point pre-type SHC, whereas GBC scores increased an average of 3.52 inches for WMAs with a 5-inch pre-type SHC.

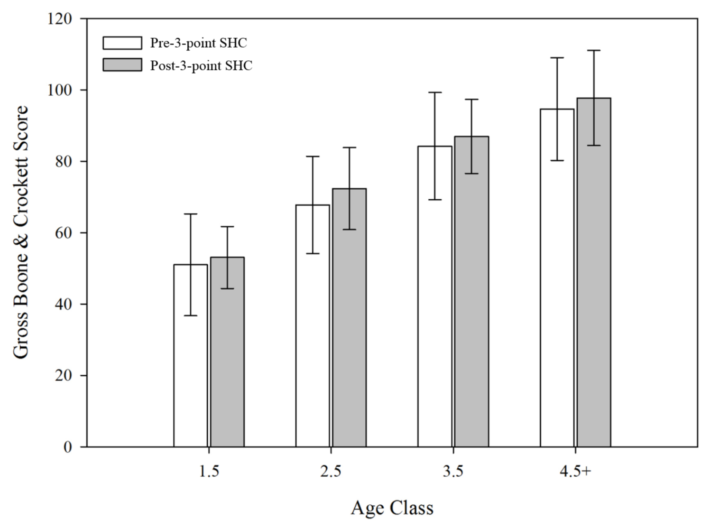

Figure 5. Observed gross Boone and Crockett score in inches (± SD) for males harvested on 20 wildlife management areas (WMAs) across Florida which had previously required legal-to-harvest males have at least one 5-inch antler. All WMAs subsequently imposed rules requiring legal-to-harvest males have at least one antler with three or more 1-inch points (3-point SHC). Observed scores increased across age classes, and pre- and post-comparisons within age classes were not statistically different ($P > 0.10$).

Discussion

Despite the commonality of SHCs (Adams and Hamilton 2011), little research has examined the effects associated with its implementation across public lands in the Southeast (Strickland et al. 2001, Demarais et al. 2005). Although SHCs may decrease the harvest of younger age classes, resulting in a more balanced sex- and age-structured deer herd (Milner et al. 2007), other researchers have raised concern that SHCs could result in long-term problems because of negative effects associated with selective pressure on younger, larger-antlered deer (Strickland et al. 2001, Demarais et al. 2005). Specifically, in areas where strong selective pressure is placed on the right-side of antler size's normal distribution, we would expect mean antler size in surviving cohorts to decrease. Although we do not know the percentage of juvenile bucks harvested from the population annually, conditions for this seem possible in Florida, where hunters are allowed to harvest two legal-antlered deer per day for the entire hunting season and the SHC previously in place (5-inch and 2-point SHCs) did not fully protect the yearling age class. Logically, if more yearling males are protected by implementing a more restrictive SHC, we would expect cohorts to be released from this effect and thereby increase average antler-scores, particularly within age-classes. We found the effects of implementing of a 3-point SHC onto WMAs in Florida already enforcing a less-restrictive SHC to be heavily dependent on the type of SHC replaced. Although harvest composition of antlered deer statistically changed across all WMAs, regardless of pre-type SHC, only on WMAs with a 5-inch pre-type SHC did we note any change in HPE and GBC scores. On WMAs with a 2-point pre-type SHC, we estimated the protection of 1.5 year olds to change from 64% to 83%, and noted a change in harvest composition of yearling males from 35% to 18% on average. Despite this increased protection of yearling males, we did not observe a change in HPE, nor did we see any increase in GBC scores relative to the pre-existing 5-inch or 2-point SHC. Thus, it may be these modest increases in protection were not strong enough to promote the increase in age-class antler size we desired, or the 2-point SHC was successfully protecting a large enough portion of each cohort to not affect our metrics of interest. However, it did change the age composition of harvest without increasing HPE, which was a desired outcome. Therefore, hereafter we discuss only what we noted on WMAs previously with a 5-inch SHC.

The 5-inch SHC, which was originally placed on these WMAs in 1994, protected an estimated 44% of 1.5-year-old males. Despite increasing protection by an estimated 39%, we noted that the number of antlered deer harvested per 100 hunter permits decreased by 24%. In other words, this decrease in harvest per hunter effort means someone would have to hunt 66 more days to kill a deer under the 3-point SHC than in the 5-inch SHCs. Previous studies have suggested a similar trend, in which SHCs tend to decrease harvest per unit effort and absolute number of older age-class antlered ungulates harvested (Boyd and Lipscomb 1976, Carpenter and Gill 1987, Weignand and Mackie 1987, Bender and Miller 1999, Demarais et al. 2005). This phenomenon may be mediated by decreased harvest susceptibility of older males (Little et al. 2014) and/or a disproportionate amount of harvest pressure applied to the antlerless segment of the population as a result of decreased eligibility of male deer for harvest. For example, on WMAs with a 5-inch pre-type SHC, female harvest increased by approximately 60% the year after the 3-point SHC was implemented (J. D. Kelly, Florida Fish and Wildlife Conservation Commission, unpublished data). Even if susceptibility and population size were largely unchanged, it is plausible that five years was not sufficient time for populations on WMAs with a 5-inch pre-type SHC to recruit sufficient numbers of males to harvest eligibility in order for HPE to return to pre-3-point SHC implementation levels. Based on historic harvest data, the 3-point SHC protects on average 83%, 44%, 19%, and 11% of the 1.5-, 2.5-, 3.5-, and ≥4.5-year-old age classes, respectively, across Florida. Assuming a stable population and only harvest-induced mortality, it would take at least five years until approximately 90% of the first cohort born under the new 3-point SHC is eligible for harvest. However, nine years was apparently enough time to return to pre-SHC harvest levels for WMAs that were previously a 2-point SHC. It is also possible that a 3-point SHC is more restrictive than its original intent. Hunters often state that it is difficult to judge the length of antler points at a distance or while a deer is moving, which likely results in missed harvest opportunities and decreased HPE.

In Mississippi, the implementation of an SHC protecting 77% of 1.5 year olds from harvest resulted in subsequent cohorts having smaller antler sizes across soil regions (Demarais et al. 2005). Given that antler size at 2.5 years old in Florida is highly correlated with antler size at 1.5 years old (Shea and Vanderhoof 1999), and our percent protection is similar to the aforementioned study in Mississippi (Demarais et al. 2005), it seems logical that SHCs would have a similar effect in Florida. Therefore, we would expect increasing protection of 1.5 year olds would to release subsequent cohorts and increase GBC scores of the harvest. Given that harvest proportion of 1.5 year olds in our study changed from 37% to 19% on WMAs with a 5-inch pre-type SHC, we successfully protected a larger portion of the cohort, yet did not influence age-specific GBC scores, suggesting that the new criteria were insufficient to reverse the process or that pre-existing SHC were not causing degradation of cohort antler sizes. It is also possible that environmental influences hindered phenotypic expression of genetic potential, lessening the probability that juvenile males with the genetic potential to grow the largest antlers were selectively harvested, which also could have weakened any effects of SHC.

When considering SHC, managers should evaluate the tradeoffs between increases in GBC scores and decreases in HPE. In our study, implementation of a more restrictive SHC resulted in increased protection of yearling males, modestly increased GBC score of the harvest, but was accompanied by an expected decline in HPE, demonstrating this clear tradeoff managers must contemplate when meeting the diverse expectations of their stakeholders. Also, because hunters may shift harvest pressure to female deer in the absence of opportunity to harvest males, managers with objectives to stabilize or increase deer populations should consider options to mitigate the antlerless harvest during the first 1–2 years post-SHC. We note that by implementing SHCs inducing small shifts in cohort protection, further increases in cohort protection are possible without significant drops in HPE. Implementation of SHC staggered over small, progressive stages until full cohort protection is achieved may minimize initial declines in harvest opportunities and avoid significant drops in HPE. Large changes in SHCs will likely decrease the proportion of young deer in the harvest, but may also decrease harvest per unit effort and associated measures of hunter satisfaction (Duda et al. 1998). However, the benefits may include quicker increase in overall antler quality of the harvest and meeting the expectations of the increasing number of hunters who request more opportunities to harvest older-age bucks.

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